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(54) **SILK PERFORMANCE APPAREL AND PRODUCTS AND METHODS OF PREPARING THE SAME**

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(58) **Field of Classification Search**

None

See application file for complete search history.

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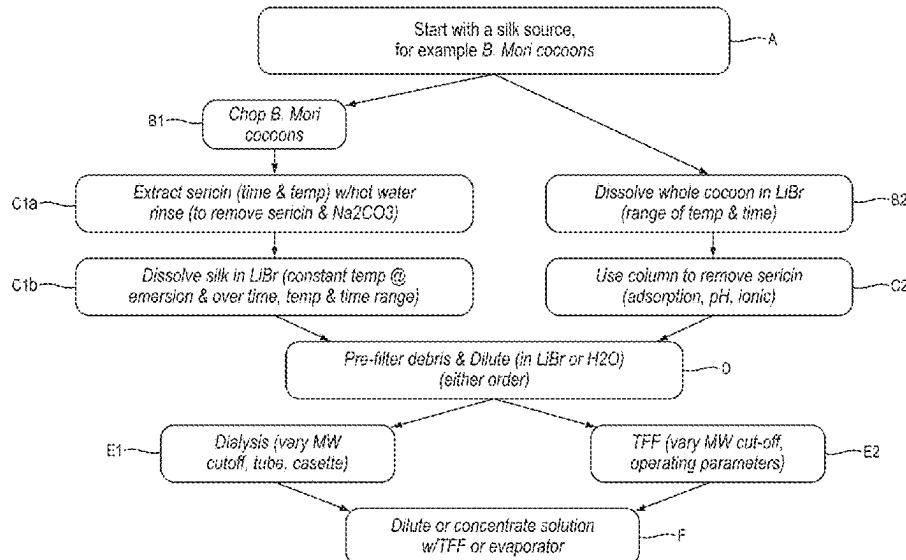
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(57) **ABSTRACT**

Silk infused performance apparel and methods of preparing the same are disclosed herein. In some embodiments, silk performance apparel includes textiles, fabrics, consumer products, leather, and other materials that are coated with aqueous solutions of pure silk fibroin based protein fragments. In some embodiments, coated apparel products, textiles, and upholstery, as well as other materials, exhibit surprisingly improved moisture management properties, resistance to microbial growth, increased abrasion resistance, and flame resistance.

17 Claims, 403 Drawing Sheets



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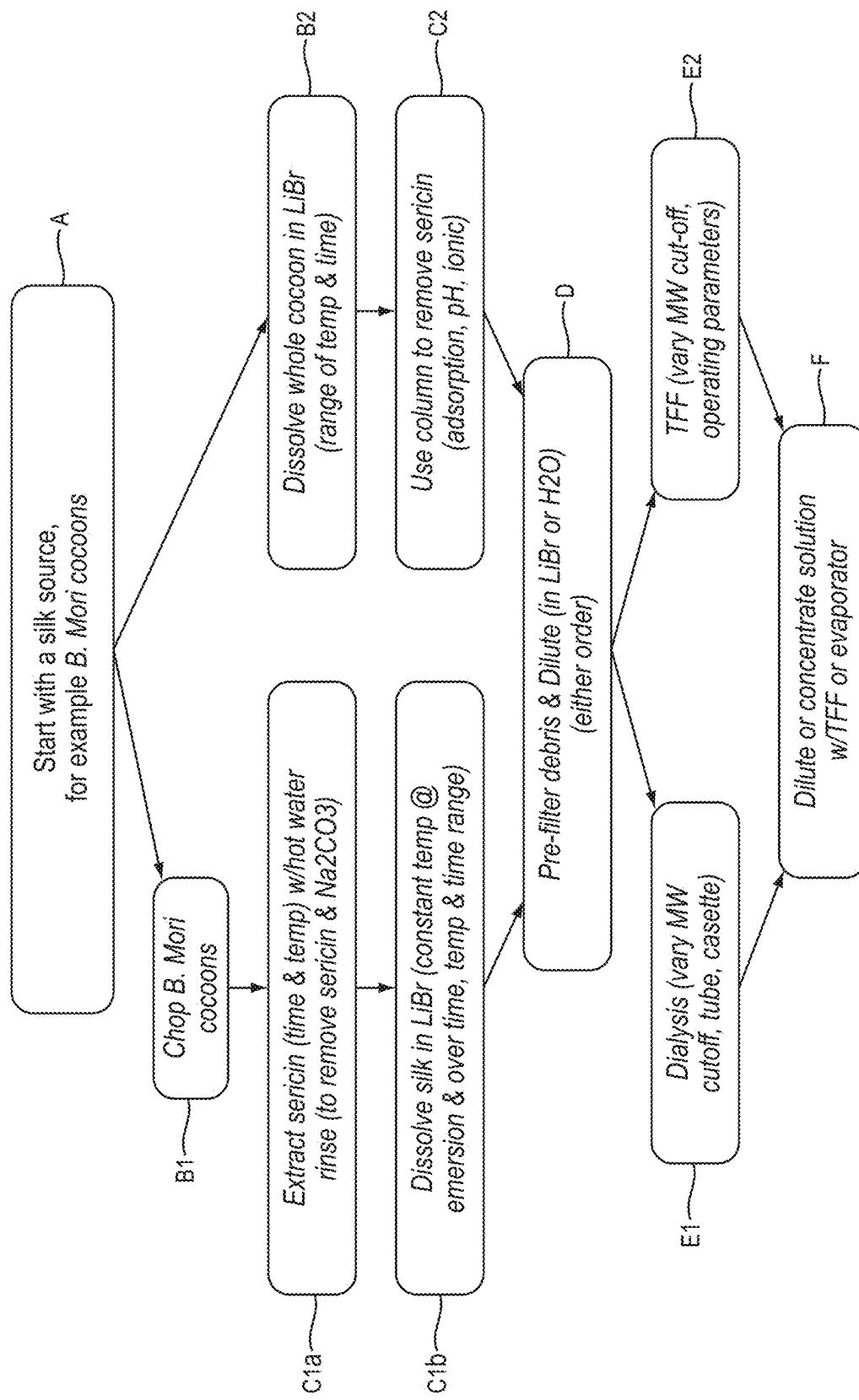


FIG. 1

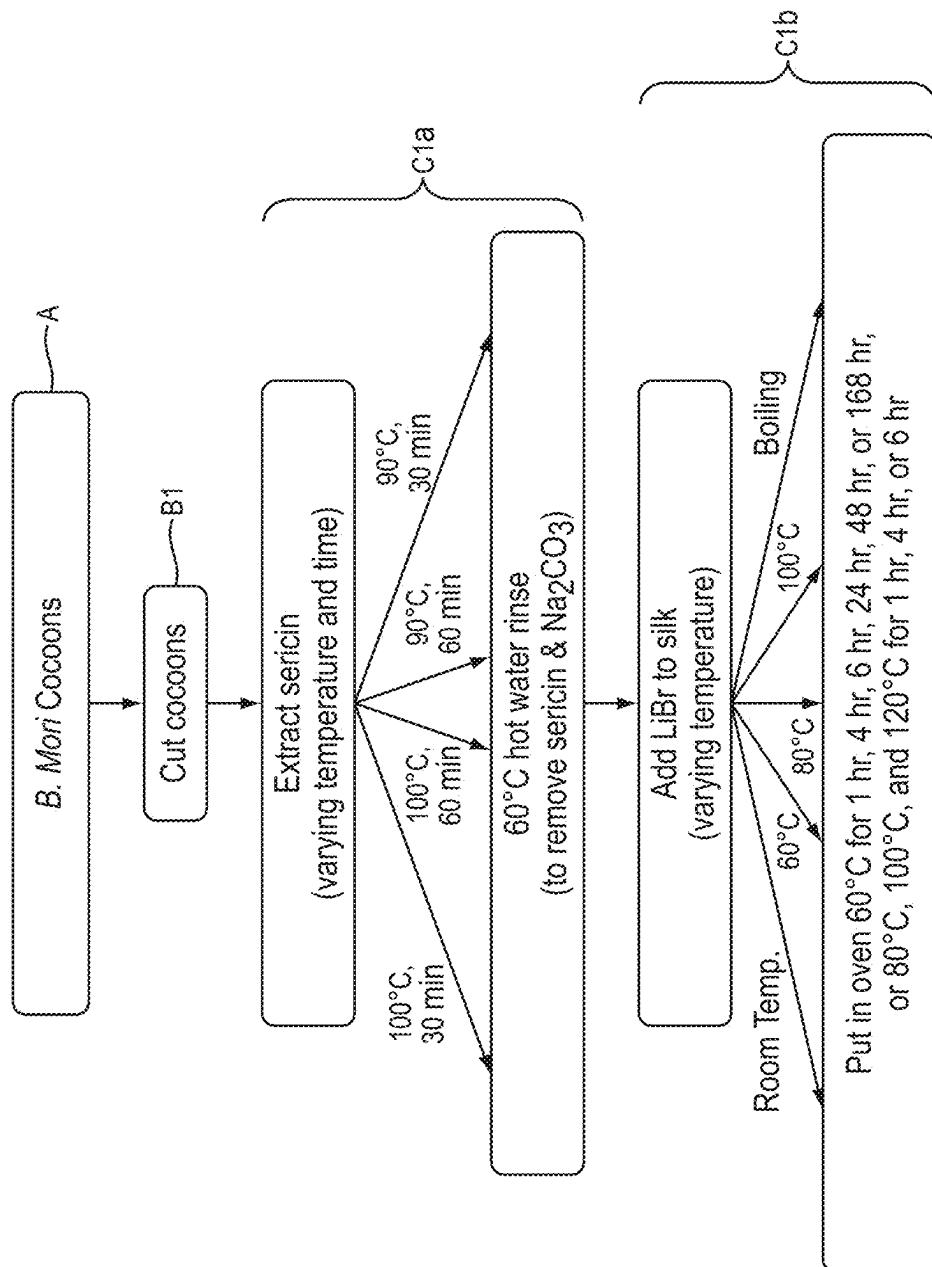


FIG. 2

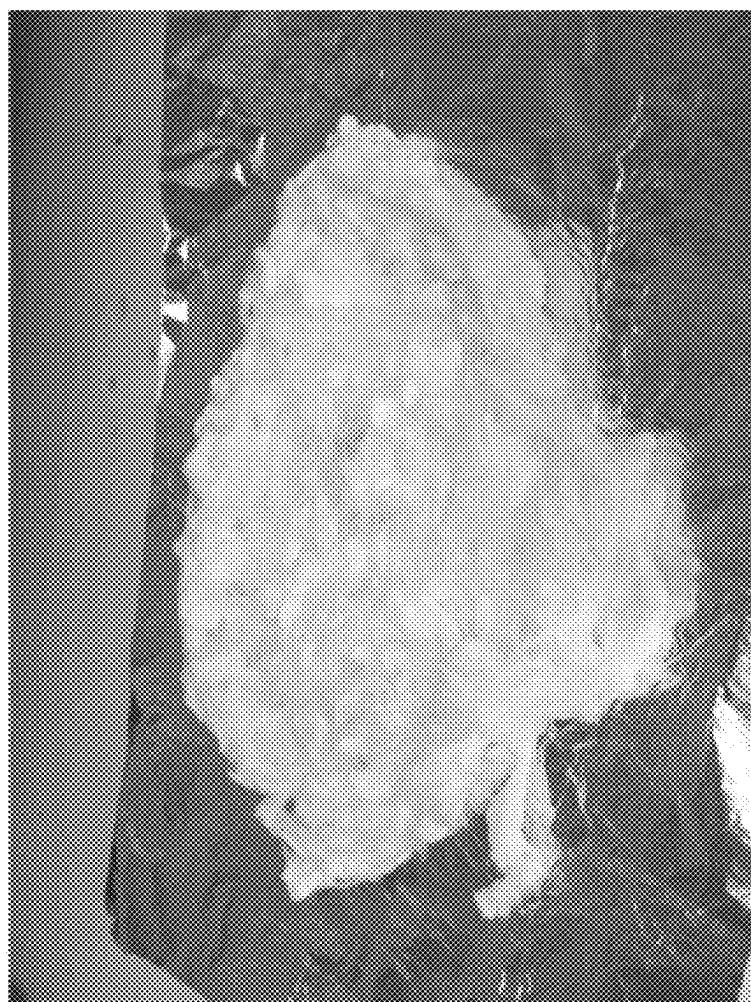


FIG. 3

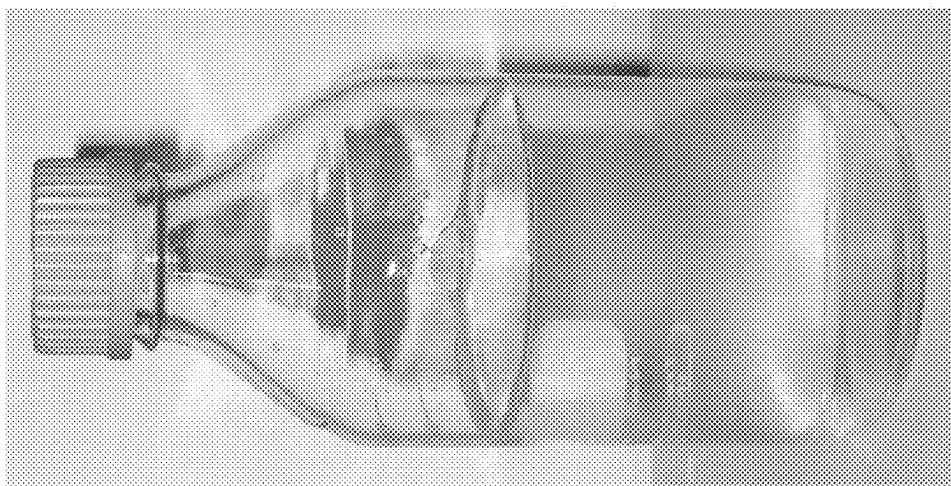


FIG. 4

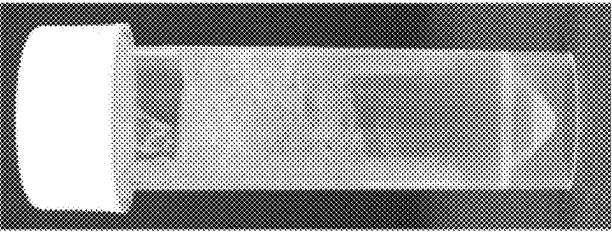
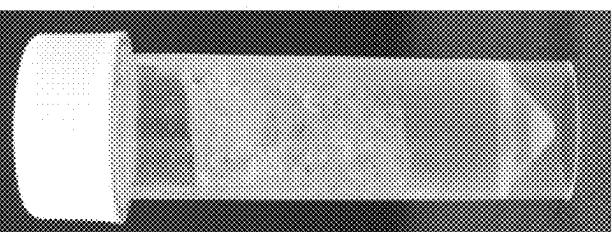
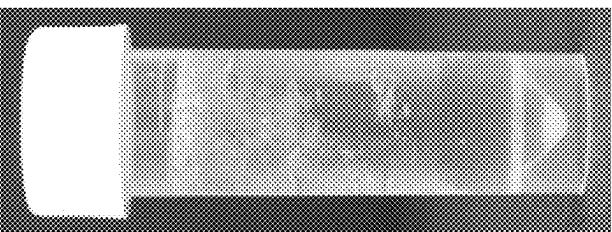
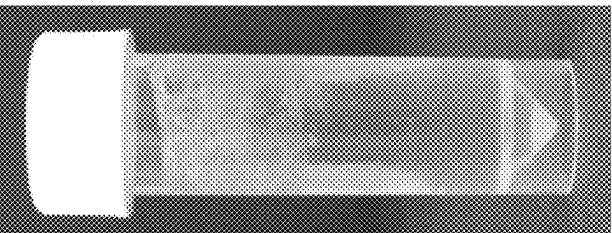
Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
	Some undissolved silk	Some undissolved silk	Significant amount of undissolved silk	Significant amount of undissolved silk
				
4 Hours				

FIG. 5A

FIG. 5B

FIG. 5C

FIG. 5D

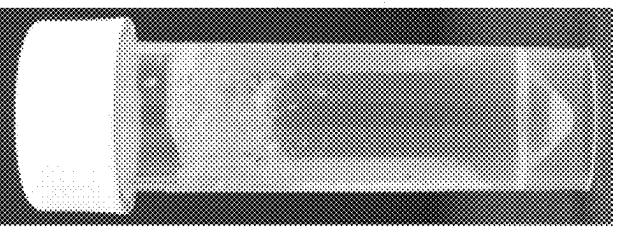
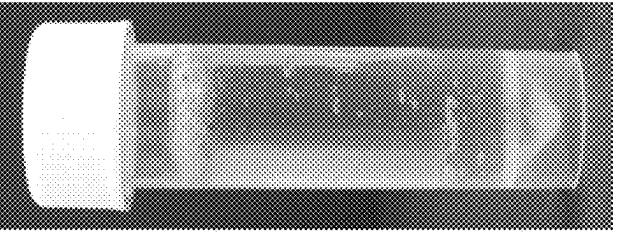
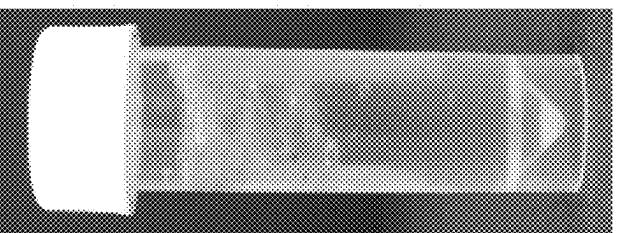
Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 60 min
	Some undissolved silk	Small amount of undissolved silk	Some undissolved silk
			
			
			
			
			6 Hours

FIG. 6A

FIG. 6B

FIG. 6C

FIG. 6D

Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
8 Hours	Small amount of undissolved silk	Little to no undissolved silk	Significant amount of undissolved silk	Some undissolved silk

FIG. 7A

FIG. 7B

FIG. 7C

Sericiп was extracted at 90°C, 60 min

Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
Small amount of undissolved silk	Little to no undissolved silk	Some undissolved silk	All but small amount of silk undissolved	

FIG. 8A

FIG. 8B

FIG. 8C

FIG. 8D

Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
24 Hours	Small amount of undissolved silk	Little to no undissolved silk	Some undissolved silk	All but small amount of silk undissolved

FIG. 9A

FIG. 9B

FIG. 9C

FIG. 9D

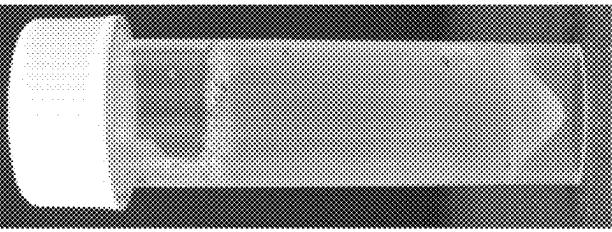
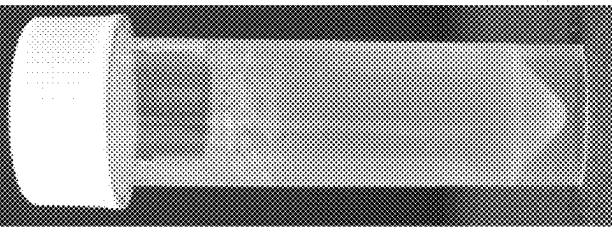
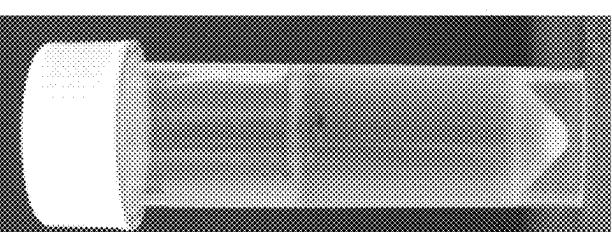
Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
	No undissolved silk, only slightly cloudy	No undissolved silk, completely clear	Some undissolved silk	Slight amount of undissolved silk
				
				
				168 Hours (1&2) 192 Hours (3&4)

FIG. 10A

FIG. 10B

FIG. 10C

FIG. 10D

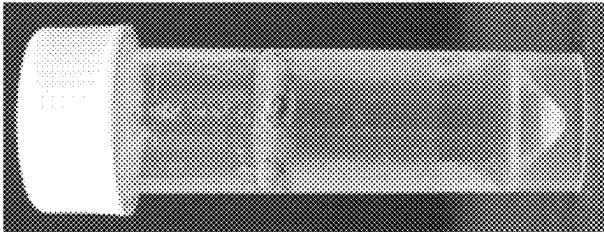
Sericin was extracted at 100°C, 60 min			
Hour 1	Hour 4	Hour 6	
Large amount of undissolved silk	Small amounts of undissolved silk and debris	Small amounts of floating debris	

FIG. 11A

FIG. 11B

FIG. 11C

Time Point	Serlicin was extracted at 100°C, 30 min	Serlicin was extracted at 100°C, 60 min	Serlicin was extracted at 90°C, 30 min	Serlicin was extracted at 90°C, 60 min
	Significant amount of undissolved silk	Significant amount of undissolved silk and debris	Significant amount of undissolved silk, highly viscous	Significant amount of undissolved silk

1 Hour

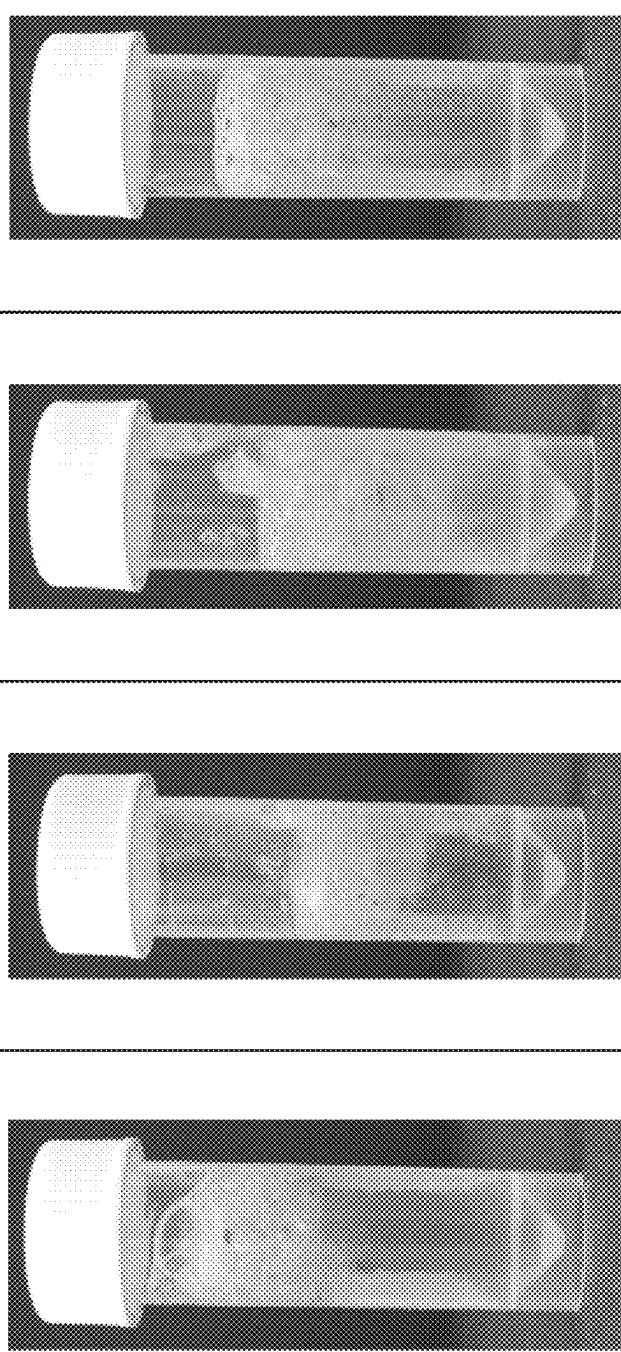


FIG. 12A

FIG. 12B

FIG. 12C

FIG. 12D

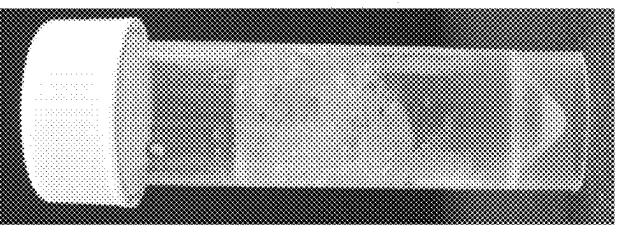
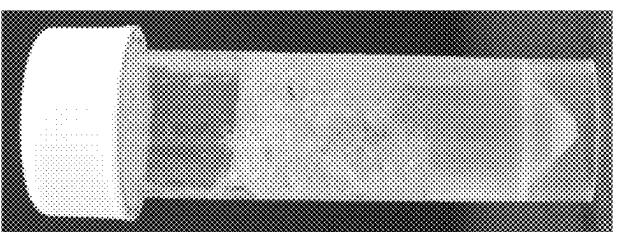
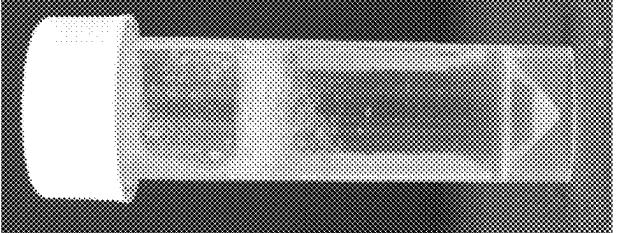
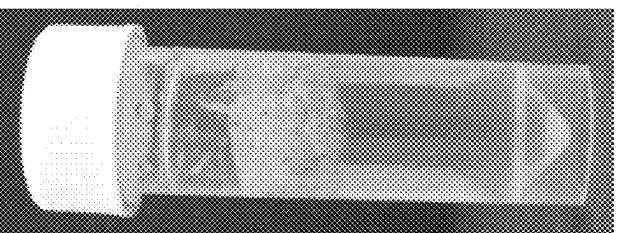
Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Some undissolved silk	Some undissolved silk	Significant amount of undissolved silk, highly viscous	Some undissolved silk
				
				
				
				
				4 Hours

FIG. 13A

FIG. 13B

FIG. 13C

FIG. 13D

Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Small amount of undissolved silk	Small amount of silk undissolved	Some undissolved silk	Some undissolved silk

6 Hours

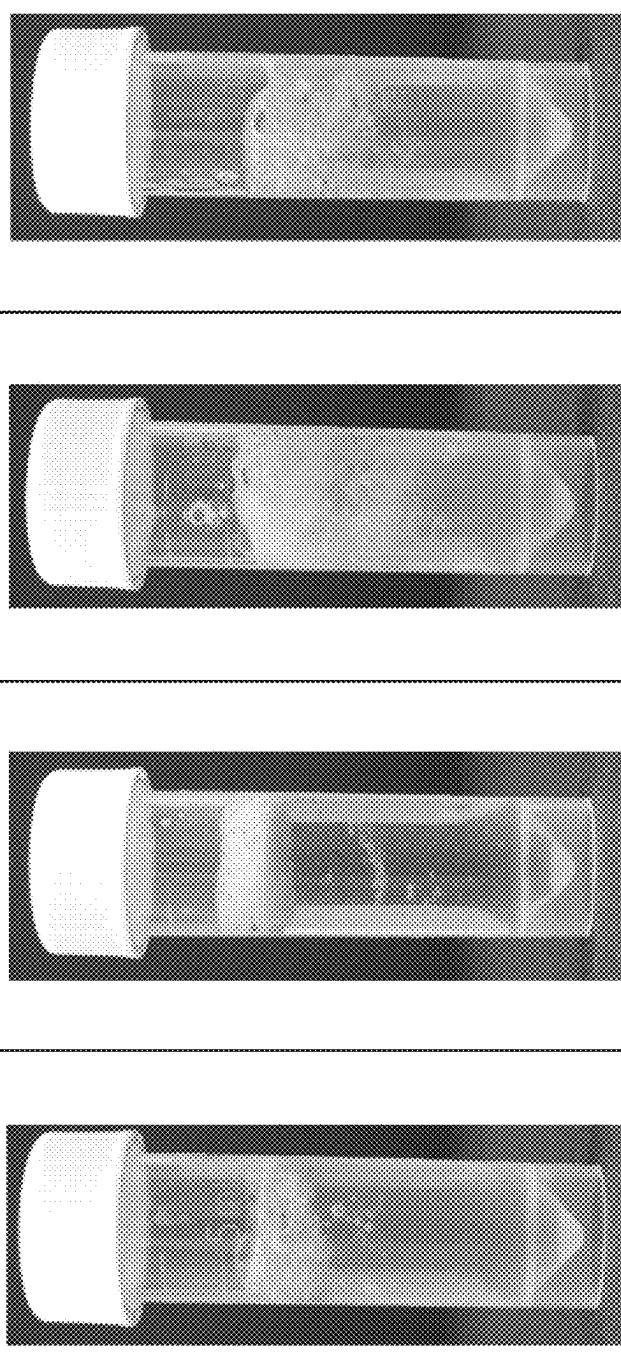


FIG. 14A

FIG. 14B

FIG. 14C

FIG. 14D

Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Very small amount of undissolved silk, quite viscous, precipitate formed from bubbles	Less viscous than set 1, no undissolved silk	Highly viscous, some undissolved silk	Less viscous than set 3, some undissolved silk

1 Hour

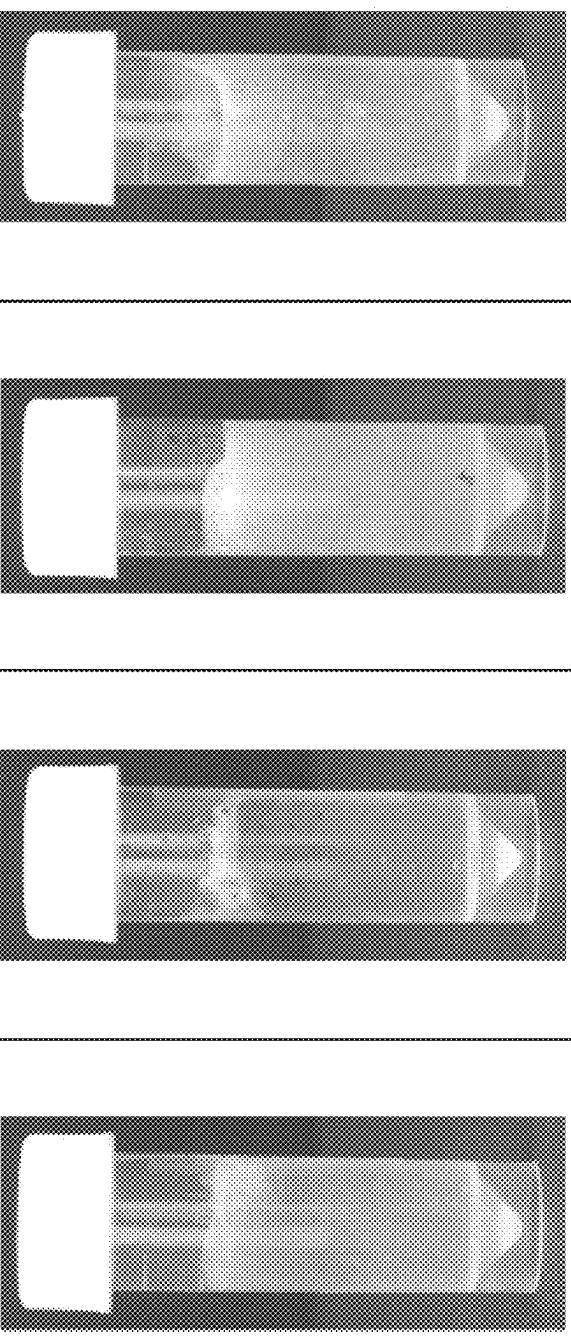


FIG. 15A

FIG. 15B

FIG. 15C

FIG. 15D

Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
Extremely small amount of undissolved silk	No undissolved silk	Highly viscous, some undissolved silk	Some undissolved silk	
4 Hours				

FIG. 16A

FIG. 16B

FIG. 16C

FIG. 16D

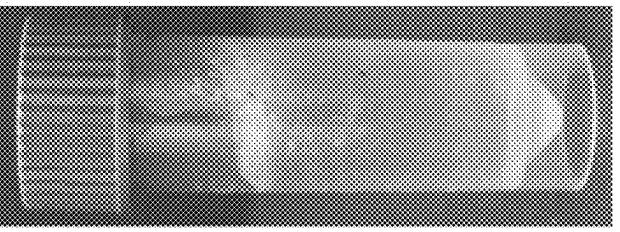
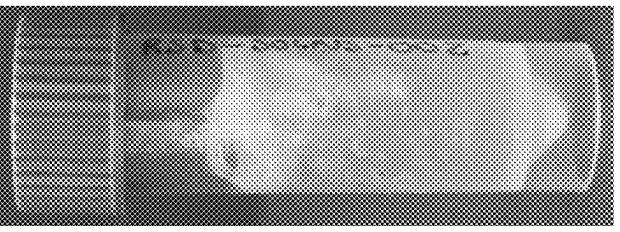
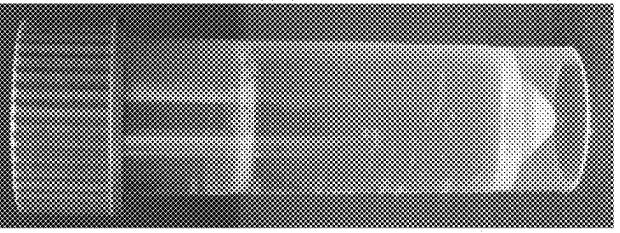
Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 60 min
	Extremely small amount of undissolved silk	No undissolved silk	Highly viscous, some undissolved silk
6 Hours			
			Almost no undissolved silk

FIG. 17A

FIG. 17B

FIG. 17C

FIG. 17D

Time Point	Serincin was extracted at 100°C, 30 min	Serincin was extracted at 100°C, 60 min	Serincin was extracted at 90°C, 30 min	Serincin was extracted at 90°C, 60 min
1 Hour	Small amount of undissolved silk, some precipitate from bubbles	All silk dissolved, some precipitate from bubbles and undissolved silk	Some precipitate from bubbles and undissolved silk	Some precipitate from bubbles and undissolved silk

FIG. 18A

FIG. 18B

FIG. 18C

FIG. 18D

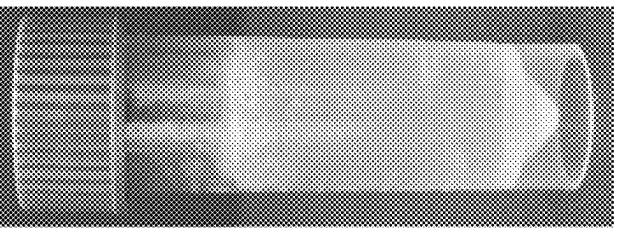
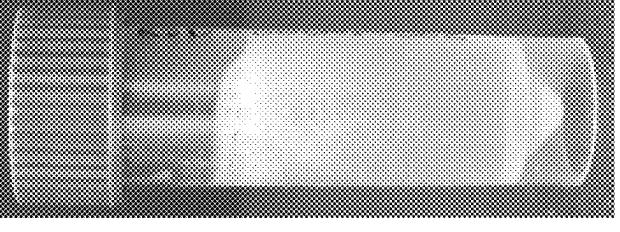
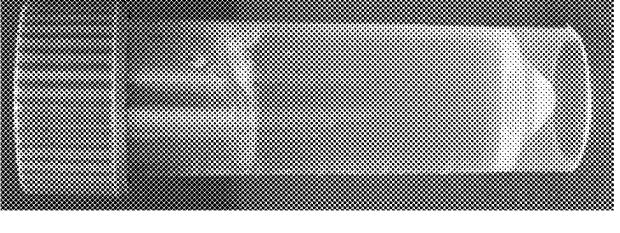
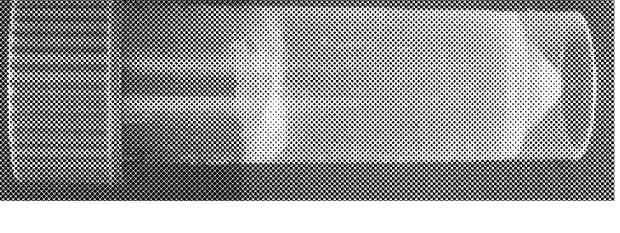
Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	All silk dissolved, some precipitate from bubbles	Completely clear with no precipitate	Some undissolved silk	Some precipitate from bubbles, mostly clear solution
4 Hours				

FIG. 19A

FIG. 19B

FIG. 19C

FIG. 19D

Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Some precipitate from bubbles, no undissolved silk	Clear with no precipitate or silk	Some undissolved silk	Clear and no undissolved silk

6 Hours

FIG. 20A

FIG. 20B

FIG. 20C

FIG. 20D

Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Most silk dissolved, some precipitate from bubbles	Most silk dissolved, some slight precipitate from bubbles	Some precipitate from bubbles and significant amount of dissolved silk	Significant amount of undissolved silk

1 Hour

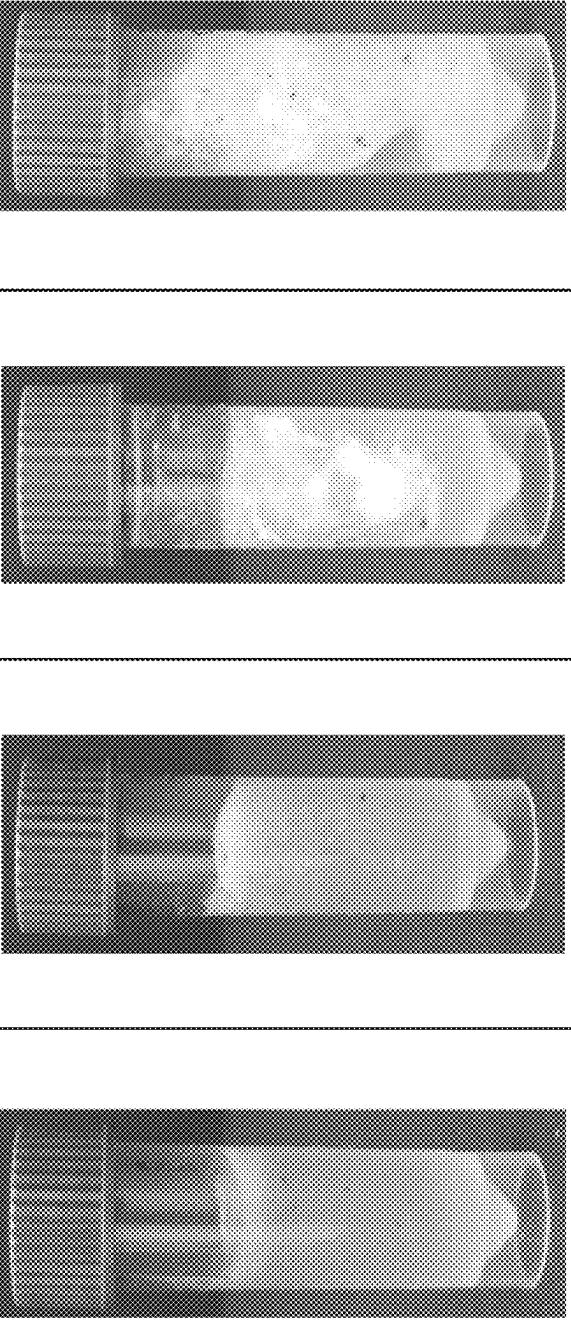


FIG. 21A

FIG. 21B

FIG. 21C

FIG. 21D

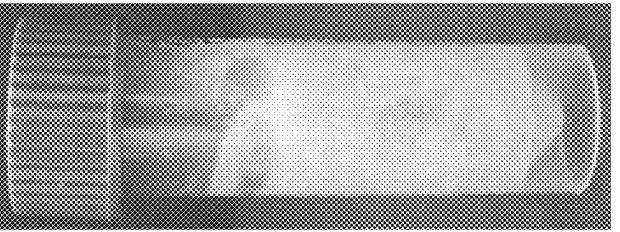
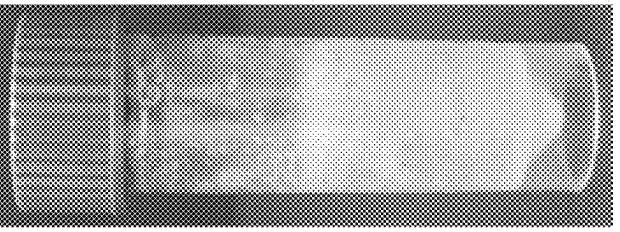
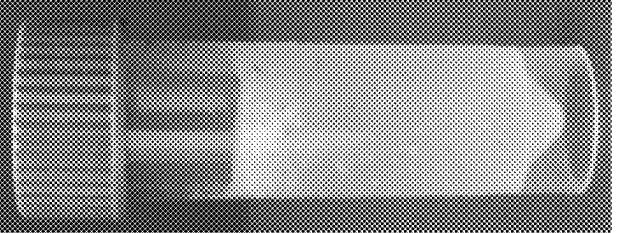
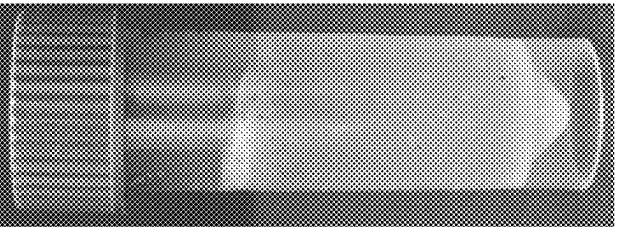
Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 60 min
	Completely clear, no silk or precipitate	Some precipitate from bubbles	Cloudy with some undissolved silk
			
4 Hours			

FIG. 22A

FIG. 22B

FIG. 22C

FIG. 22D

Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 60 min
	Slightly cloudy with silk particles on top	Cloudy with precipitate from bubbles	Highly viscous, cloudy, almost solid
6 Hours			

FIG. 23A

FIG. 23B

FIG. 23D

FIG. 23C

Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Some undissolved silk, viscosity slightly higher than set 2	Viscosity similar to water, nearly all silk completely dissolved and no precipitate; clear orange/yellow	Highly viscous, some undissolved silk and bubbles	Some undissolved silk but not too viscous

1 Hour

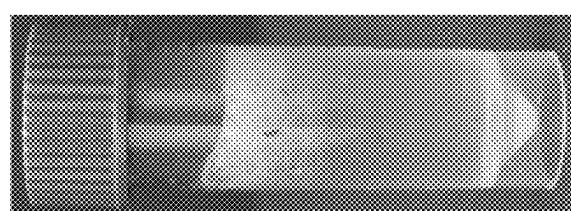
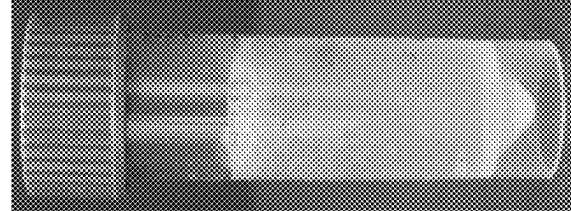
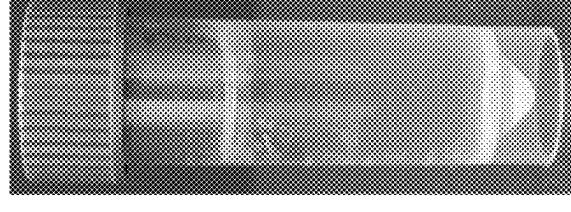


FIG. 24A

FIG. 24B

FIG. 24C

FIG. 24D

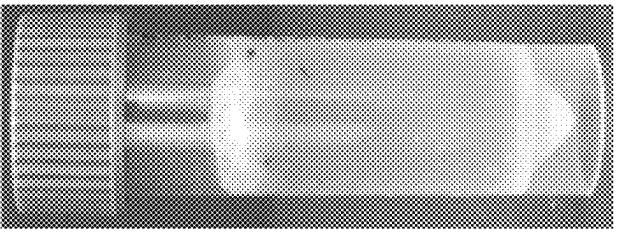
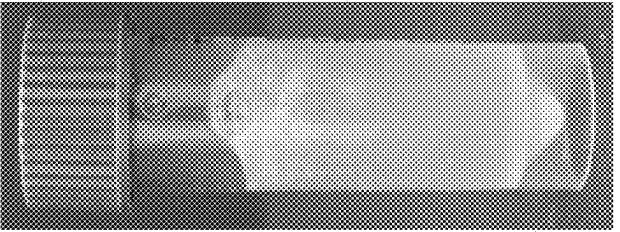
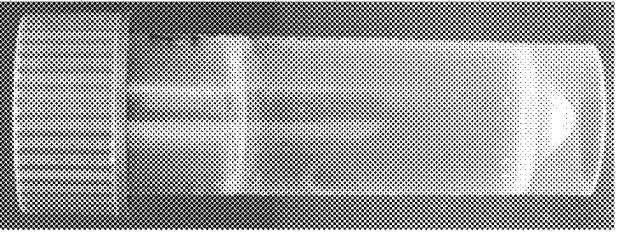
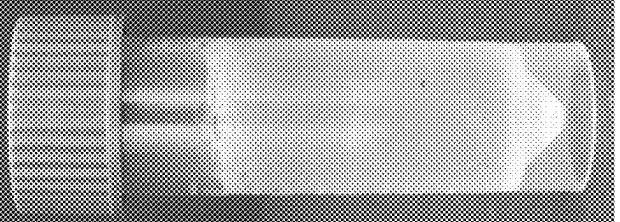
Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Some undissolved silk, cloudy, slightly viscous	Very slight amount of silk undissolved, clear with darker color	Some undissolved silk, highly viscous	Small amount of undissolved silk, not too viscous
4 Hours				

FIG. 25A

FIG. 25B

FIG. 25C

FIG. 25D

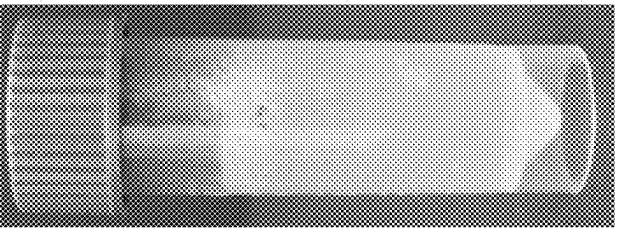
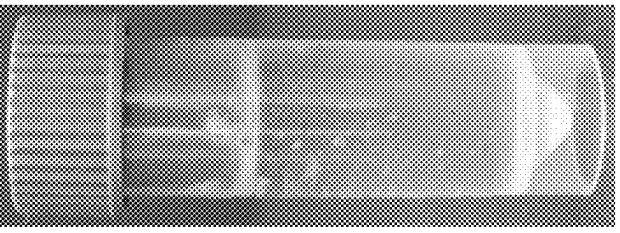
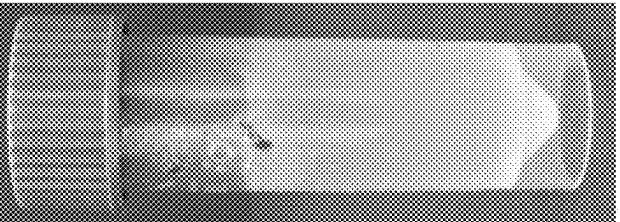
Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
	Slightly cloudy with some undissolved silk	Clear with darker color	Some undissolved silk, viscous	Darker color, some undissolved silk, slightly cloudy
				
				
6 Hours				

FIG. 26A

FIG. 26B

FIG. 26C

FIG. 26D

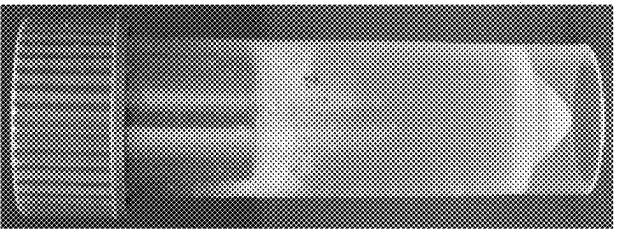
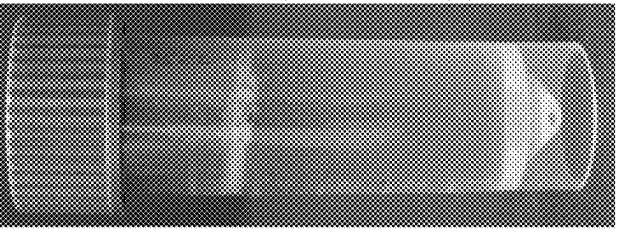
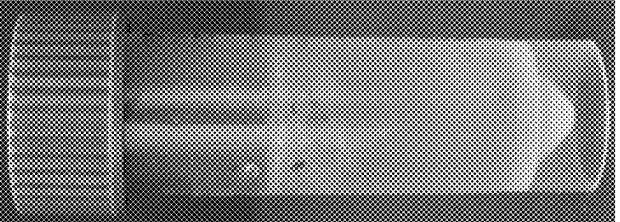
Time Point	Sericin was extracted at 100°C, 30 min	Serinc was extracted at 100°C, 60 min	Serinc was extracted at 90°C, 30 min	Serinc was extracted at 90°C, 60 min
	Somewhat cloudy with darker color, some silk particles	Completely clear with dark color, slight amount of silk particles	Cloudy, some undissolved silk, highly viscous	Small amount of undissolved silk, partially cloudy, darker color
1 Hour				

FIG. 27A

FIG. 27B

FIG. 27C

FIG. 27D

Time Point	Sericin was extracted at 100°C, 30 min	Sericin was extracted at 100°C, 60 min	Sericin was extracted at 90°C, 30 min	Sericin was extracted at 90°C, 60 min
4 Hours	Small amount of undissolved silk, highly cloudy	Little to no undissolved silk, deep auburn color	Some undissolved silk, highly cloudy	Slight amount of silk particles, dark color, less viscous

FIG. 28A

FIG. 28B

FIG. 28C

FIG. 28D

Time Point	Serincin was extracted at 100°C, 30 min	Serincin was extracted at 100°C, 60 min	Serincin was extracted at 90°C, 30 min	Serincin was extracted at 90°C, 60 min
6 Hours	Slightly cloudy, slight amount of dissolved silk	No undissolved silk, completely clear, dark auburn	Cloudy, viscous, some undissolved silk	Slight amount of undissolved silk, slightly cloudy

FIG. 29A

FIG. 29B

FIG. 29C

FIG. 29D

Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
All silk dissolved, cloudy	All silk dissolved, clear	All silk dissolved, viscous, cloudy	All silk dissolved, viscous, cloudy	All silk dissolved, viscous, cloudy
1 Hour				

FIG. 30A

FIG. 30B

FIG. 30C

FIG. 30D

Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
4 Hours	All silk dissolved, slightly cloudy but mostly clear	All silk dissolved, clear, dark	All silk dissolved, cloudy	All silk dissolved, cloudy

FIG. 31A

FIG. 31B

FIG. 31C

FIG. 31D

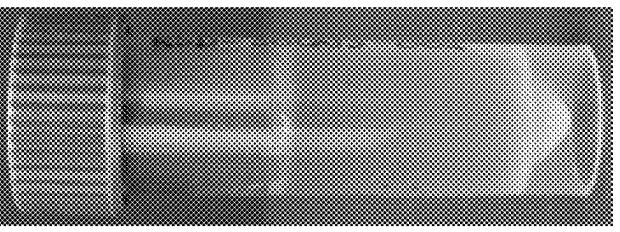
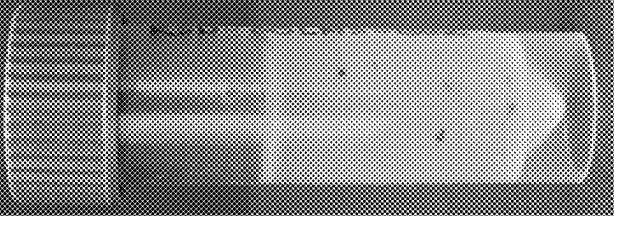
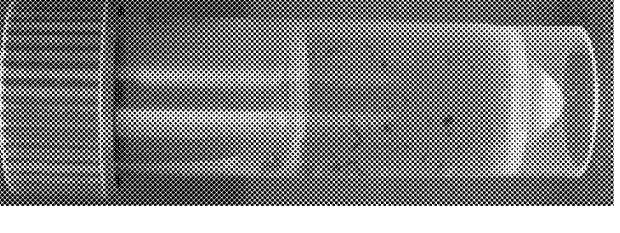
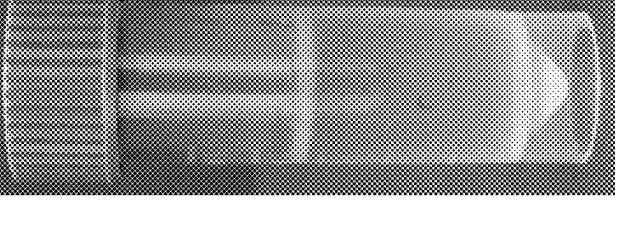
Time Point	Sericiп was extracted at 100°C, 30 min	Sericiп was extracted at 100°C, 60 min	Sericiп was extracted at 90°C, 30 min	Sericiп was extracted at 90°C, 60 min
All silk dissolved, cloudy	All silk dissolved, clear	All silk dissolved, cloudy	All silk dissolved, only slightly cloudy	
				
6 Hours				

FIG. 32A

FIG. 32B

FIG. 32C

FIG. 32D

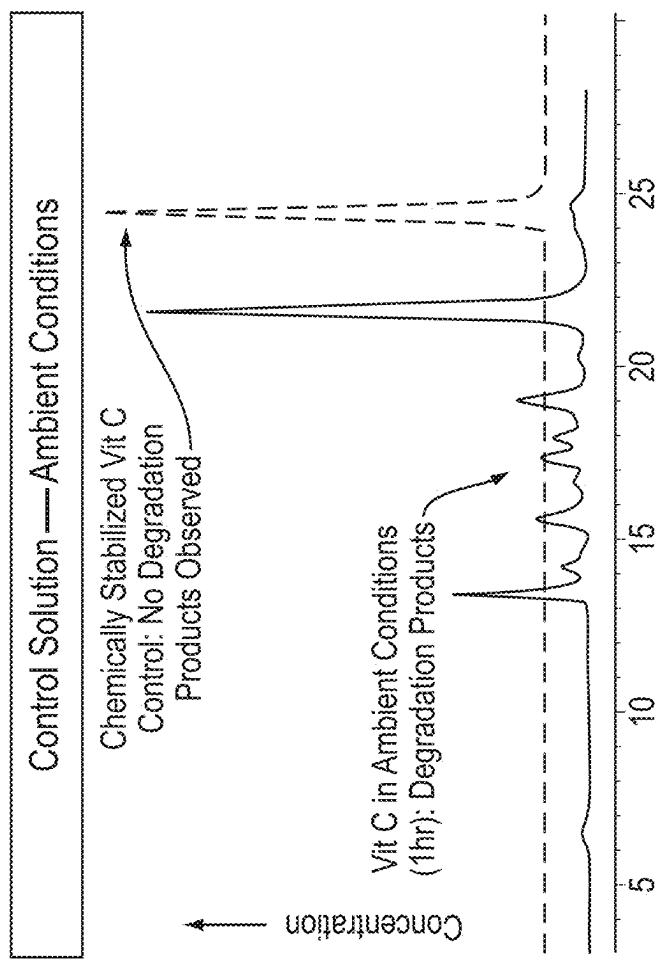


FIG. 33

Lithium Bromide and Sodium Carbonate Concentration in Silk Protein Solution

Sample ID	Sample Description	Average Concentration of Na ₂ CO ₃ (ppm)	Average Concentration of LiBr (ppm)
A	TFF 5kDa	32.13	90.85
B	TFF 10 kDa	42.91	107
C	TFF 10 kDa	49.06	78.55
D	STI 1(TFF-10-0019)	2.17	129.07
E	STI 2(TFF-10-0033)	2.63	196.2
F	STI 3(TFF-10-0034)	4.18	248.93

Method: 100C extraction for 60 min, 60C rinse, 100C LiBr in 100C oven for 60 min.
Note that TFF could be run for longer and/or at different flow rates (as varied between A-C and D-F) to alter ppm of Na₂CO₃ and LiBr.

FIG. 34

Lithium Bromide and Sodium Carbonate content in Silk Protein Solution

Sample ID	Solution Volume Equivalent to (X) Films	Sample Weight (mg)	Concentration	
			Na ₂ CO ₃	LiBr
1	6	0.171	ND	ND
2	8	0.228	ND	ND
3	10	0.285	ND	ND
4	12	0.342	ND	ND
5	Neat	-	ND	ND

*ND = None Detected

Method: 100C boil for 60 min, 60C rinse, LiBr in 60C oven for 4-6 hours

FIG. 35

Stability to Vitamin C in Solution

Sample ID	Time (hour)	Actual Conc. ($\mu\text{g/mL}$)	Area	Concentration Vit C ($\mu\text{g/mL}$)	Recovered (%)	Stability (%) After 24 hrs.
A	0	82.4	4277.9	80.53	97.73	
B	26	82.4	4088.94	77.62	94.2	
Average =			4183.42	79.07	95.96	96.39
Std. Dev. =			133.62	2.06	2.49	
% Error			3%	3%	3%	

Method: Vitamin C solution (no silk)

FIG. 36

Molecular Weights of Silk Protein Solutions

Sample ID	Sample Description	Mn	Mw	Polydispersity (PD) (Mw/Mn)
A	TFF 5kDa	14,497	33,874	2.3366
B	TFF 10 kDa	14,542	33,455	2.3006
C	TFF 10 kDa	14,972	34,026	2.2726
D	Silk protein solution in water	12,055	26,531	2.2008

Method:

TFF: 100C extraction for 60 min, 60C rinse, 100C LiBr in 100C oven for 60 min.
Silk Protein: 100C extraction for 20 min, RT rinse, LiBr in 60C oven for 4-6 hours

FIG. 37

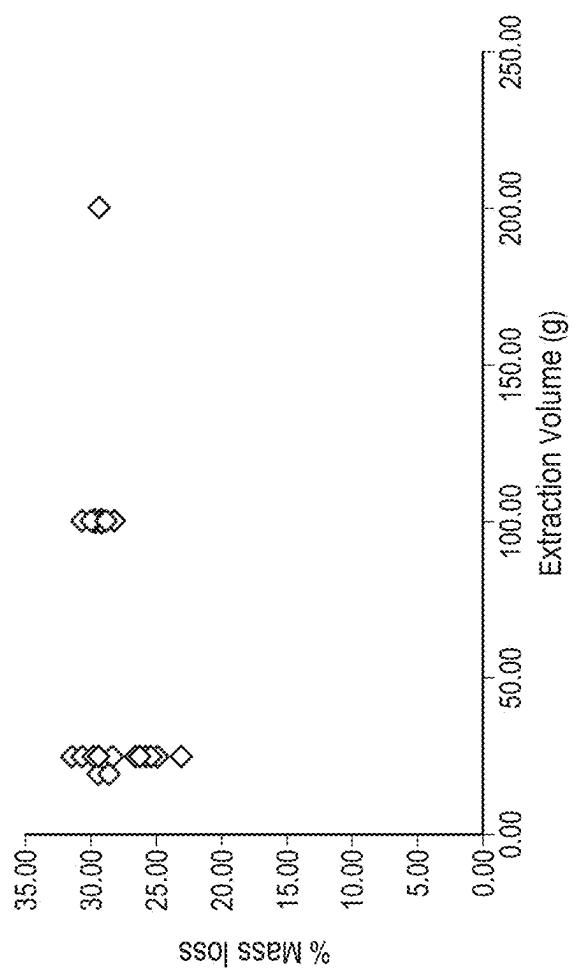


FIG. 38A

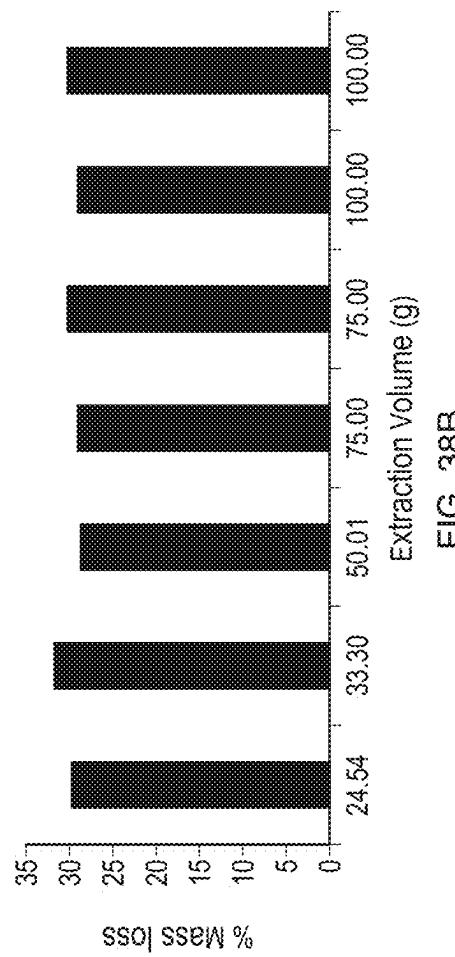


FIG. 38B

Sample	LiBr (M)	Avg MW	PD
STI 1(TFF-10-0019)	9.3	15727	2.033
STI 2(TFF-10-0033)	9.3	24587	2.3669
STI 3(TFF-10-0034)	9.3	25273	2.338
STI 9.3 M Avg		21862	2.25
STI 1(TFF-10-0031)	~7.5	29645	3.0868
STI 2(TFF-10-0030)	~7.5	26856	2.9748
STI 7.5M avg		28250.5	3.0308

* TFF-10-0019 from 2.25g extraction/ 35g dissolution

* TFF-10-0034 from 100g extraction/ 17.35 g dissolution

* TFF-10-0033 from 100g extraction/ 100 g dissolution

FIG. 39

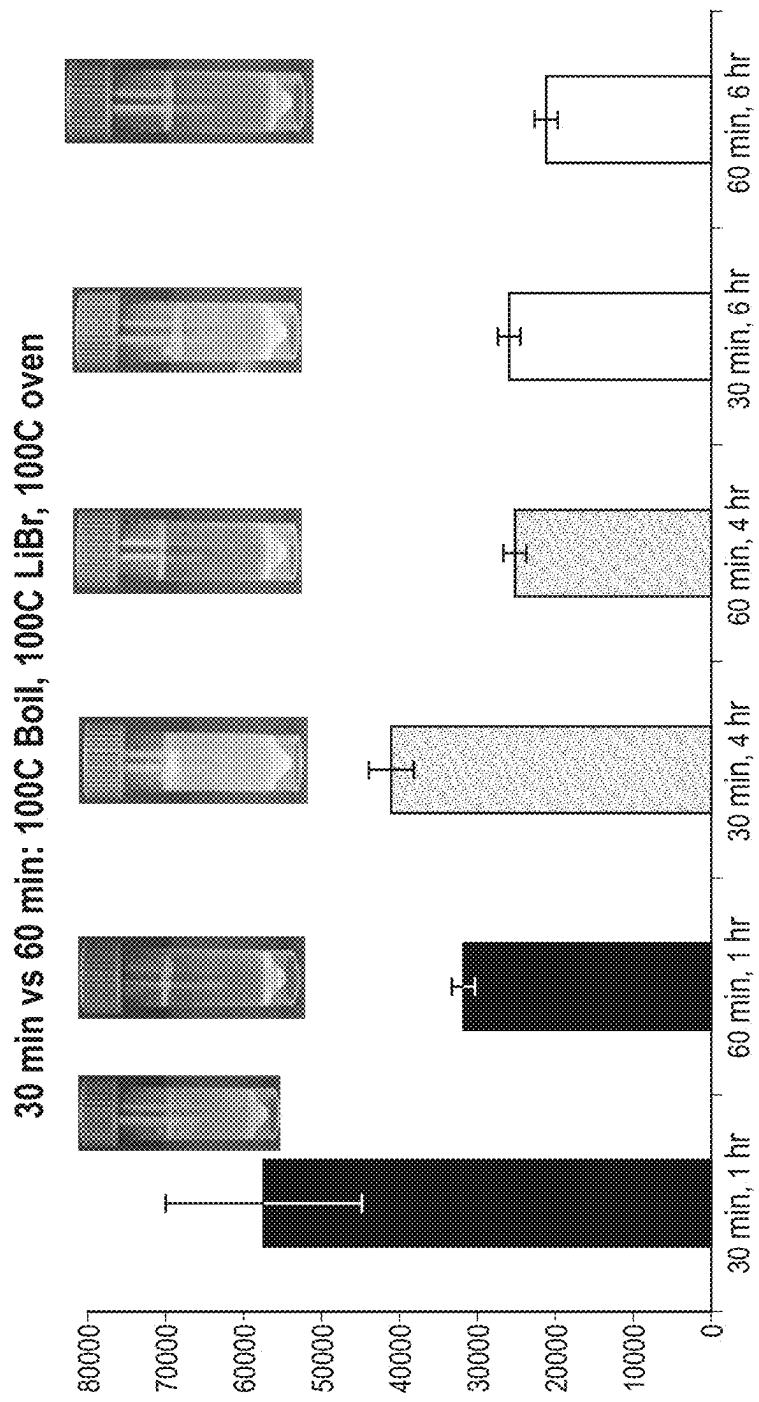


FIG. 40

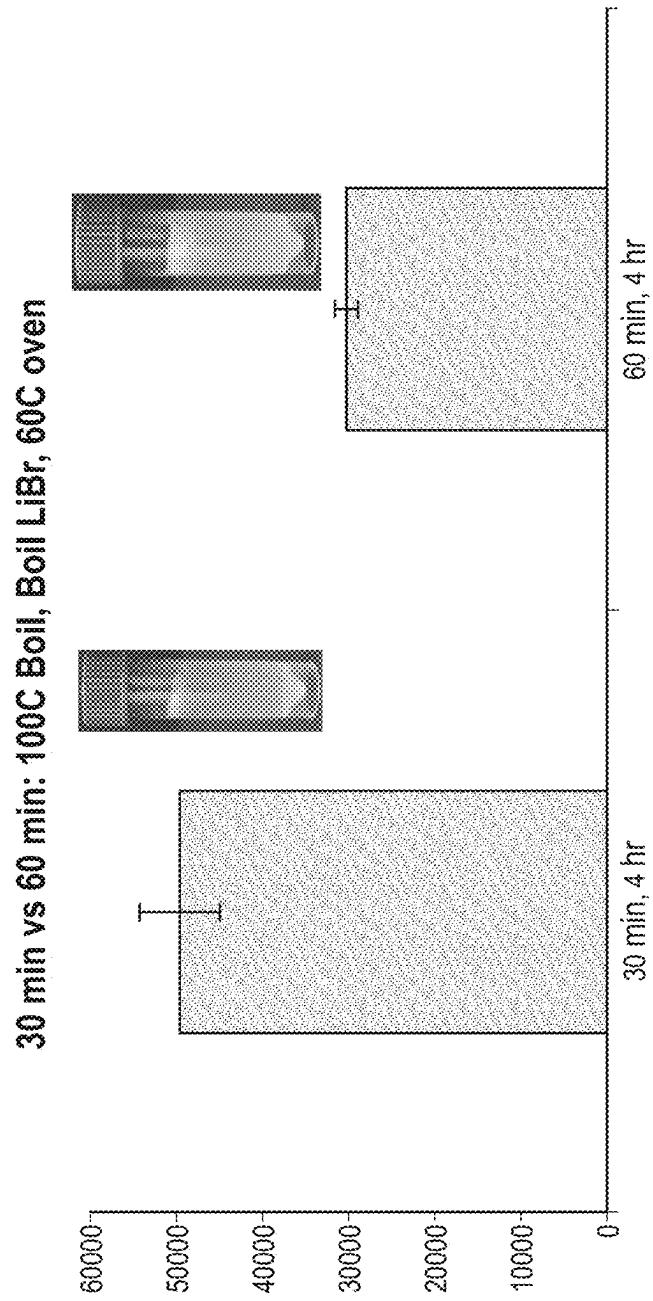


FIG. 41

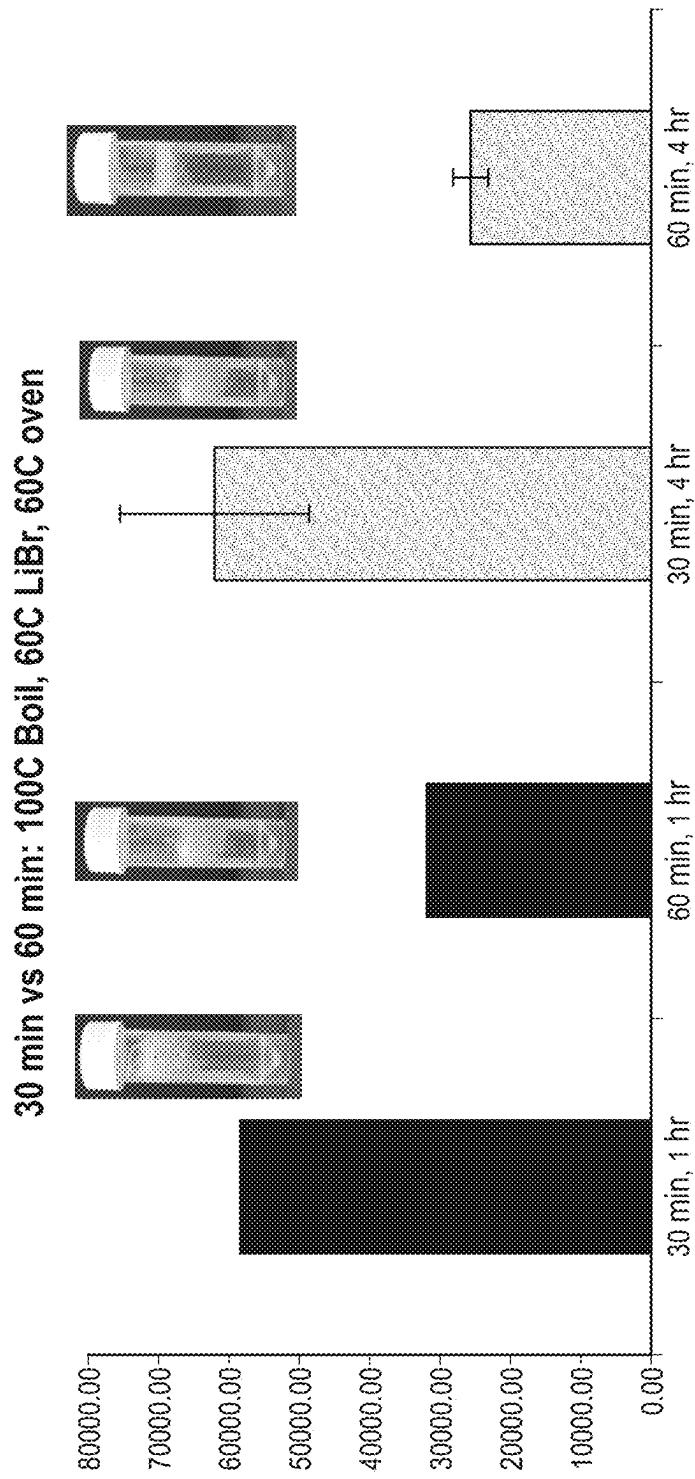


FIG. 42

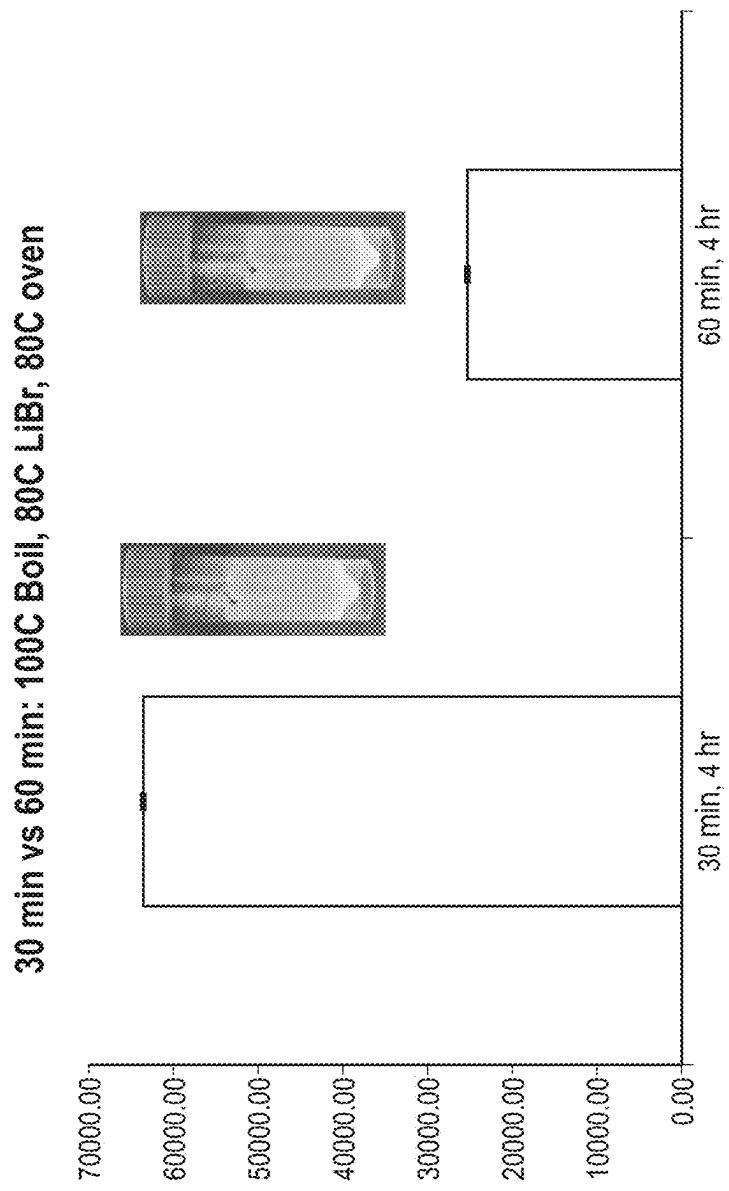


FIG. 43

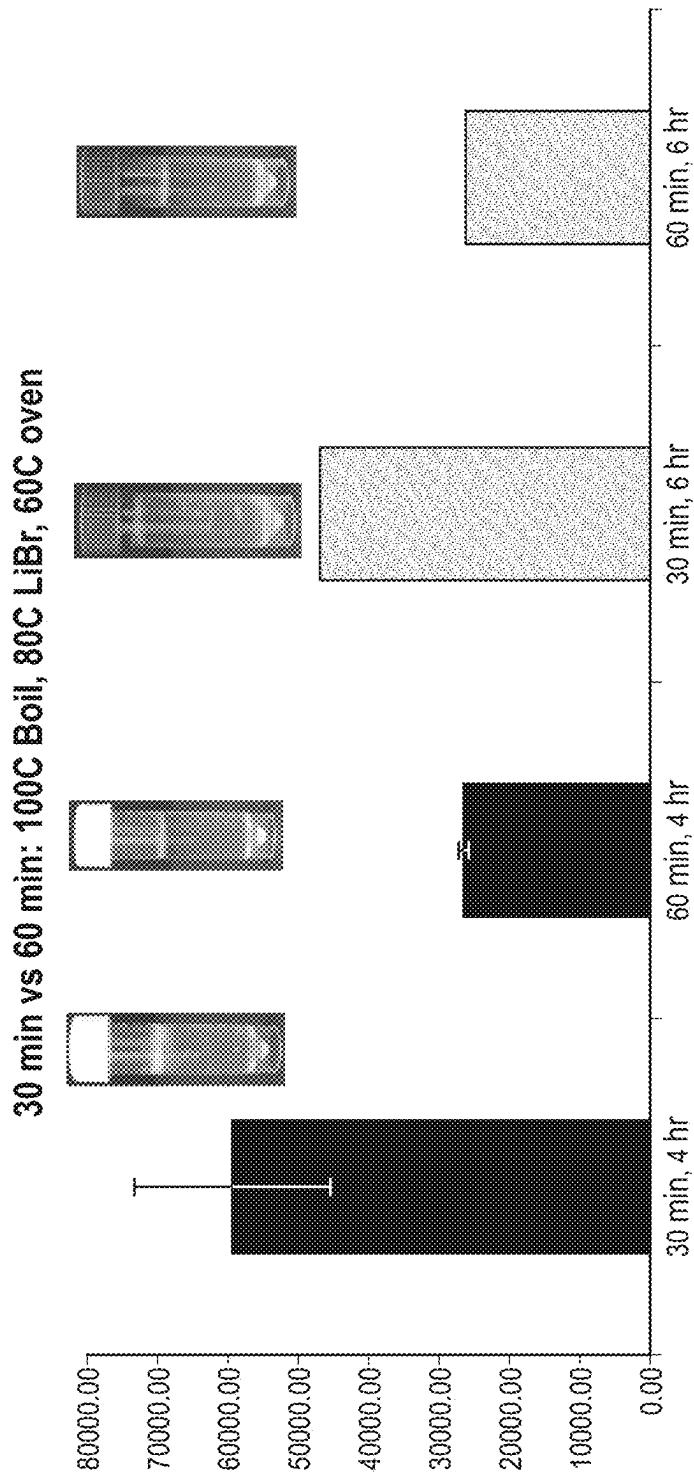


FIG. 44

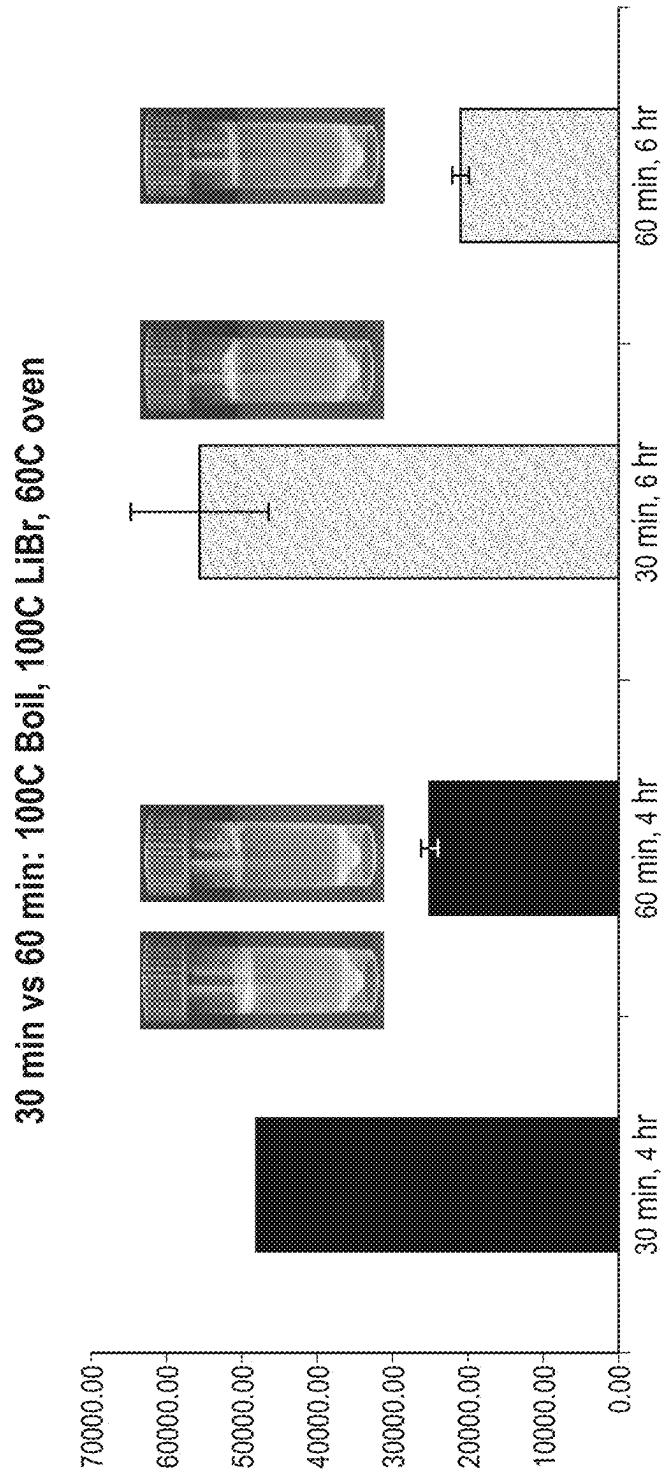


FIG. 45

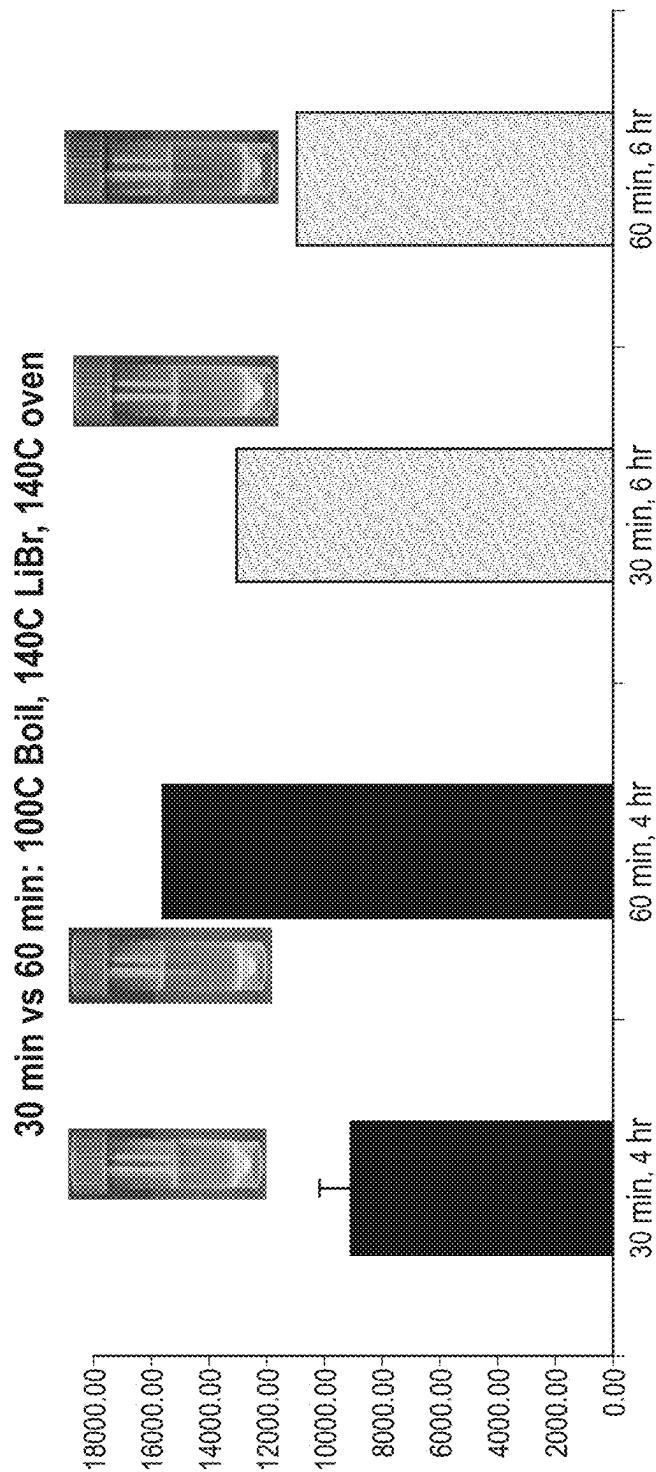


FIG. 46

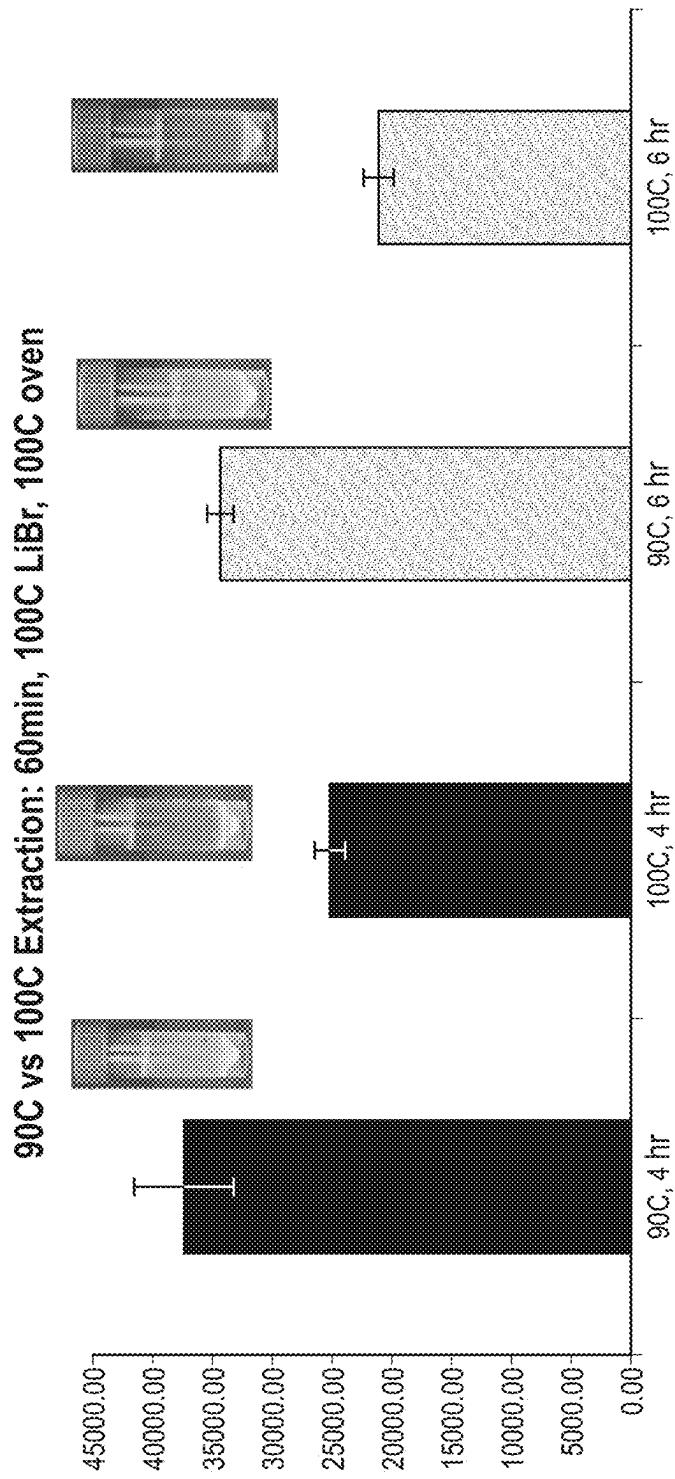


FIG. 47

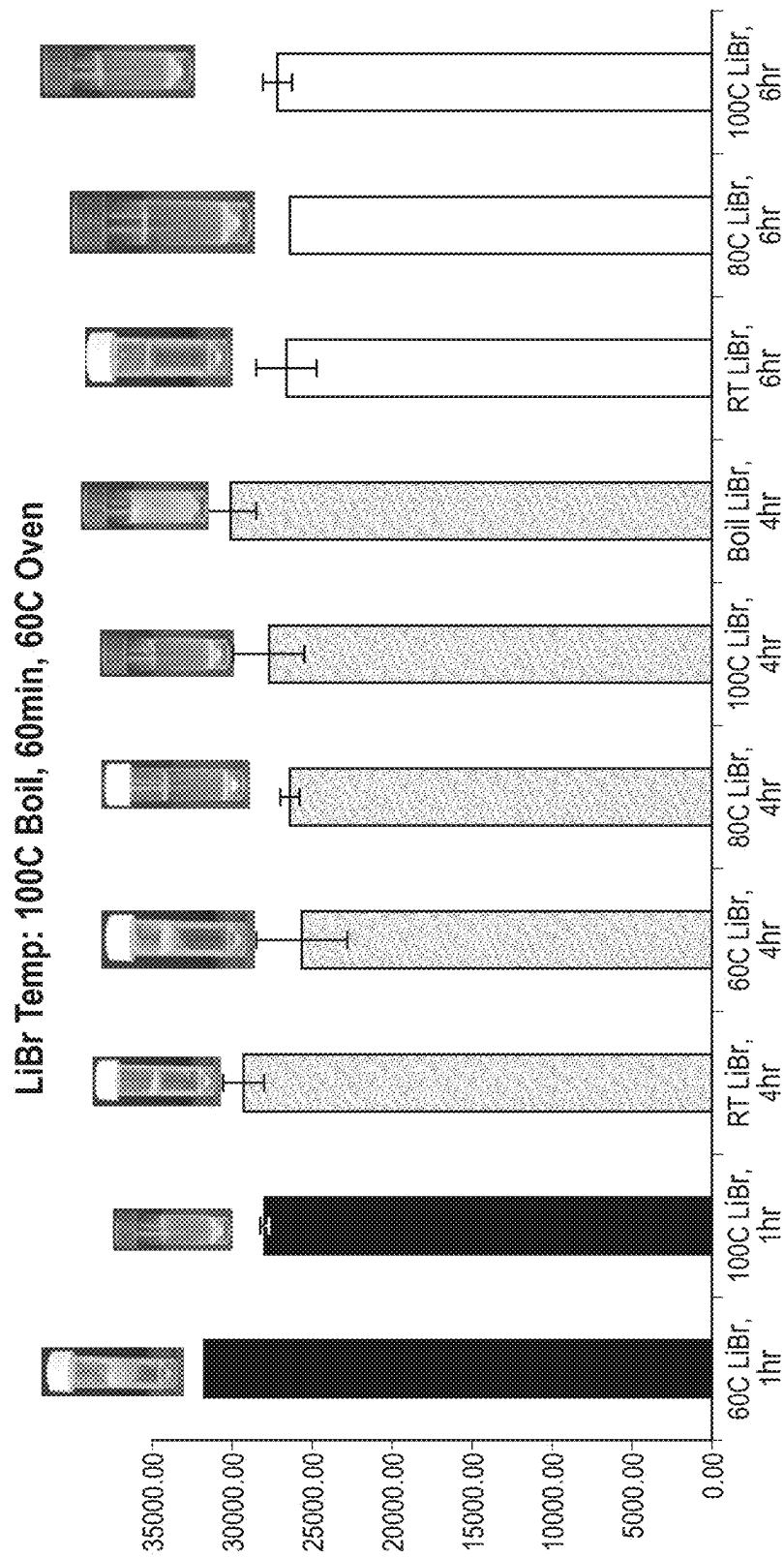


FIG. 48

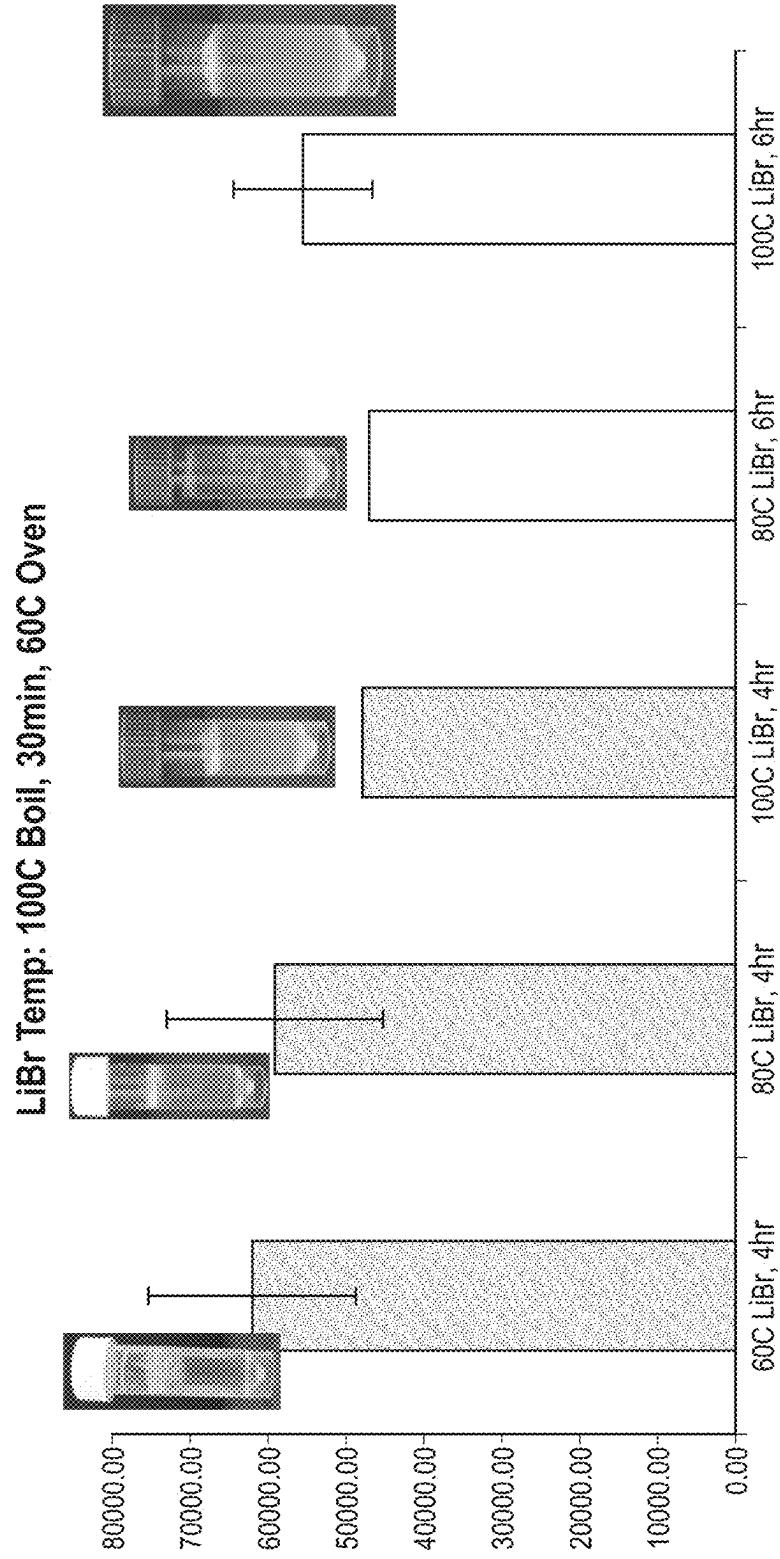


FIG. 49

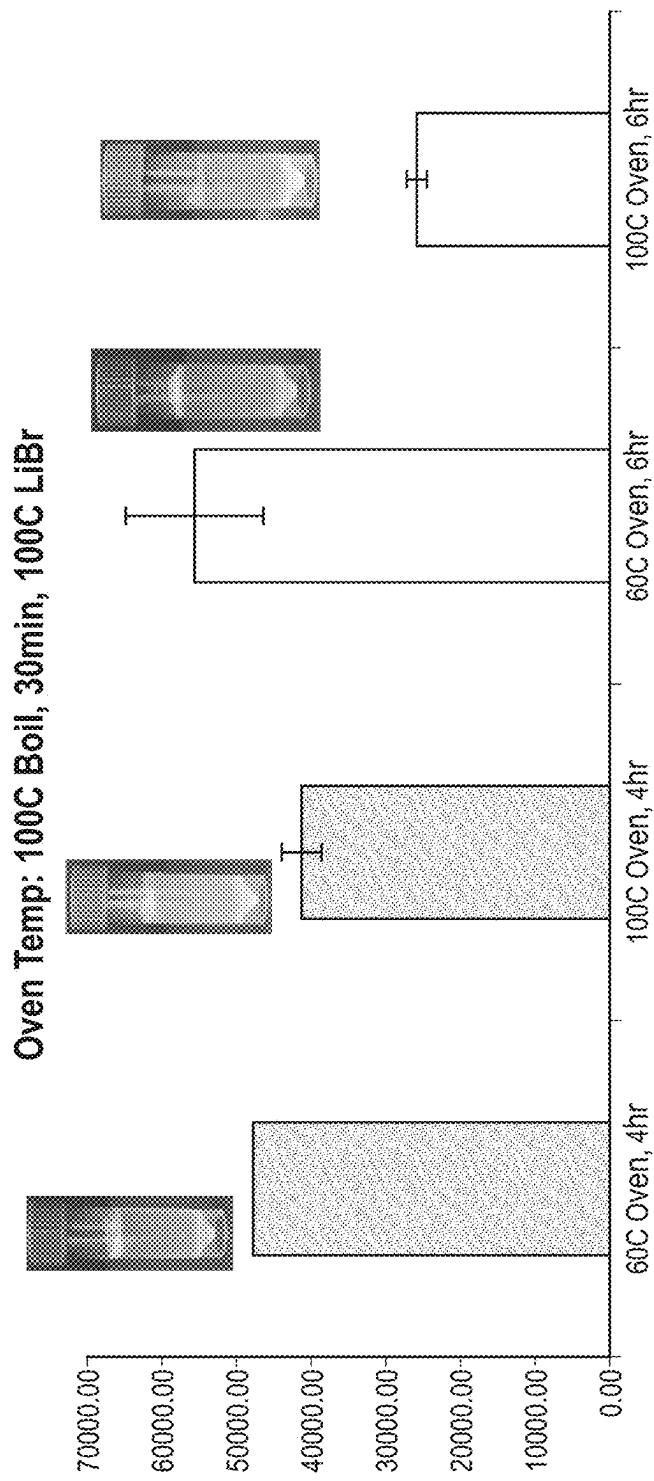


FIG. 50

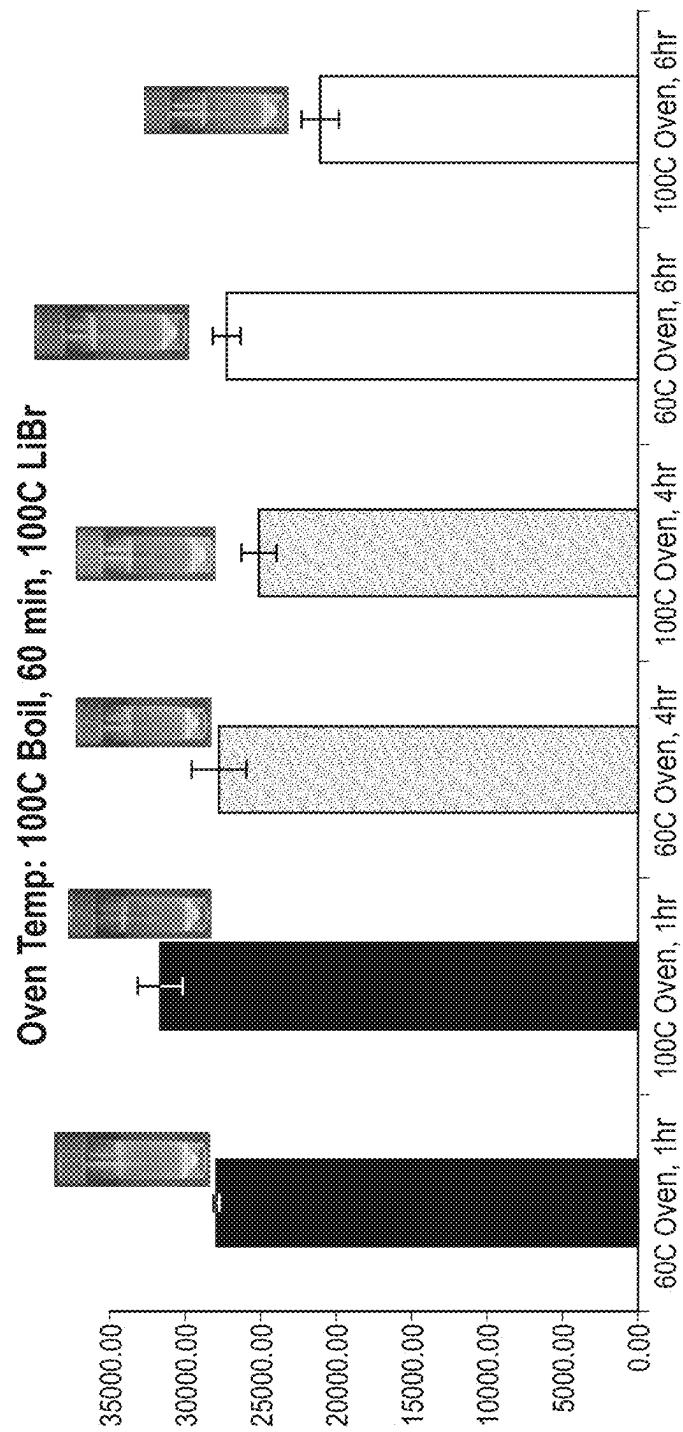


FIG. 51

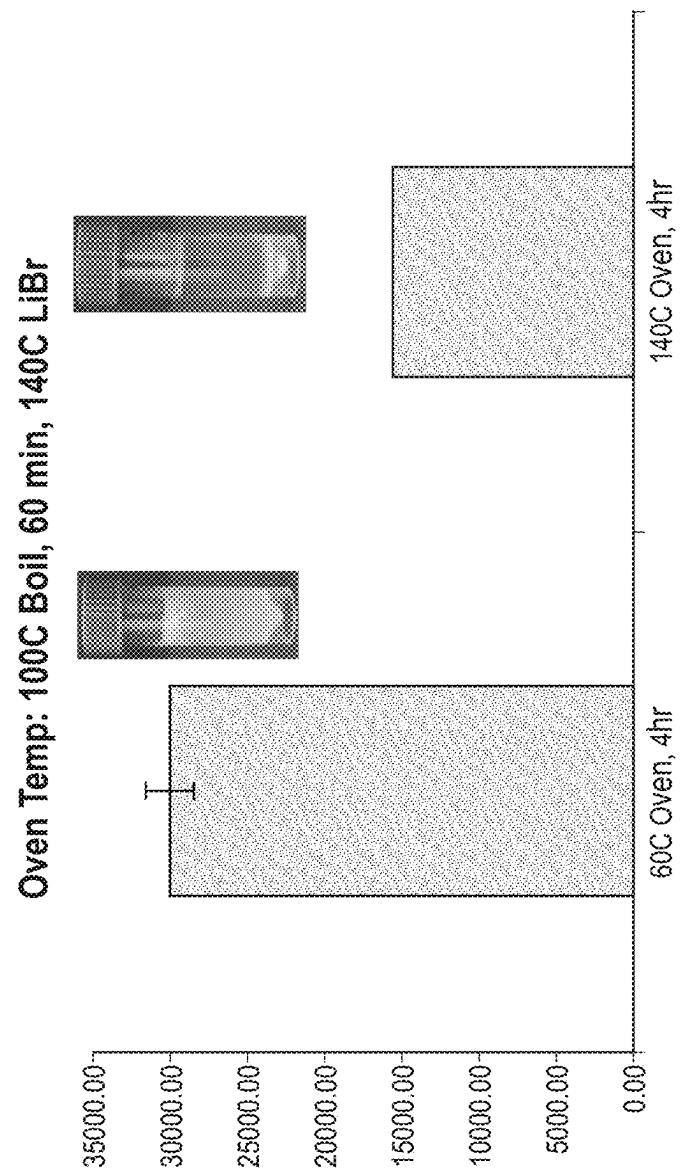


FIG. 52

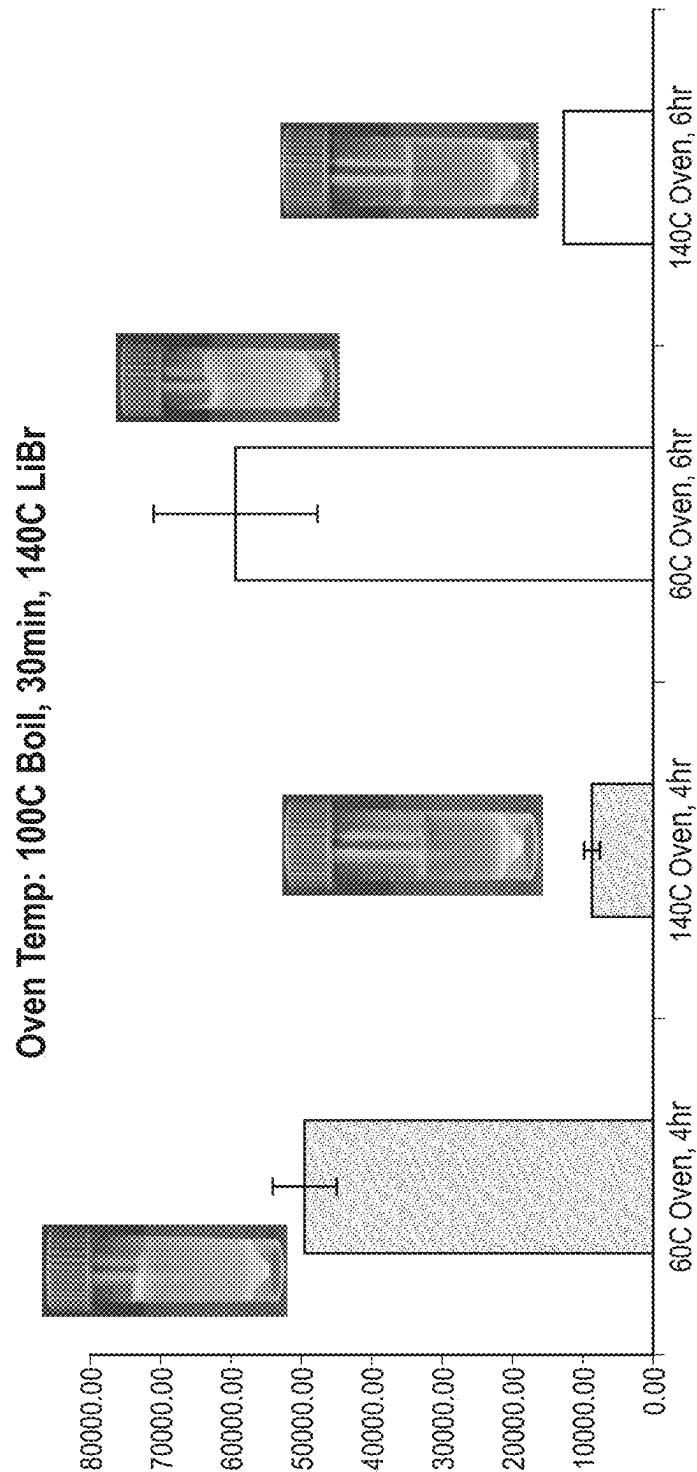


FIG. 53

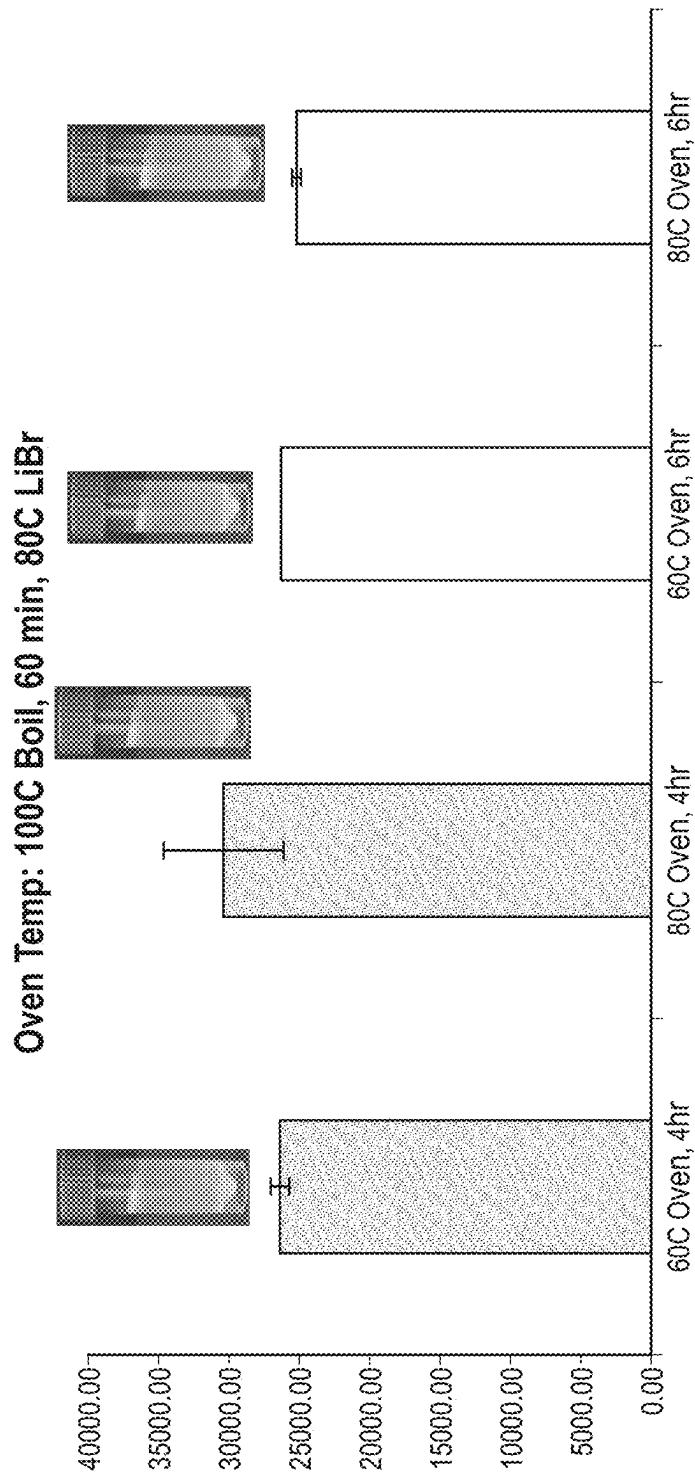
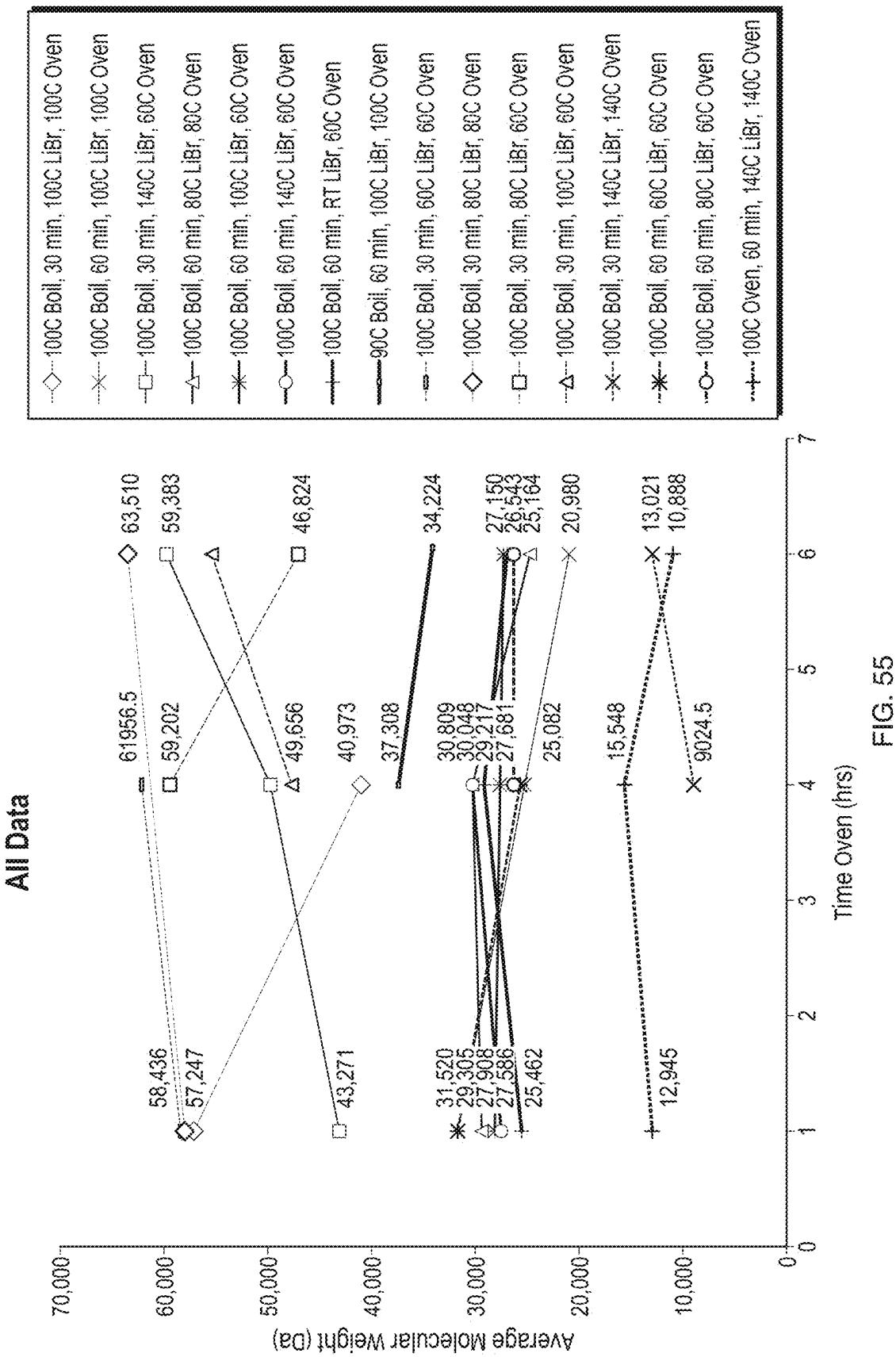


FIG. 54



Oven Temp=LiBr Temp Data: Round 2

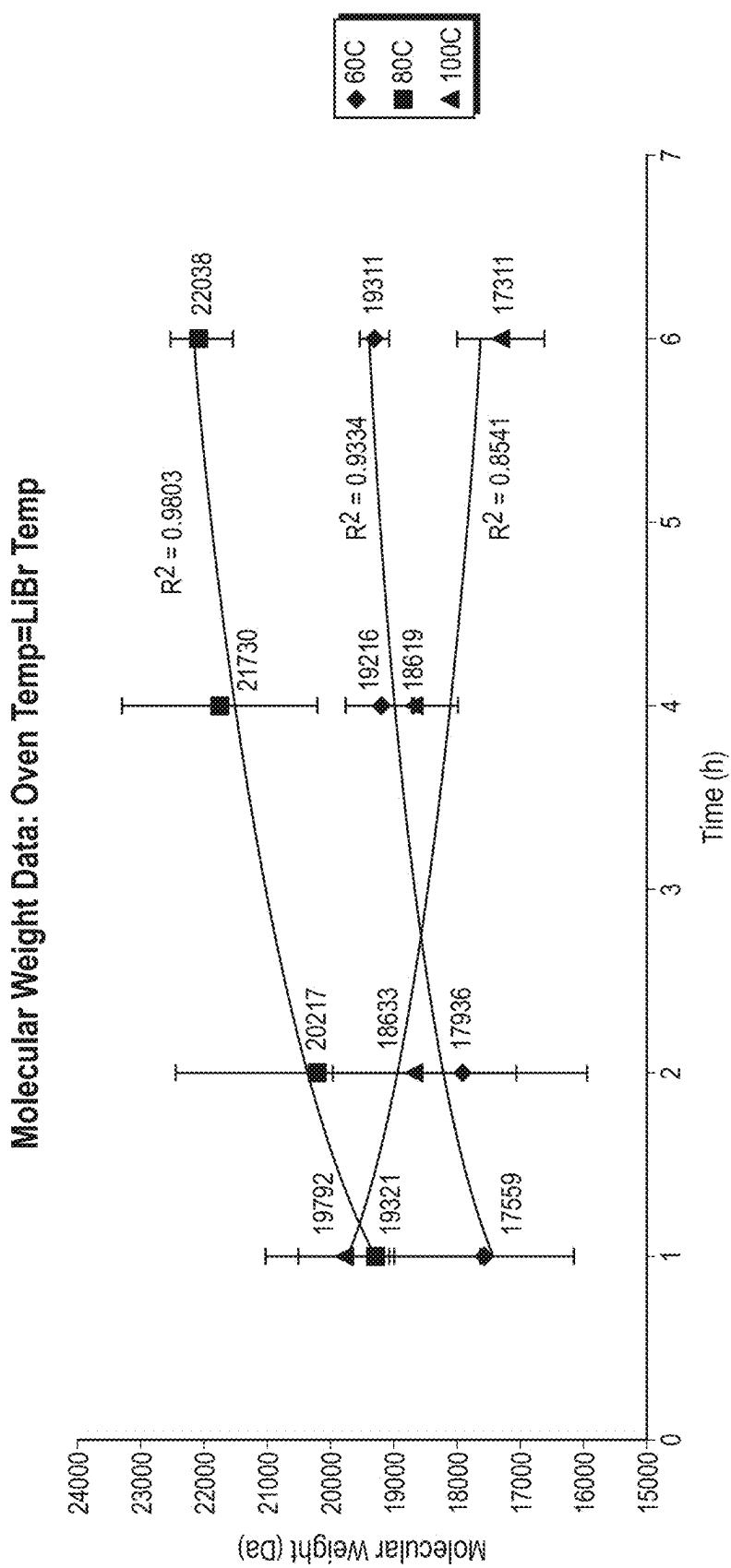


FIG. 56

wetting time with spray coating

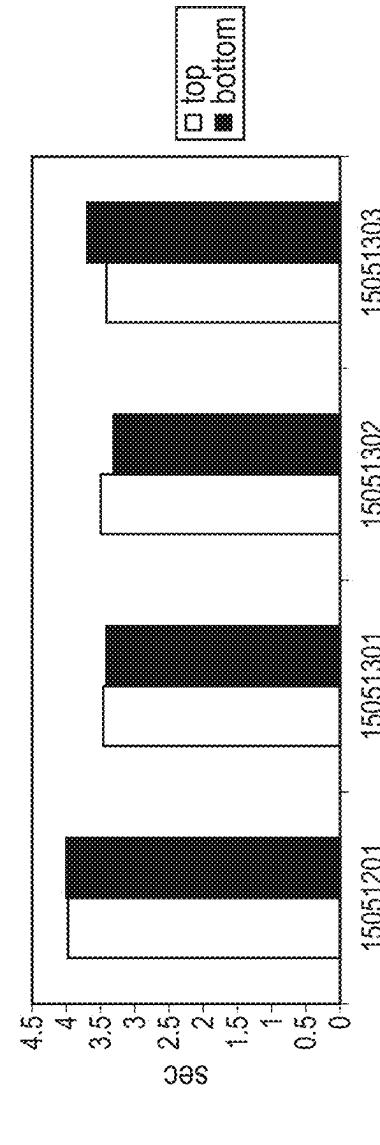


FIG. 57A

wetting time with spray coating

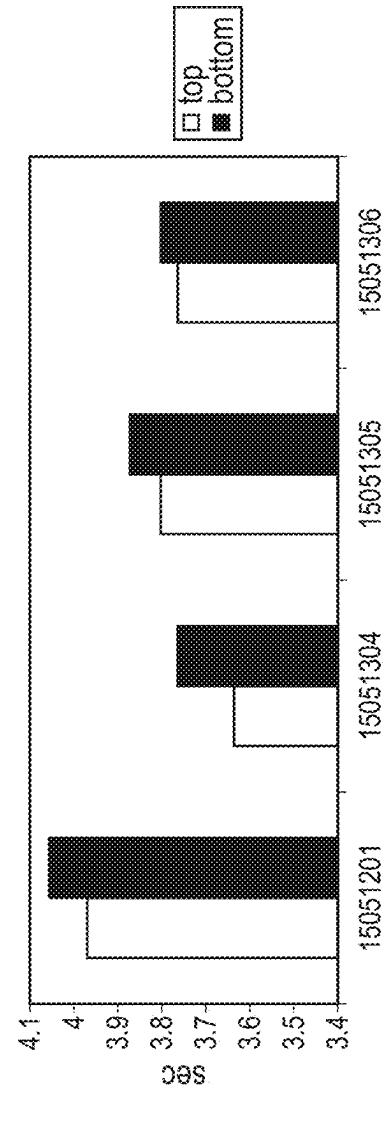


FIG. 57B

wetting time with bath coating

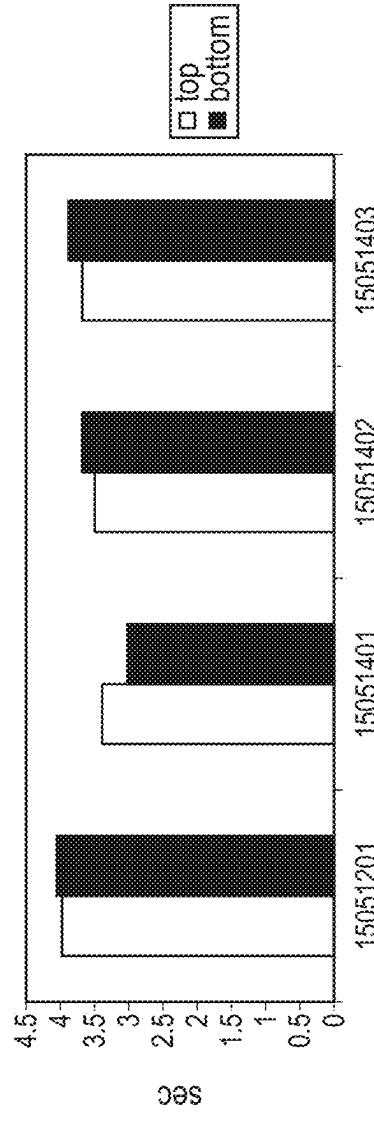


FIG. 57C

wetting time with screen coating

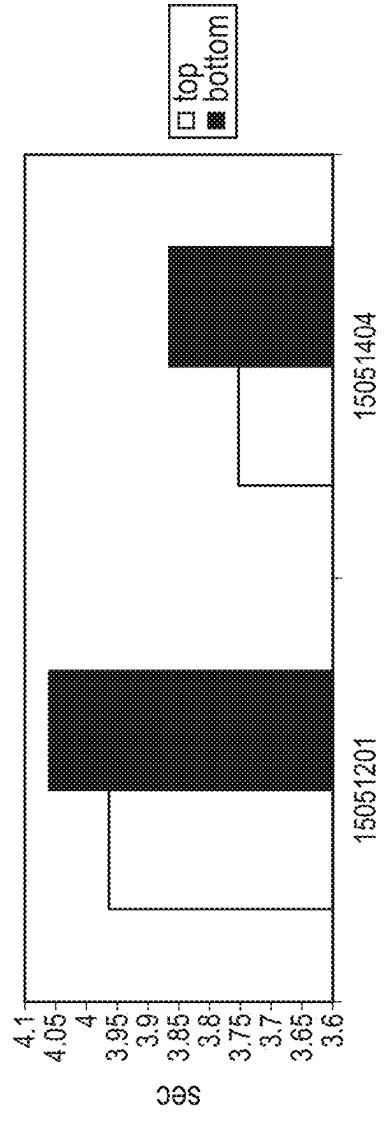


FIG. 57D

absorption time with spray coating

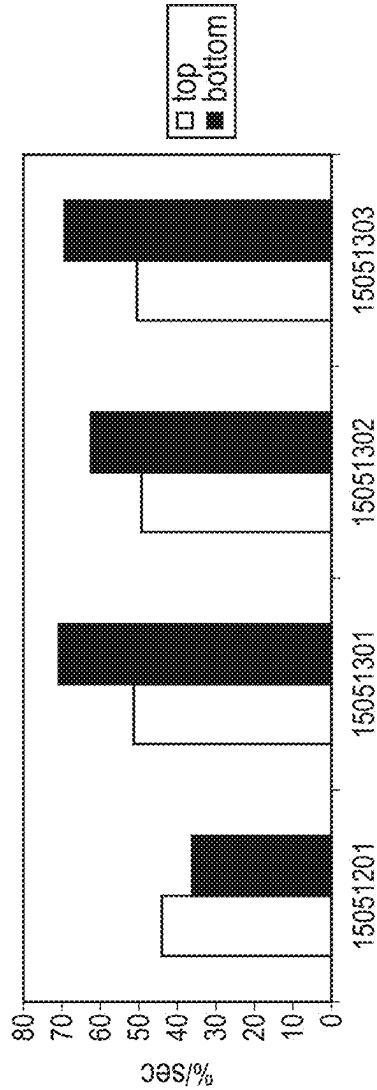


FIG. 58A

absorption time with stencil coating

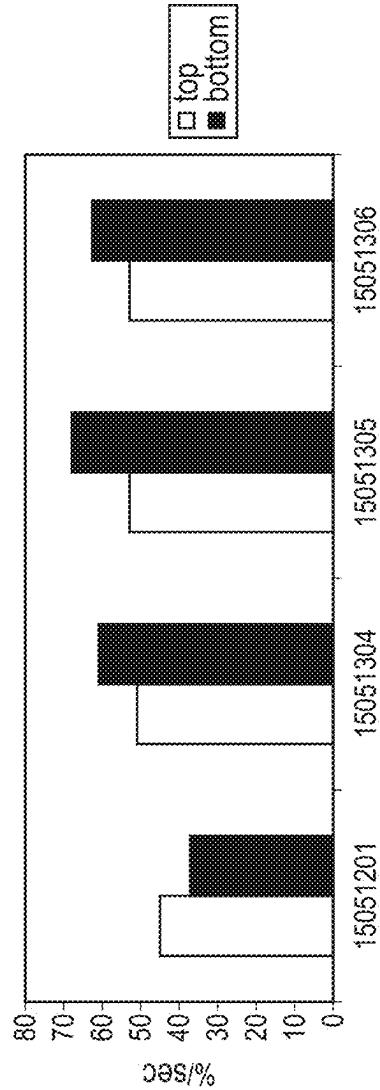


FIG. 58B

absorption time with bath coating

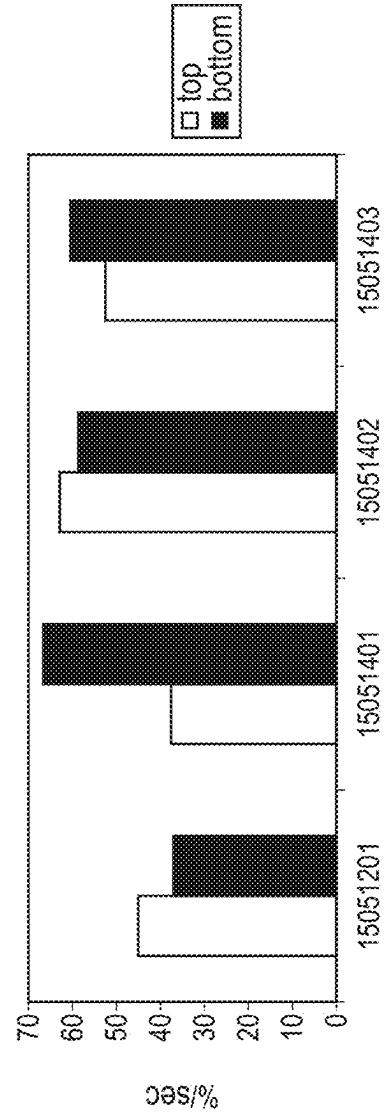


FIG. 58C

absorption time with screen coating

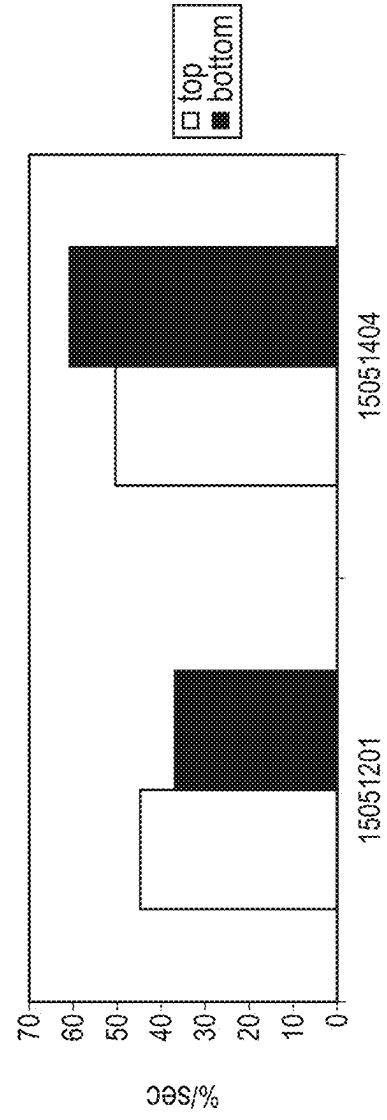


FIG. 58D

spreading speed with spray coating

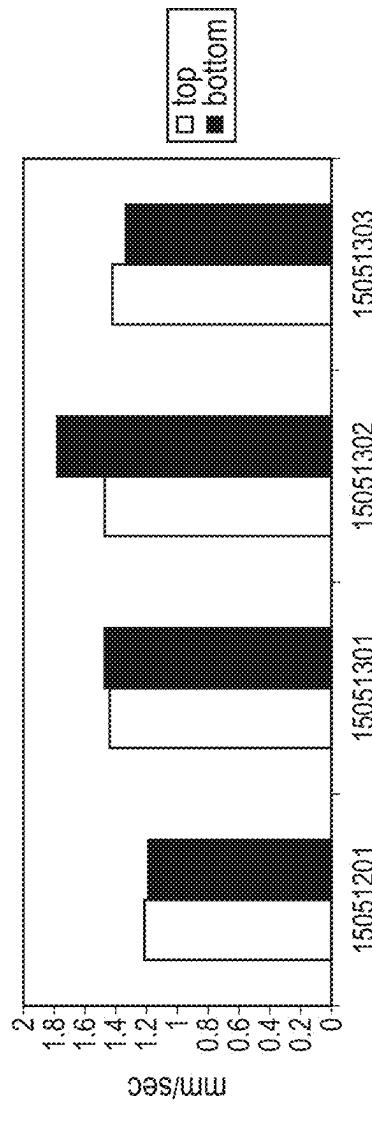


FIG. 59A

spreading speed with stencil coating

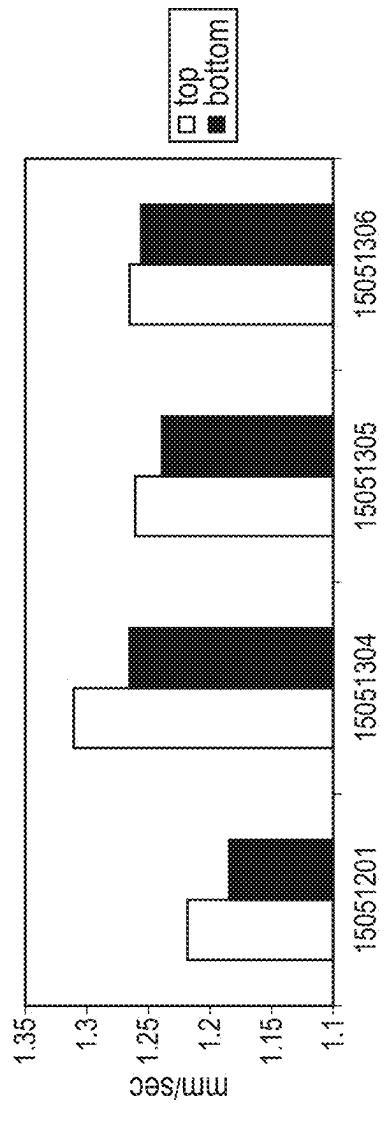


FIG. 59B

spreading speed with bath coating

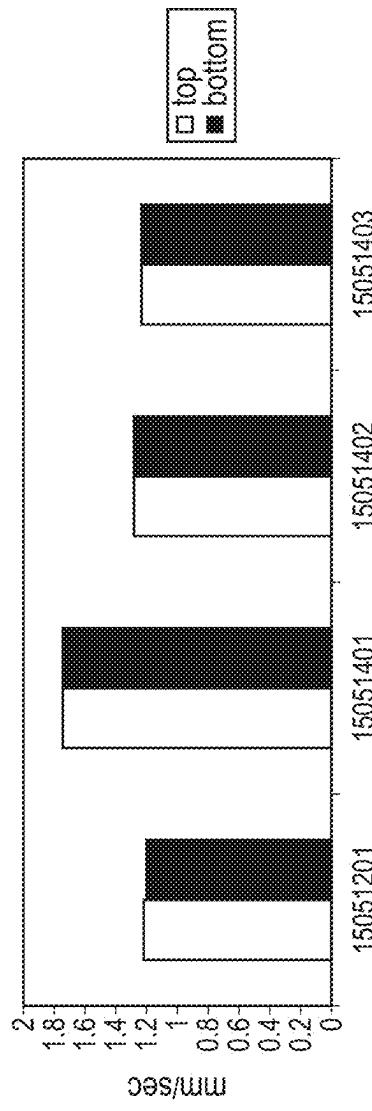


FIG. 59C

spreading speed with screen coating

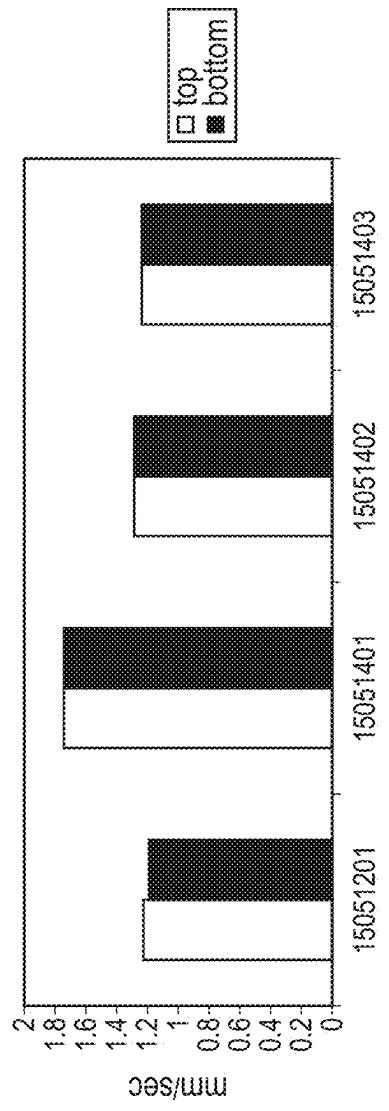


FIG. 59D

accumulative one way transport index with spray coating

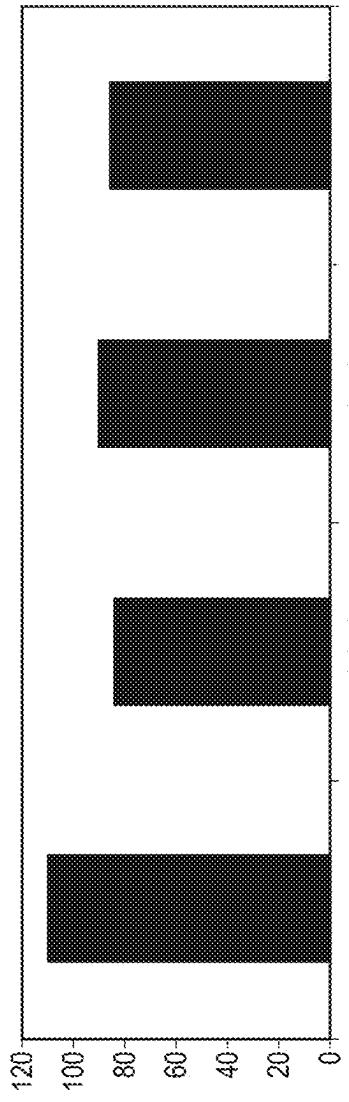


FIG. 60A

accumulative one way transport index with stencil coating

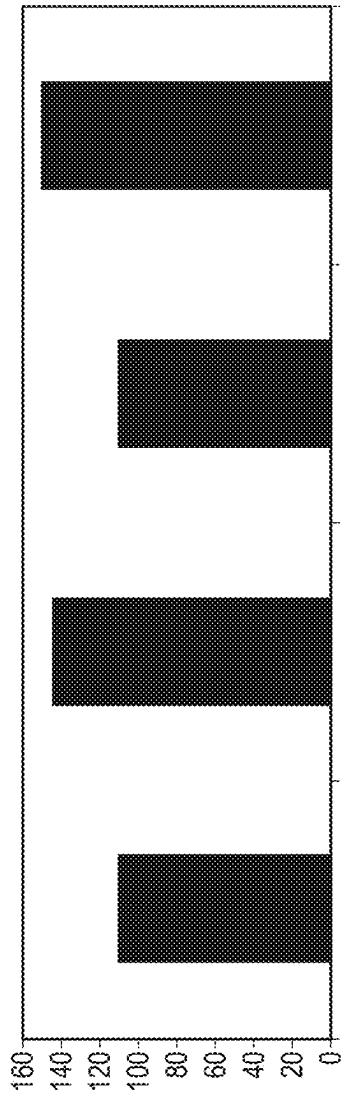


FIG. 60B

accumulative one way transport index with bath coating

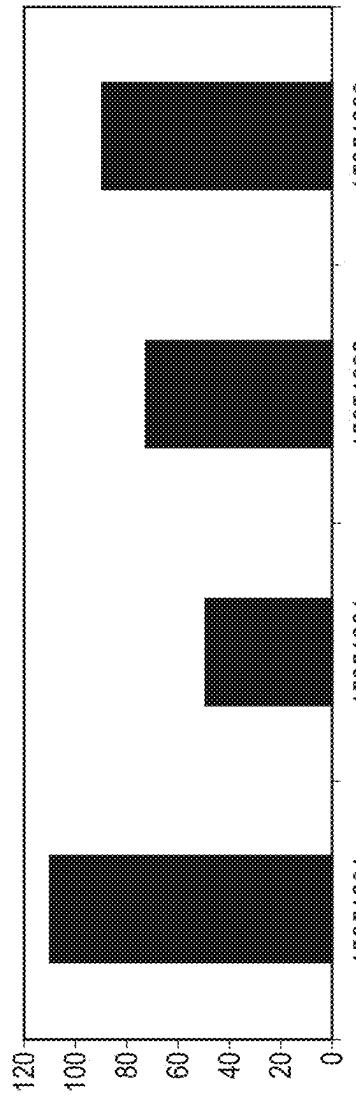


FIG. 60C

accumulative one way transport index with screen coating

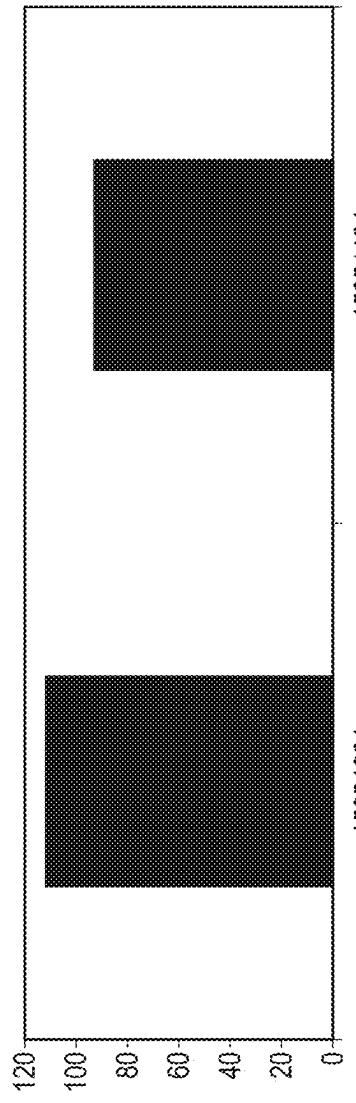


FIG. 60D

overall moisture management capability with spray coating

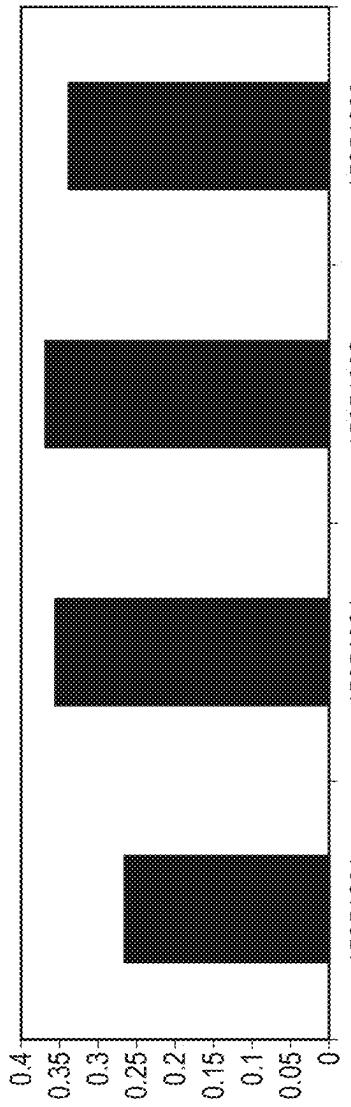


FIG. 61A

overall moisture management capability with stencil coating

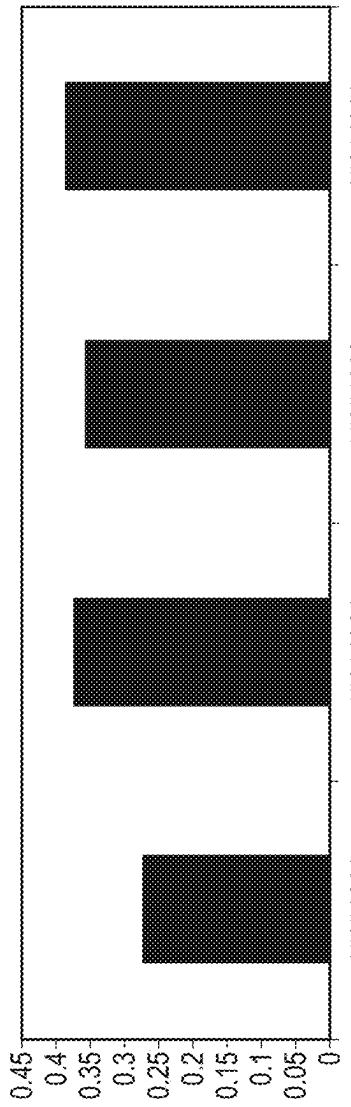


FIG. 61B

overall moisture management capability with bath coating

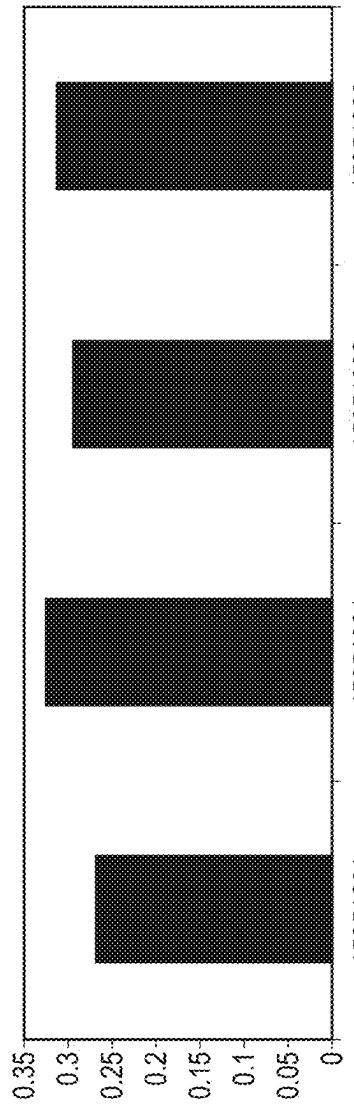


FIG. 61C

overall moisture management capability with screen coating

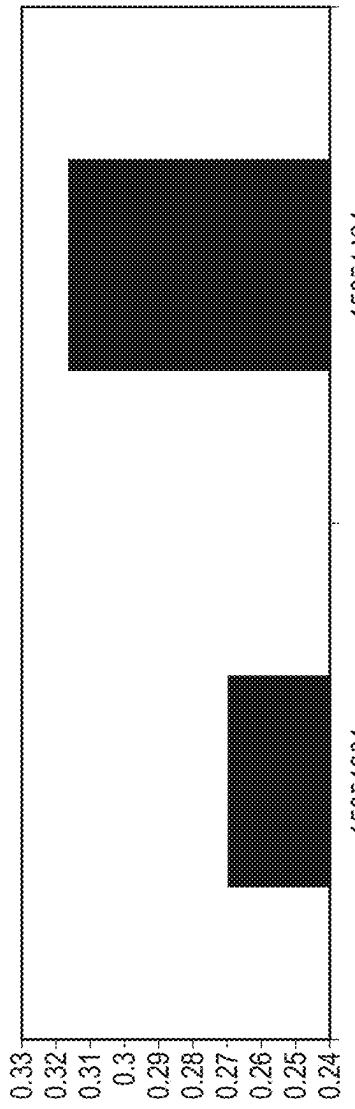


FIG. 61D

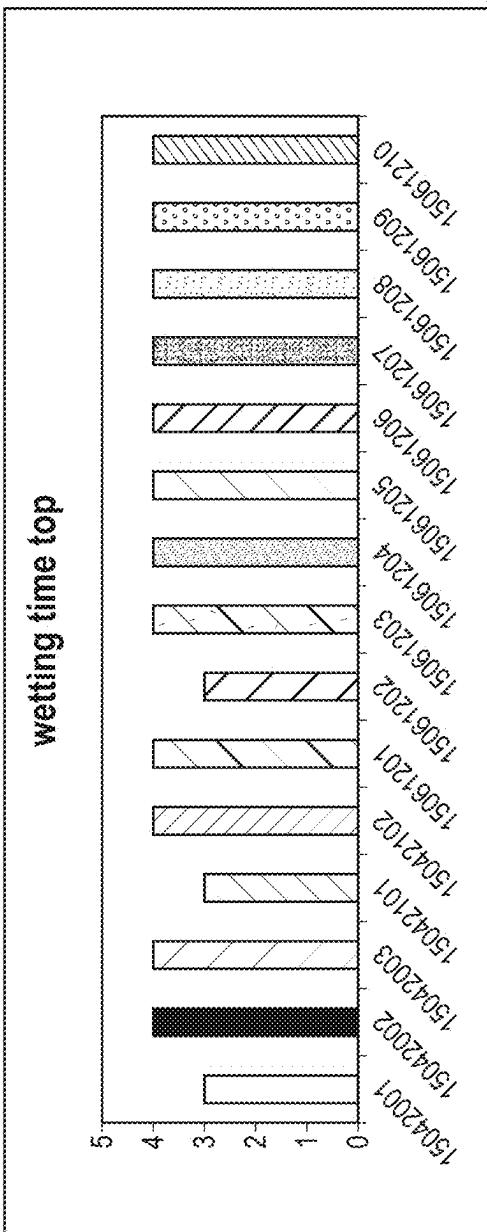


FIG. 62A

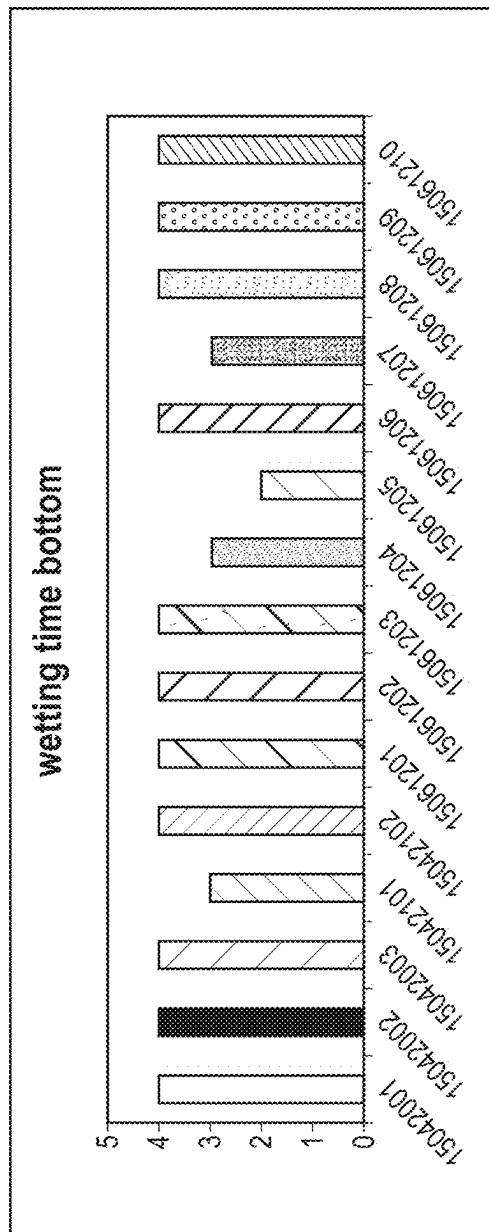


FIG. 62B

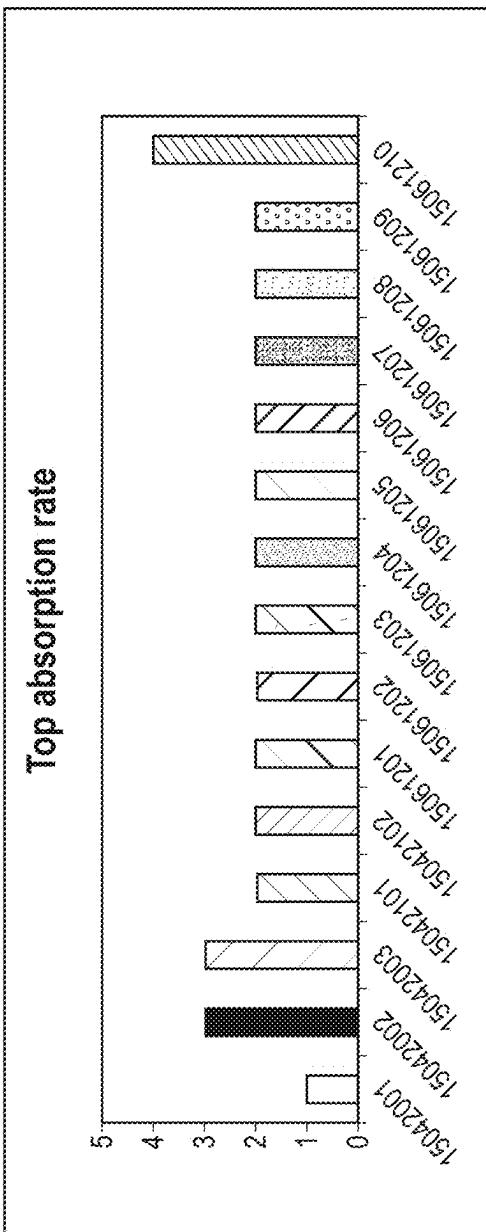


FIG. 63A

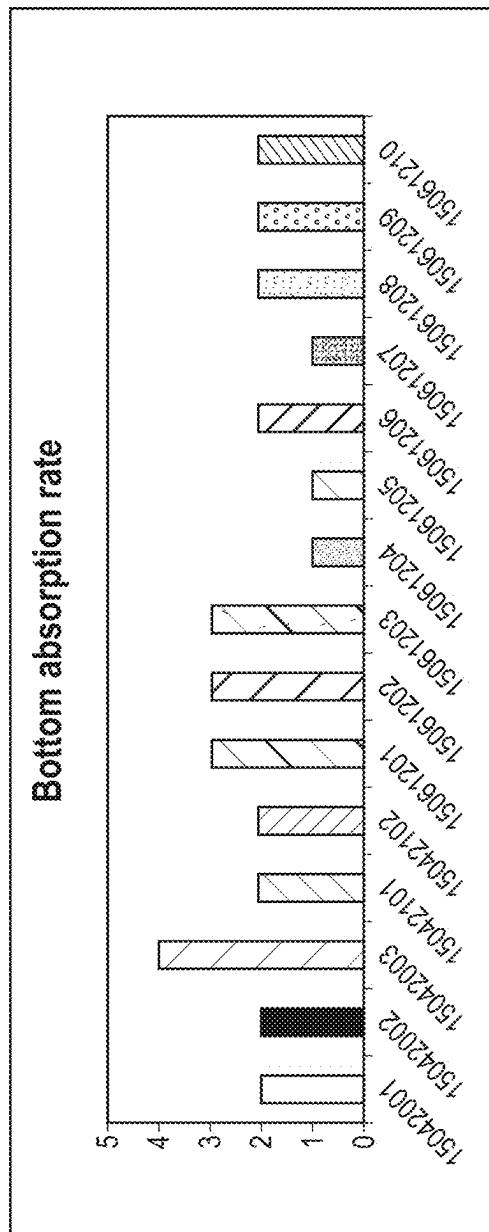


FIG. 63B

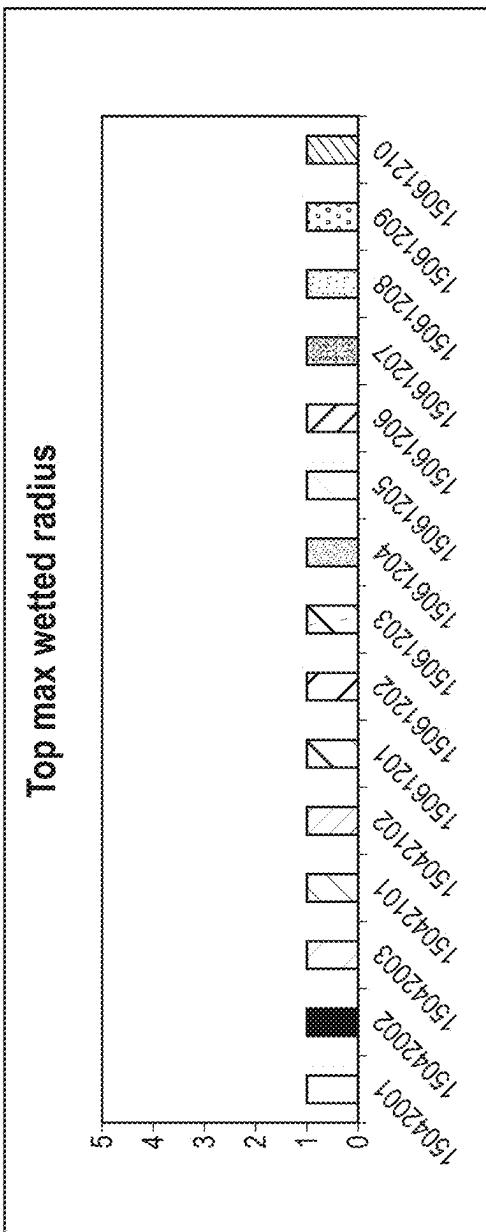


FIG. 64A

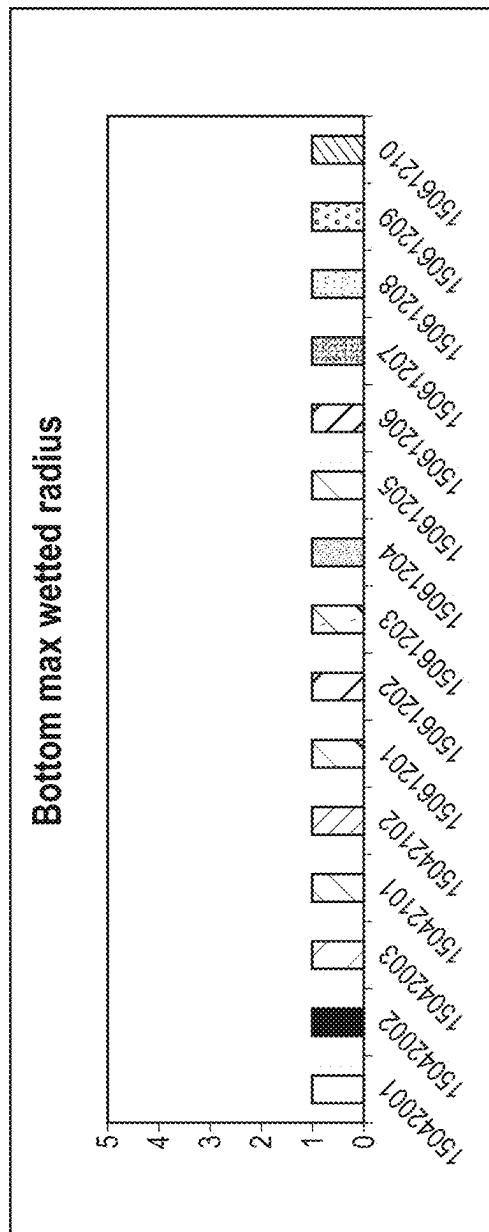


FIG. 64B

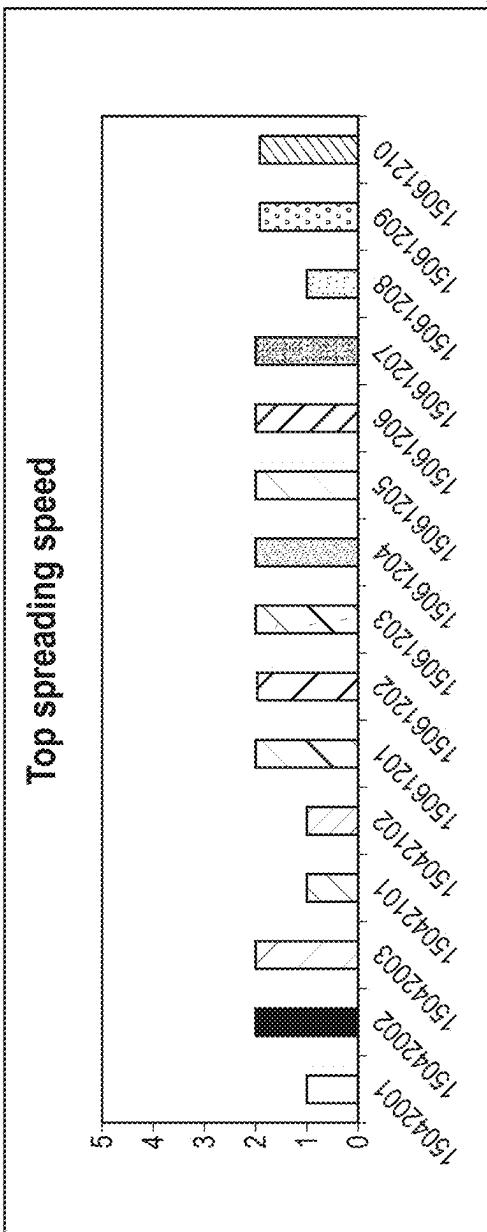


FIG. 65A

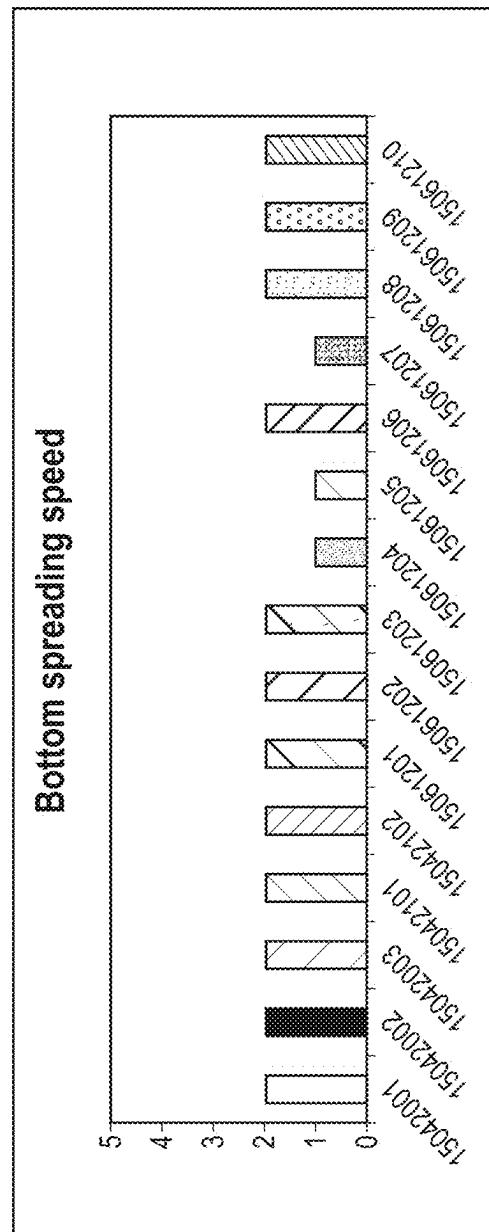
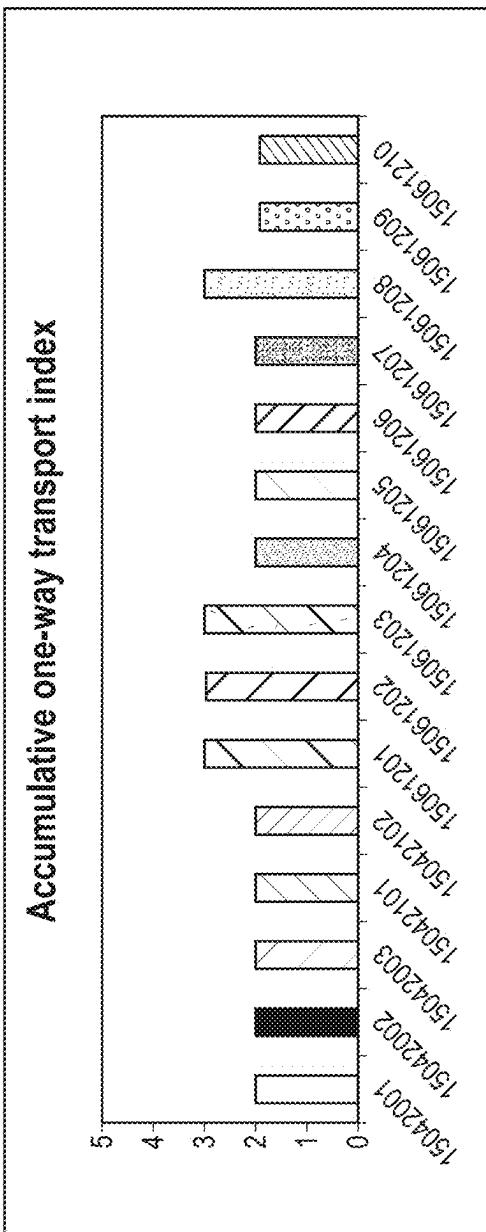


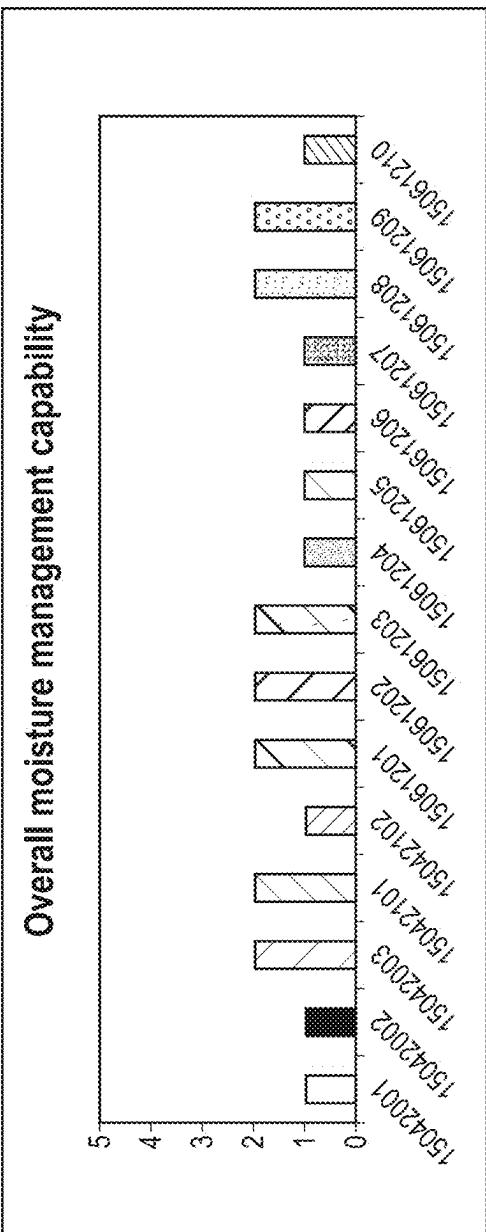
FIG. 65B

Accumulative one-way transport index



EIG. 66A

Overall moisture management capability



115

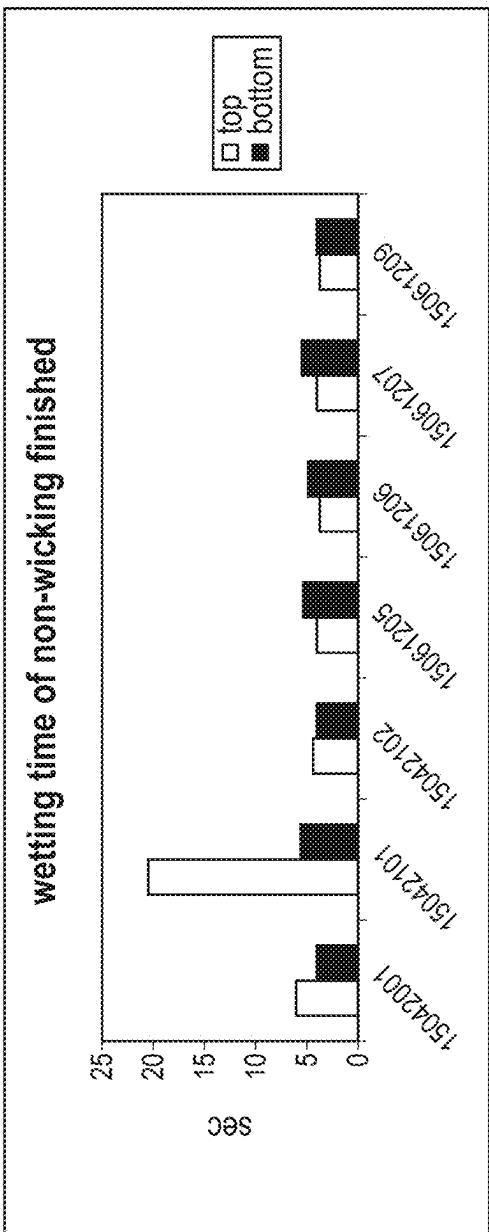


FIG. 67A

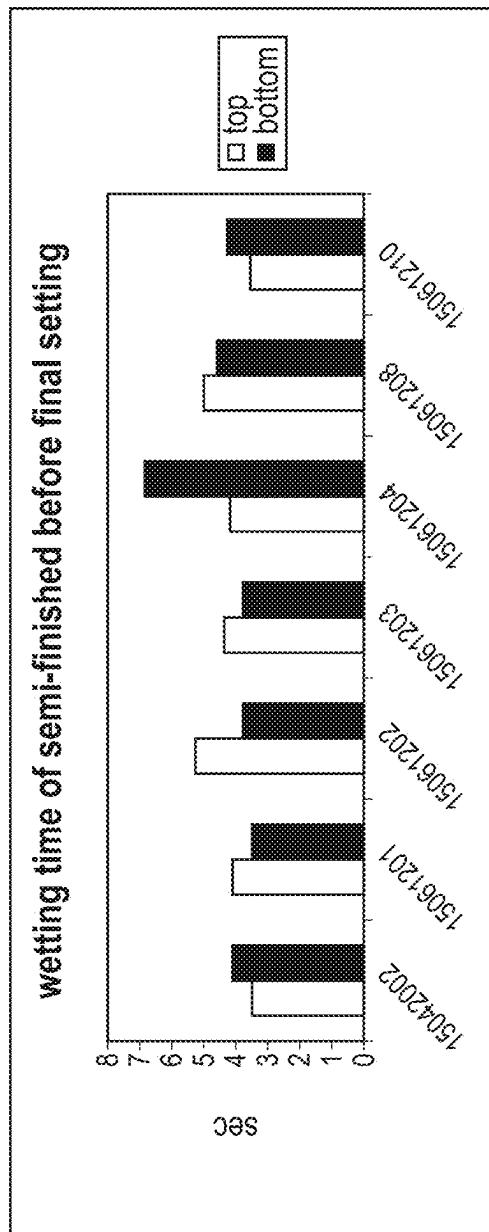
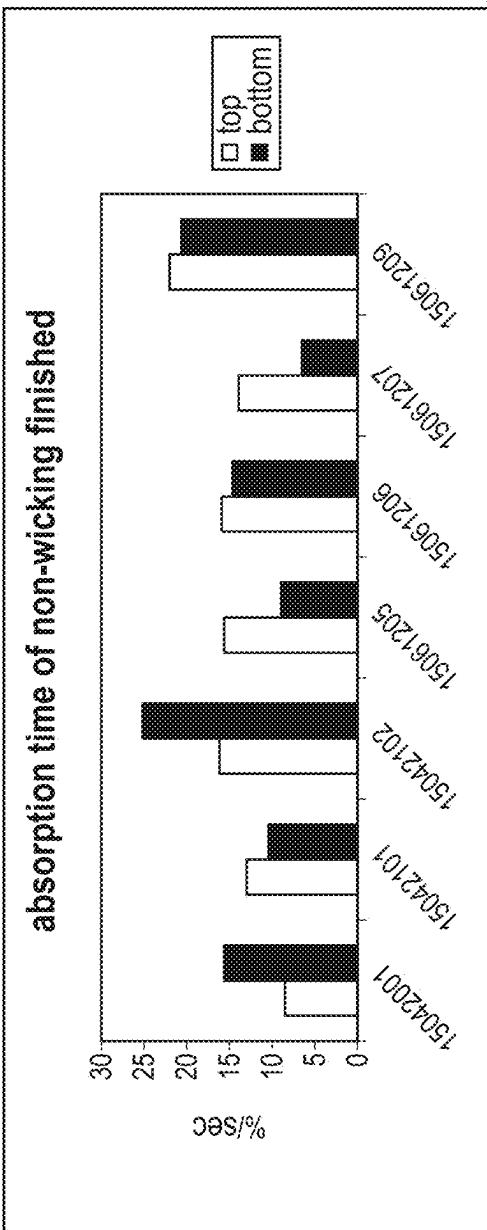
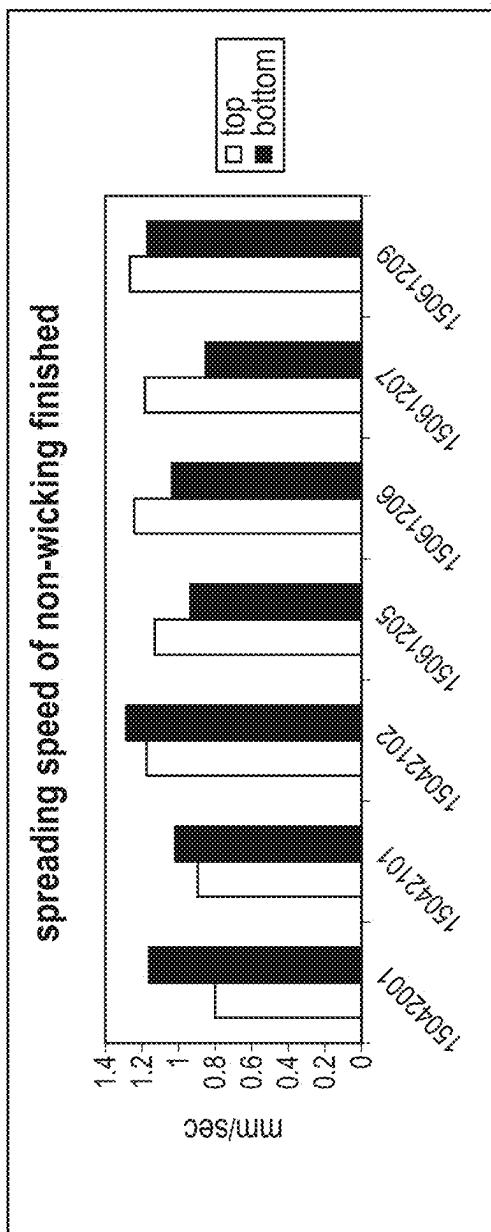


FIG. 67B





EIG. 69A

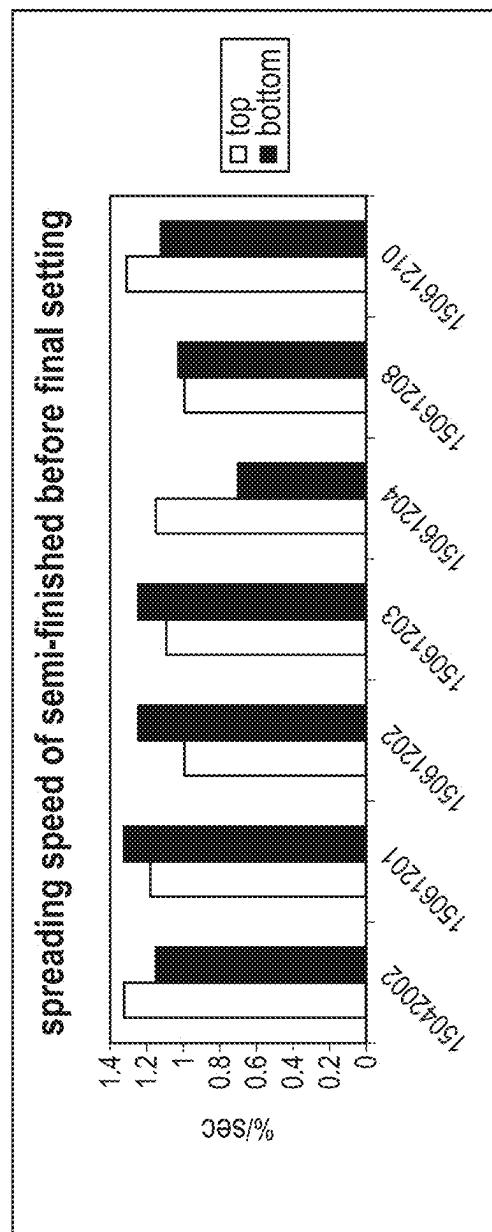


FIG. 69B

accumulative one way transport index of non-wicking finished

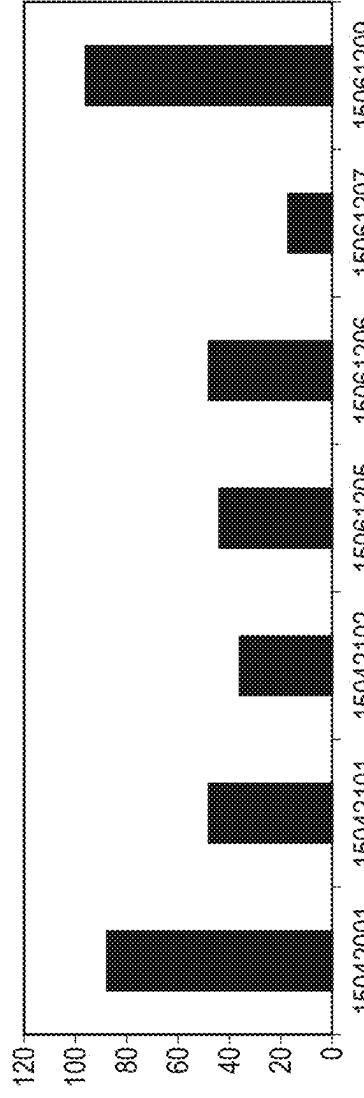


FIG. 70A

accumulative one way transport index of semi-finished before final setting

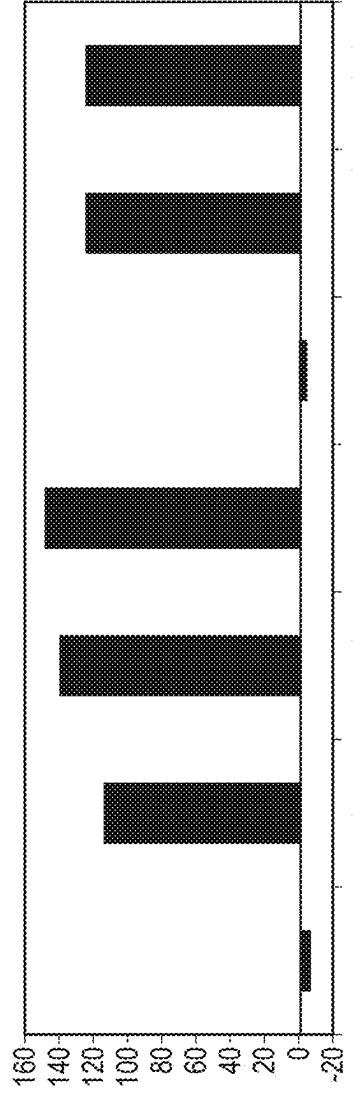


FIG. 70B

Overall moisture management capability of non-wicking finished

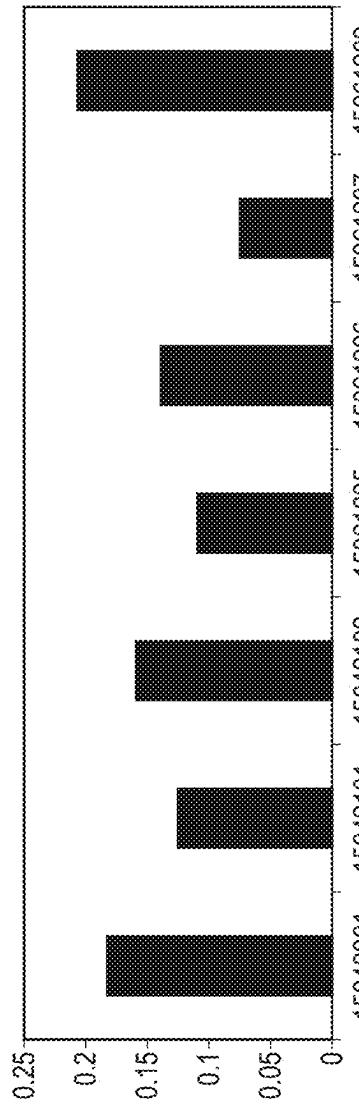


FIG. 71A

overall moisture management capability of semi-finished before final setting

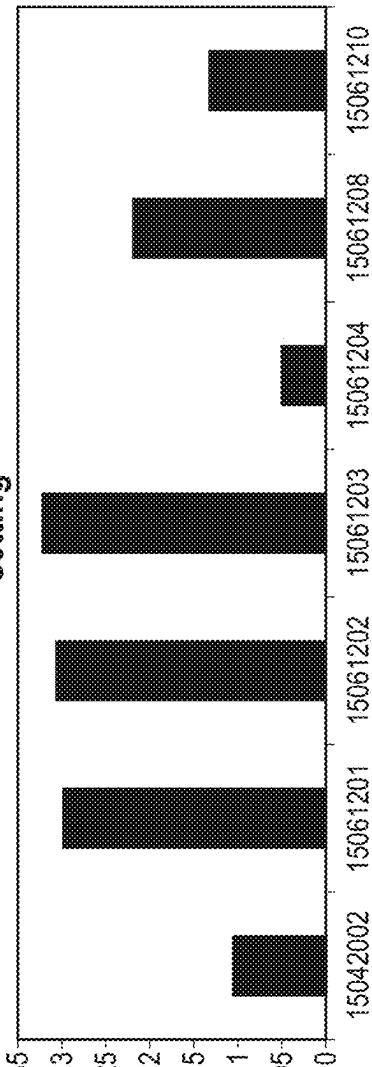


FIG. 71B

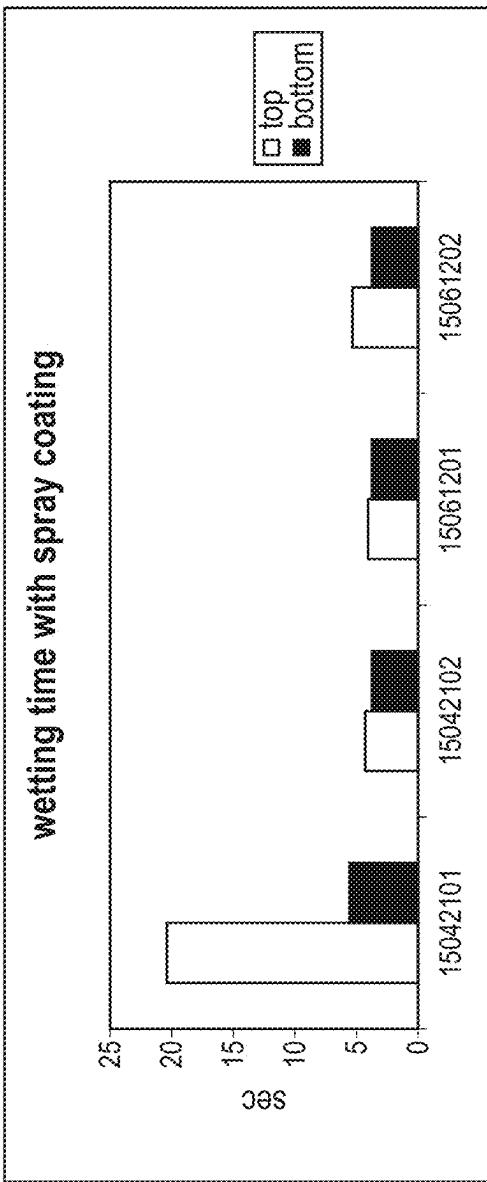


FIG. 72A

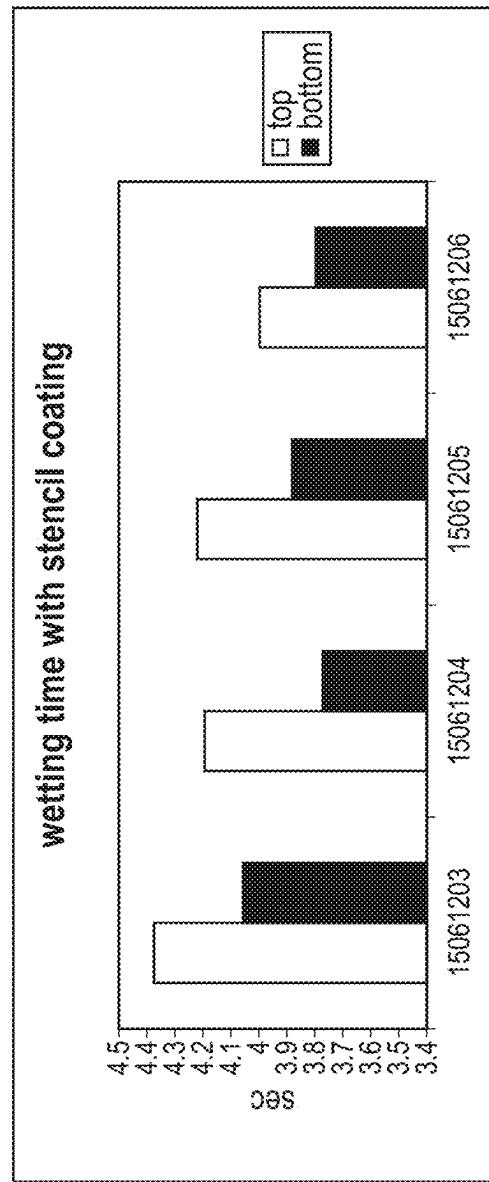


FIG. 72B

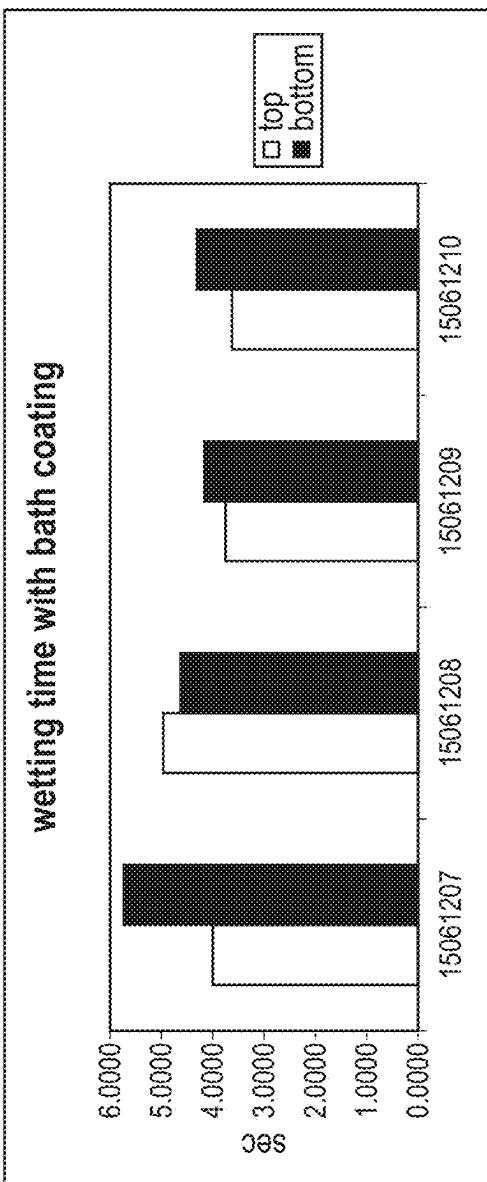


FIG. 72C

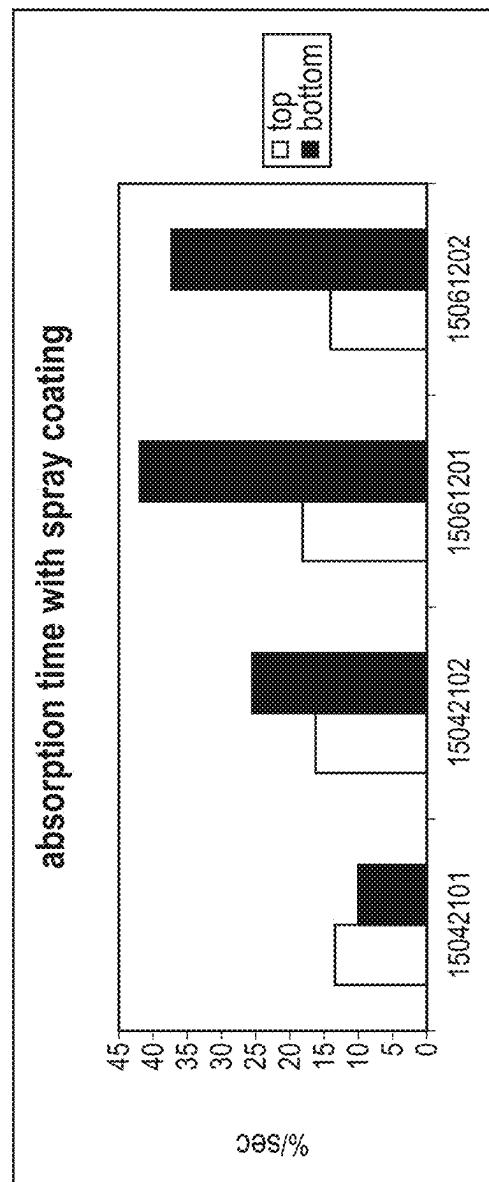


FIG. 73A

absorption time with stencil coating

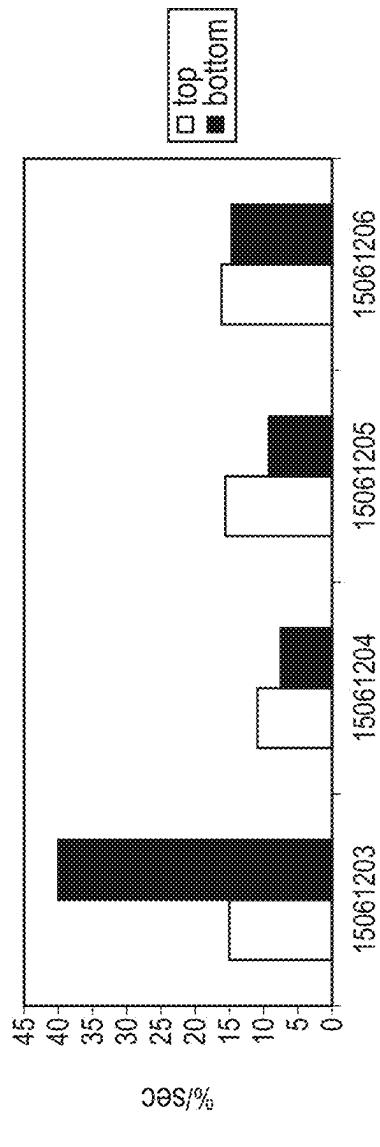


FIG. 73B

absorption time with bath coating

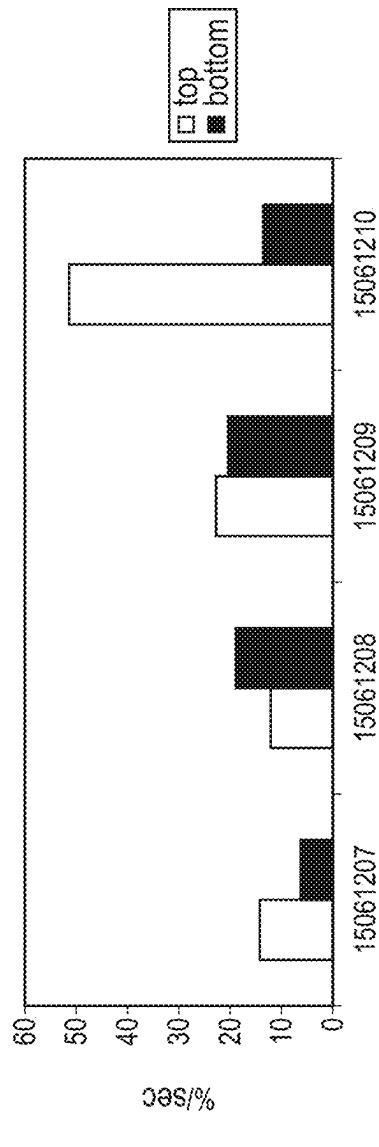


FIG. 73C

spreading speed with spray coating

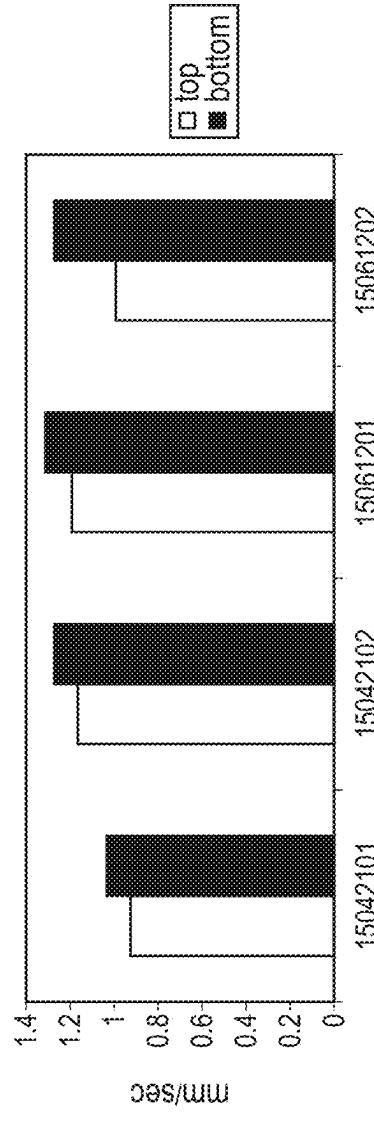


FIG. 74A

spreading speed with stencil coating

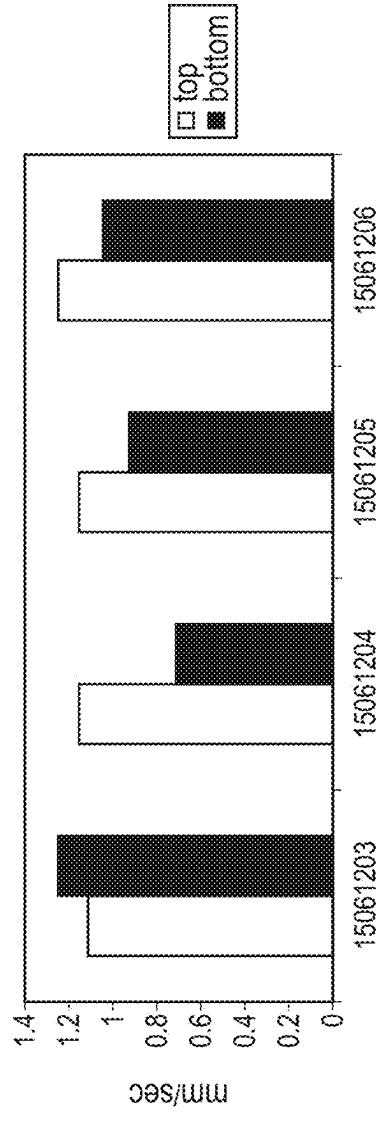


FIG. 74B

spreading speed with bath coating

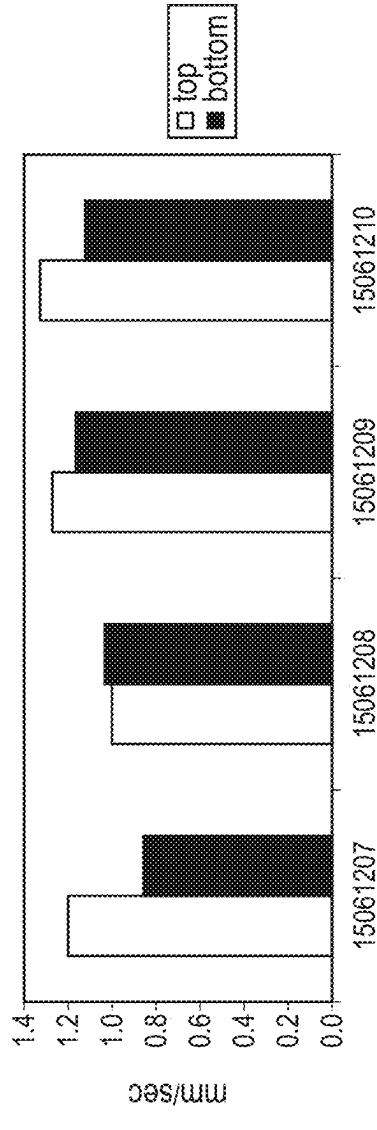


FIG. 74C

accumulative one way transport index with spray coating

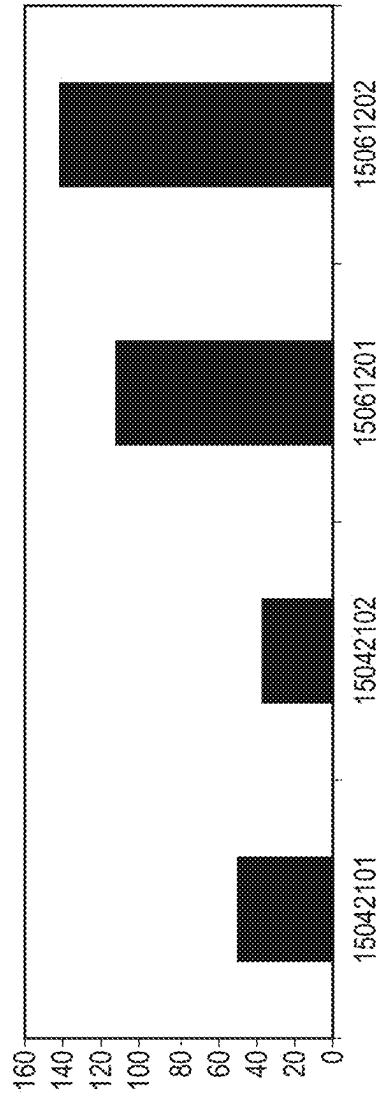


FIG. 75A

accumulative one way transport index with stencil coating

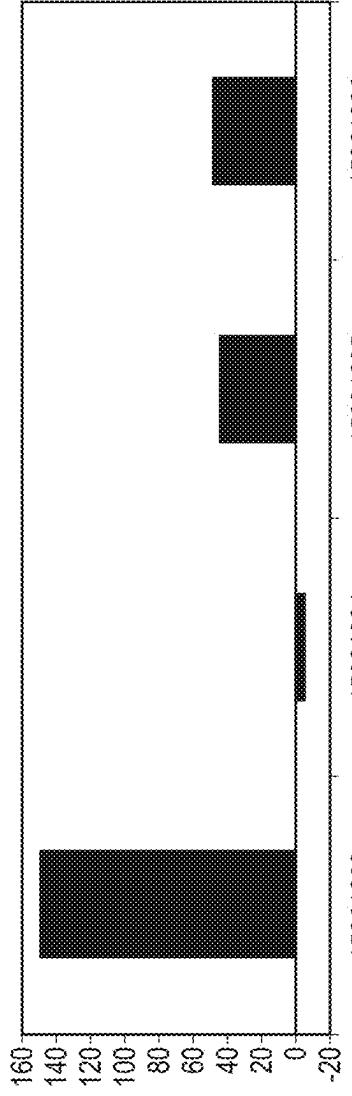


FIG. 75B

accumulative one way transport index with bath coating

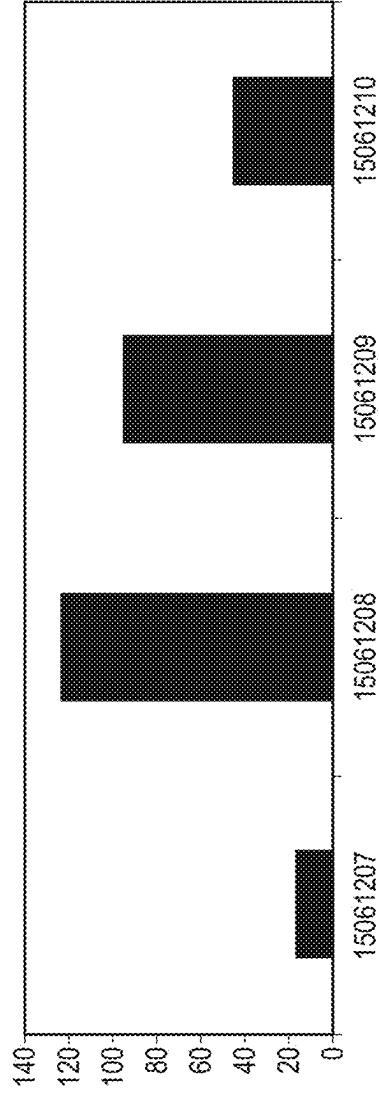


FIG. 75C

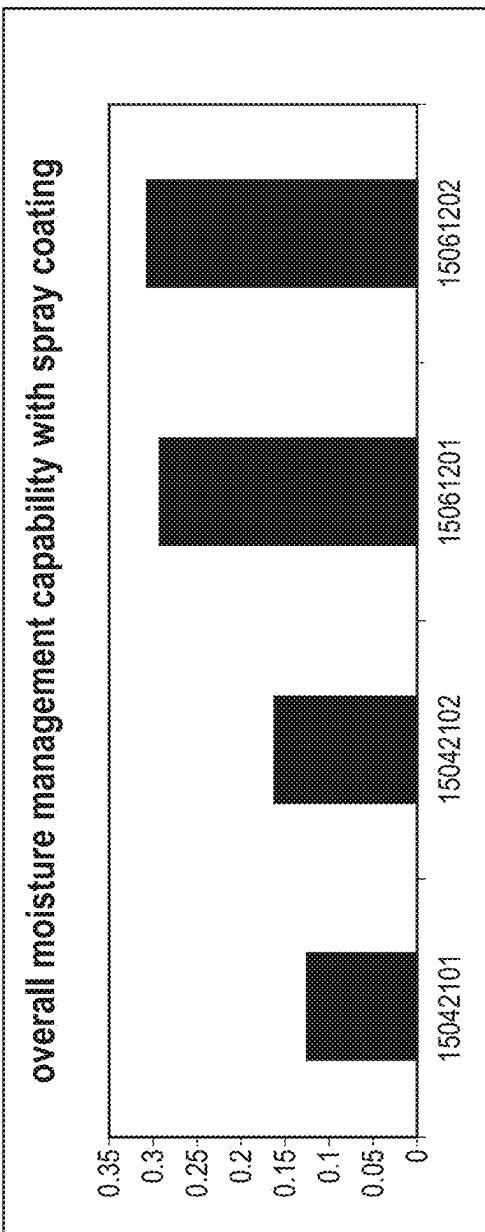


FIG. 76A

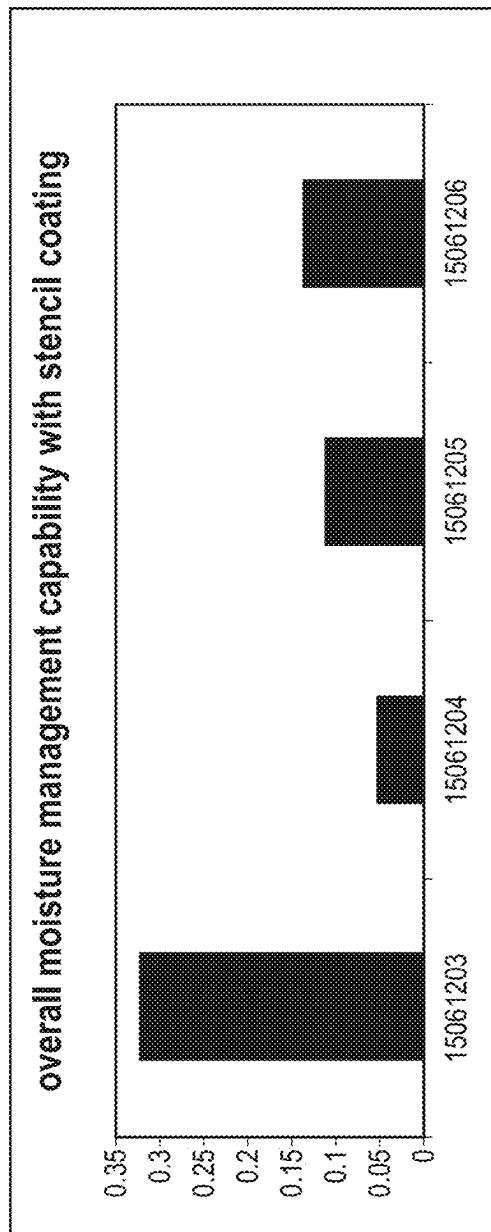


FIG. 76B

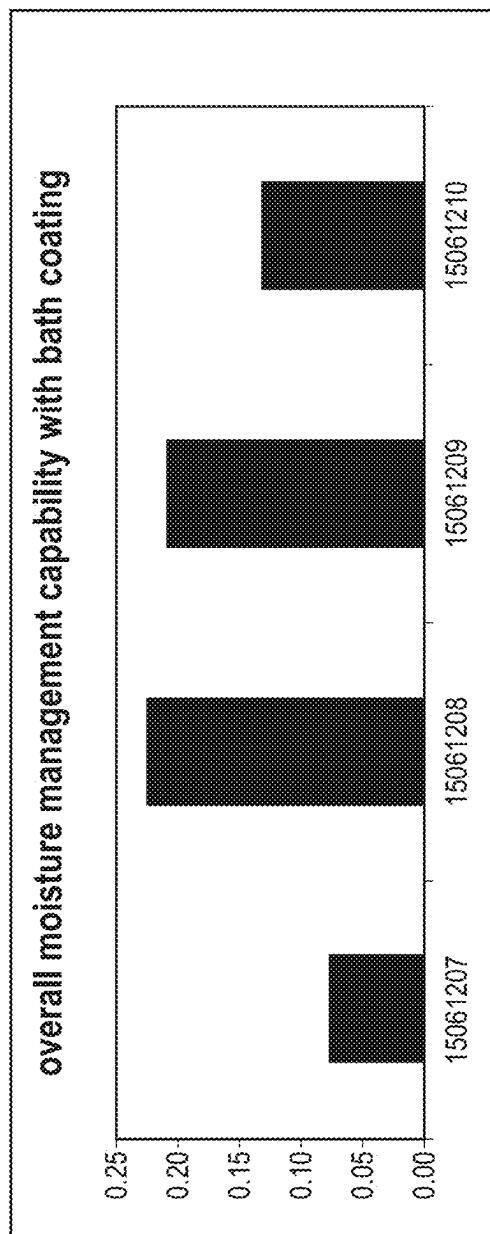


FIG. 76C

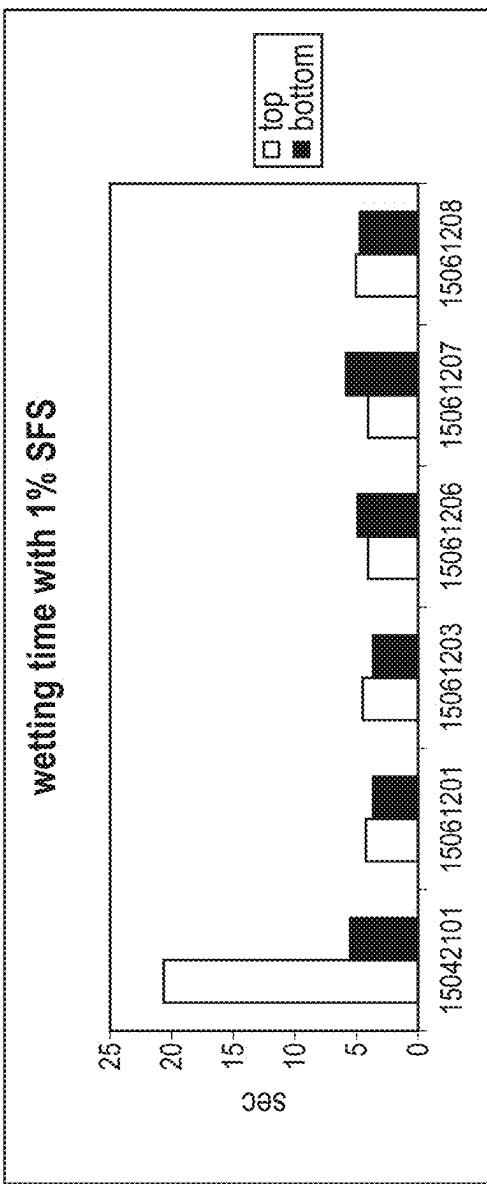


FIG. 77A

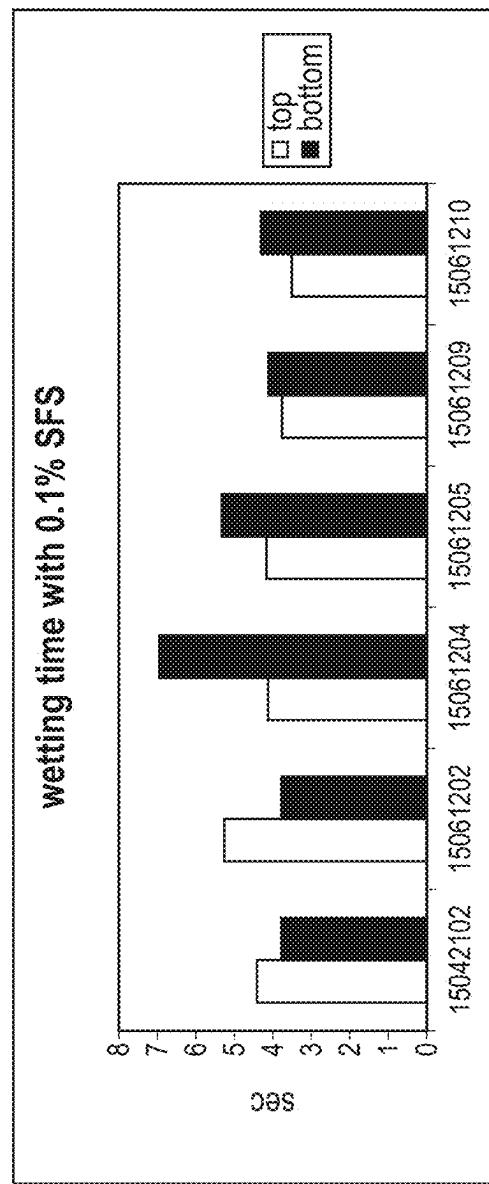


FIG. 77B

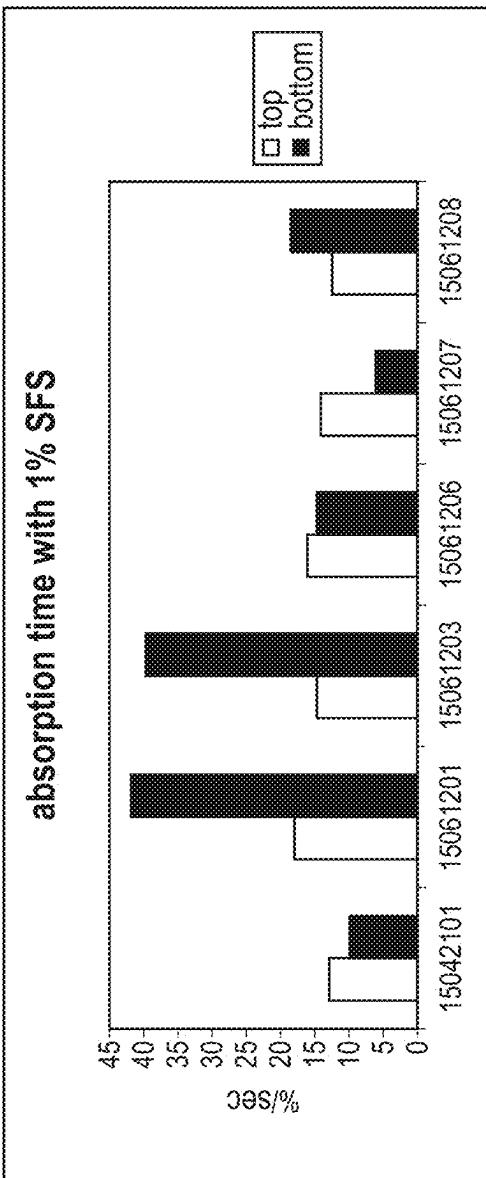


FIG. 78A

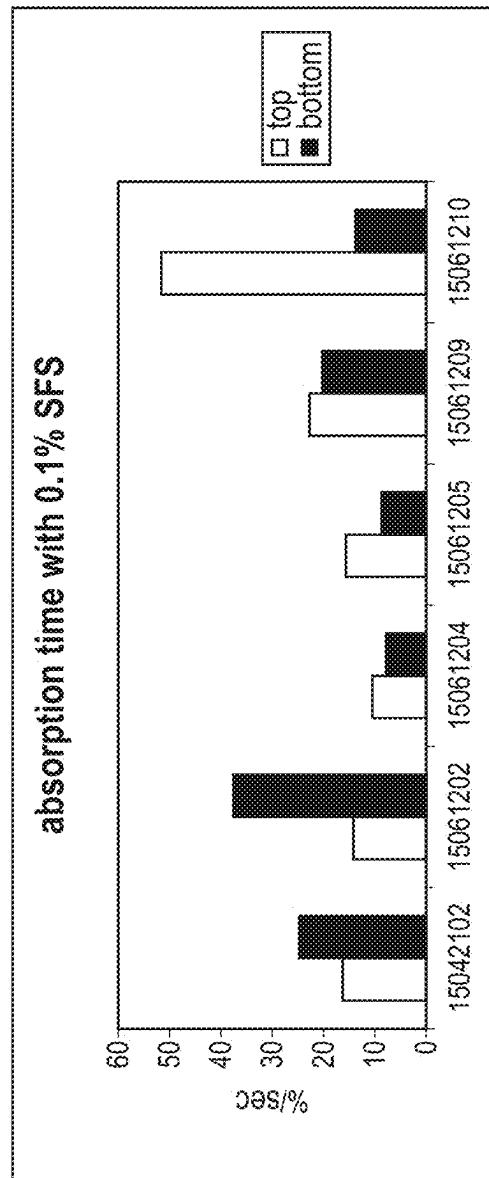


FIG. 78B

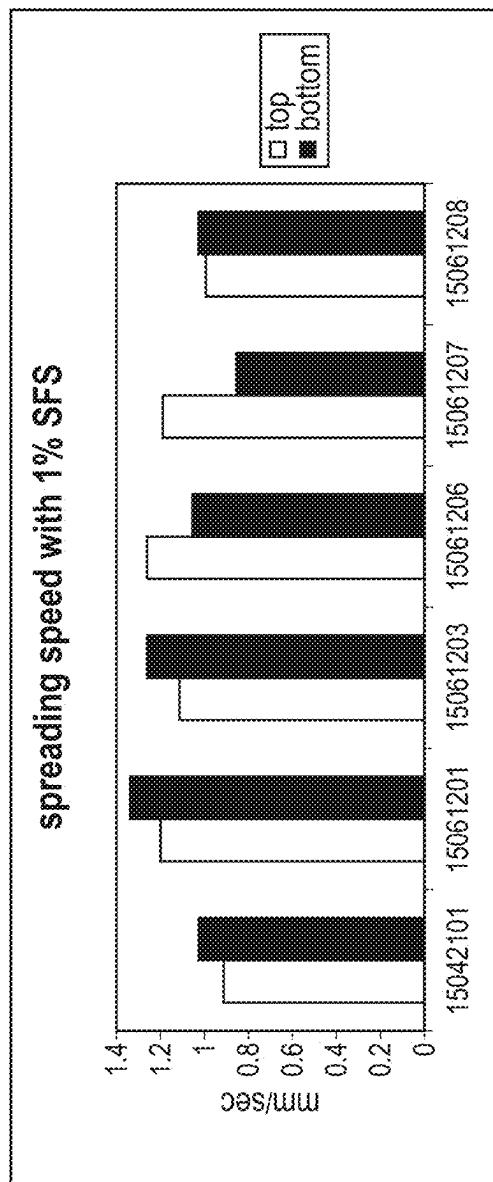


FIG. 79A

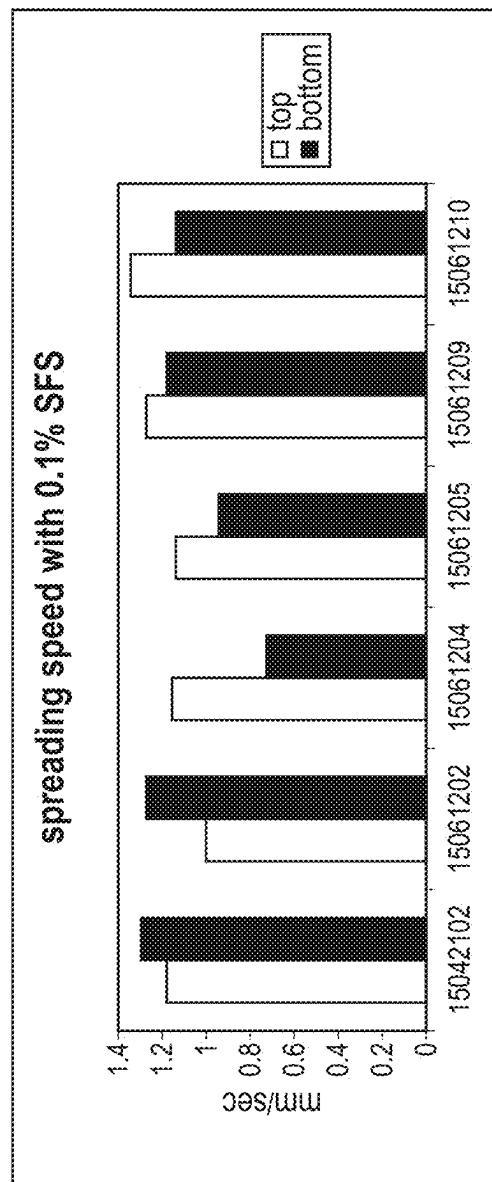


FIG. 79B

accumulative one way transport index with 1% SFS

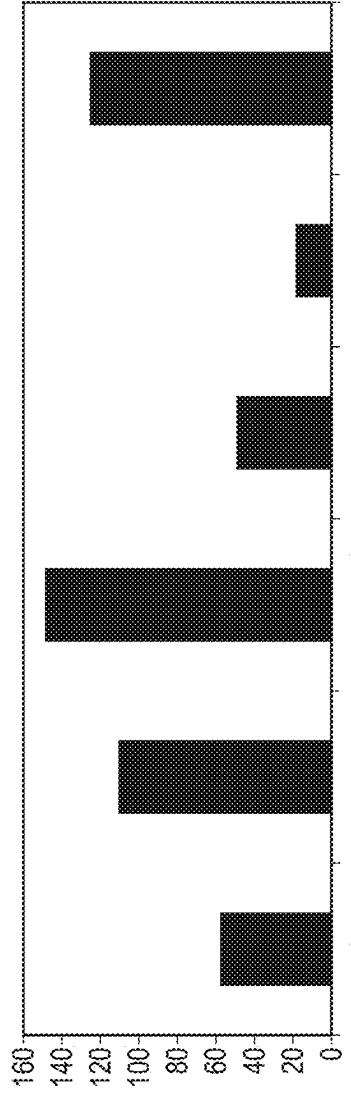


FIG. 80A

accumulative one way transport index with 0.1% SFS

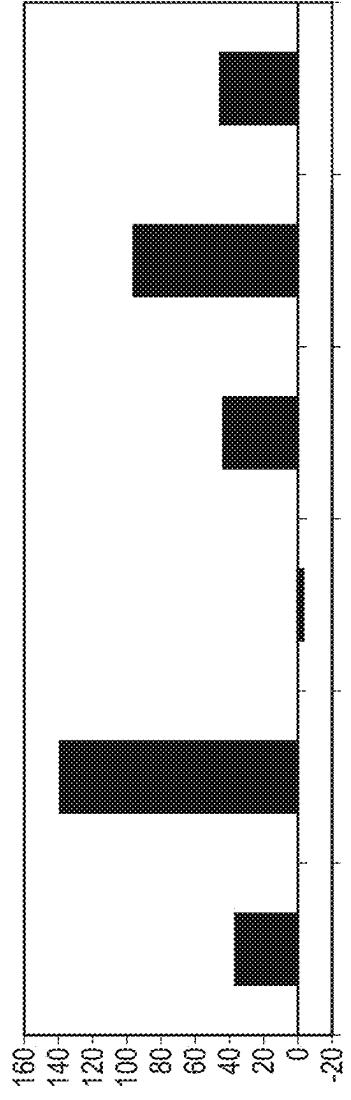


FIG. 80B

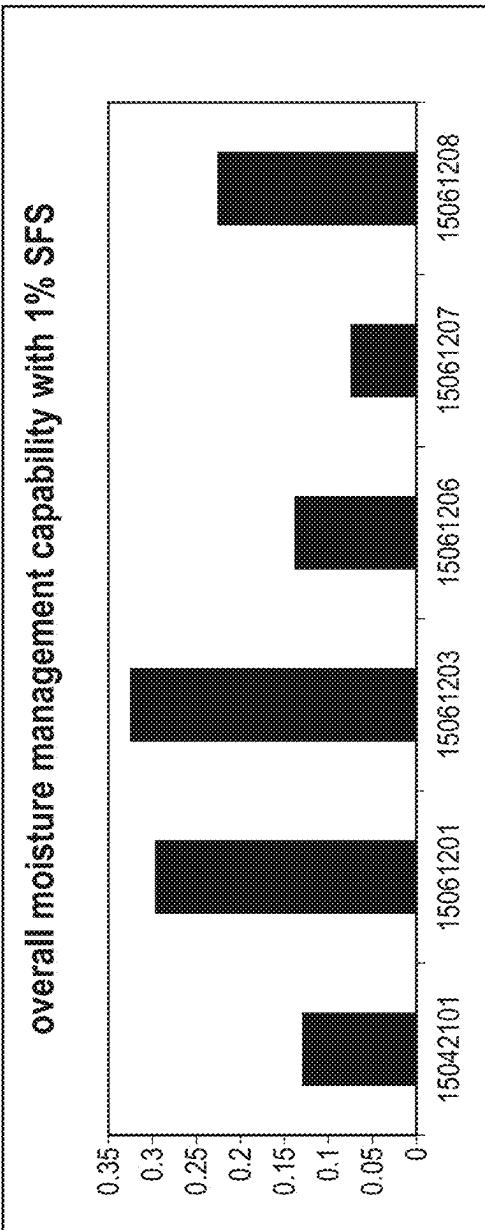


FIG. 81A

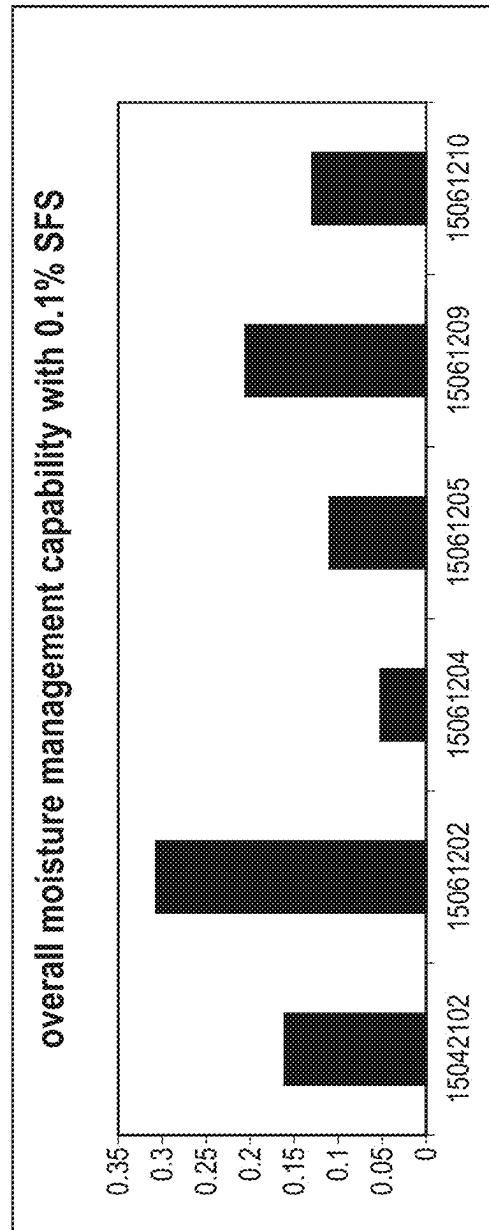


FIG. 81B

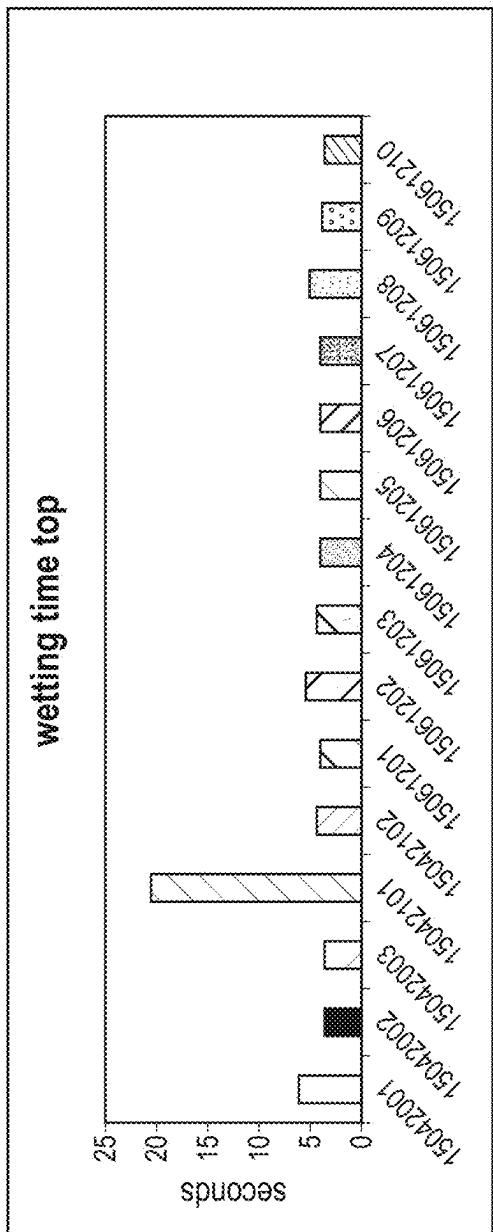


FIG. 82A

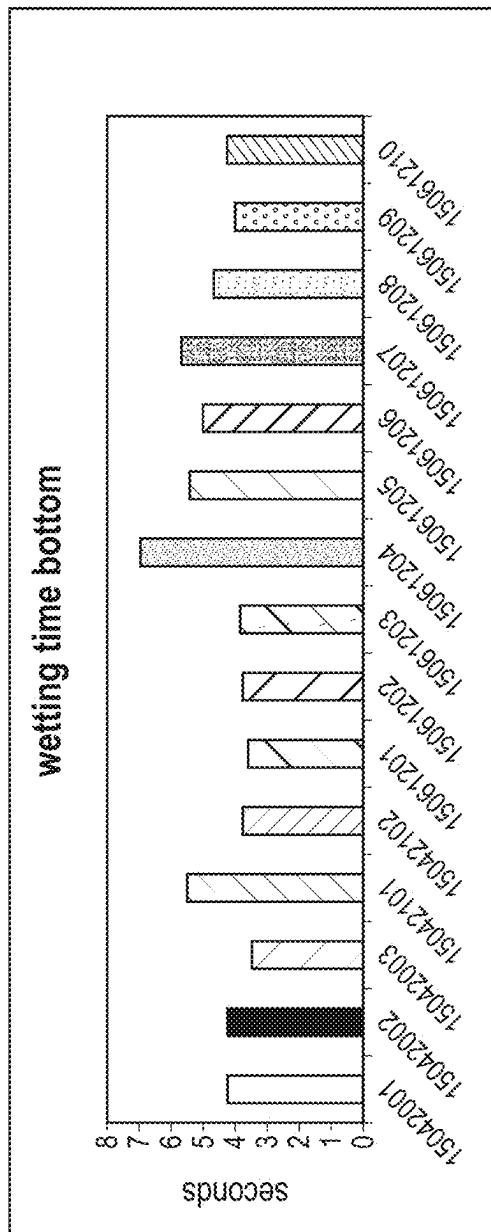


FIG. 82B

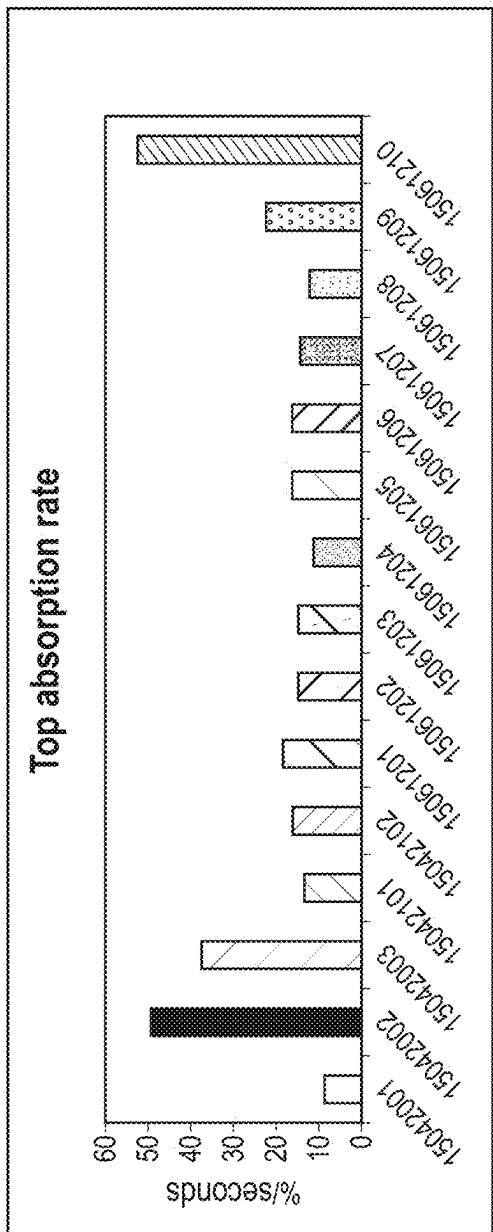


FIG. 83A

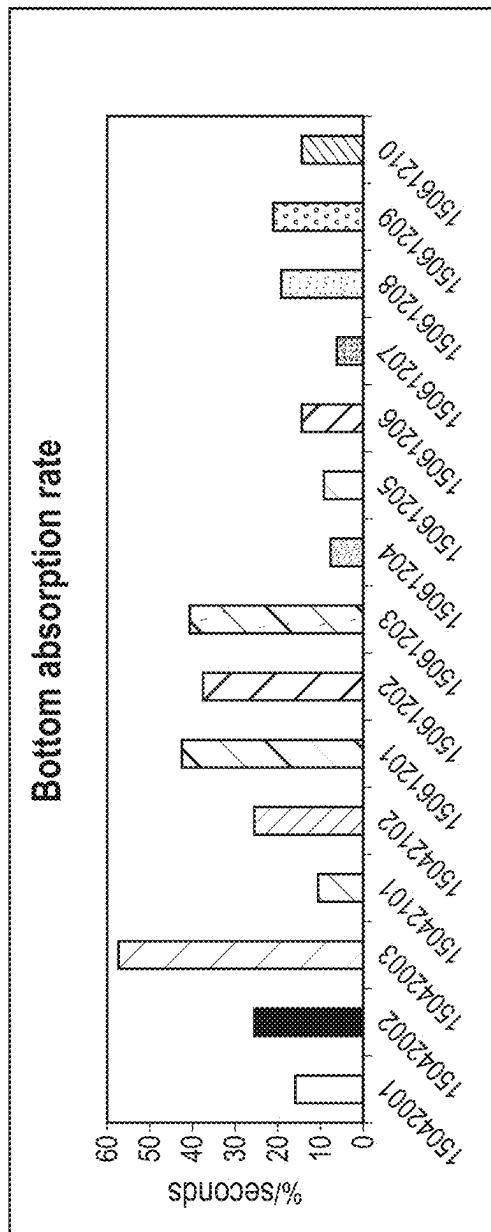


FIG. 83B

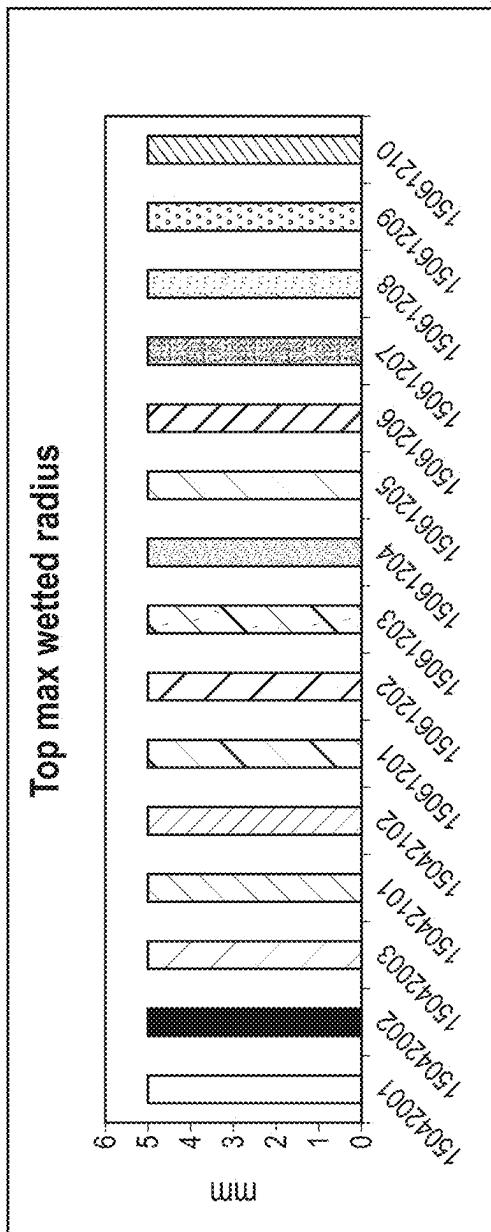


FIG. 84A

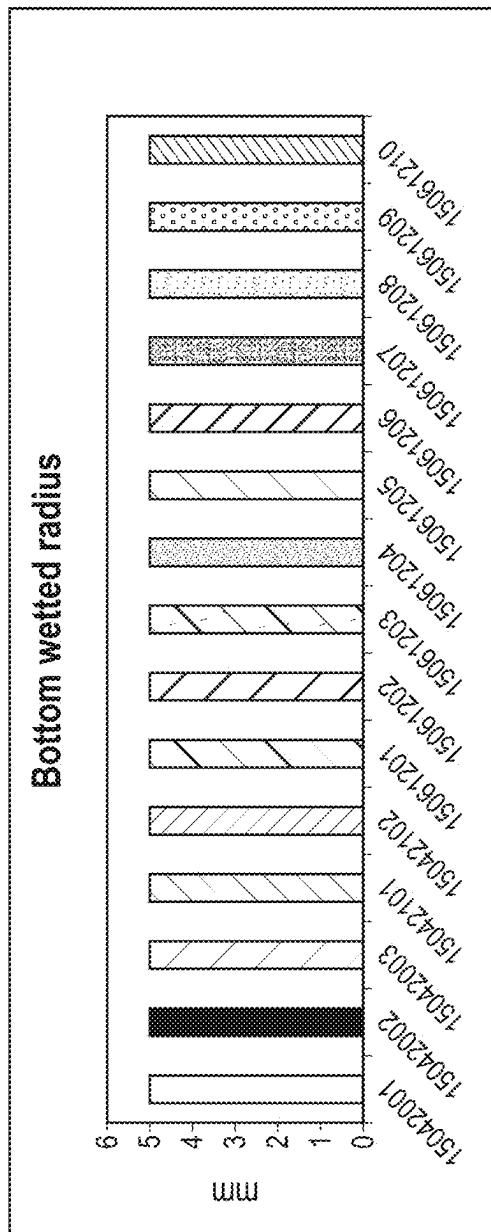


FIG. 84B

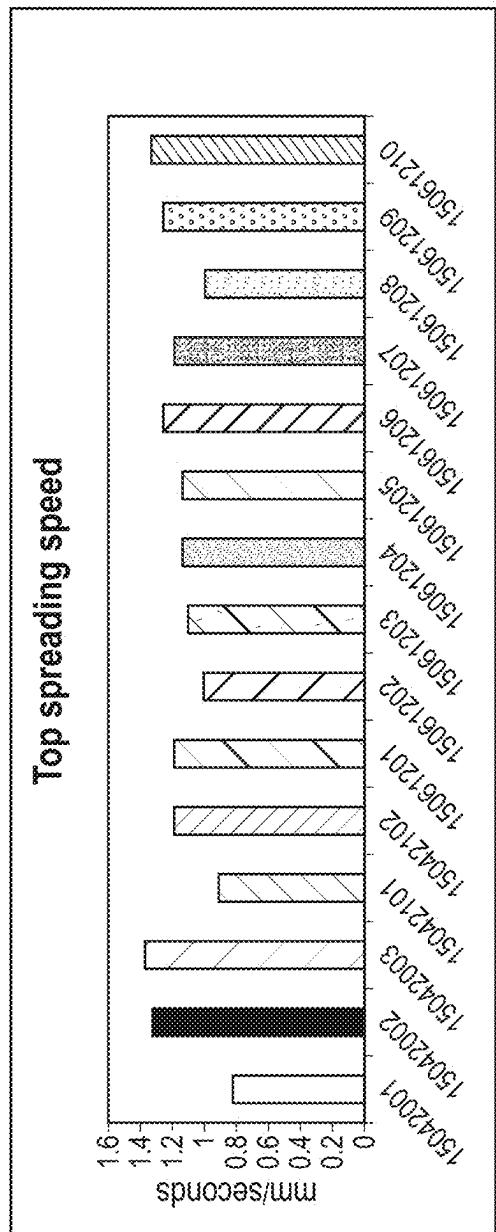


FIG. 85A

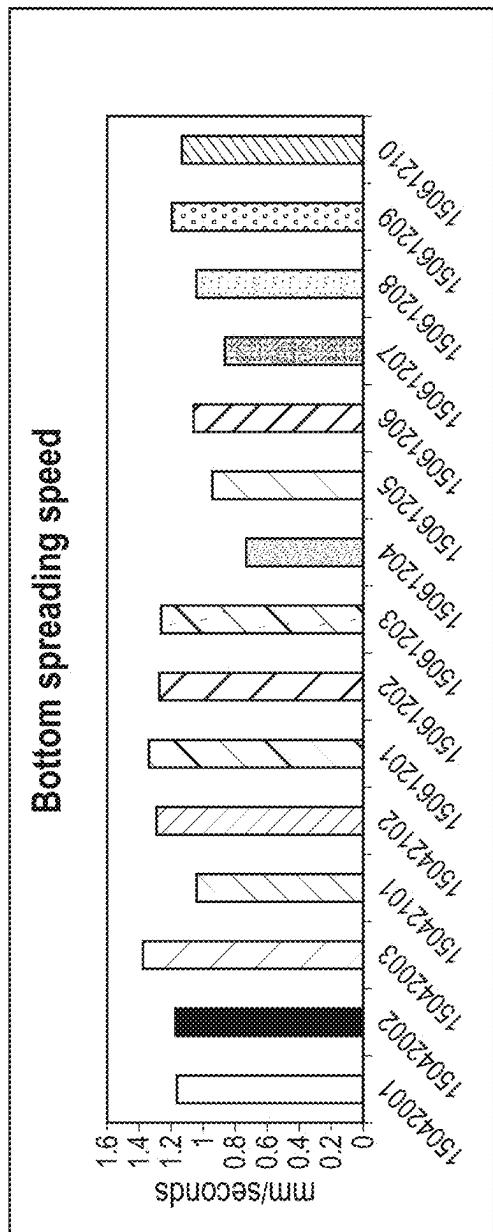
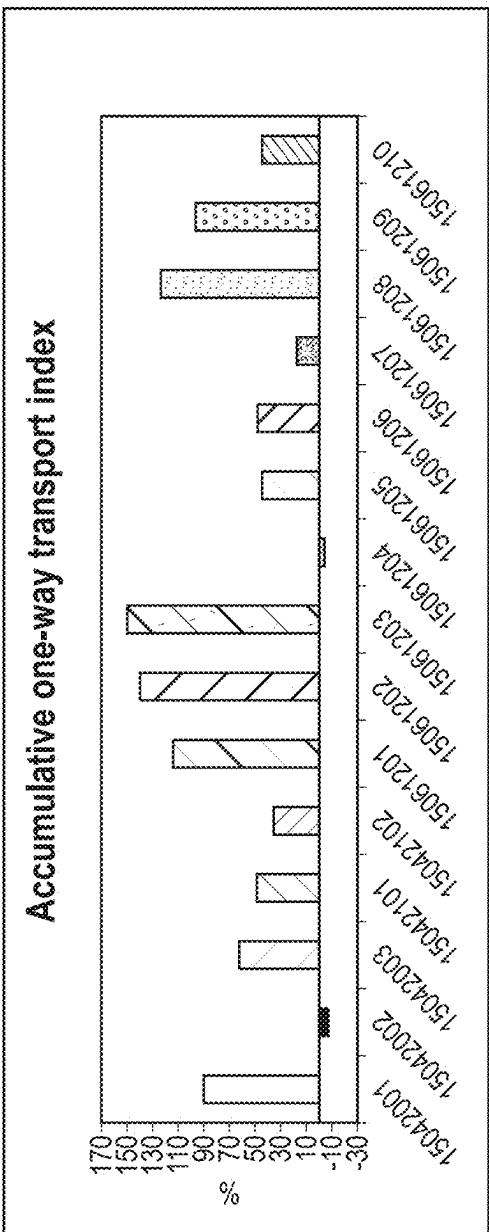


FIG. 85B



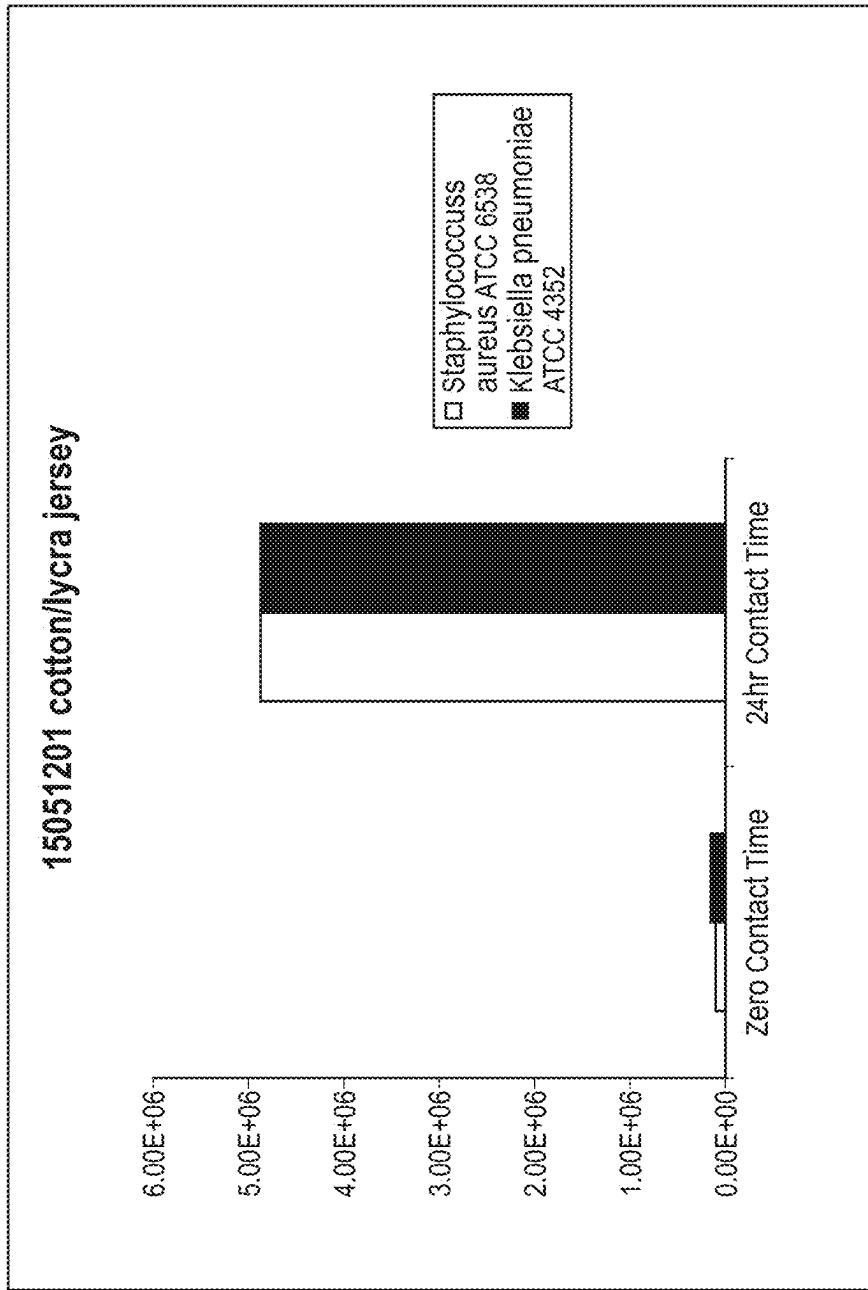


FIG. 87

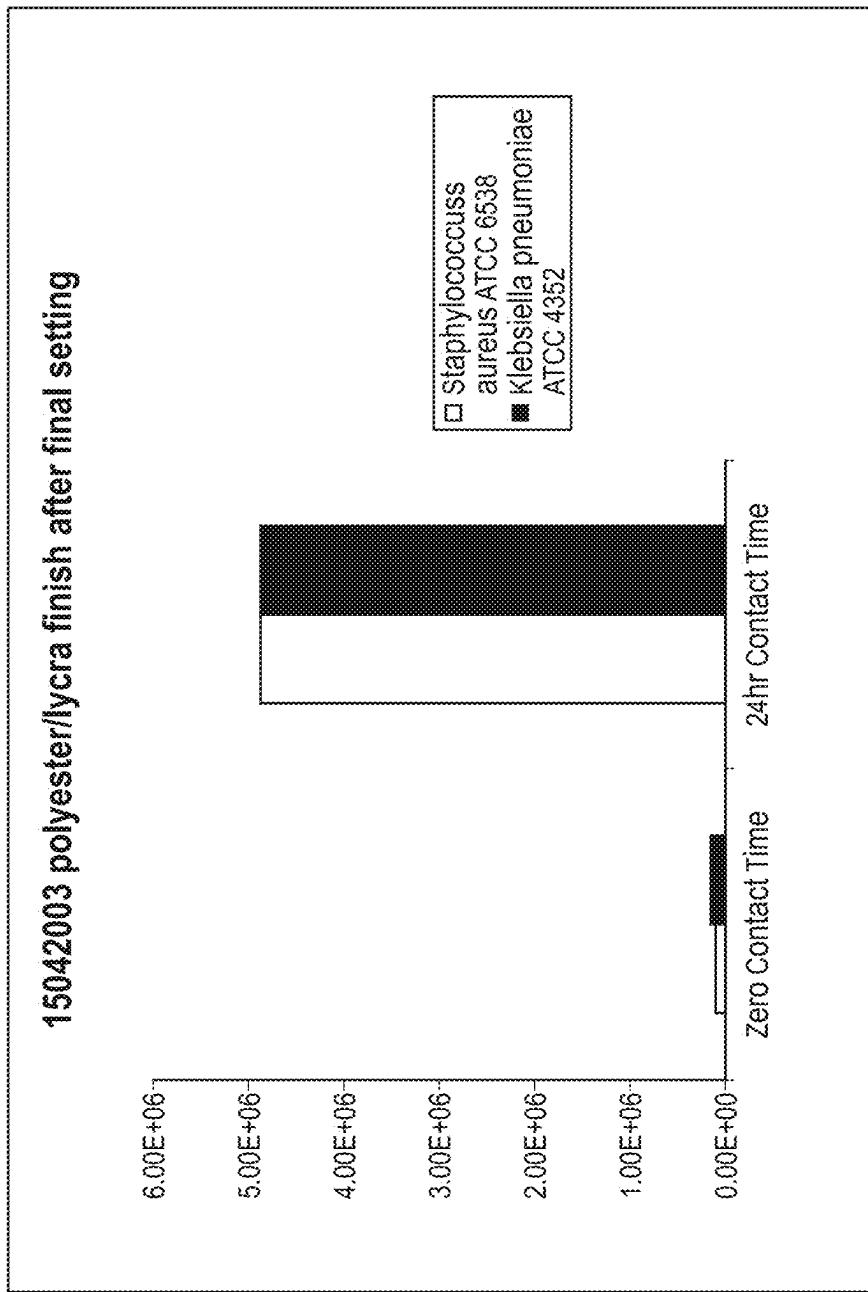


FIG. 88

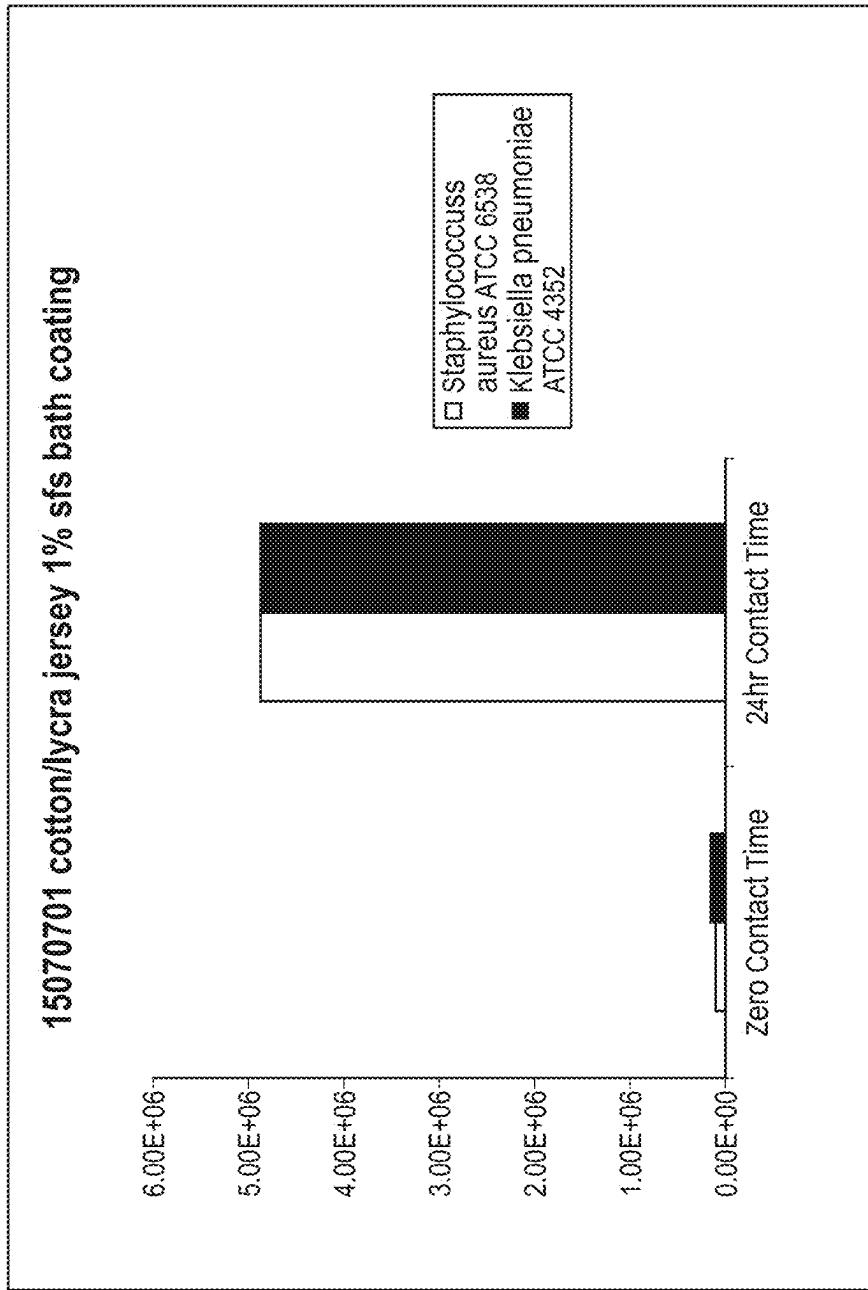


FIG. 89

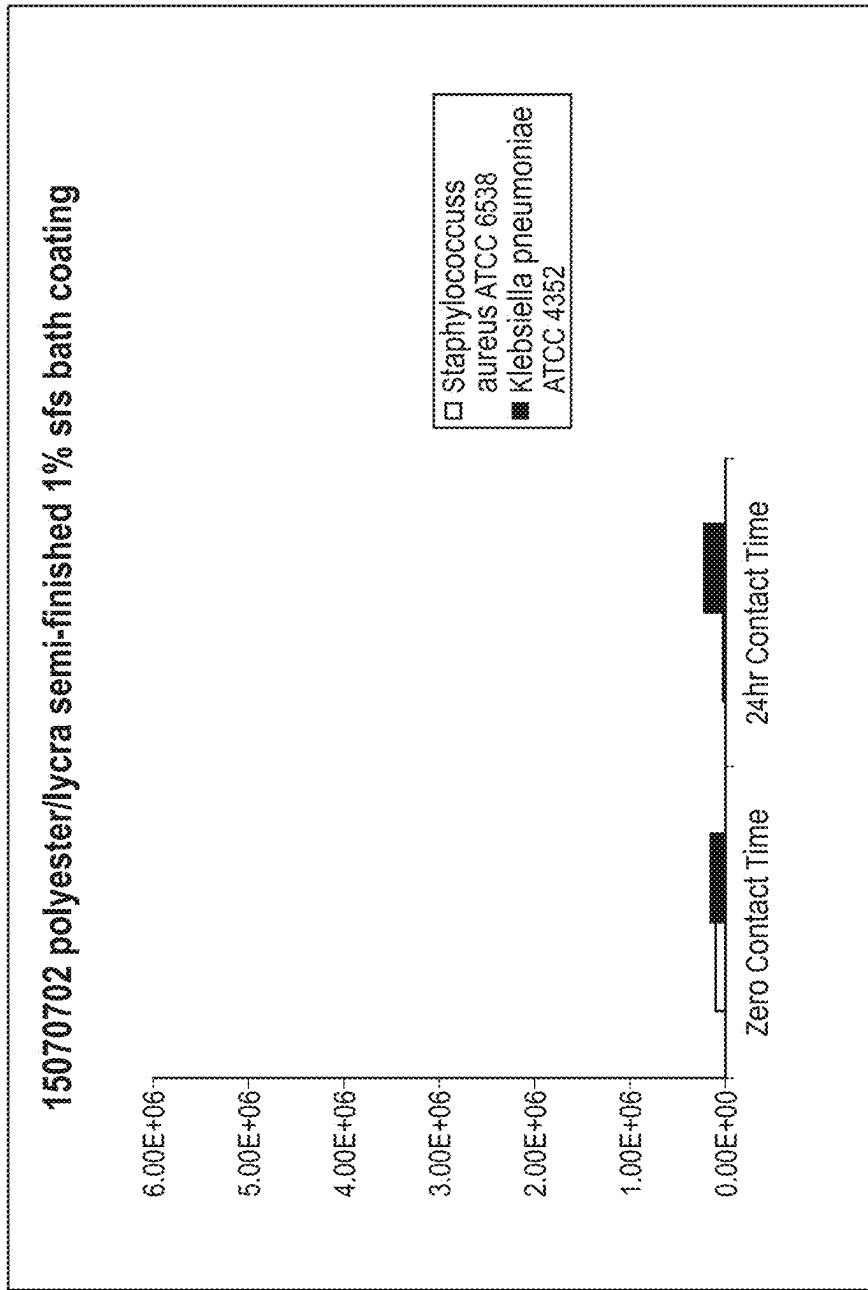


FIG. 90

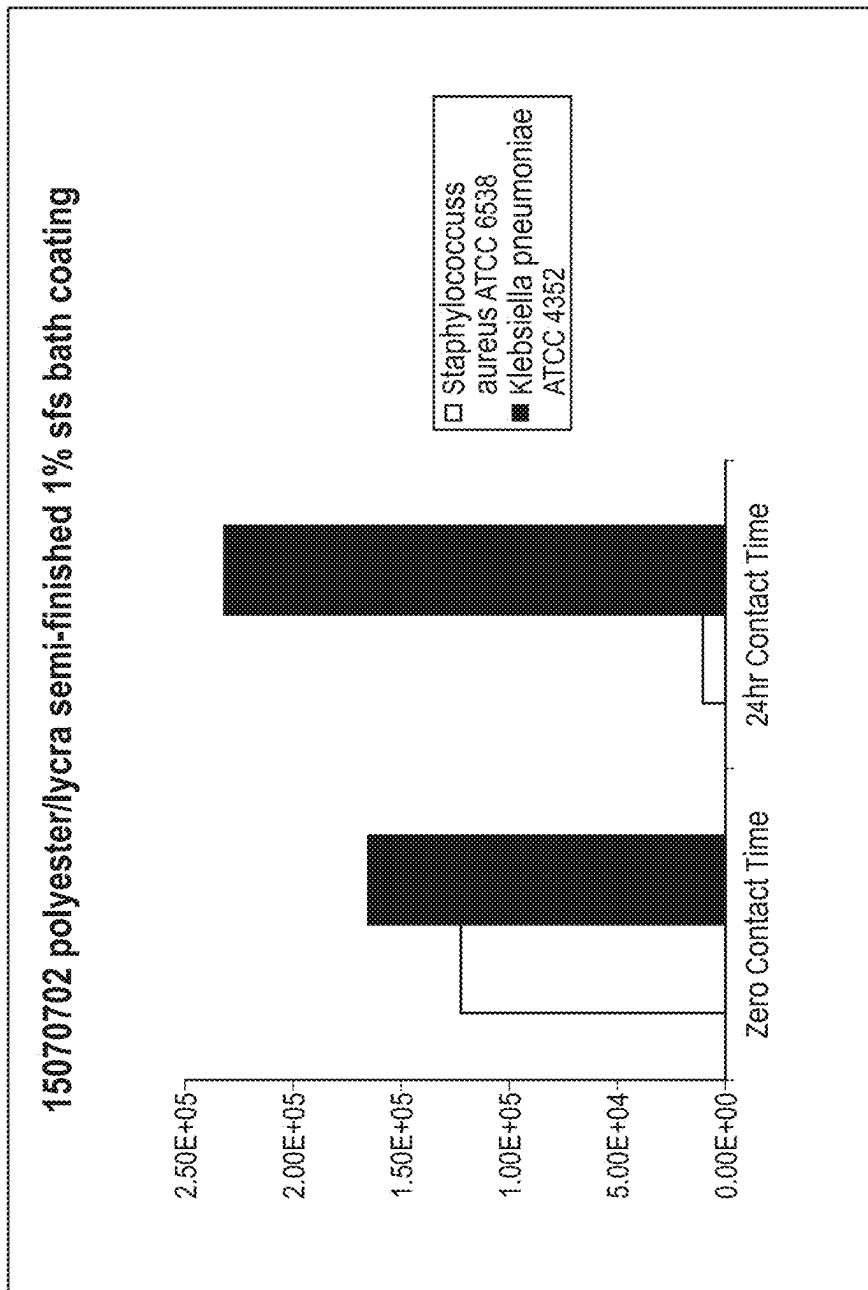


FIG. 91

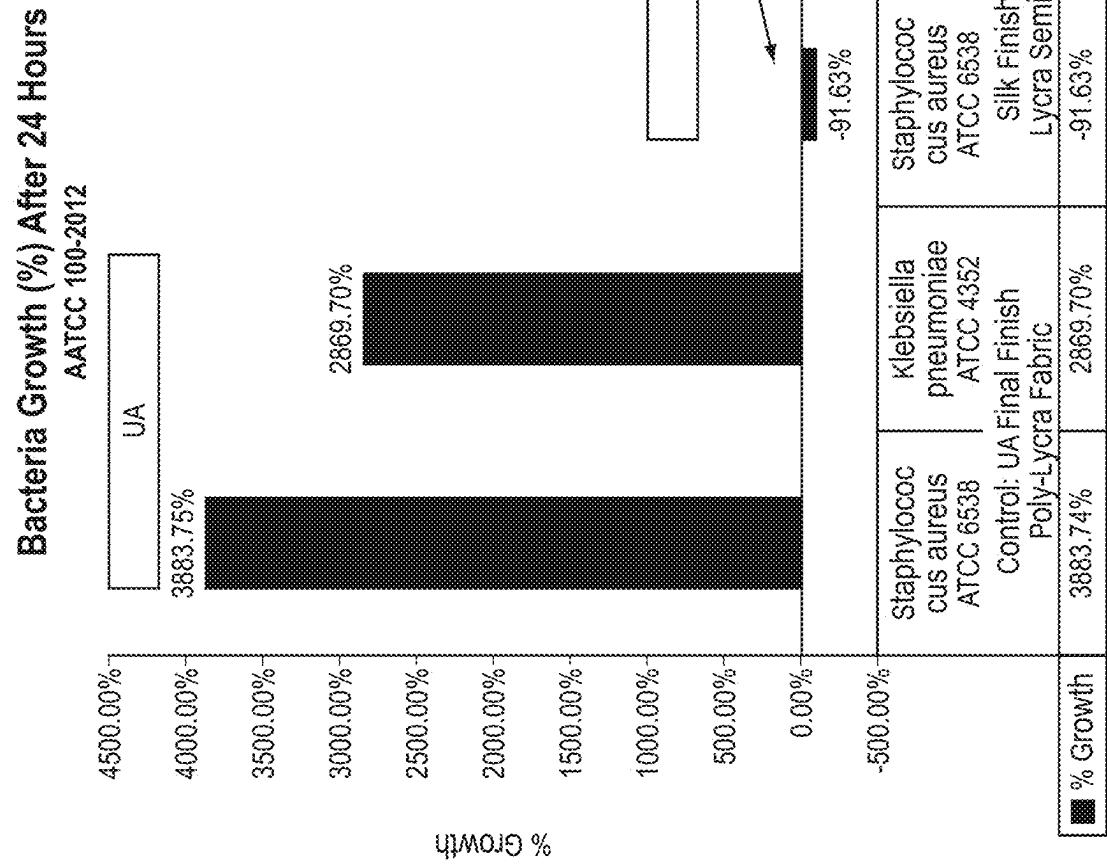


FIG. 92

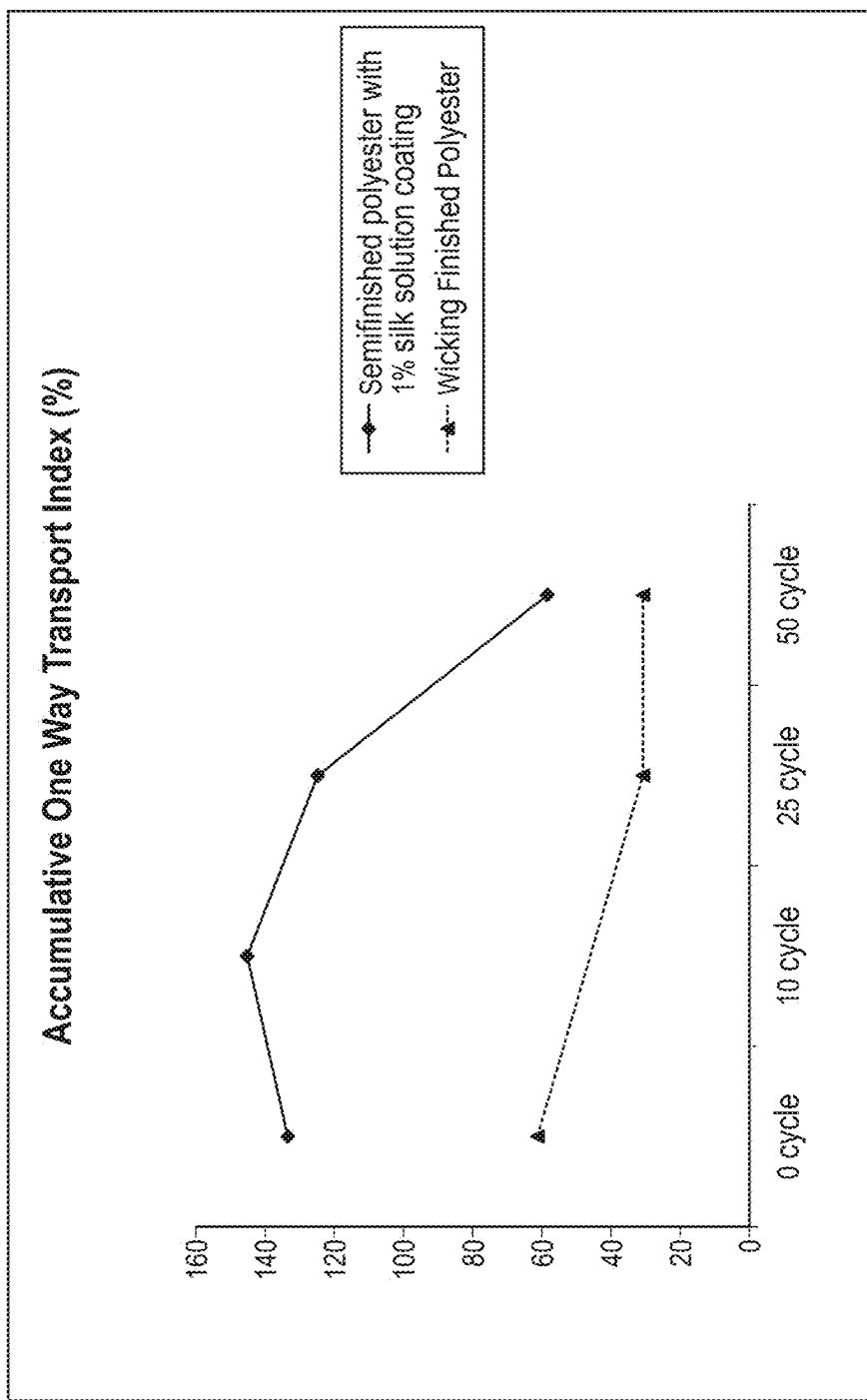


FIG. 93

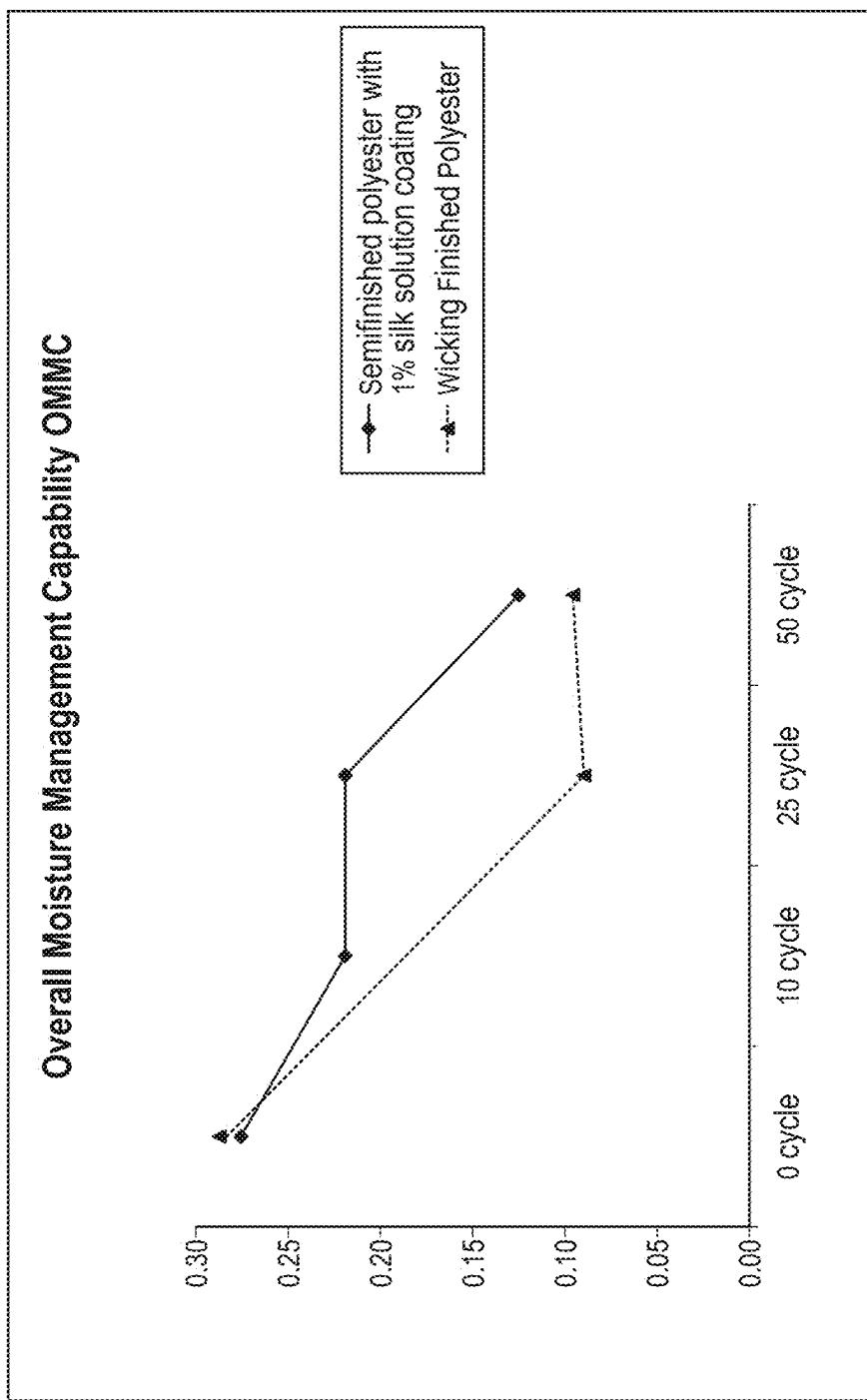


FIG. 94

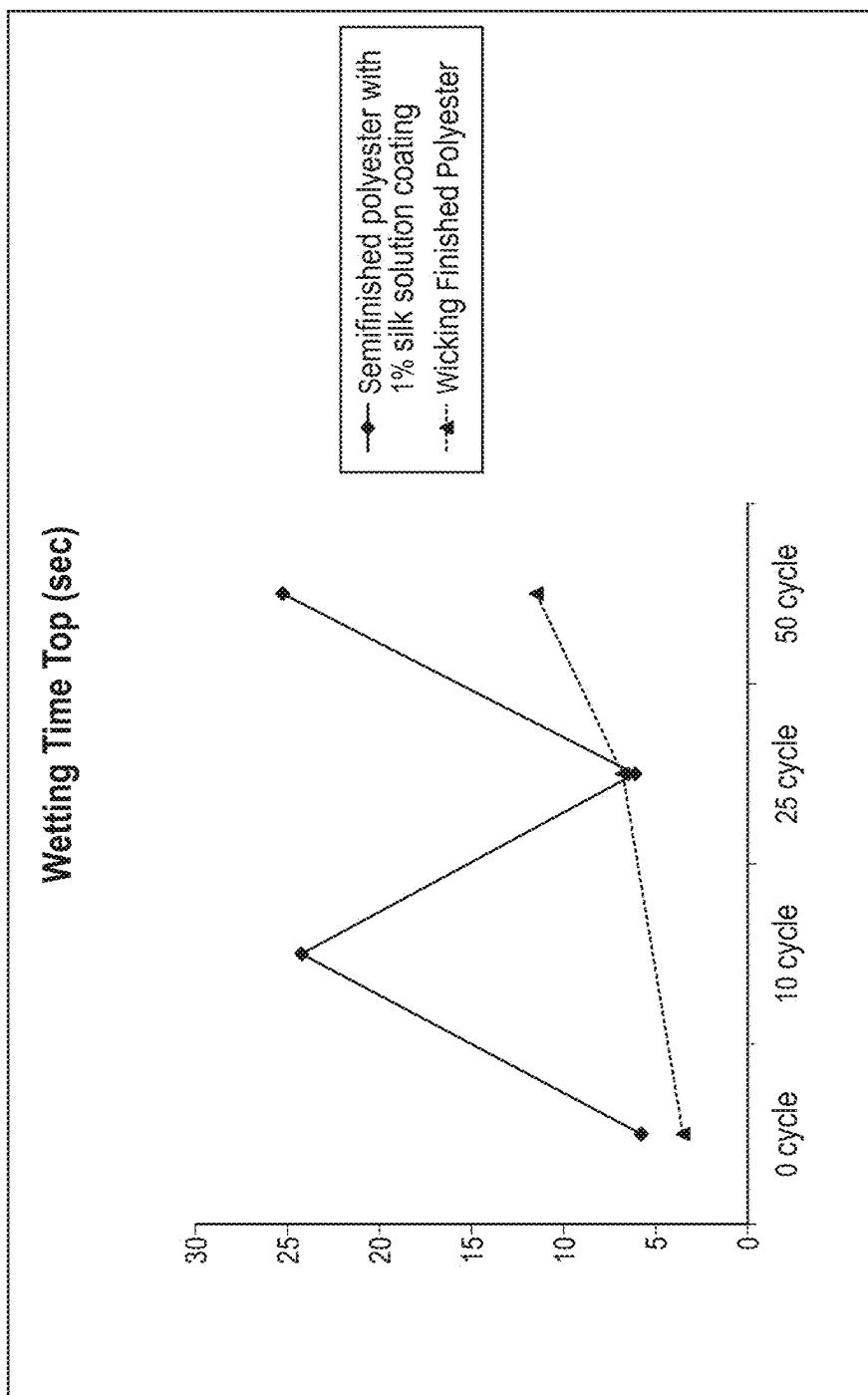


FIG. 95

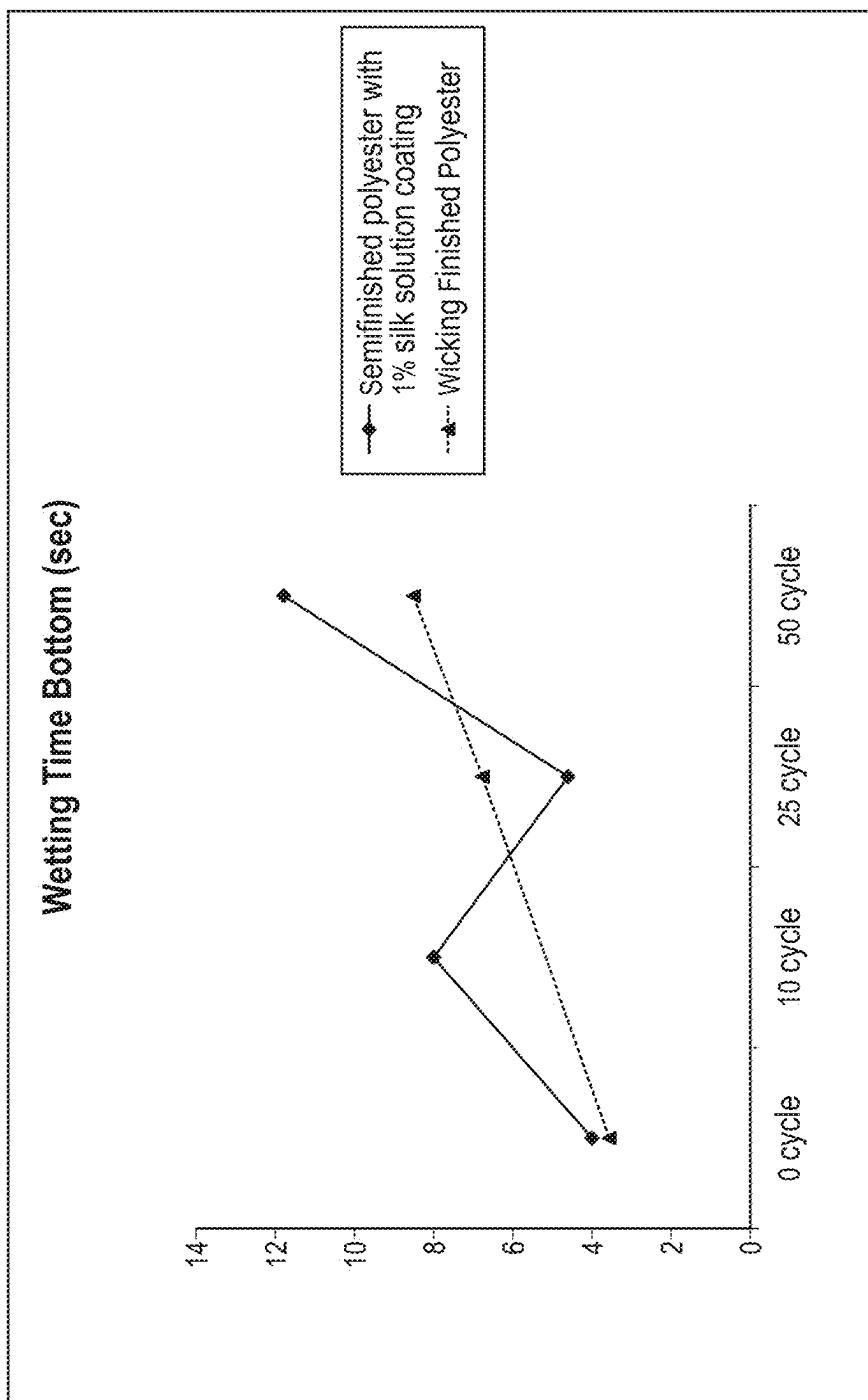


FIG. 96

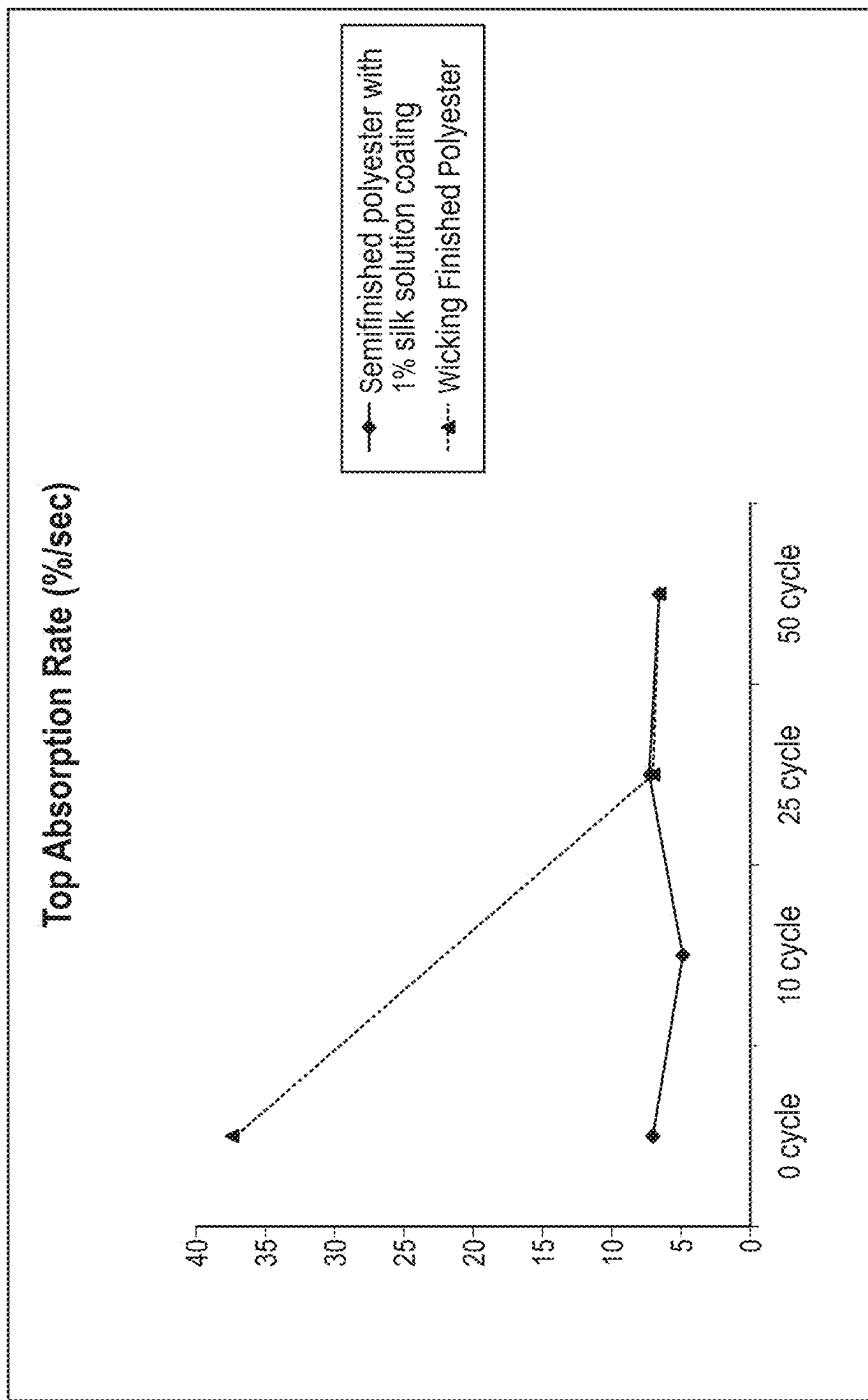


FIG. 97

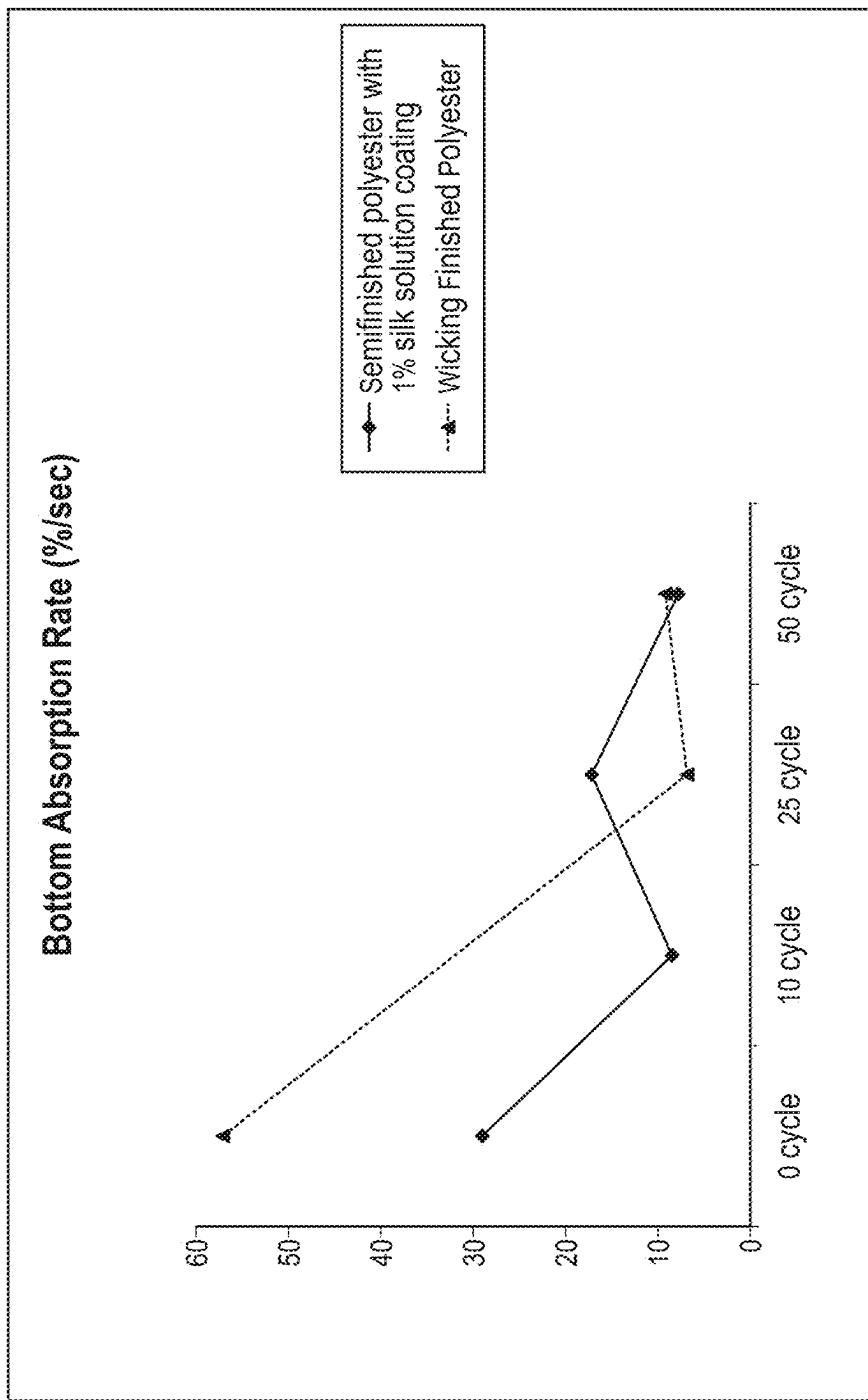


FIG. 98

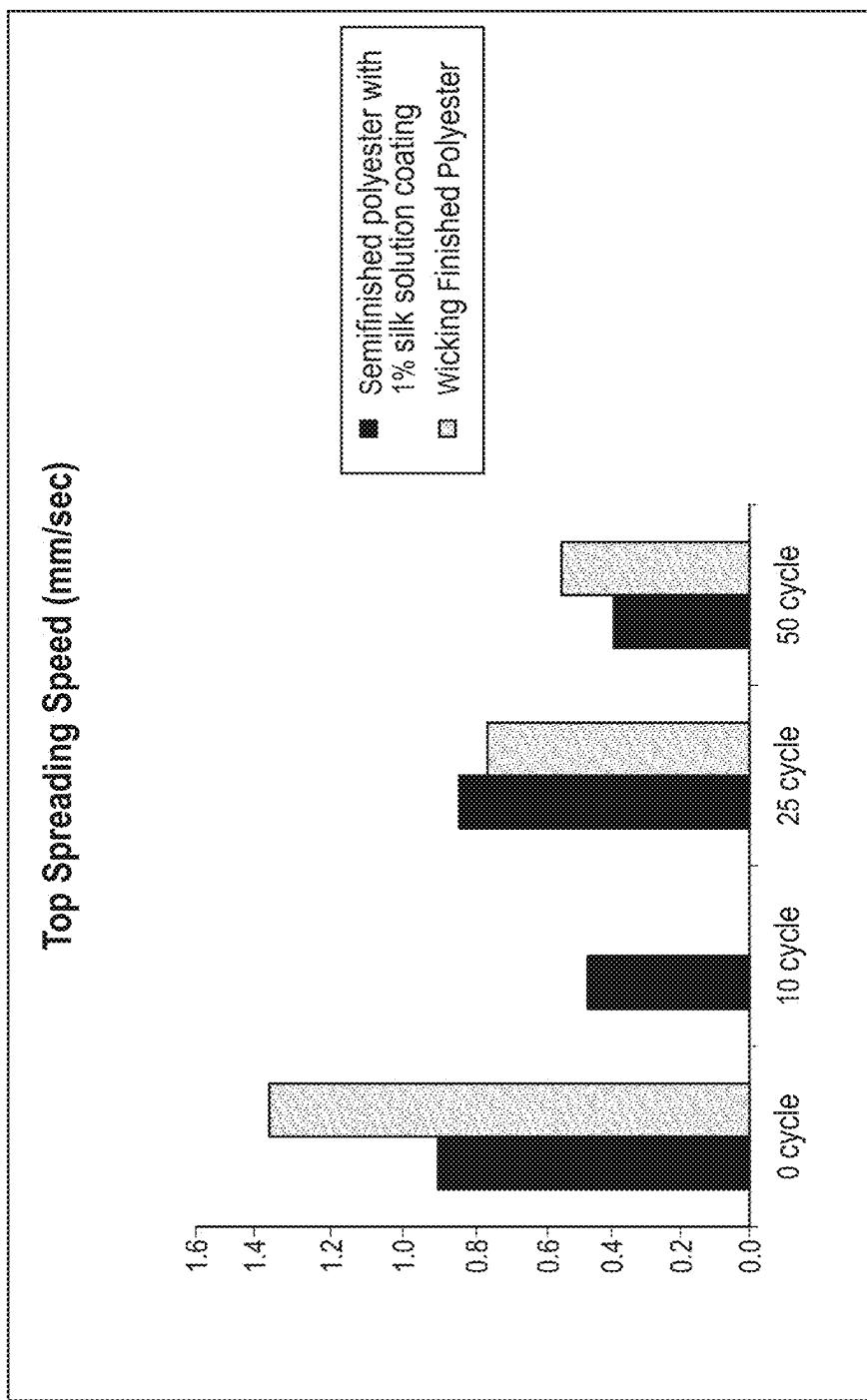


FIG. 99

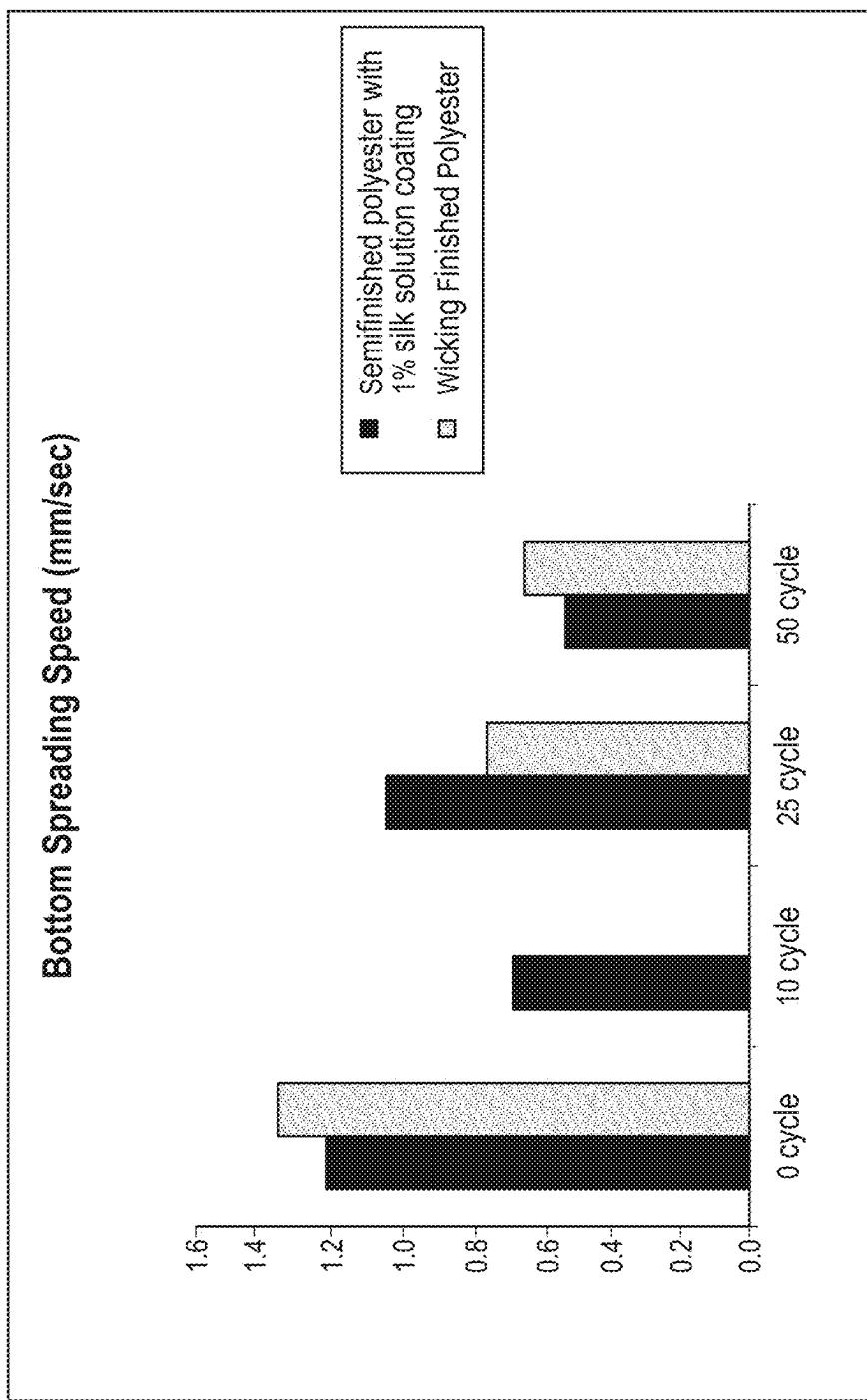


FIG. 100

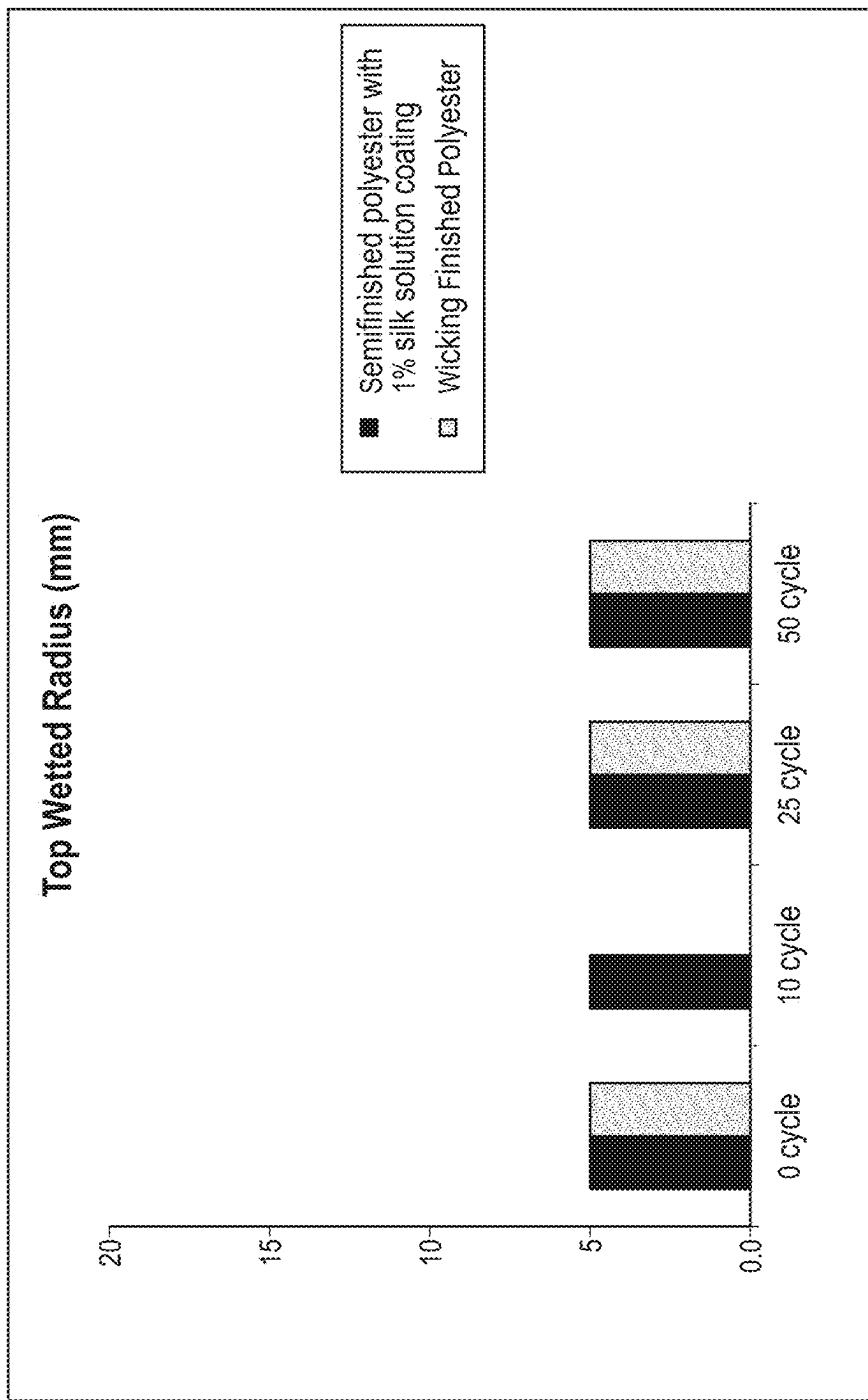


FIG. 101

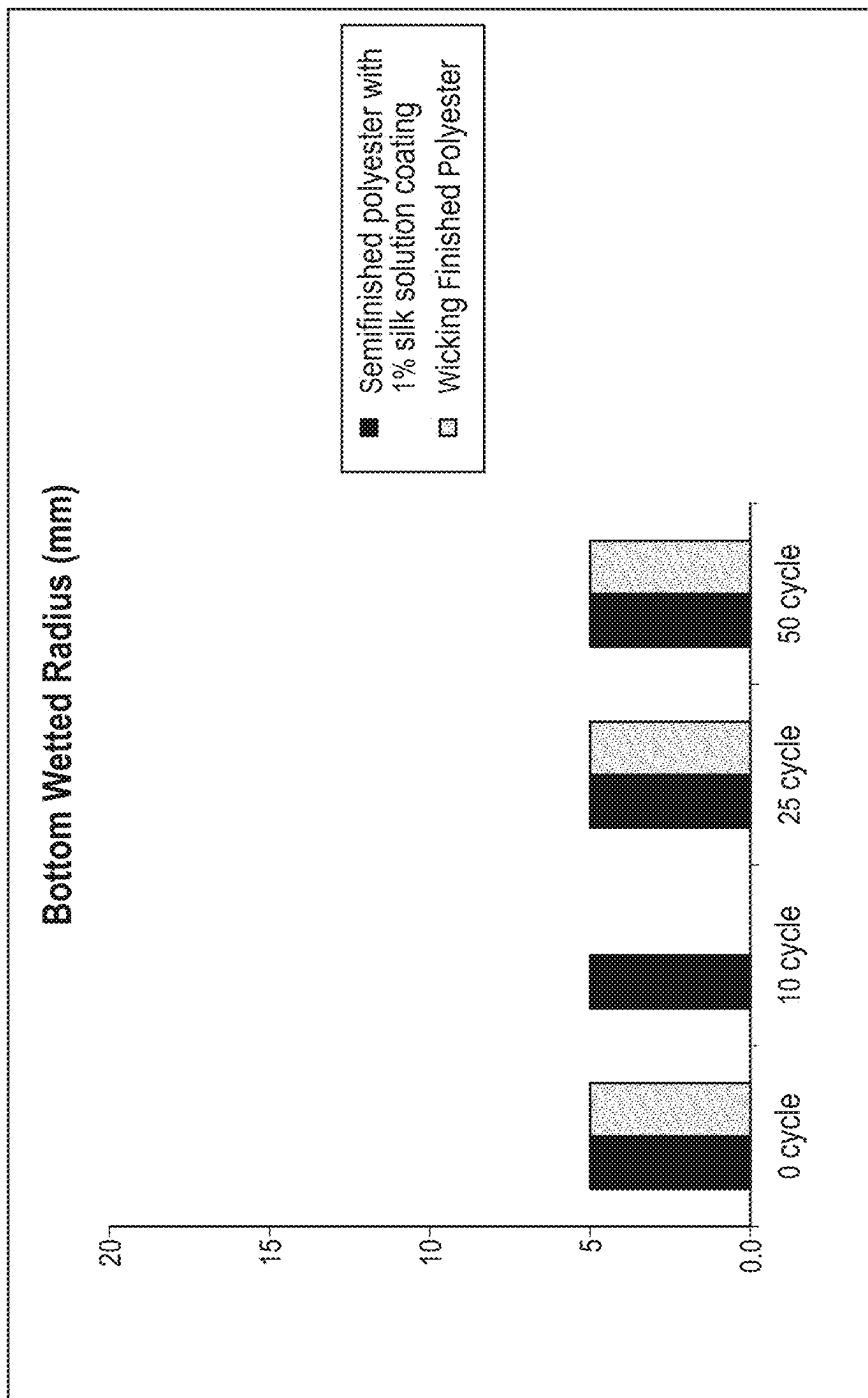


FIG. 102

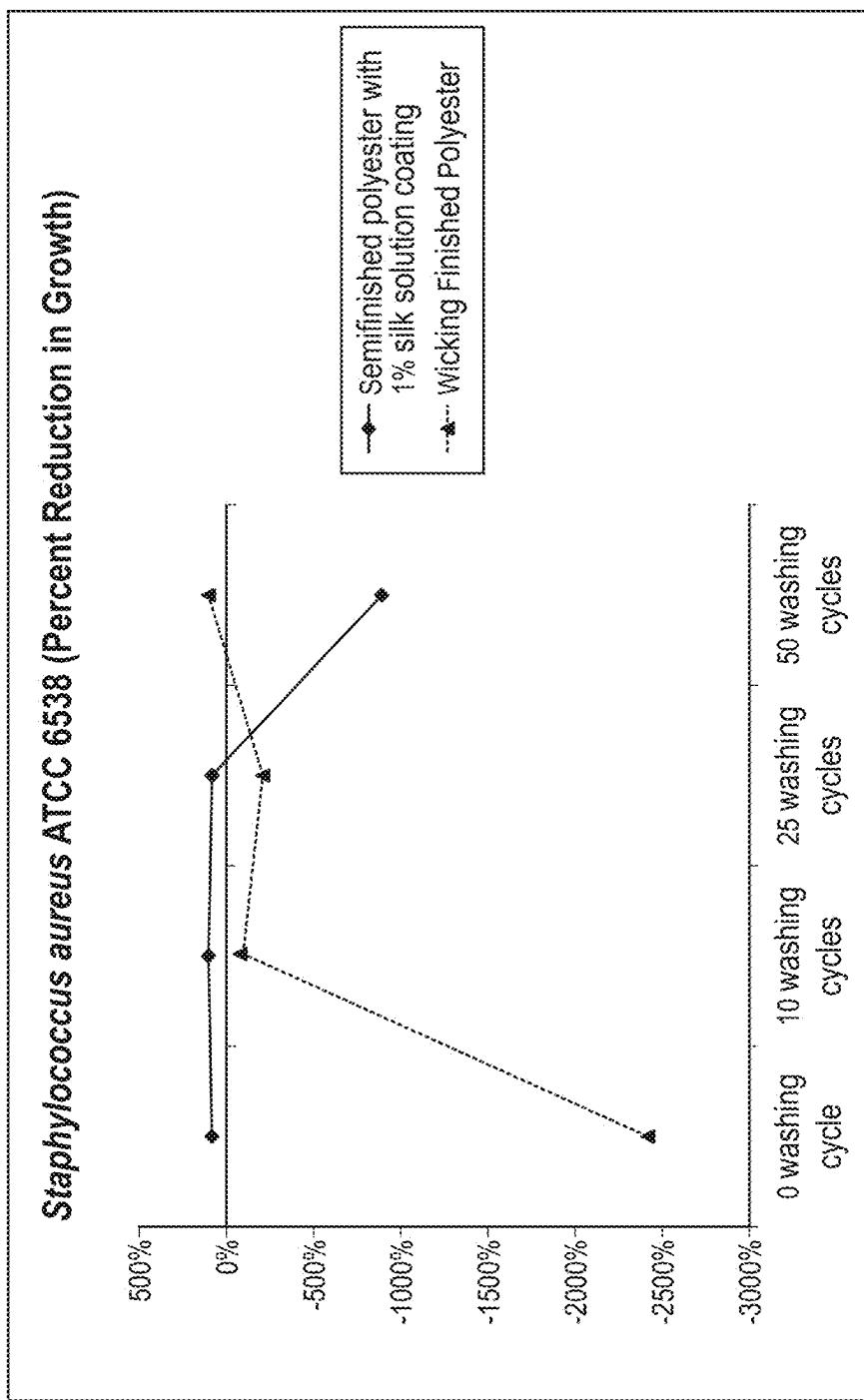


FIG. 103

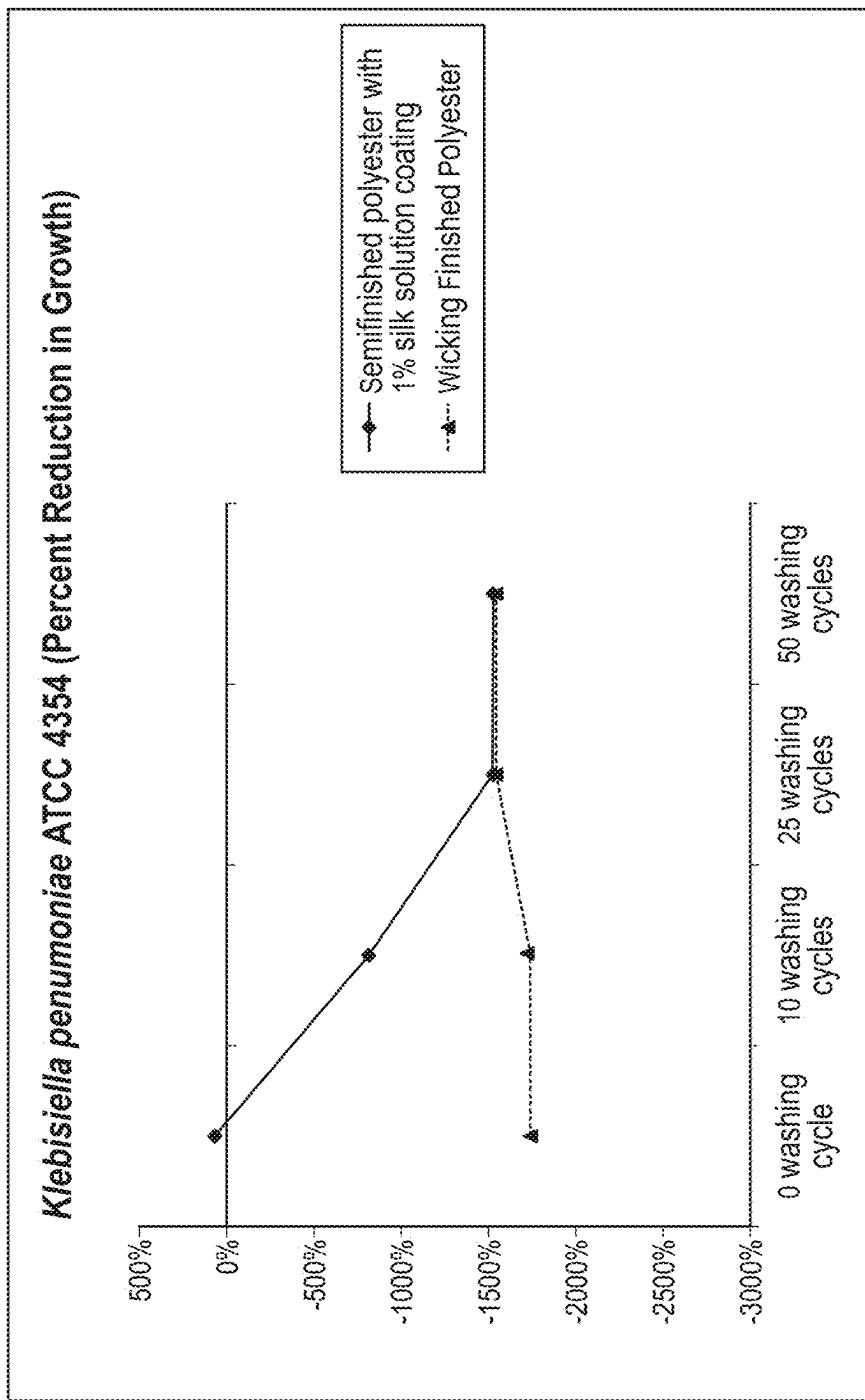


FIG. 104

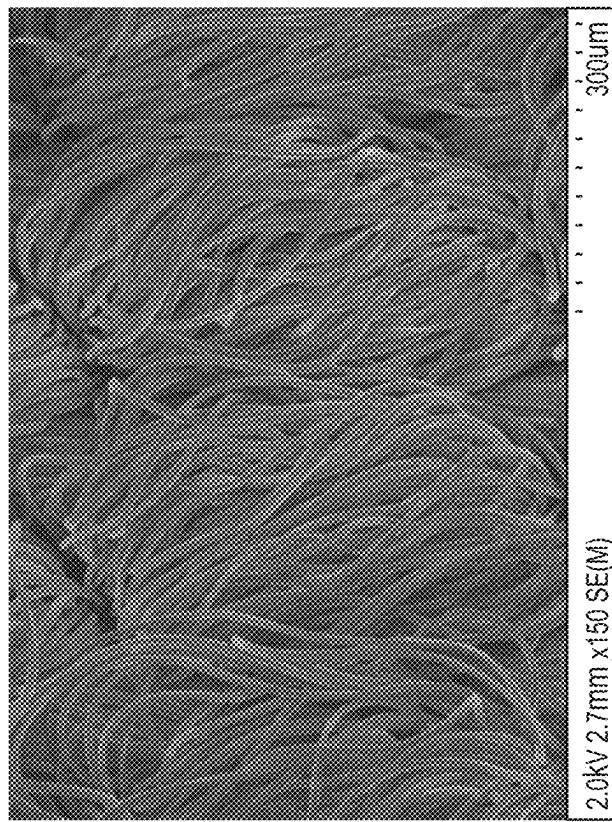


FIG. 105

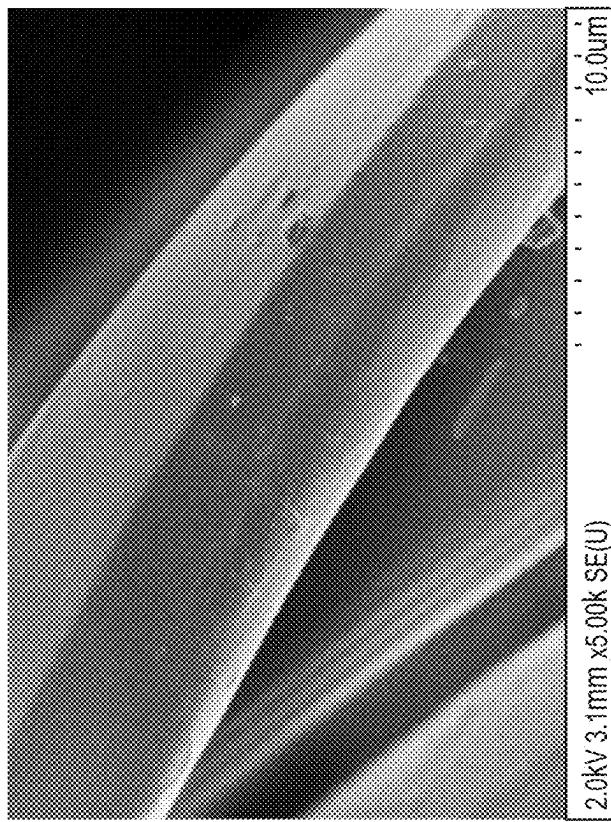


FIG. 106

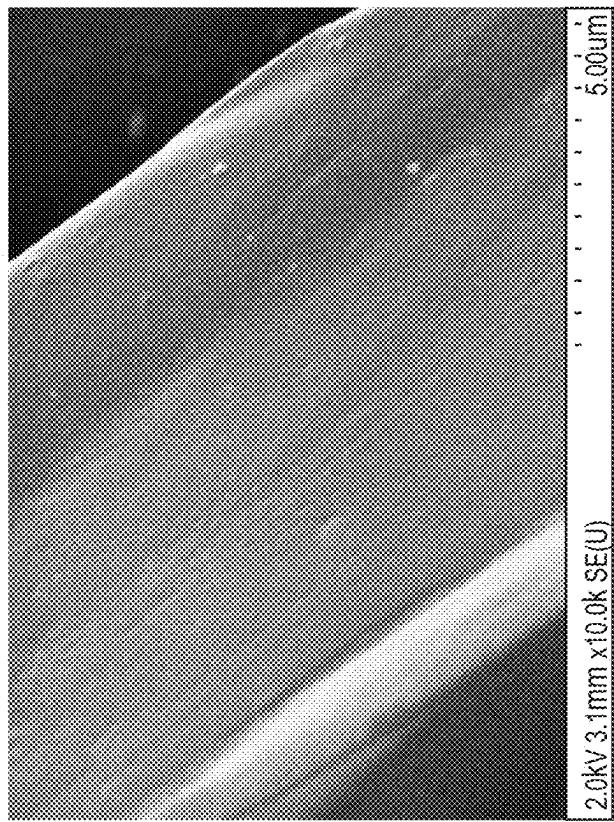


FIG. 107

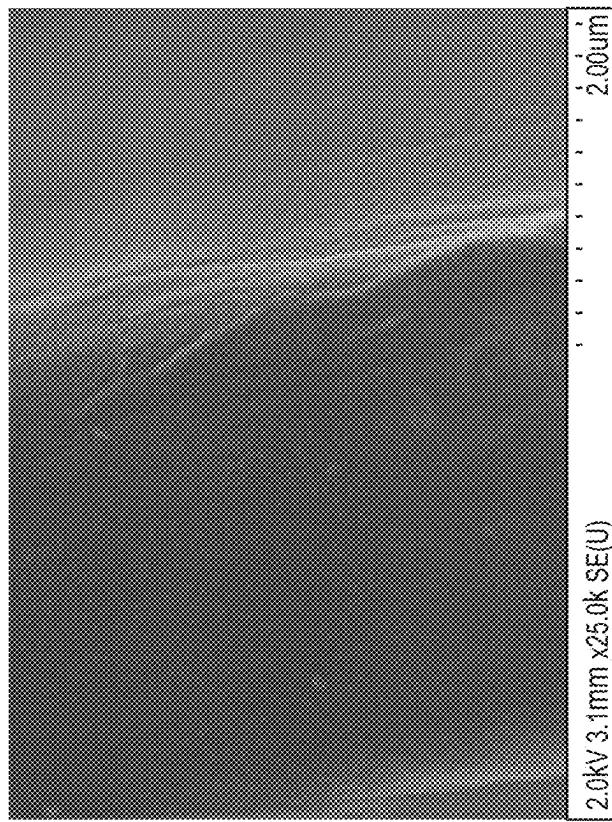


FIG. 108

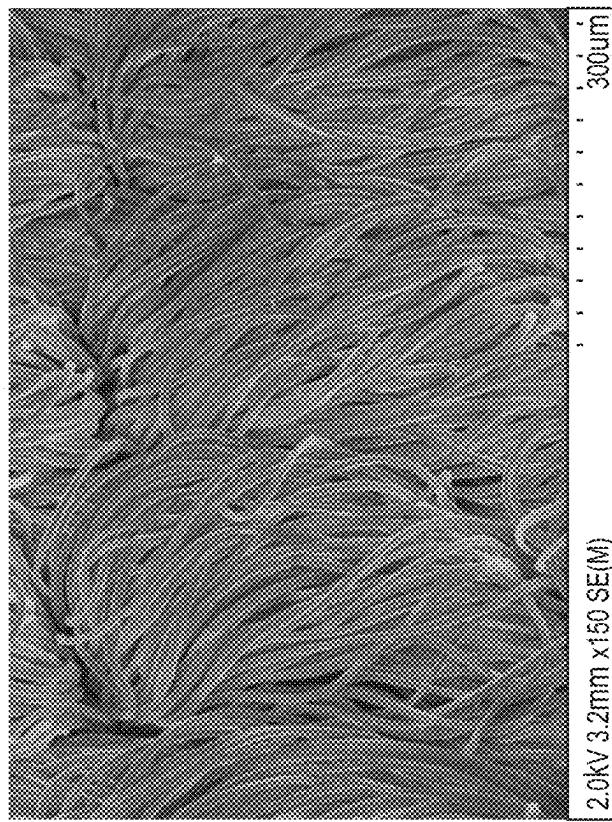


FIG. 109

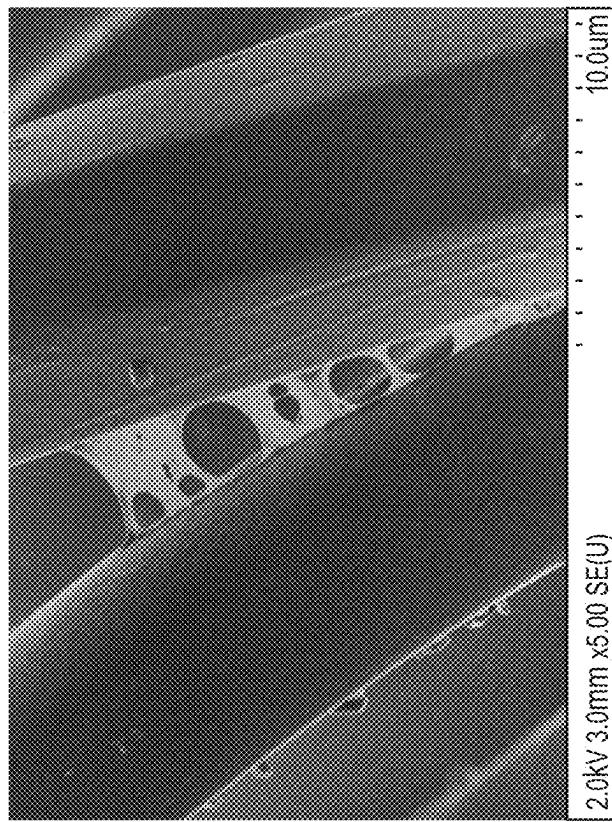


FIG. 110

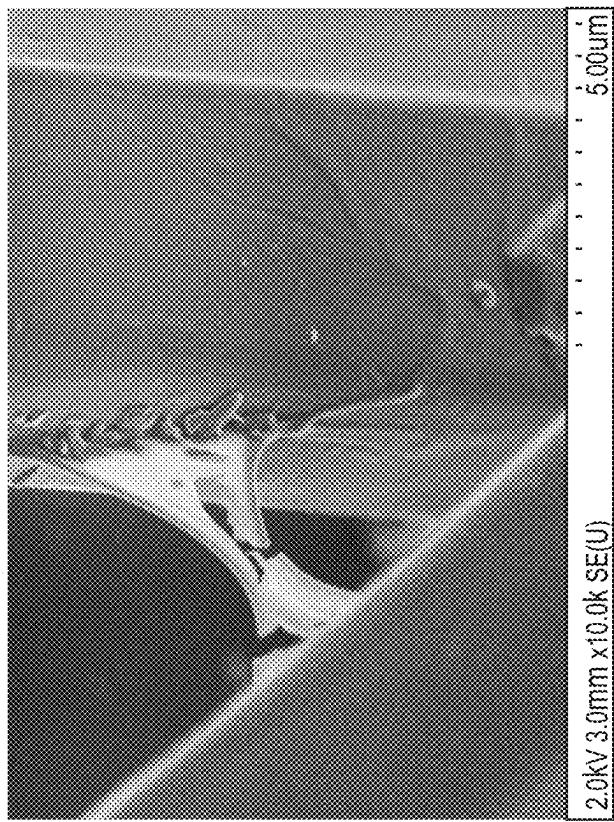


FIG. 111

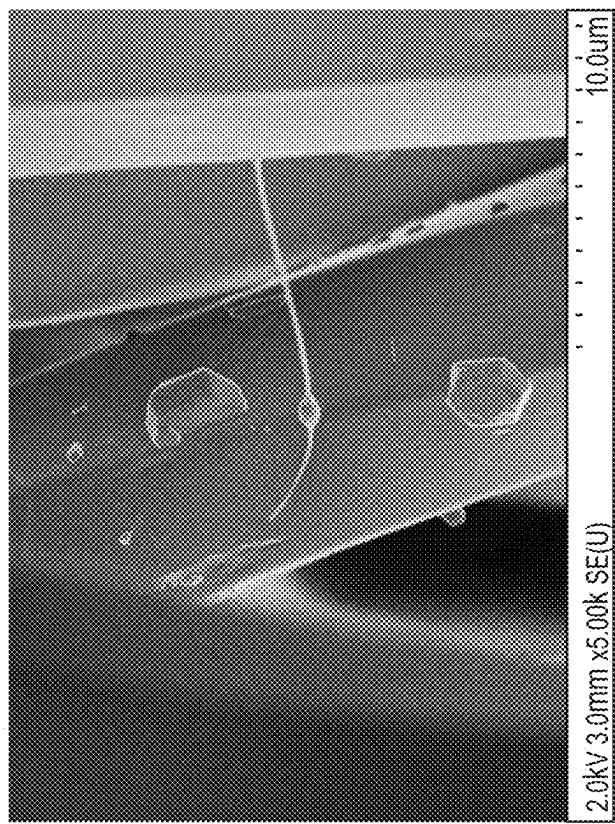


FIG. 112

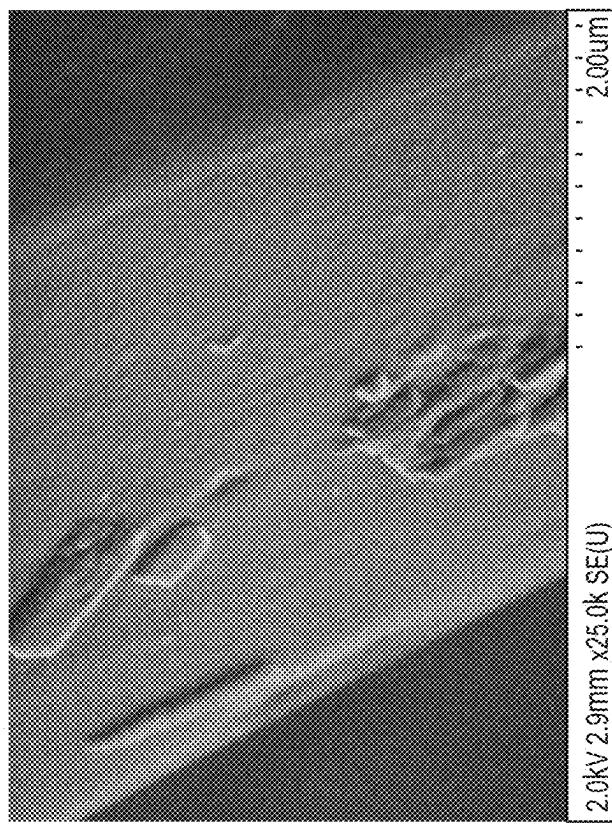


FIG. 113

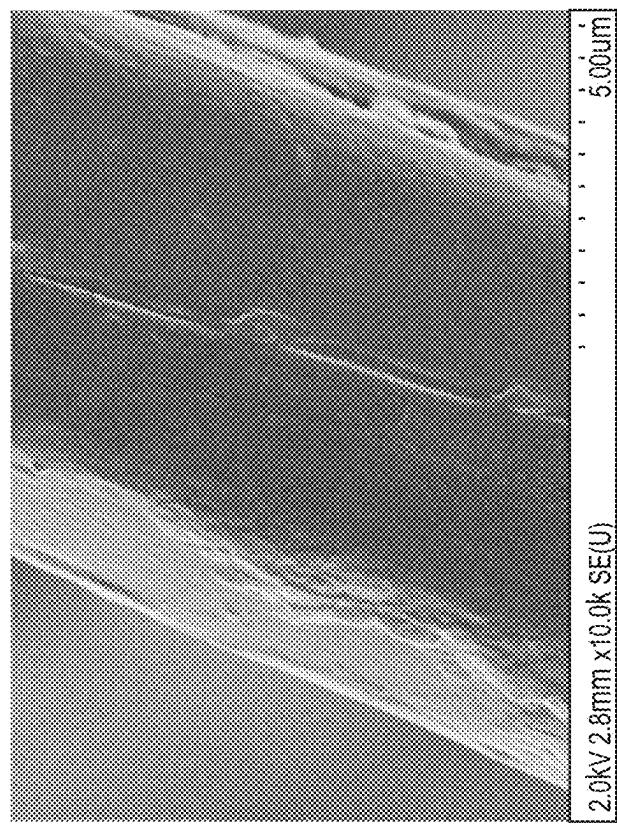


FIG. 114

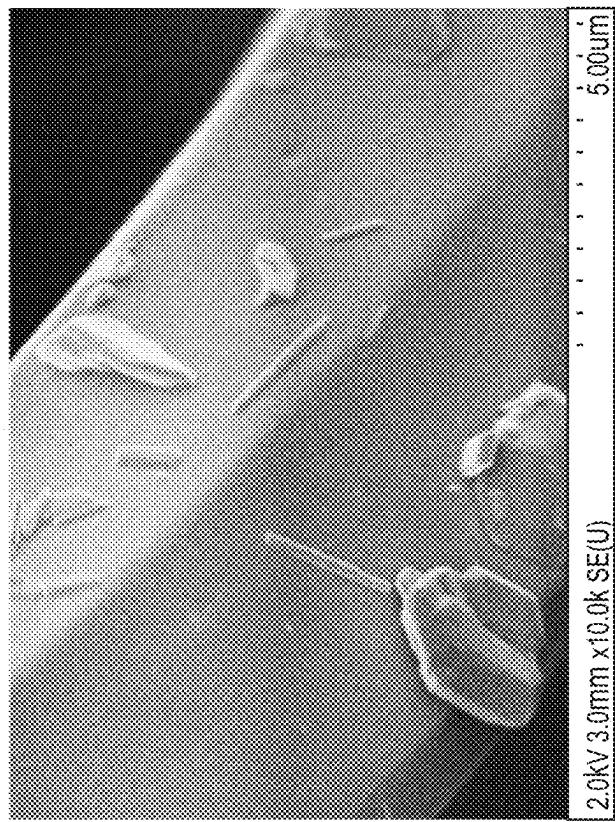


FIG. 115

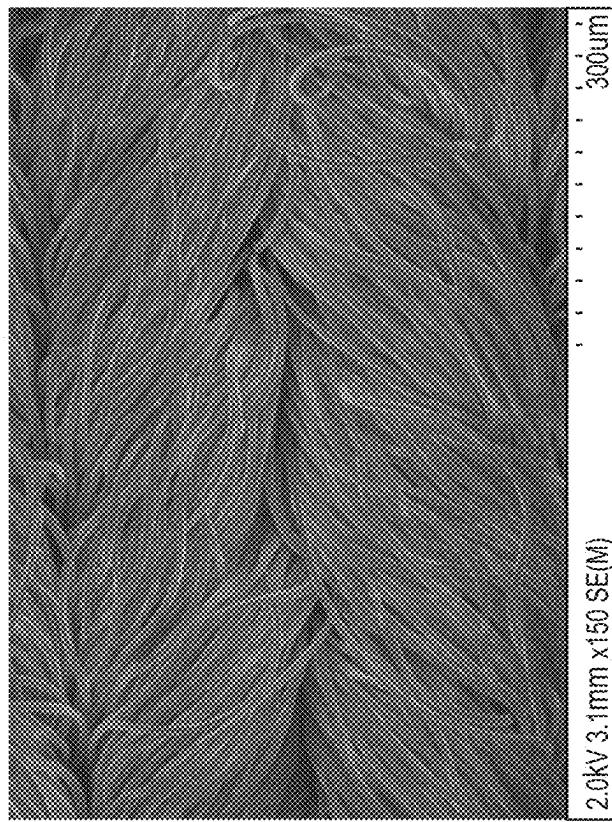


FIG. 116

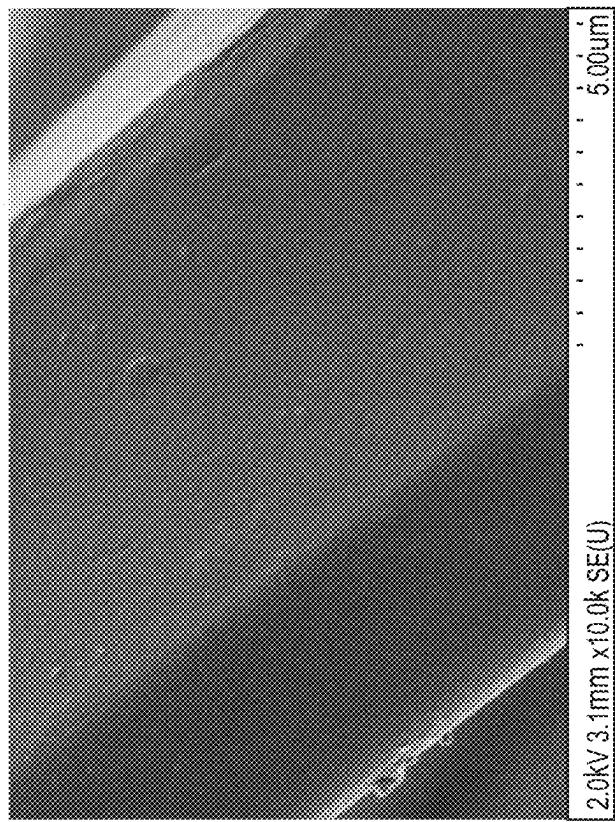


FIG. 117

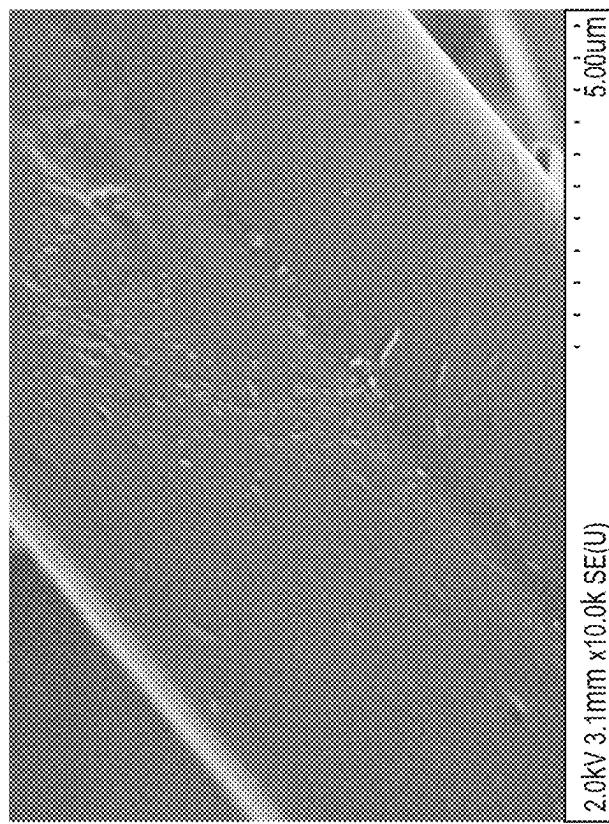


FIG. 118

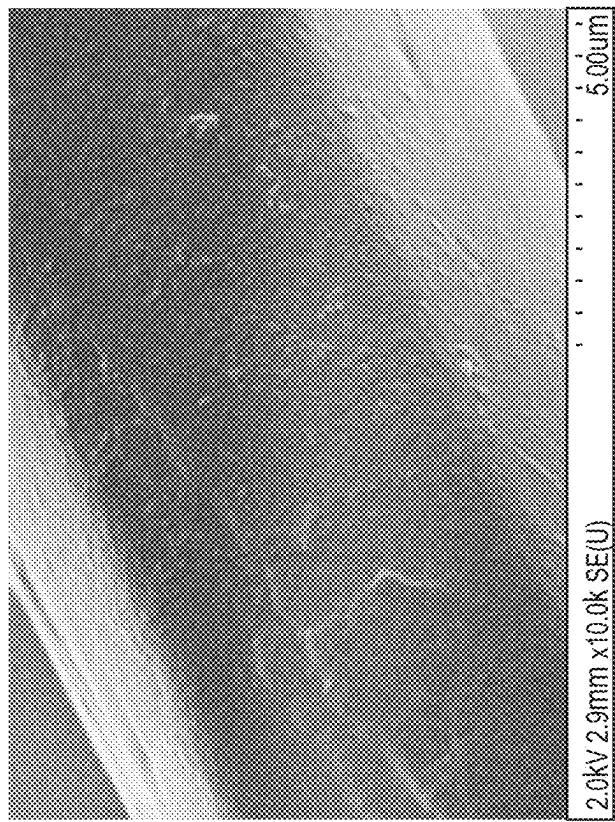


FIG. 119

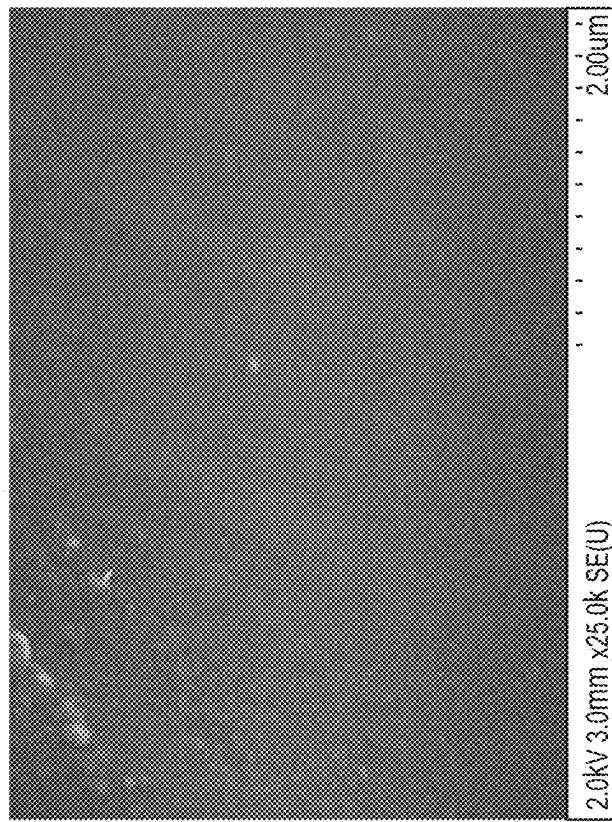


FIG. 120

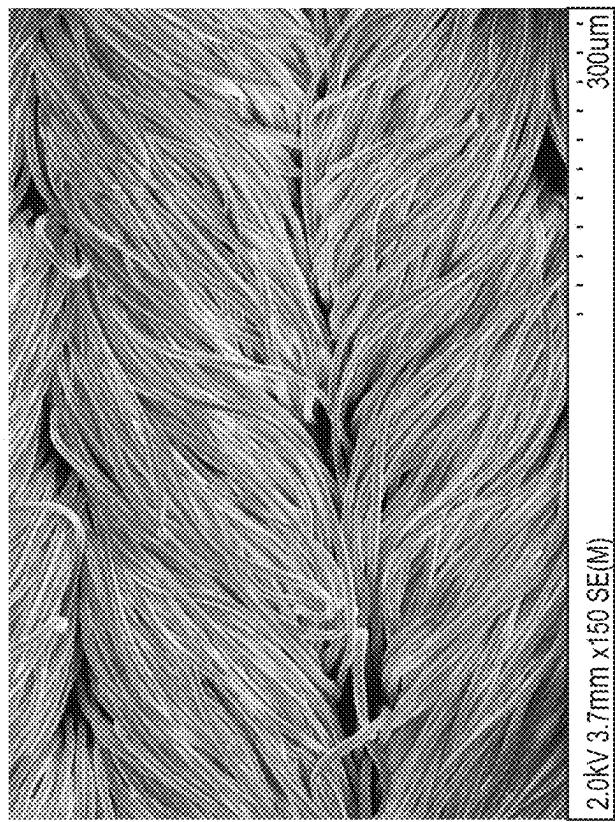


FIG. 121

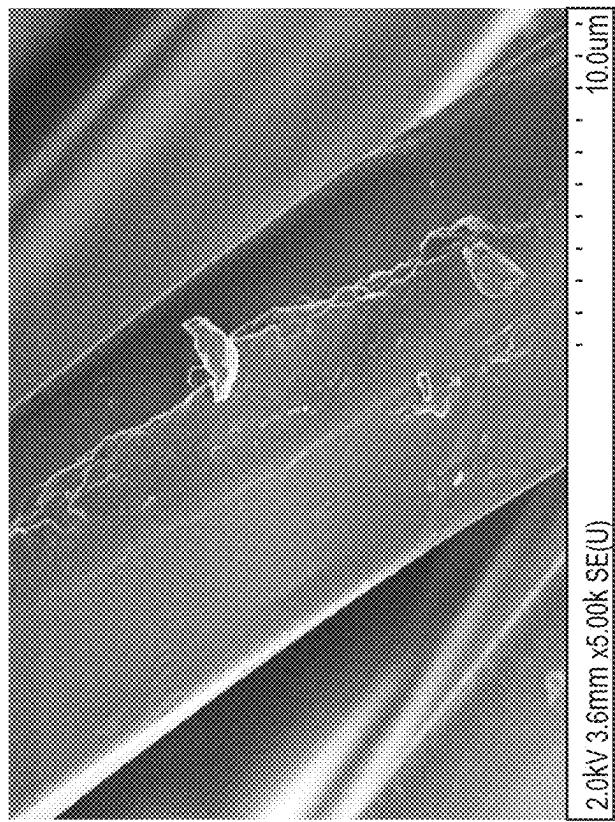


FIG. 122

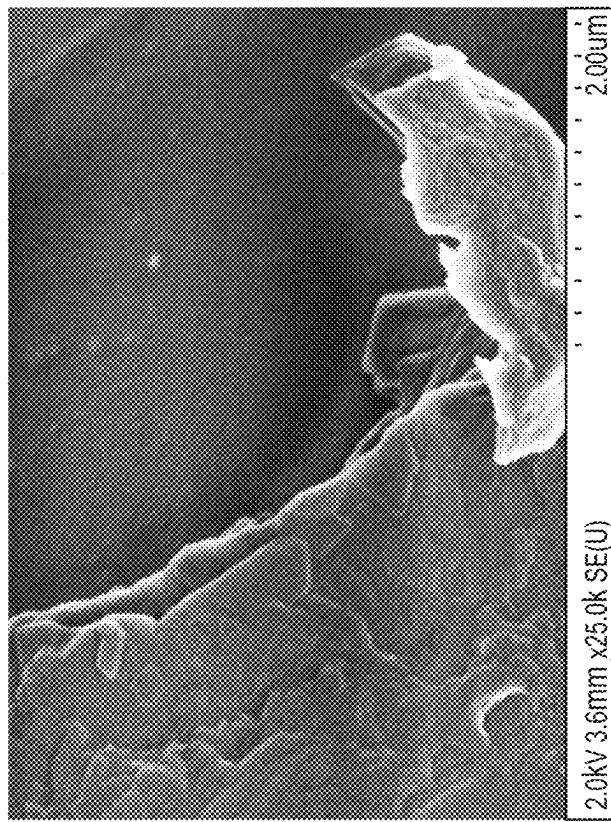


FIG. 123

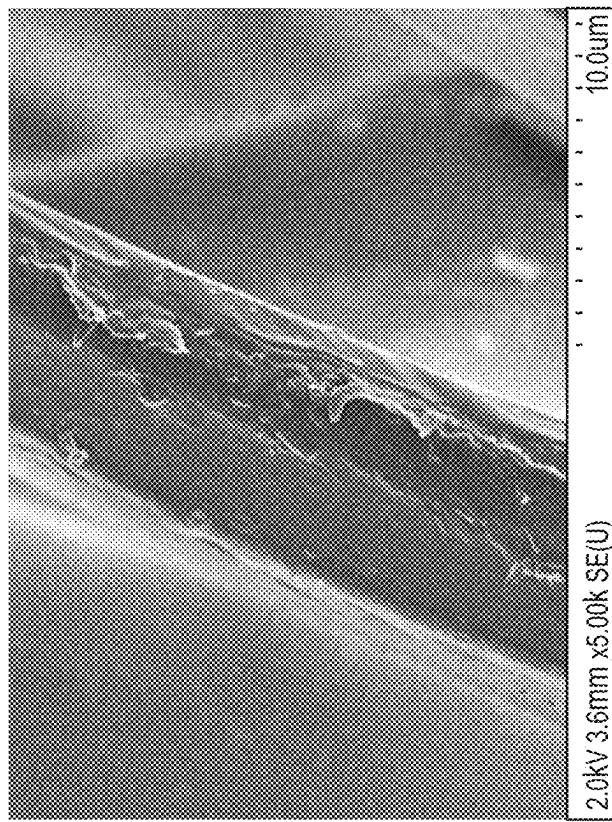


FIG. 124

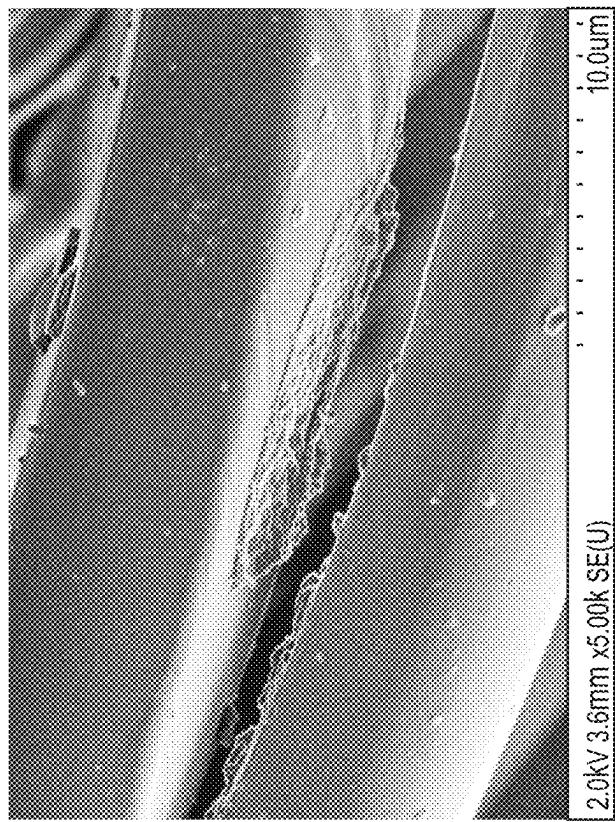


FIG. 125

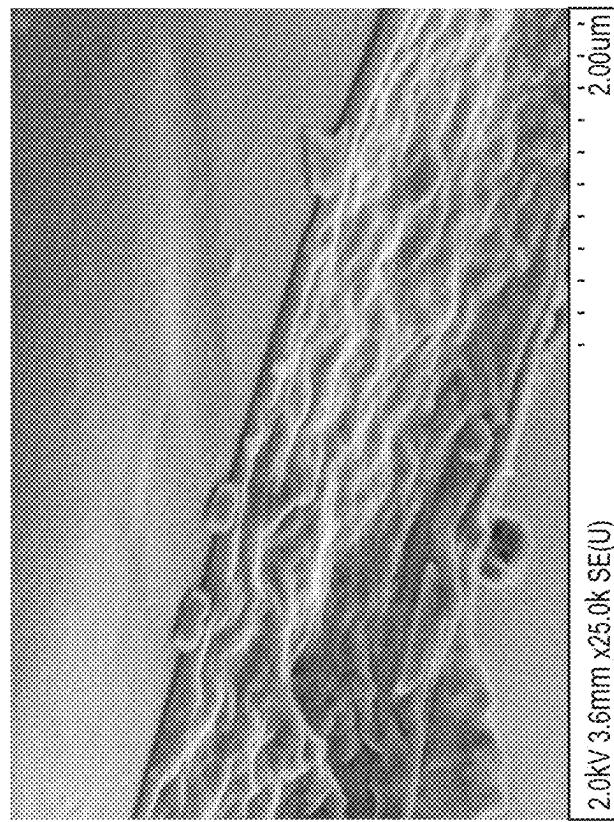


FIG. 126

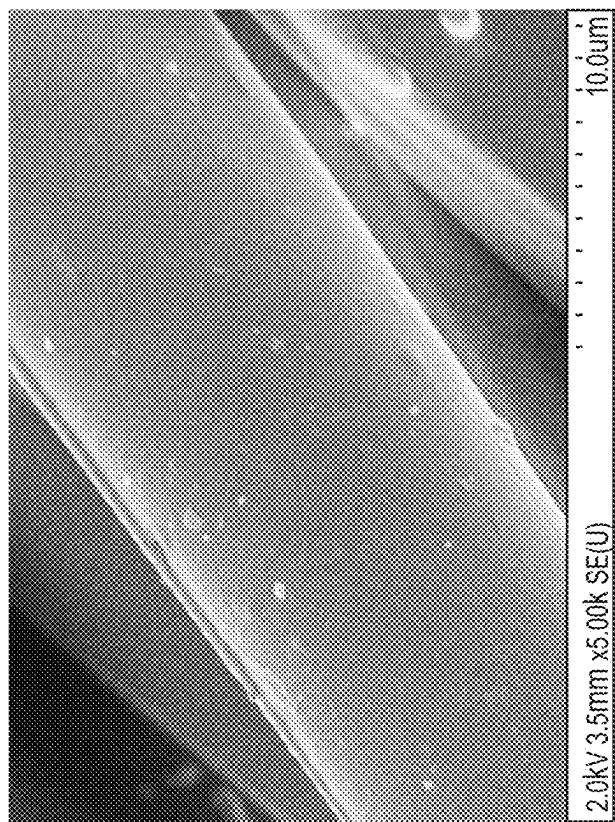


FIG. 127

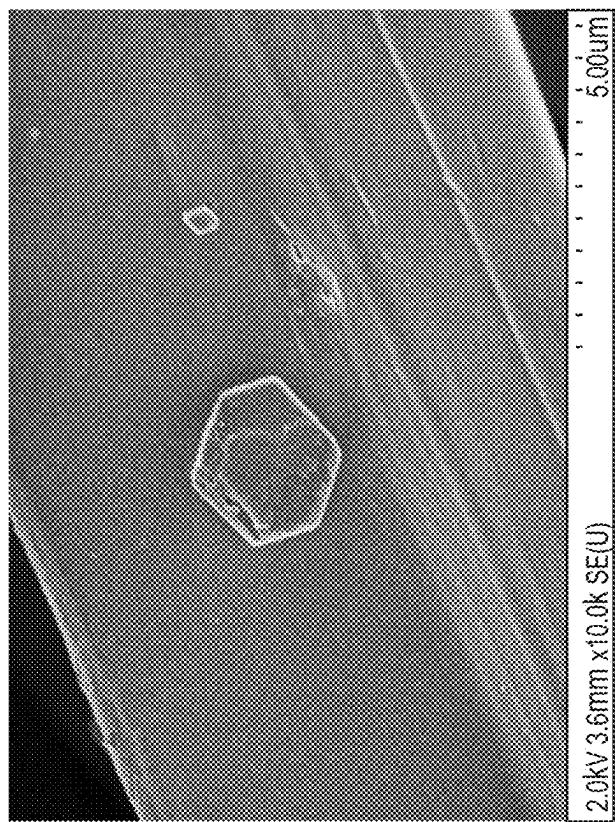


FIG. 128

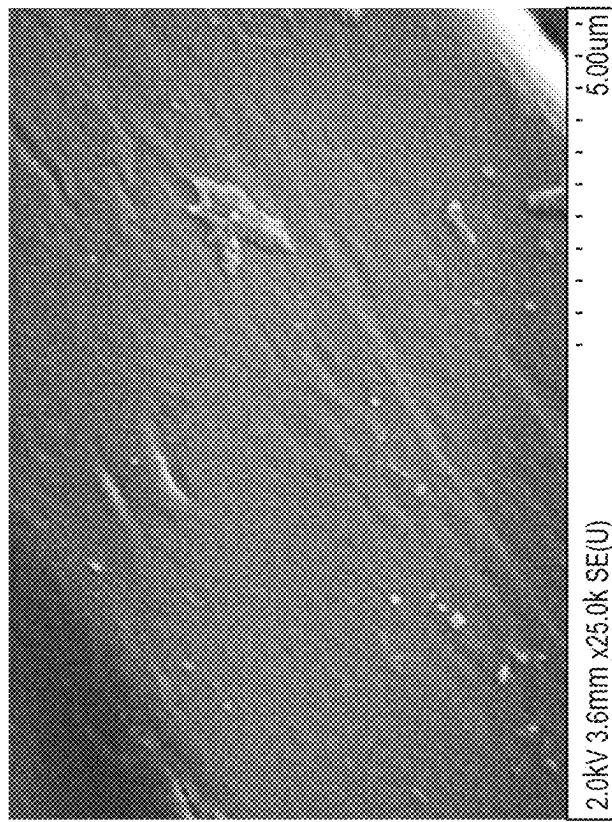


FIG. 129

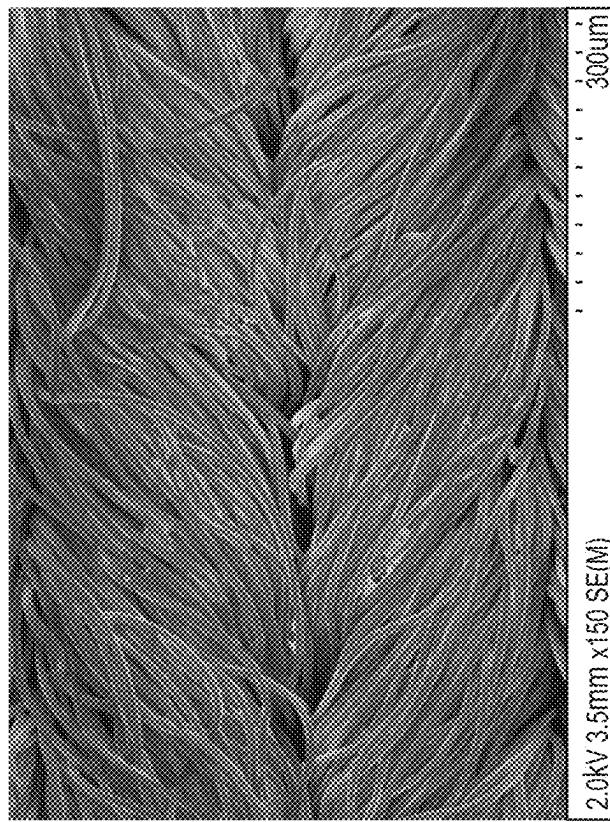


FIG. 130

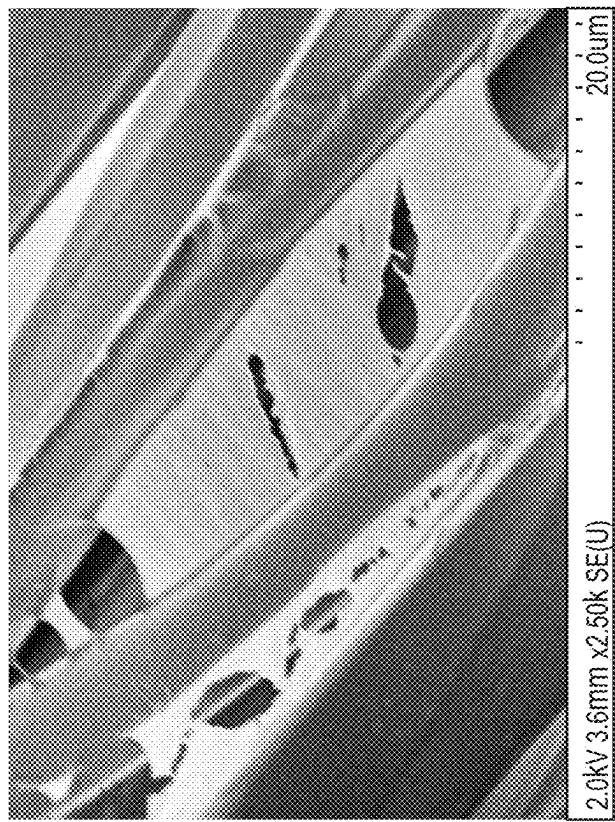


FIG. 131

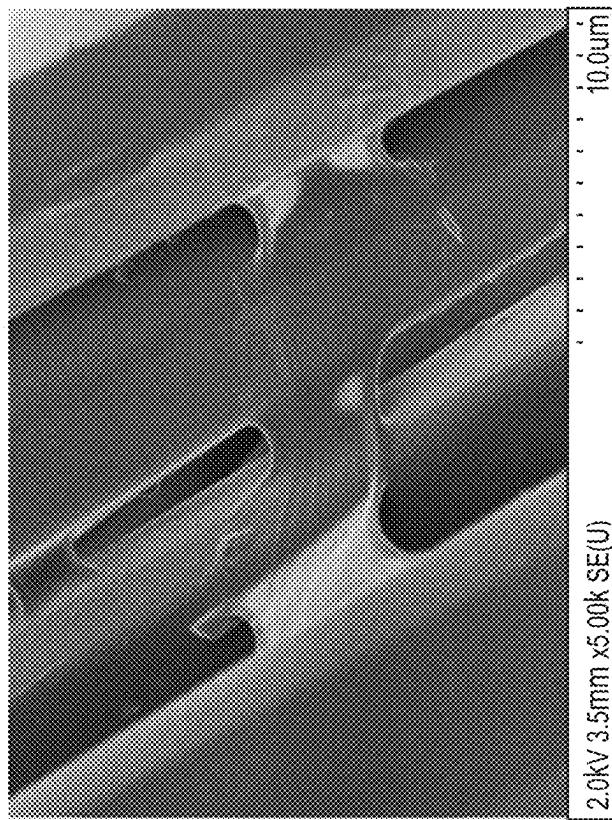


FIG. 132

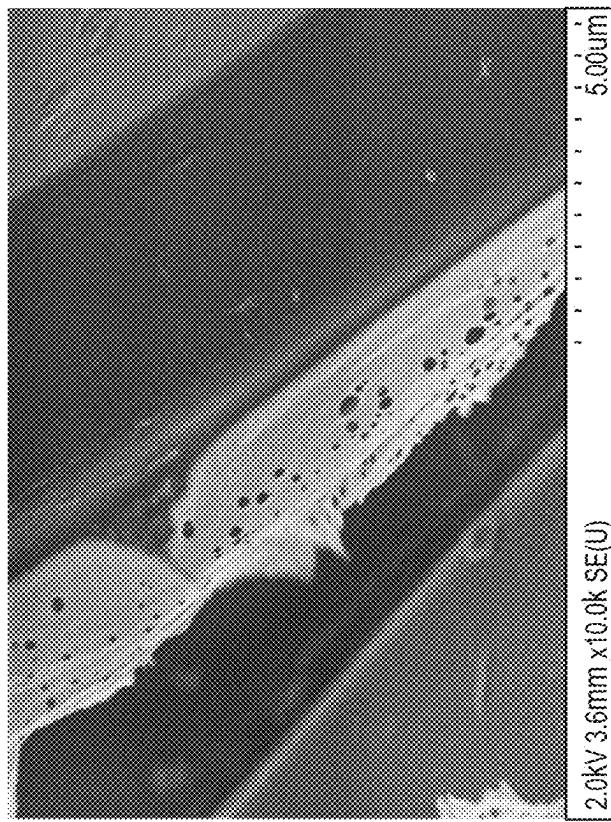


FIG. 133

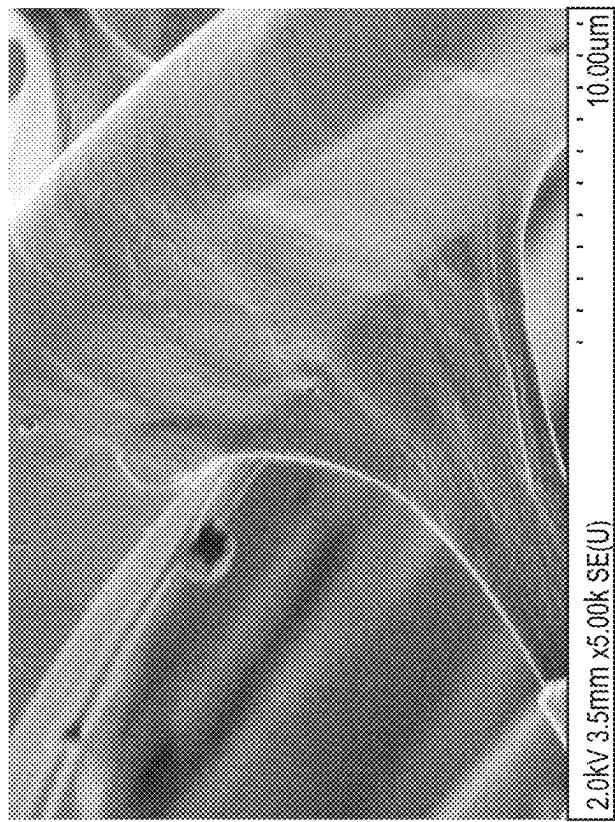


FIG. 134

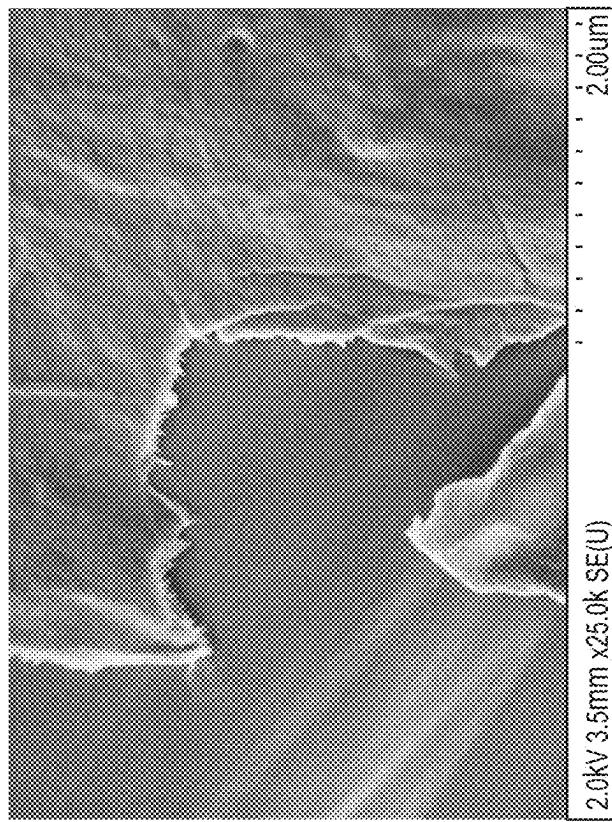


FIG. 135

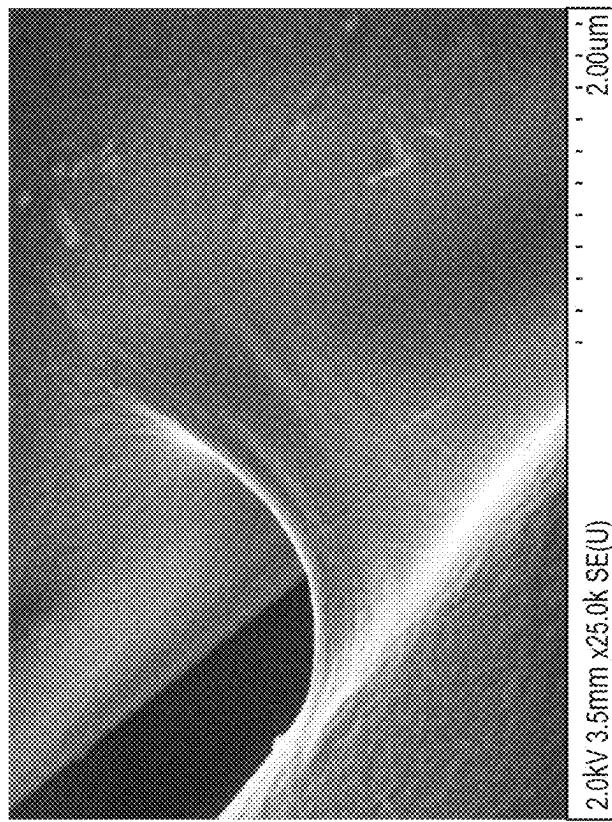


FIG. 136

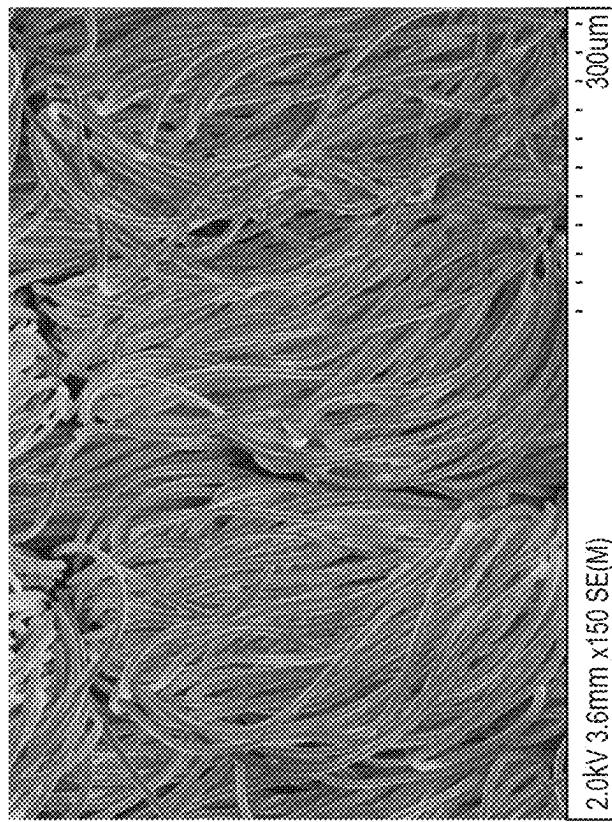


FIG. 137

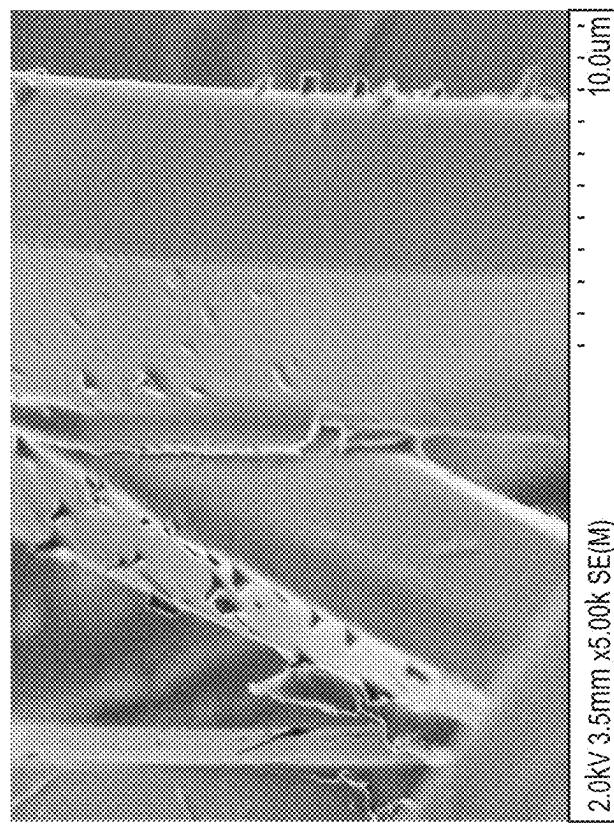


FIG. 138

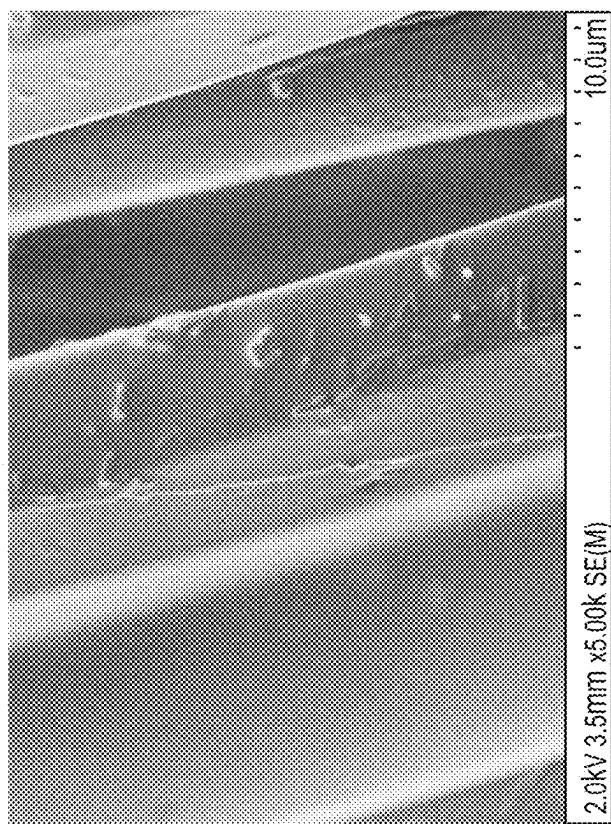


FIG. 139

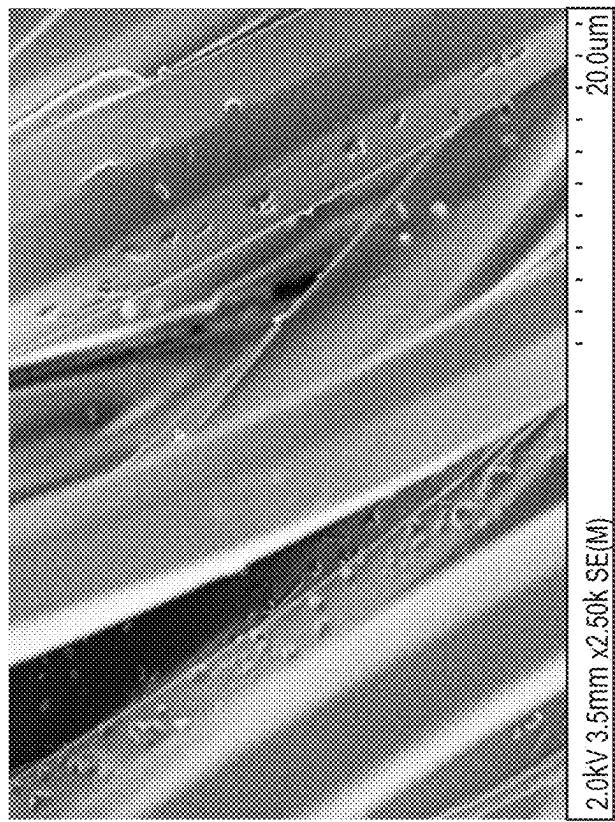


FIG. 140

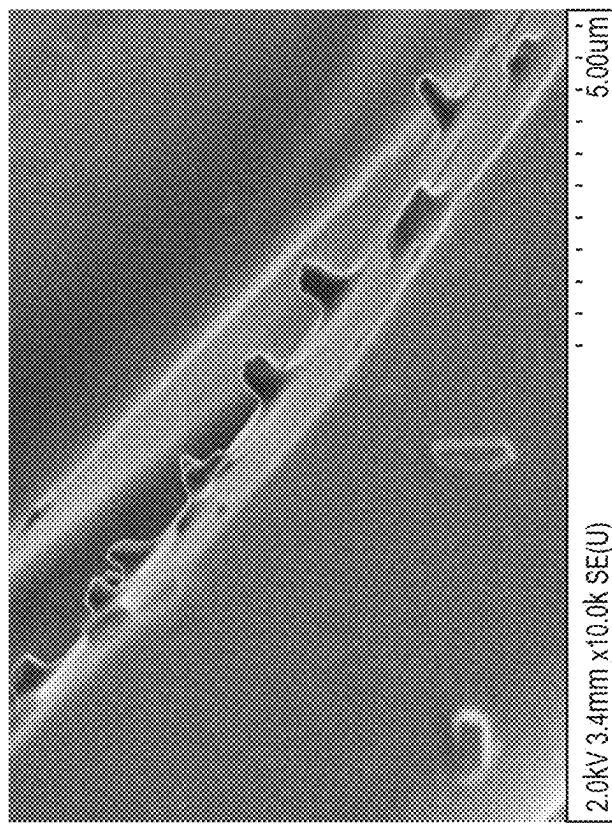


FIG. 141

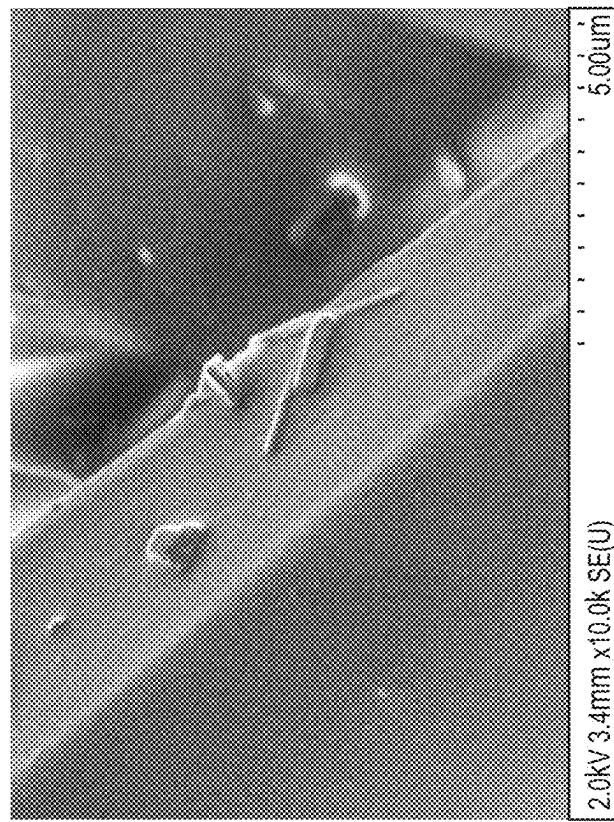


FIG. 142

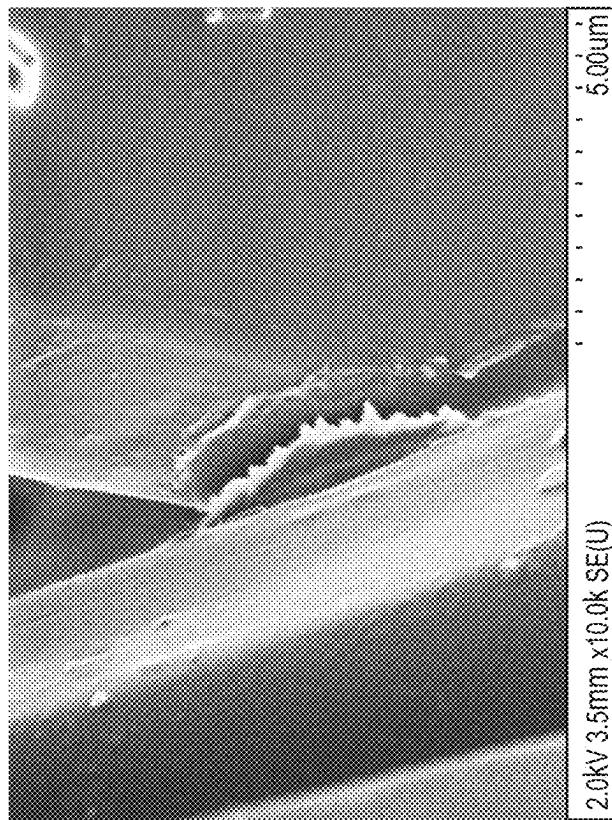


FIG. 143

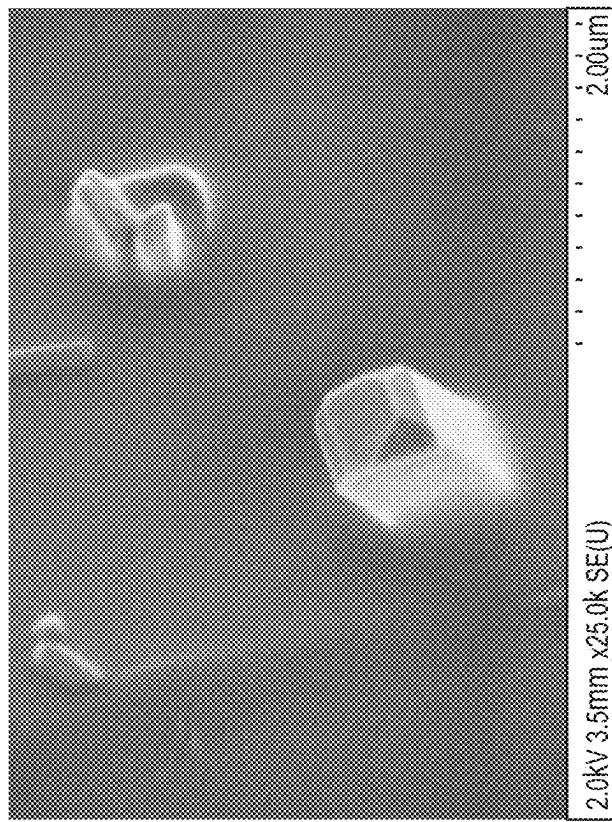


FIG. 144

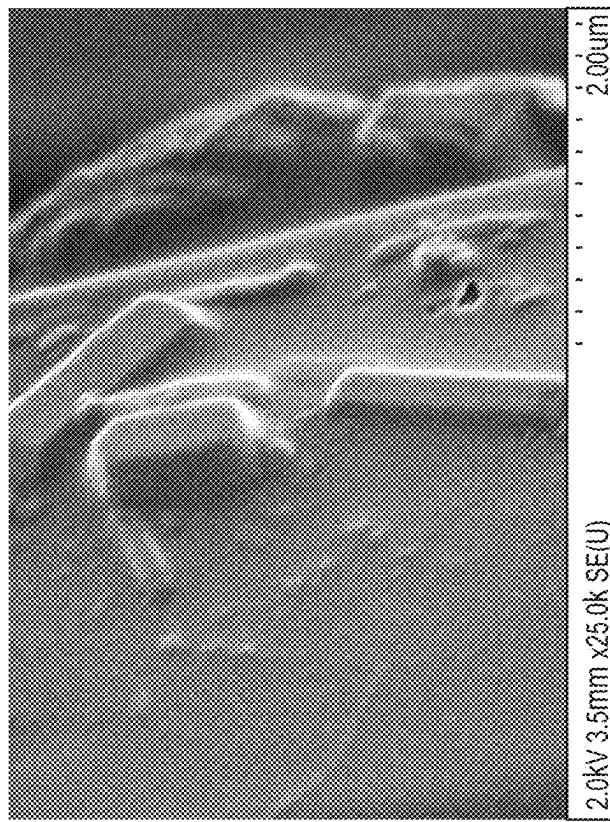


FIG. 145

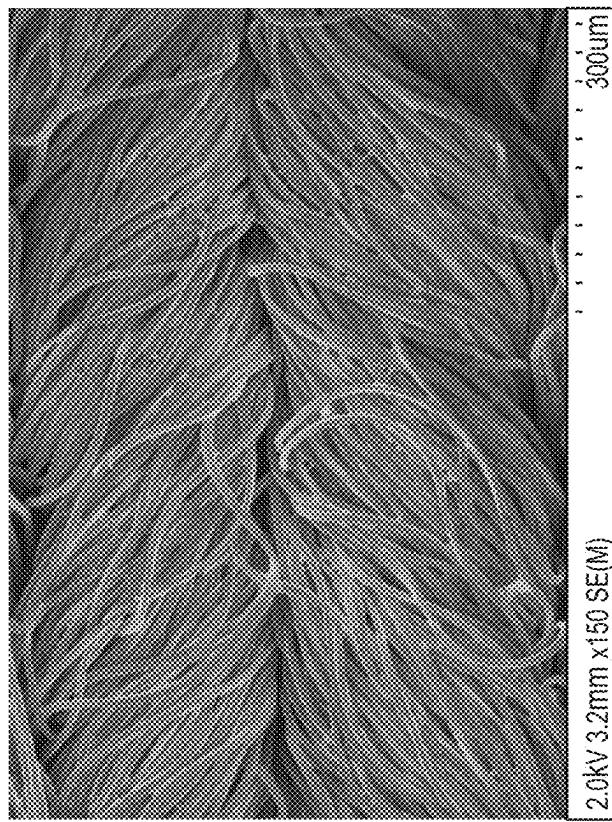


FIG. 146

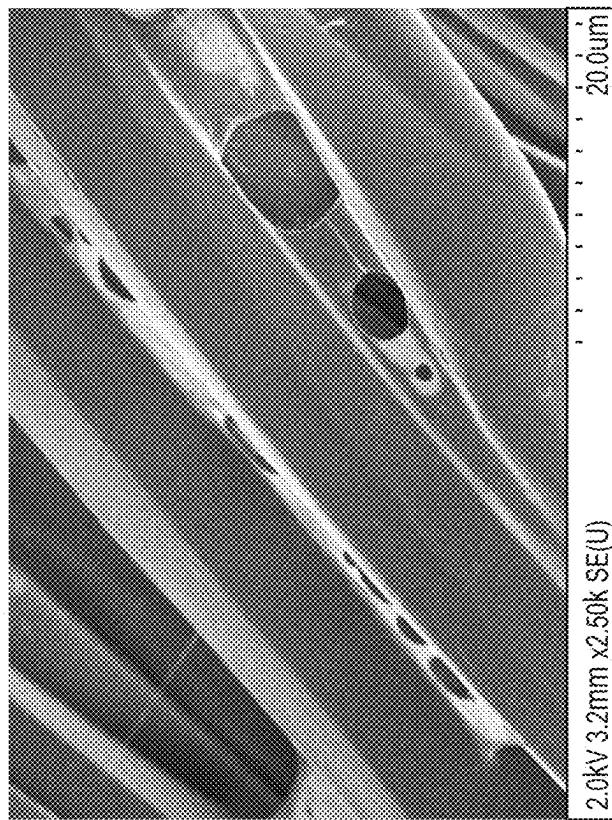


FIG. 147

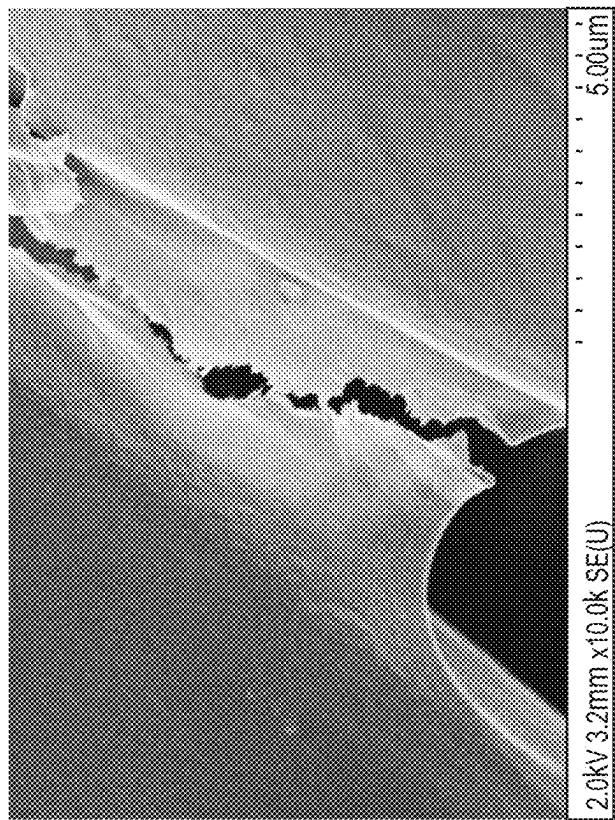


FIG. 148

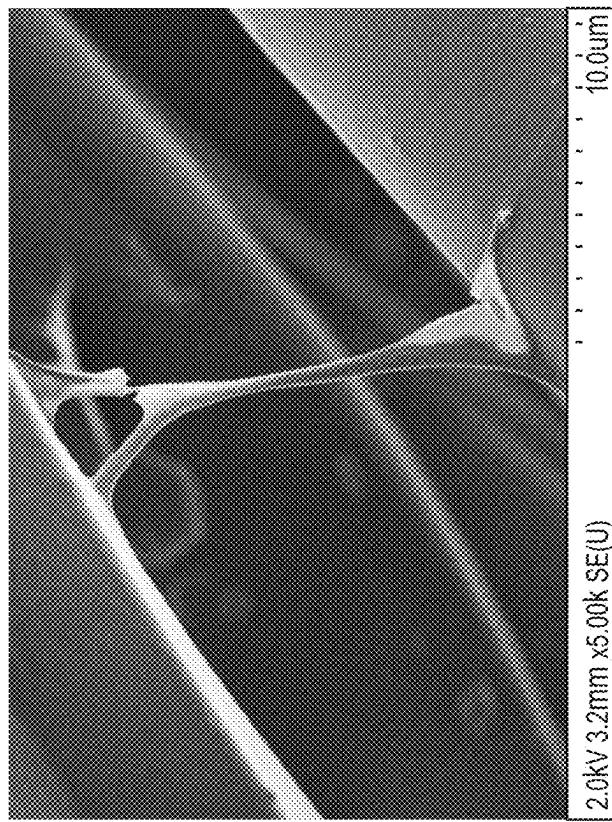


FIG. 149

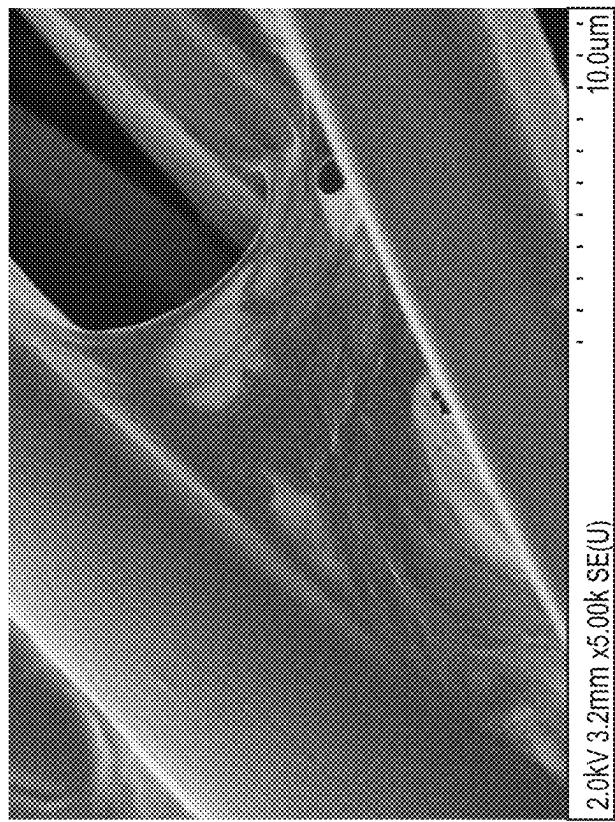


FIG. 150

2.0kV 3.2mm x5.00K SEM

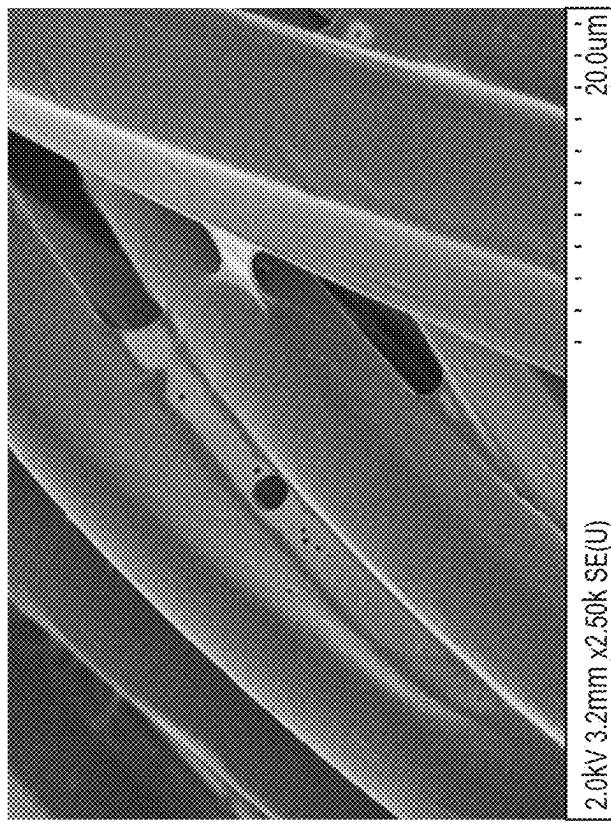


FIG. 151

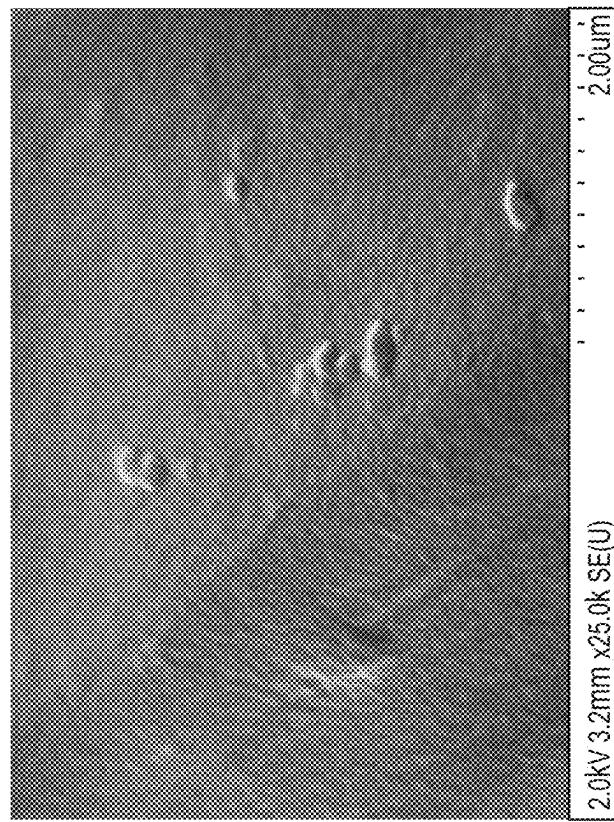


FIG. 152

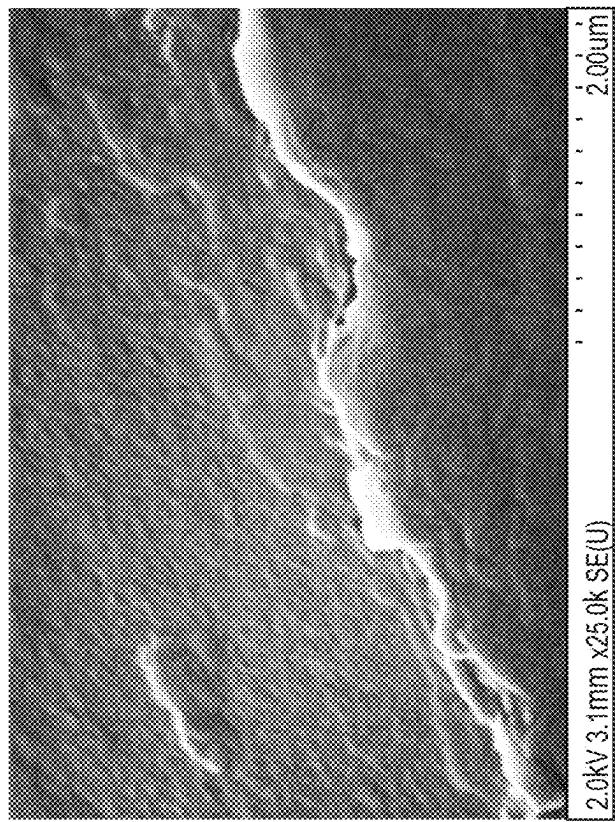


FIG. 153

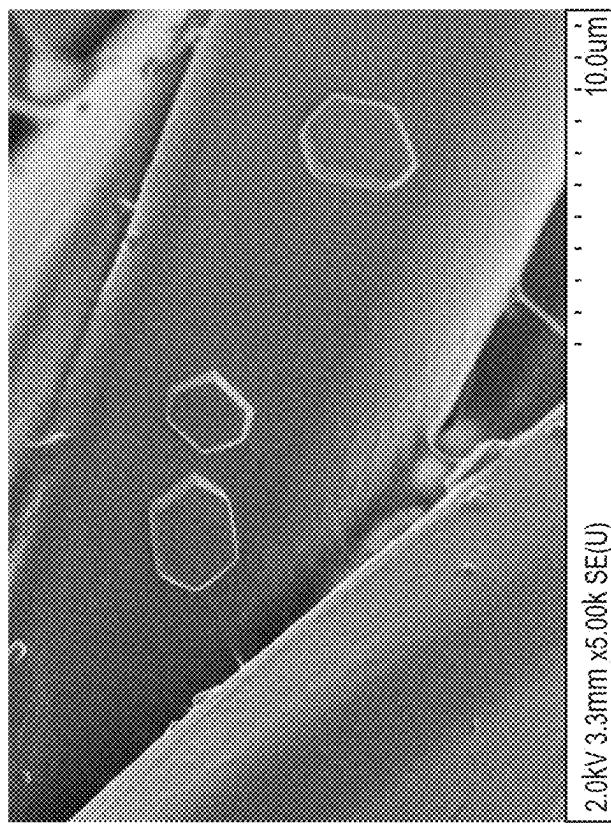


FIG. 154

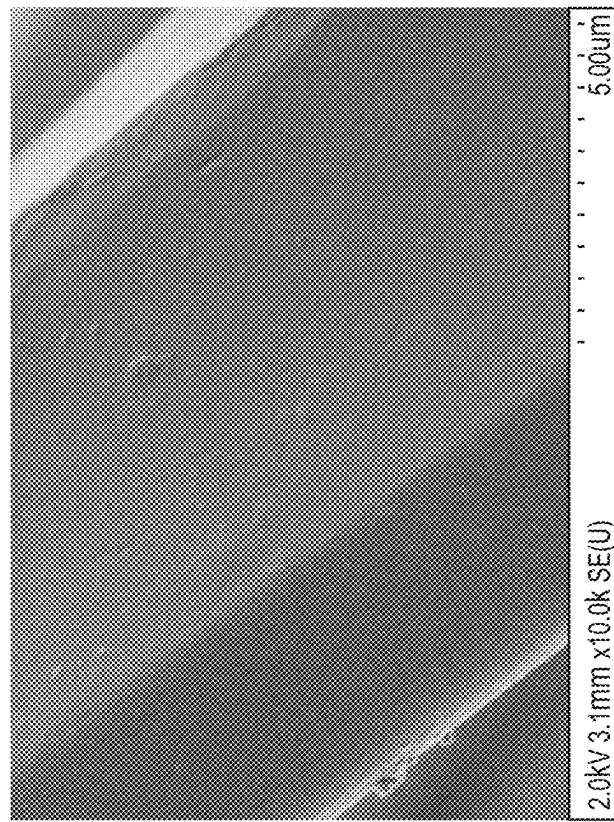


FIG. 155

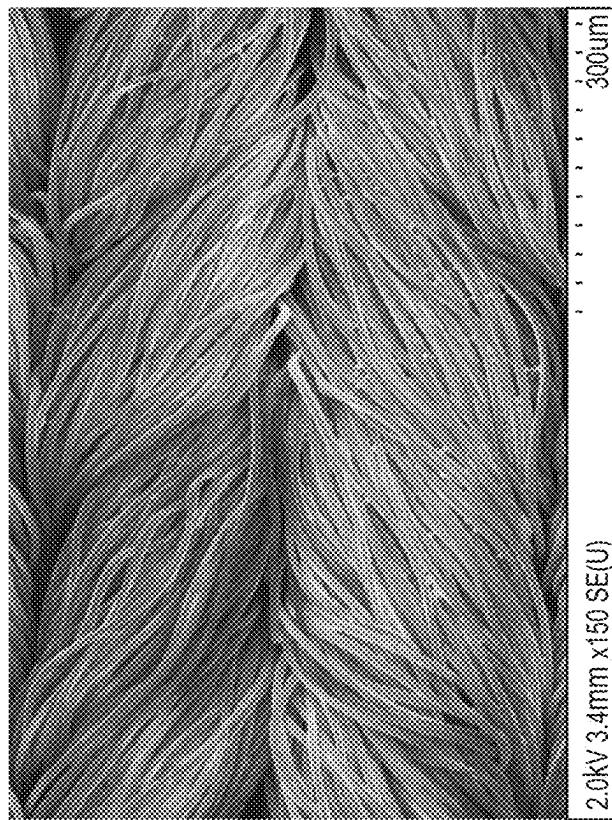


FIG. 156

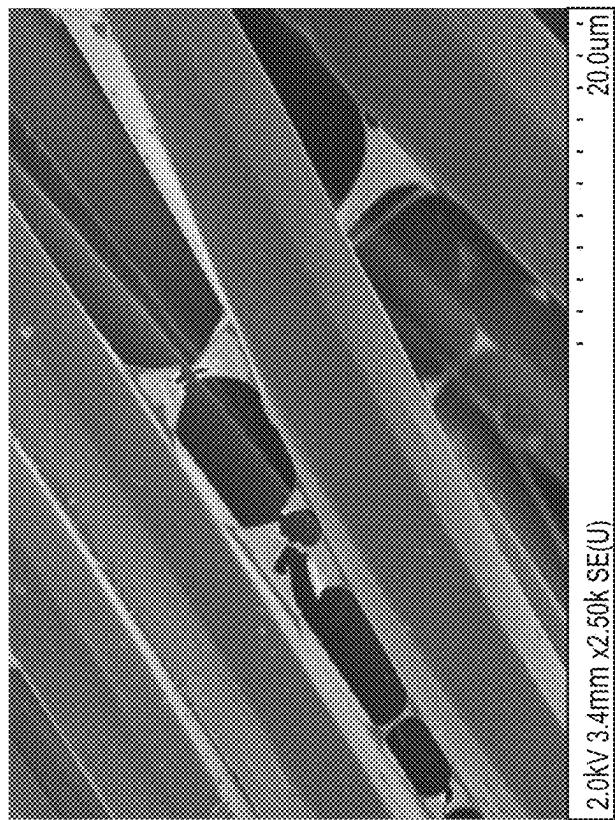


FIG. 157

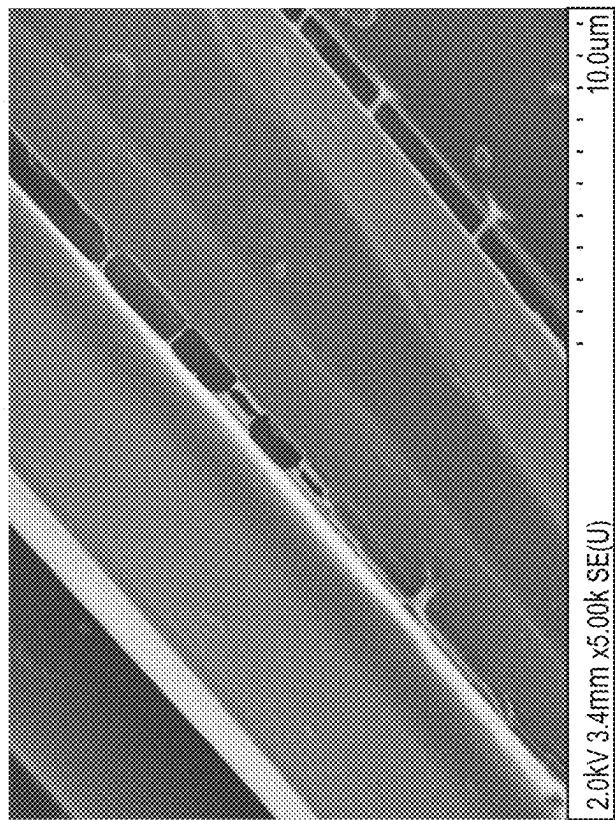


FIG. 158

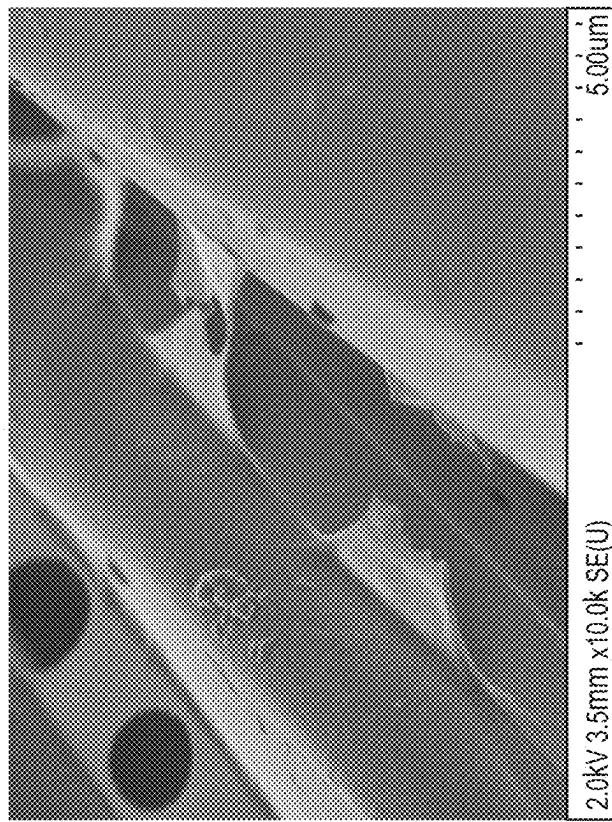


FIG. 159

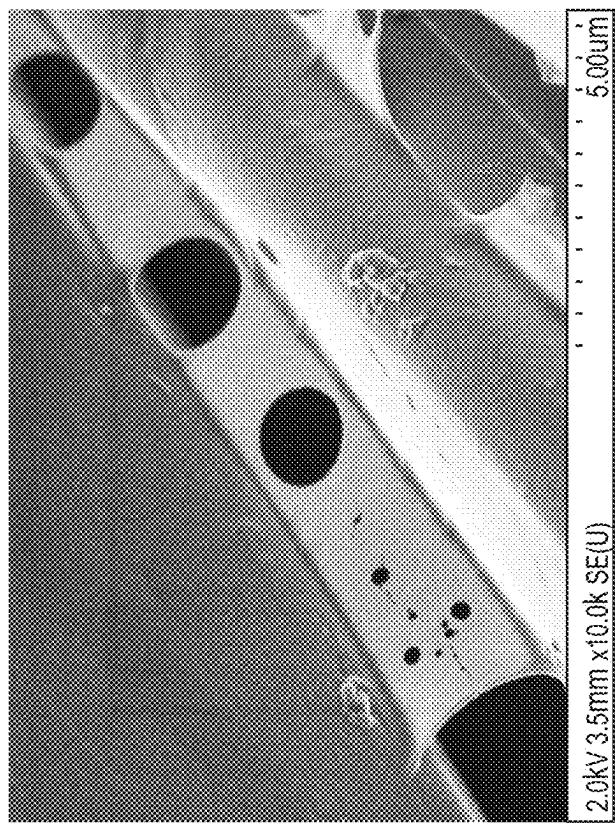


FIG. 160



FIG. 161

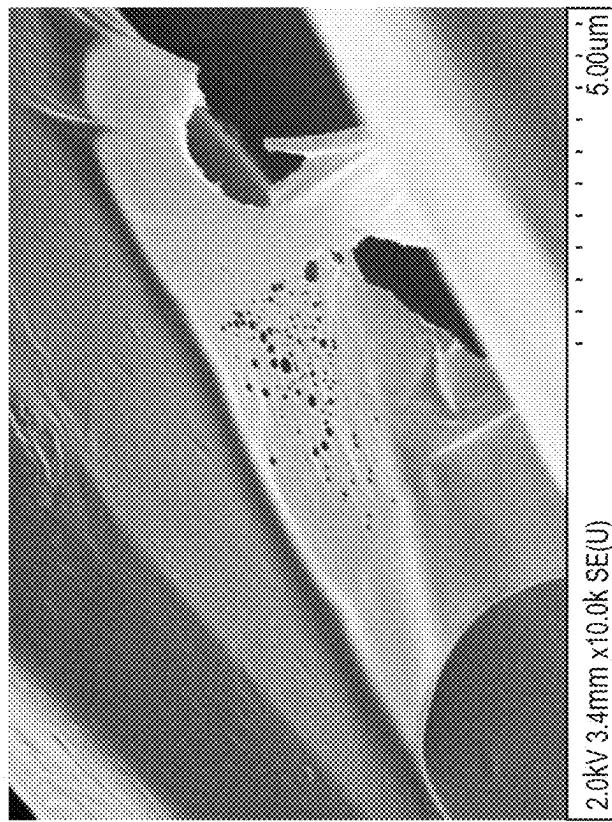


FIG. 162

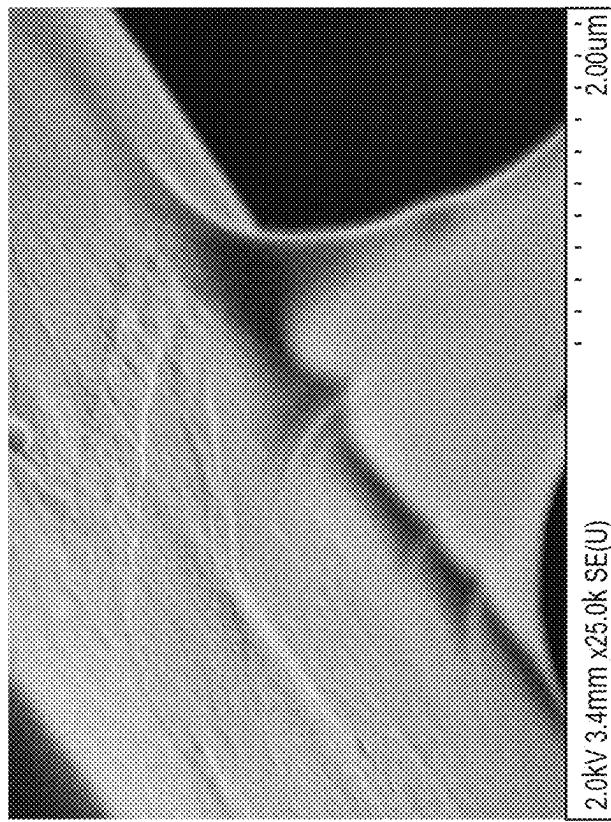


FIG. 163



FIG. 164

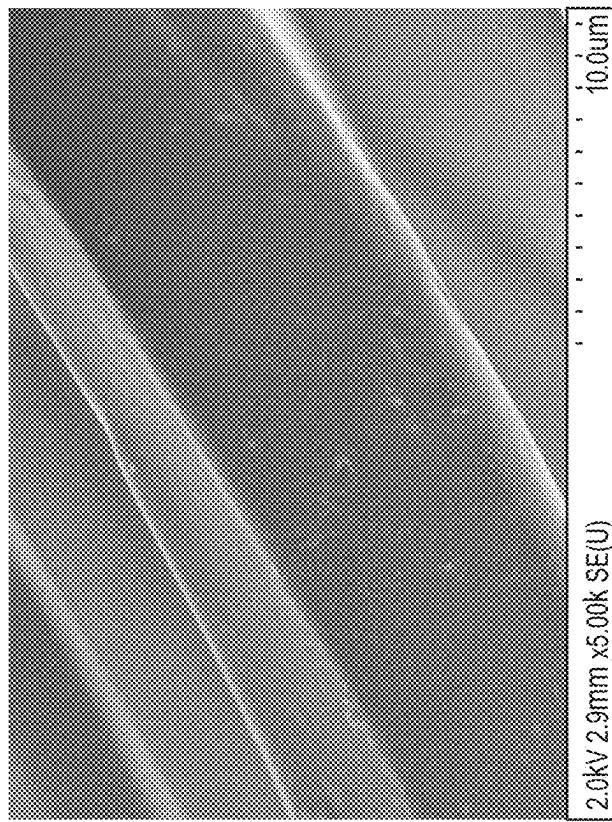


FIG. 165

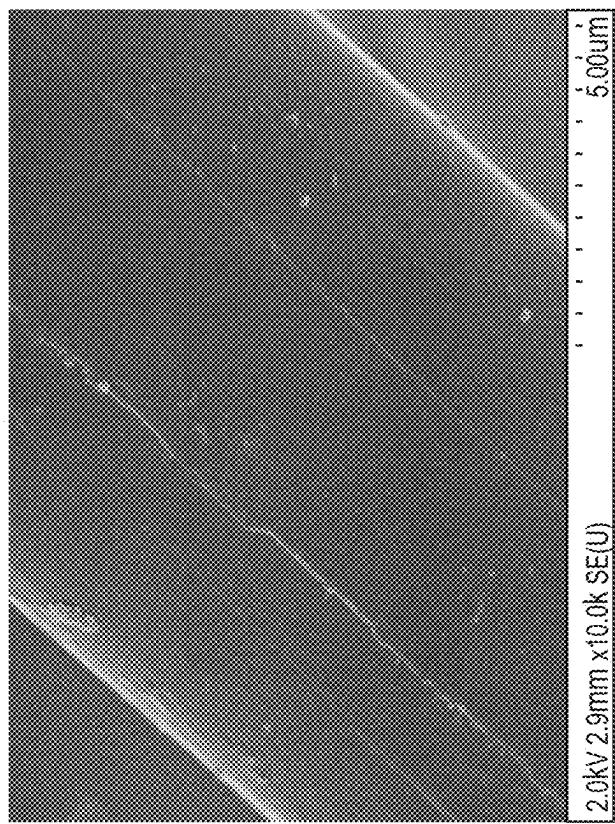


FIG. 166

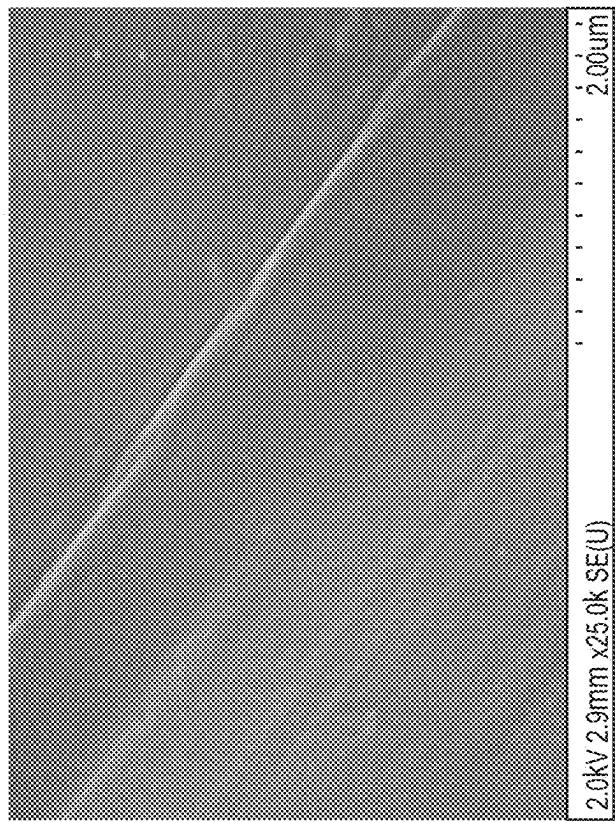


FIG. 167

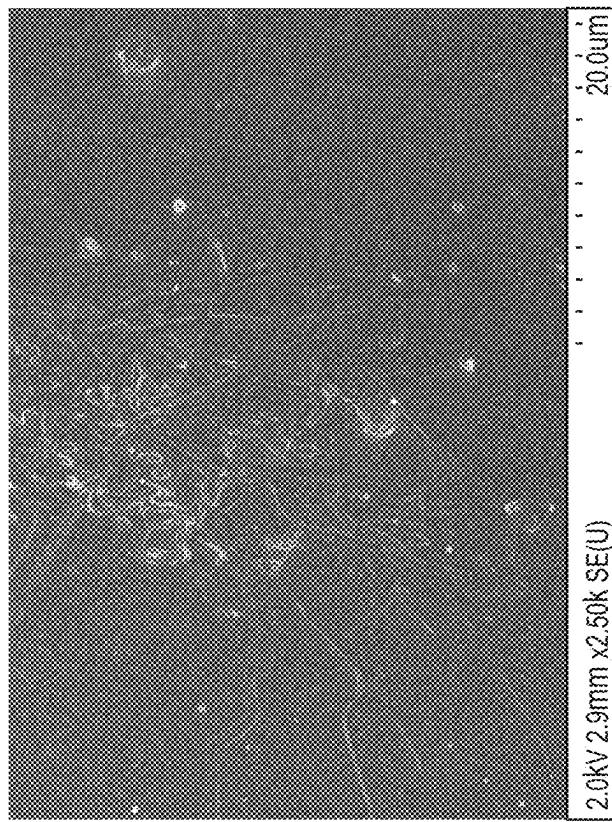


FIG. 168

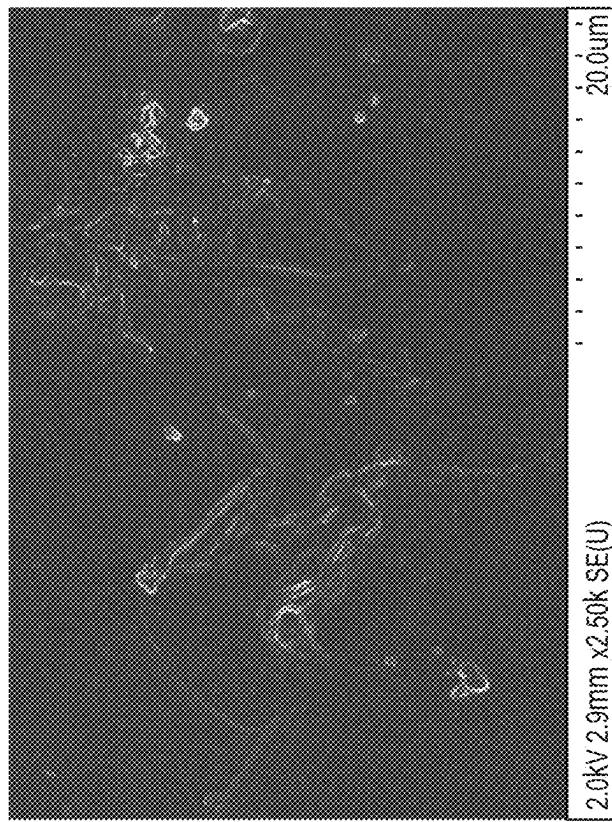


FIG. 169

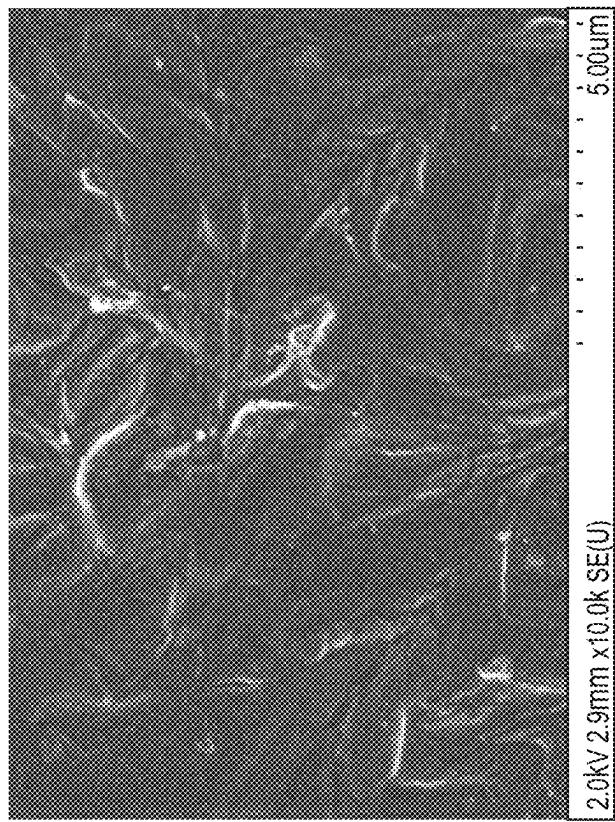


FIG. 170



FIG. 171

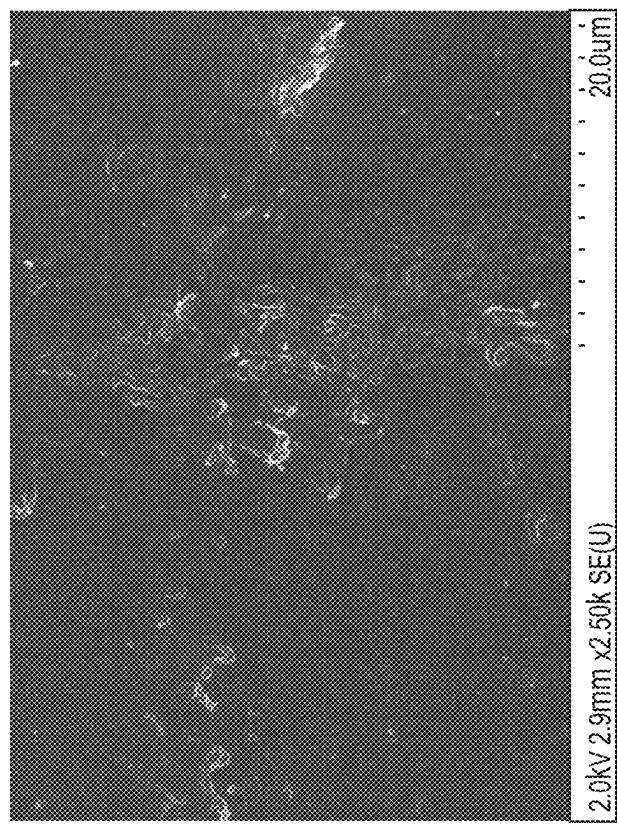


FIG. 172

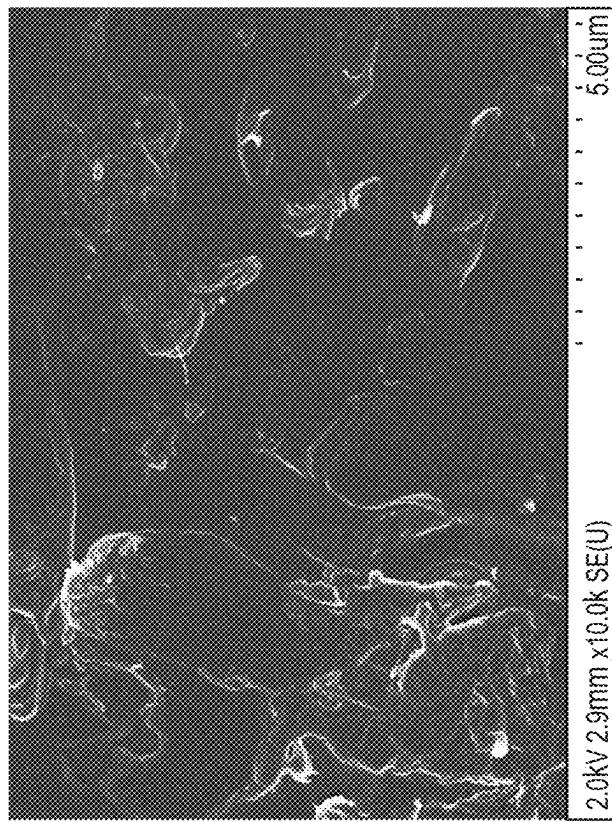


FIG. 173



FIG. 174

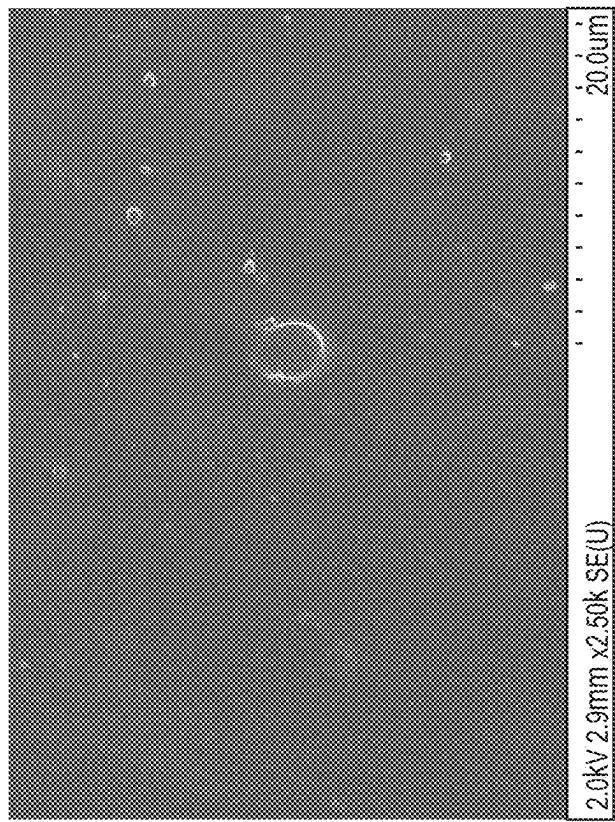


FIG. 175

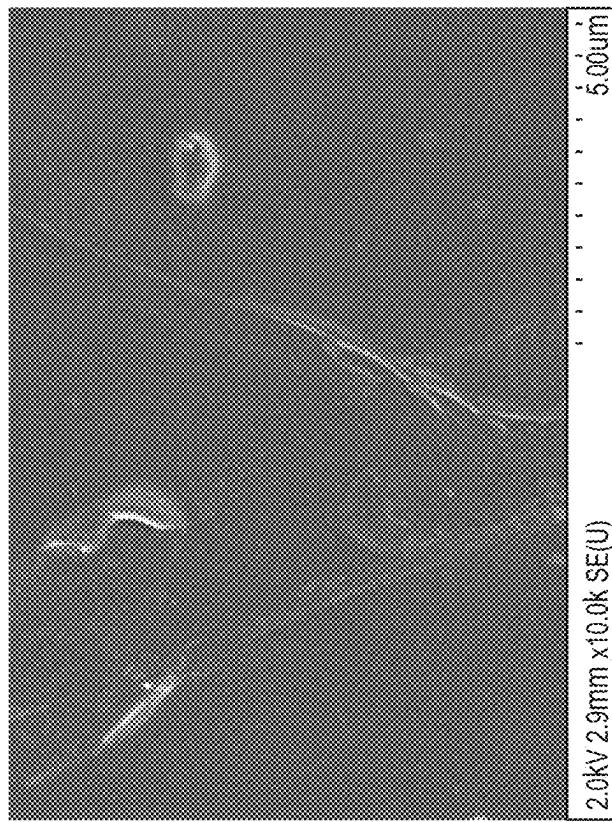


FIG. 176

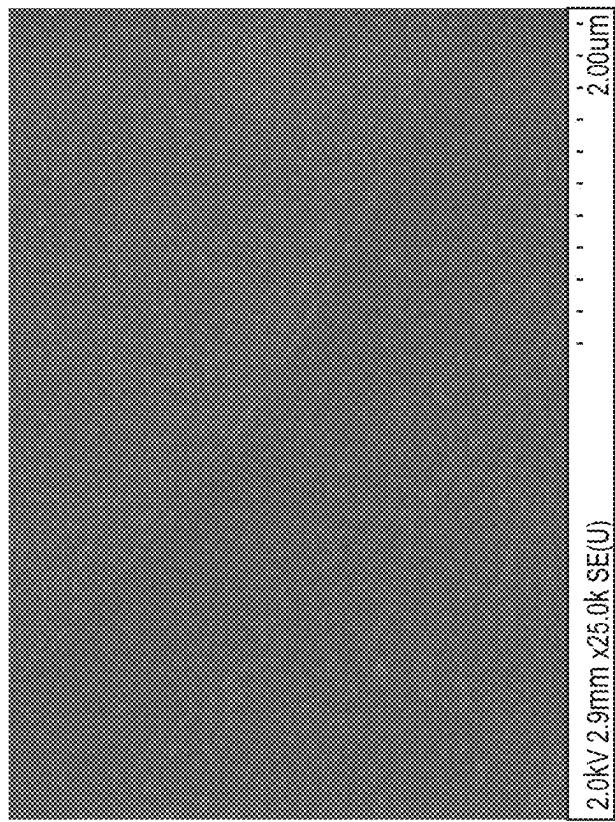


FIG. 177

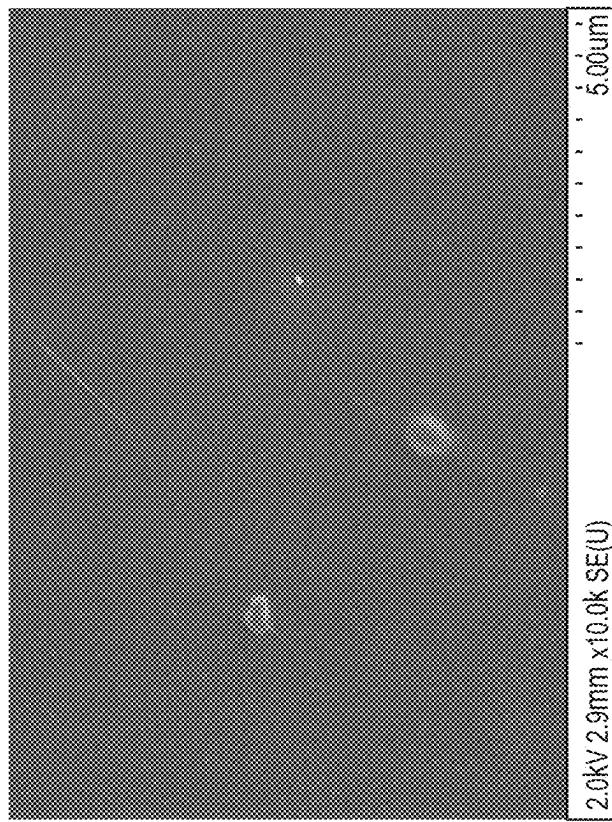


FIG. 178

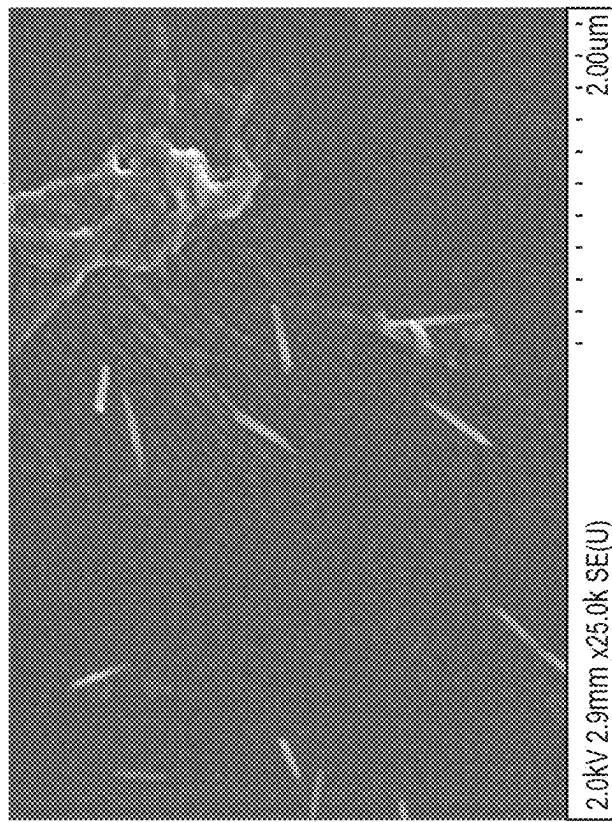


FIG. 179

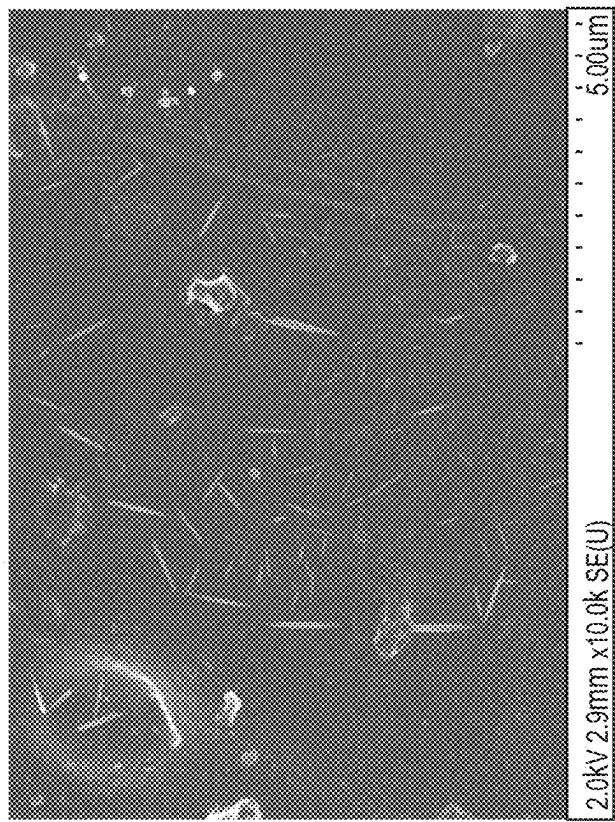


FIG. 180

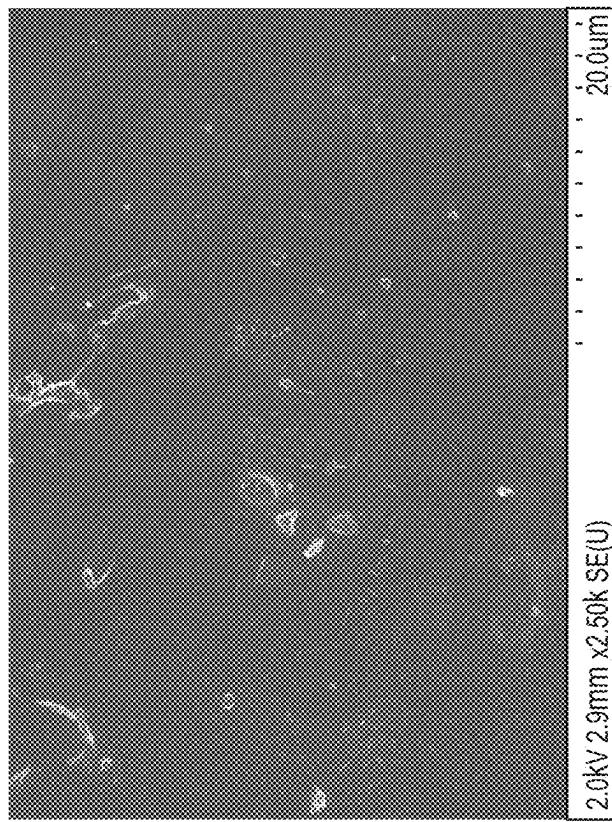


FIG. 181

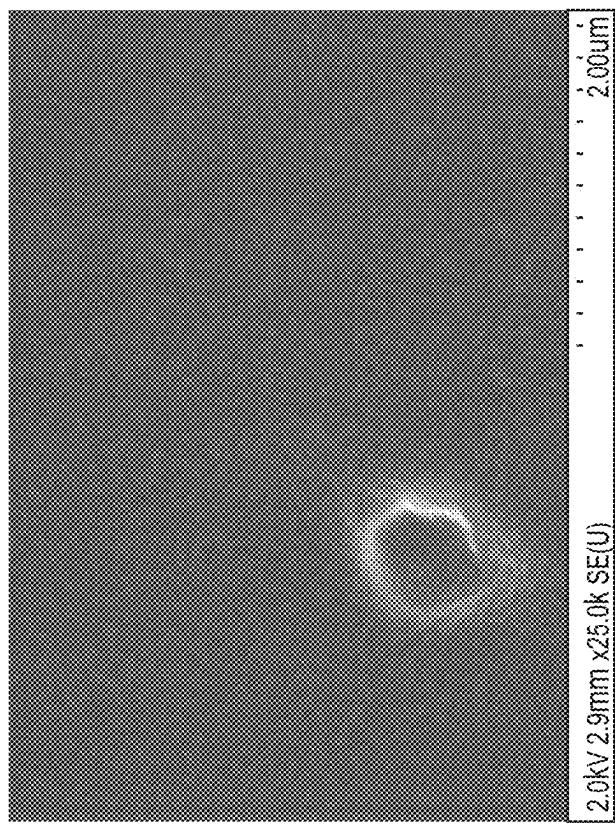


FIG. 182

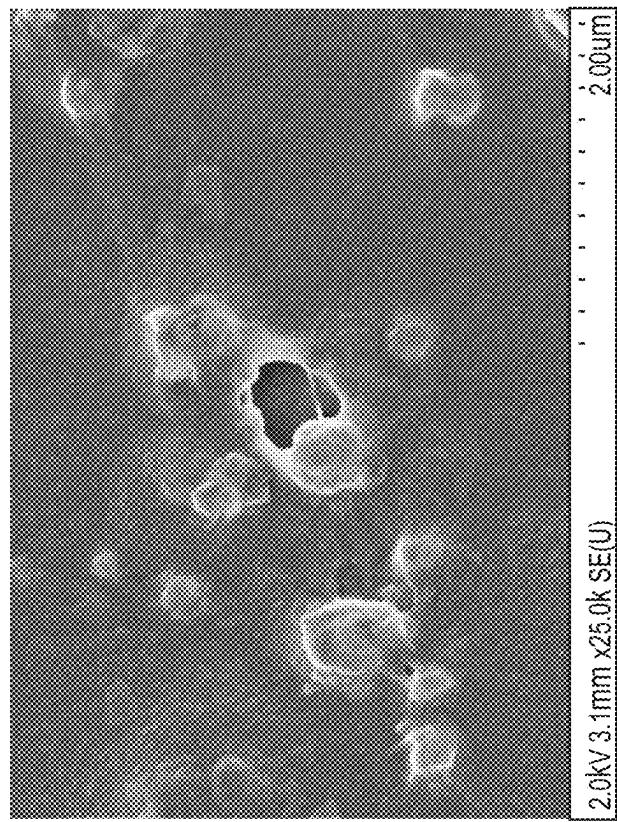


FIG. 183

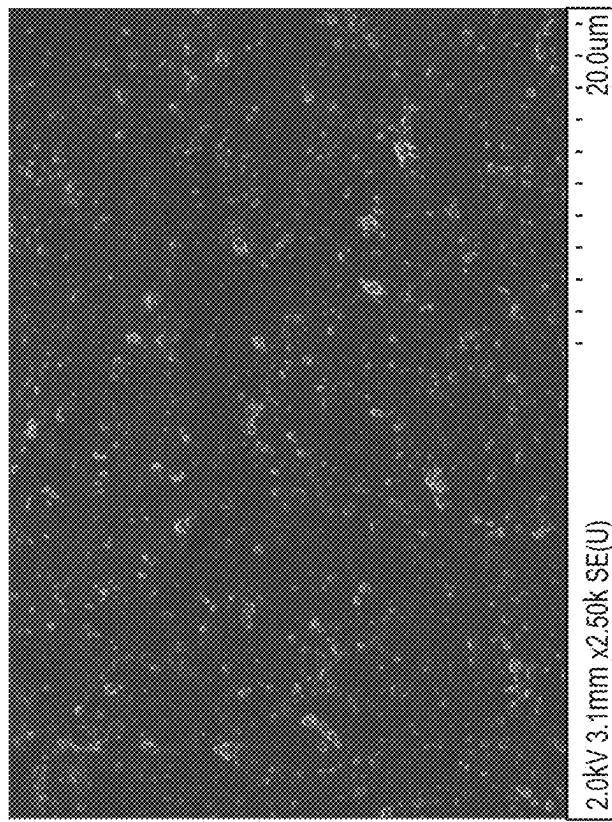


FIG. 184

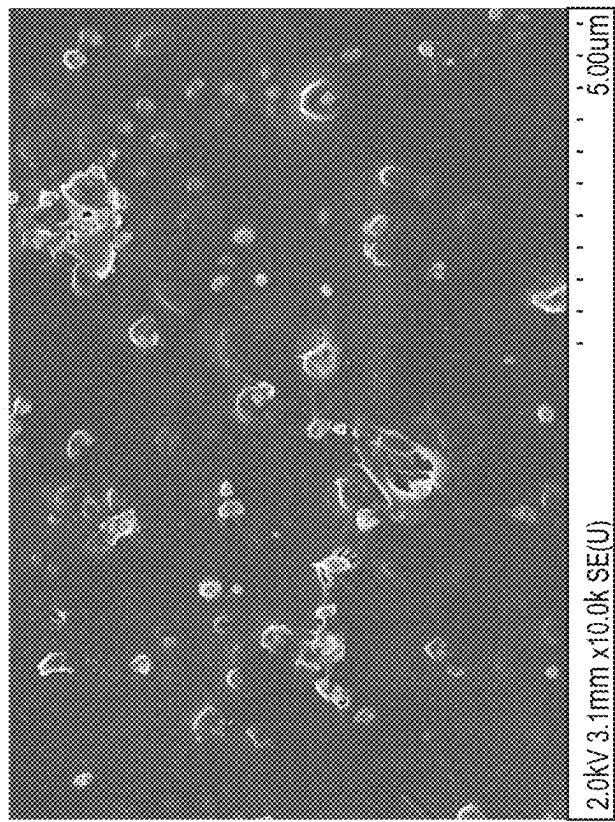


FIG. 185

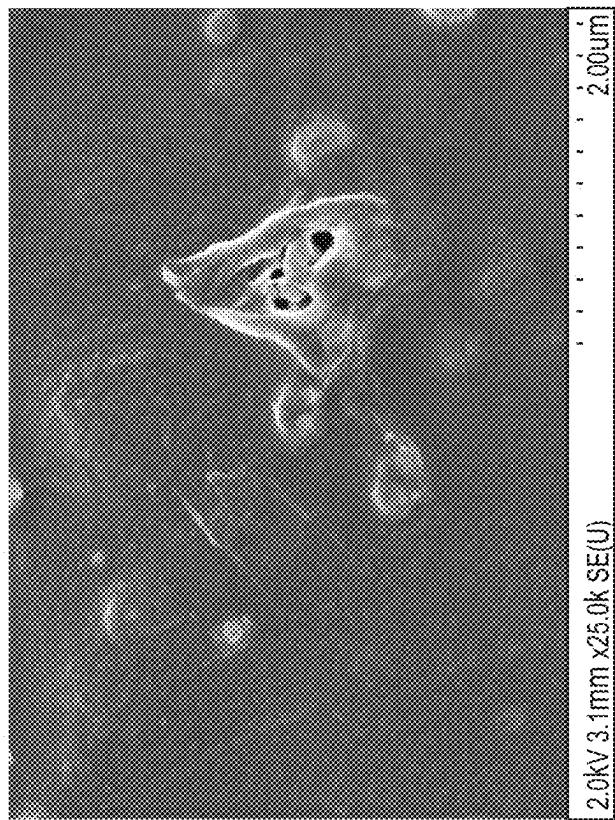


FIG. 186

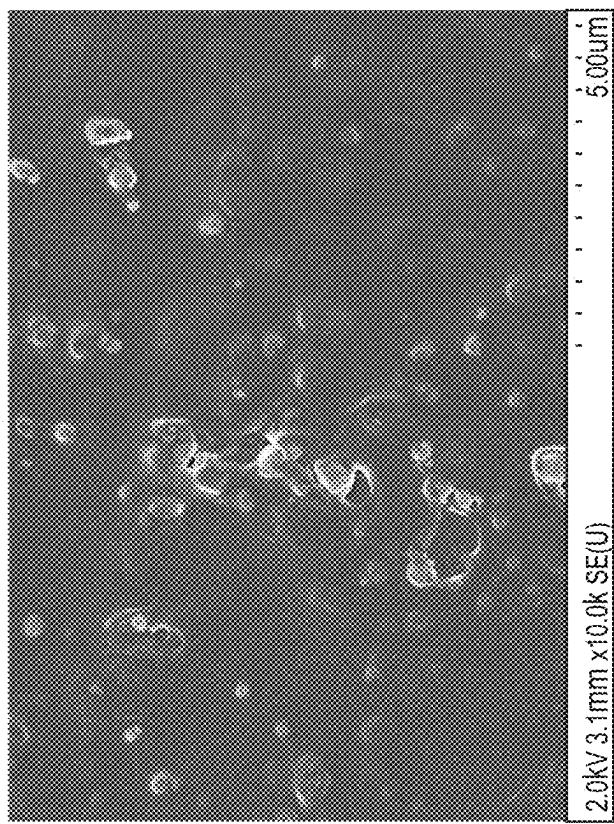


FIG. 187

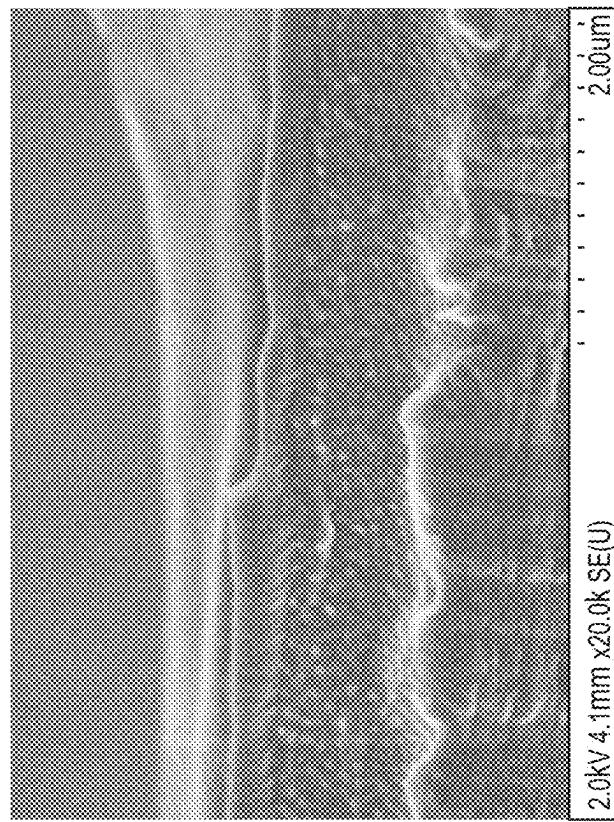


FIG. 188

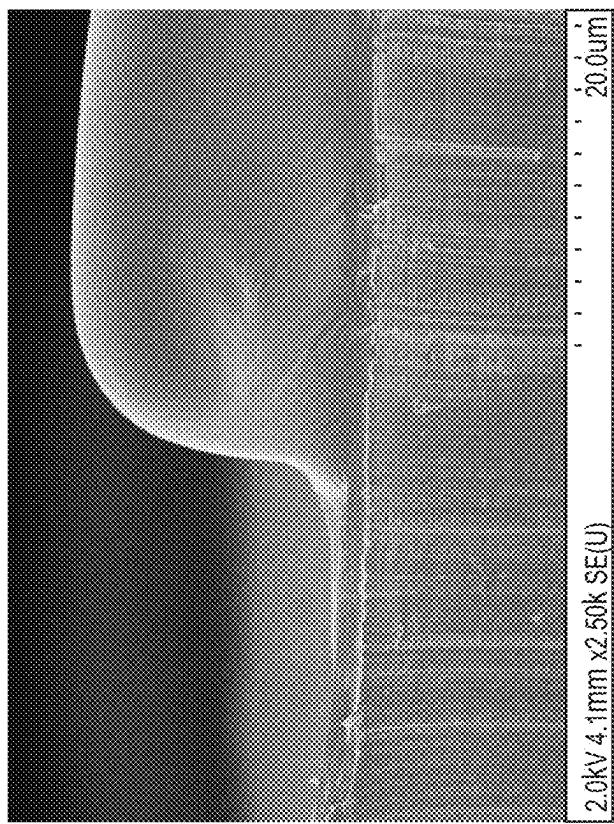


FIG. 189

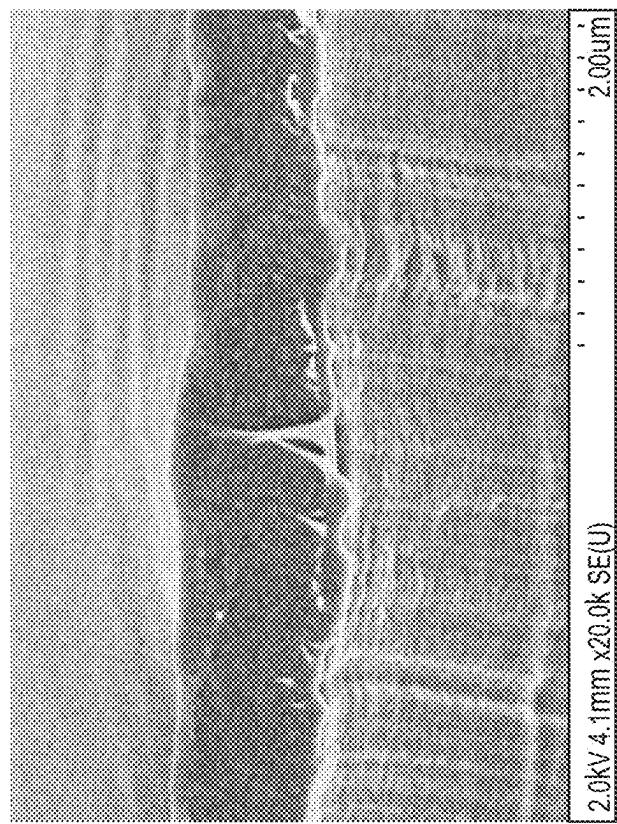


FIG. 190

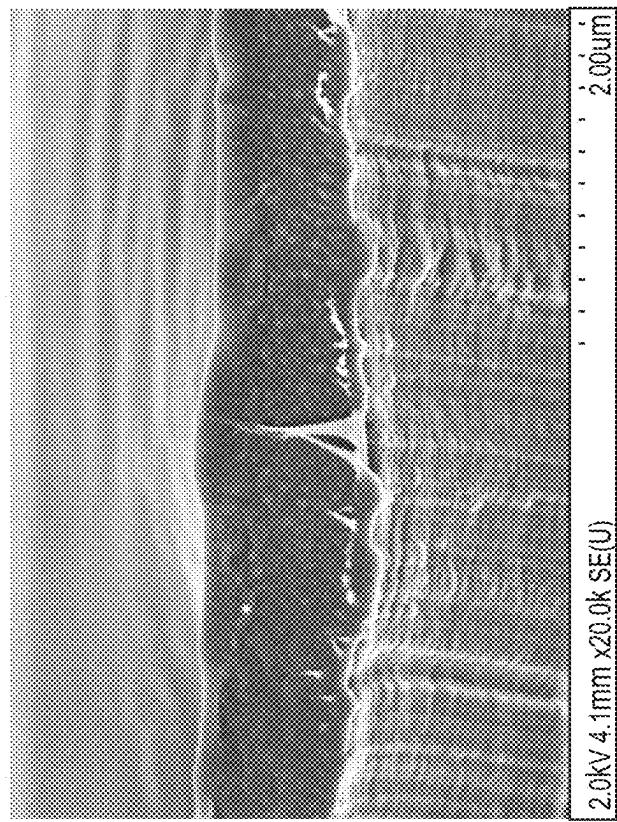


FIG. 191

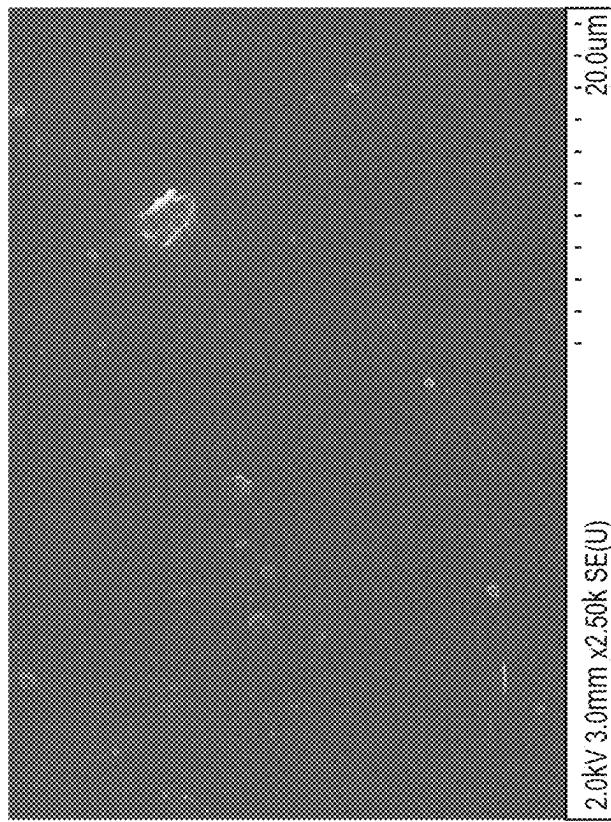


FIG. 192

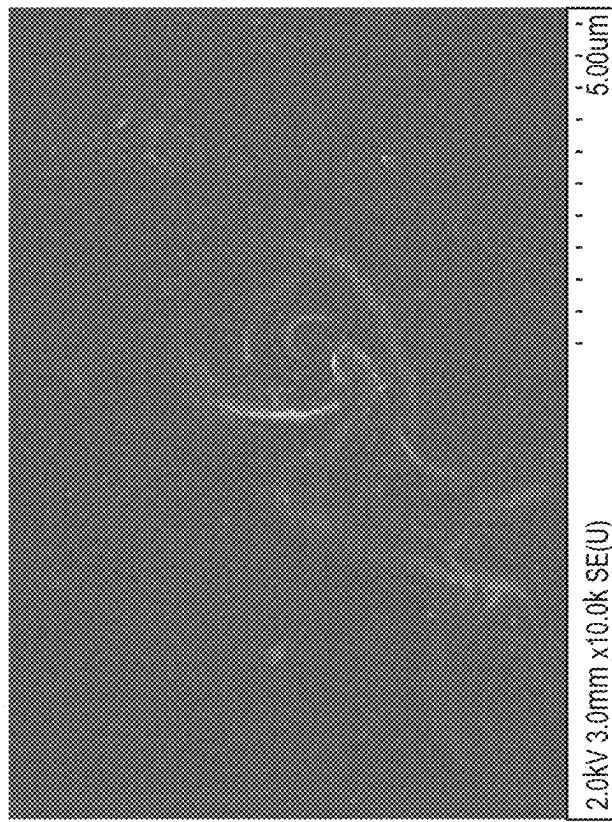


FIG. 193

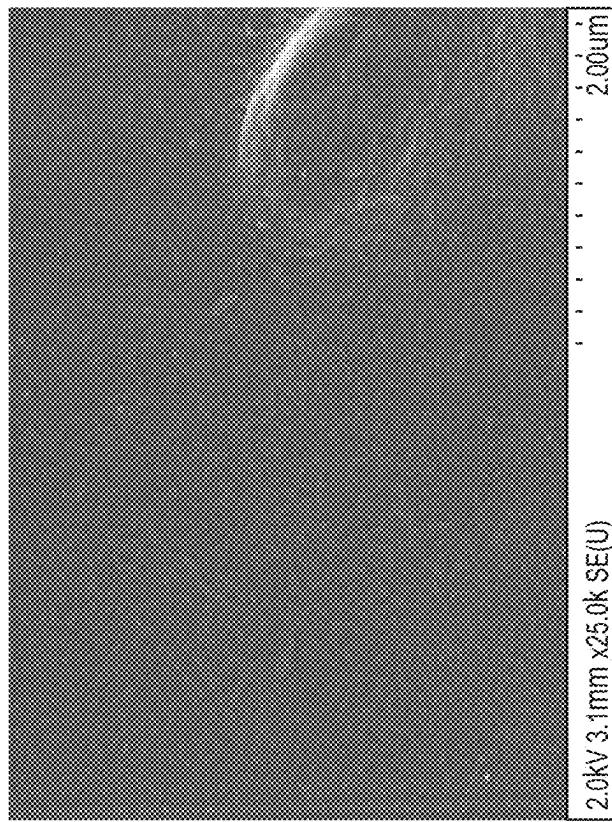


FIG. 194

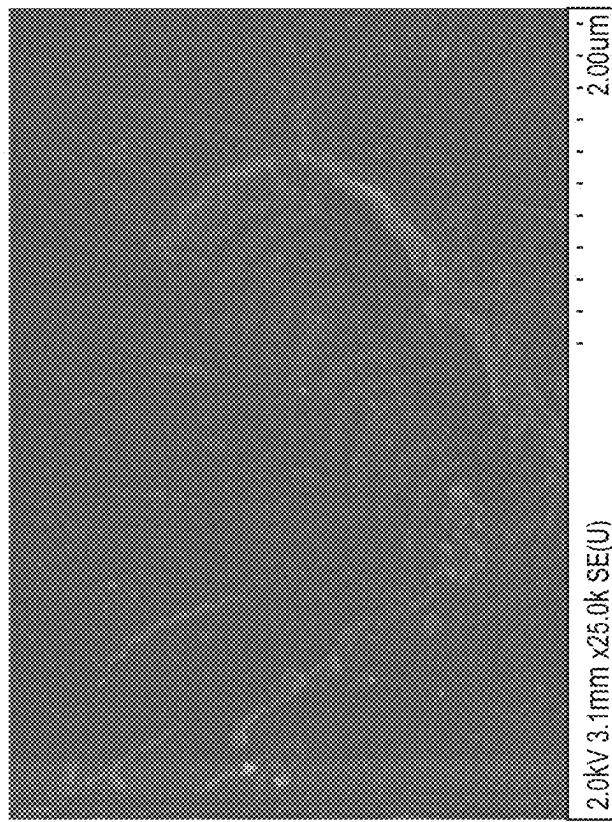


FIG. 195

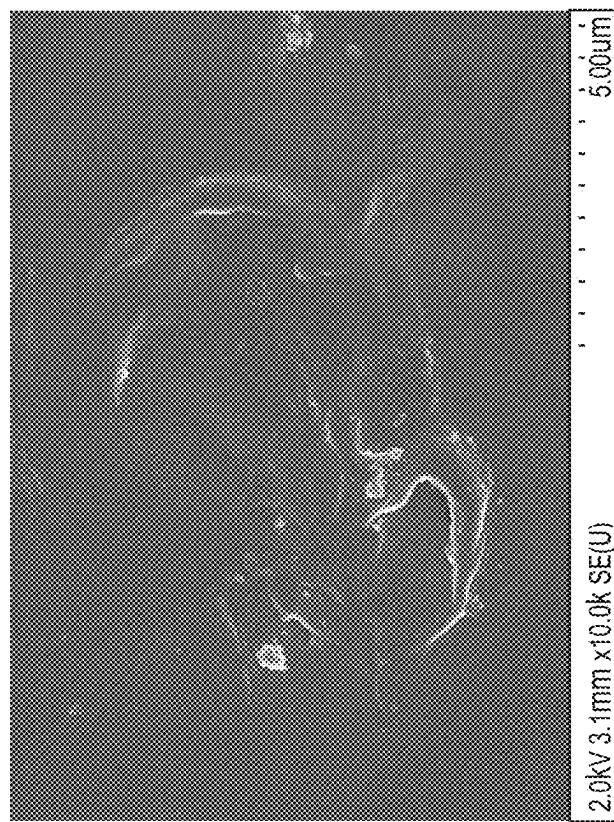


FIG. 196

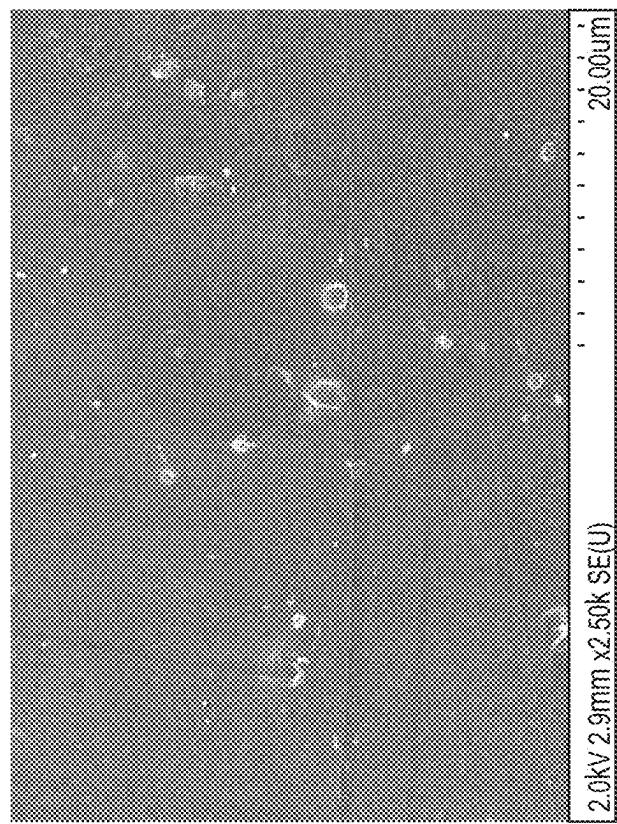


FIG. 197

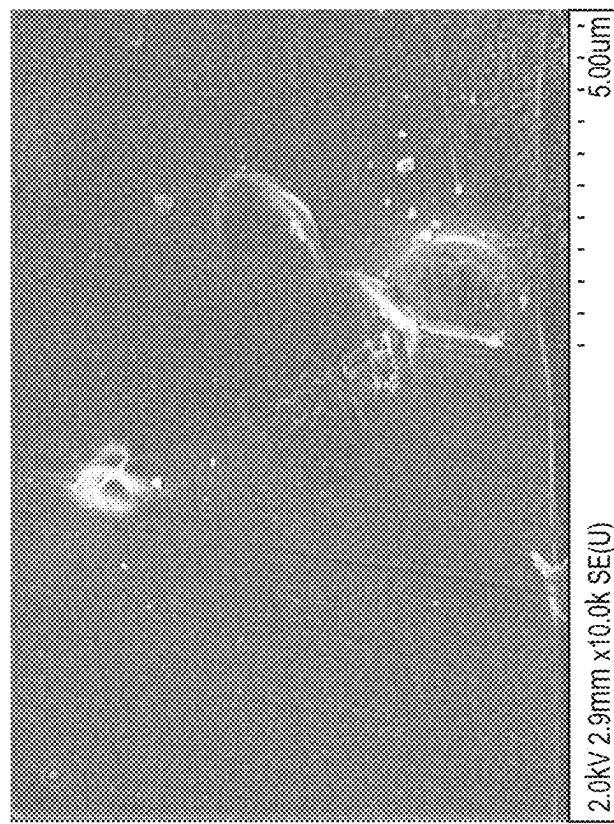


FIG. 198



FIG. 199

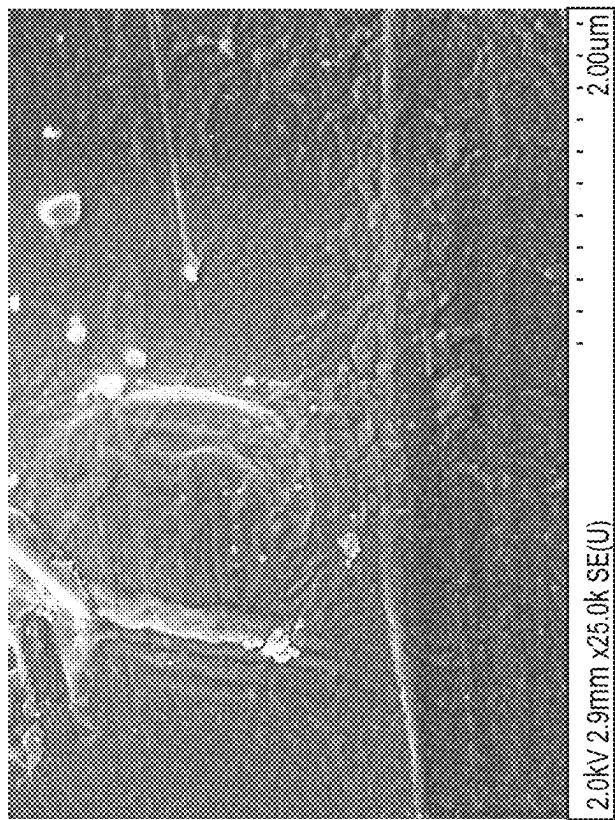


FIG. 200

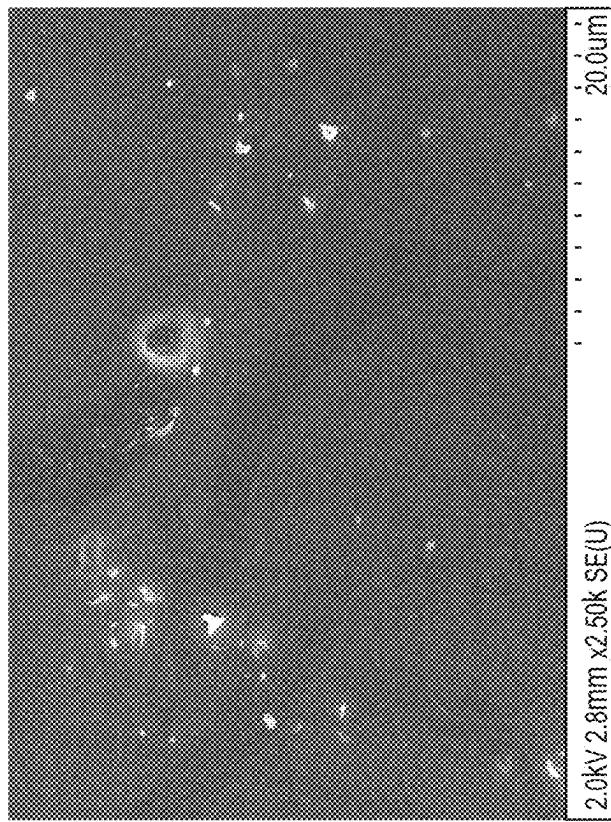


FIG. 201

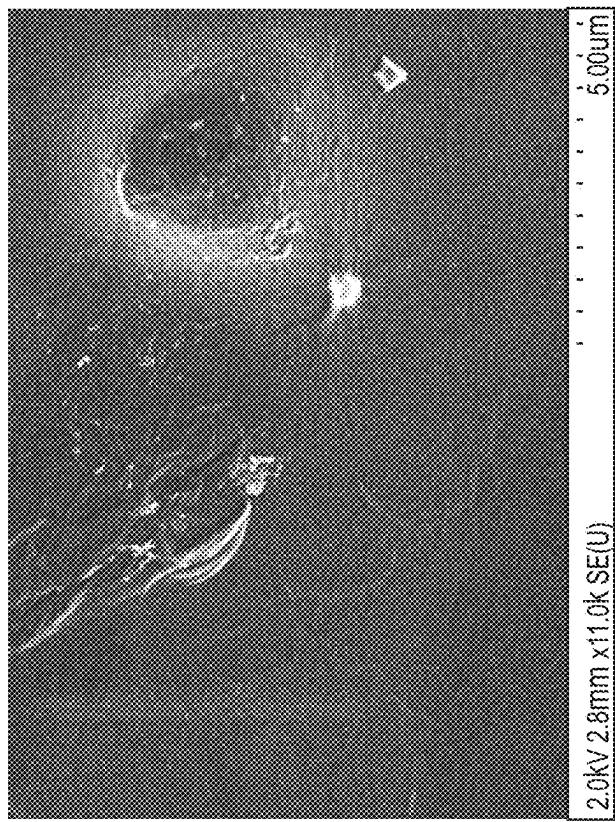


FIG. 202

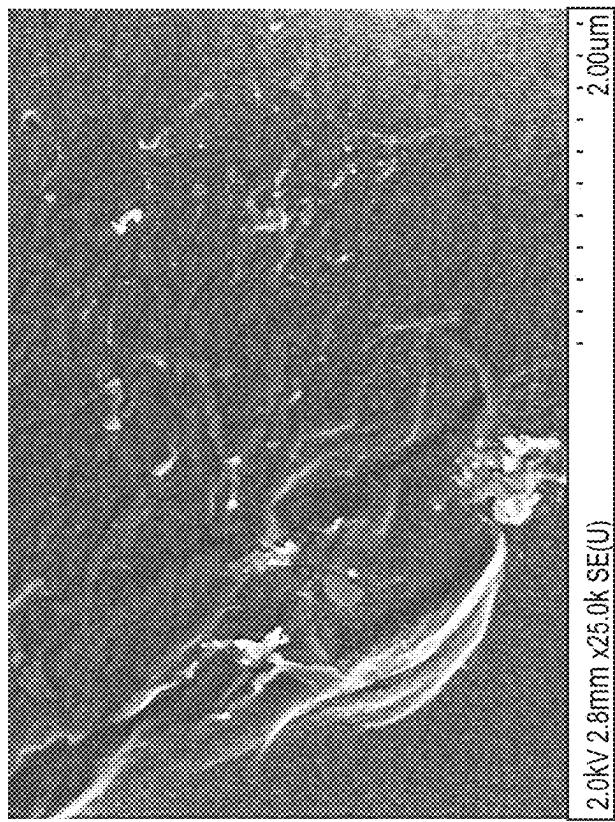


FIG. 203

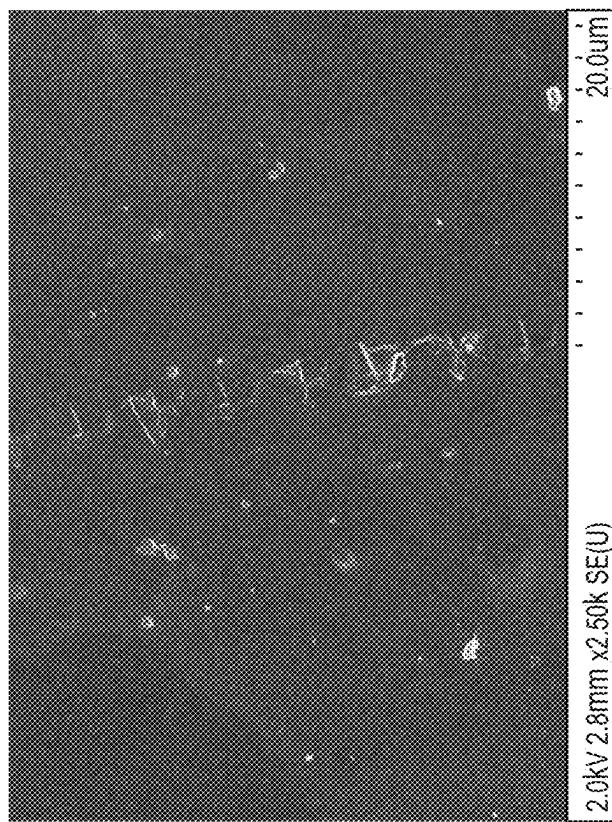


FIG. 204

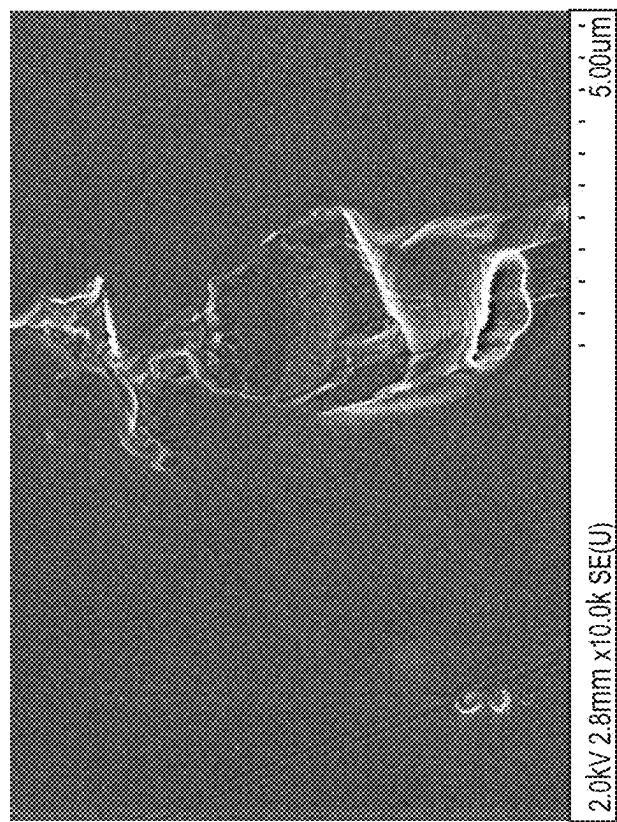


FIG. 205

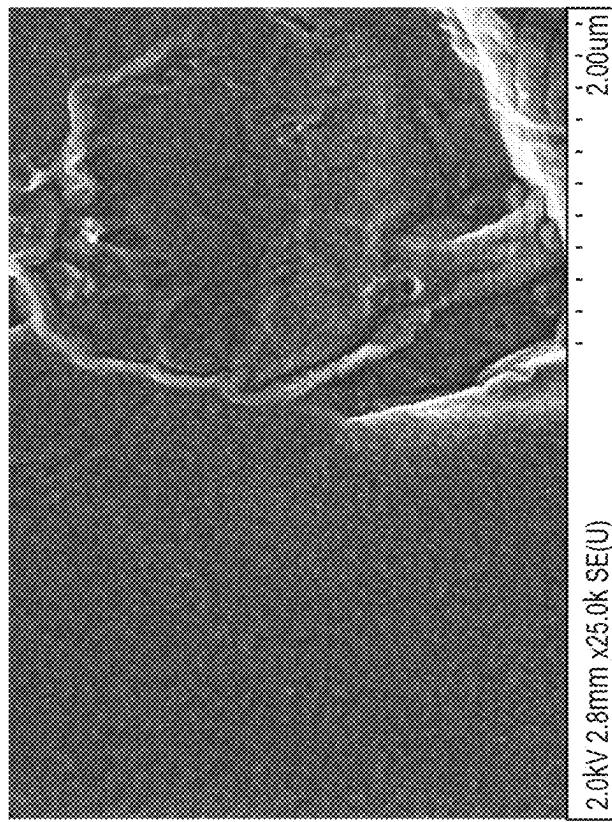


FIG. 206

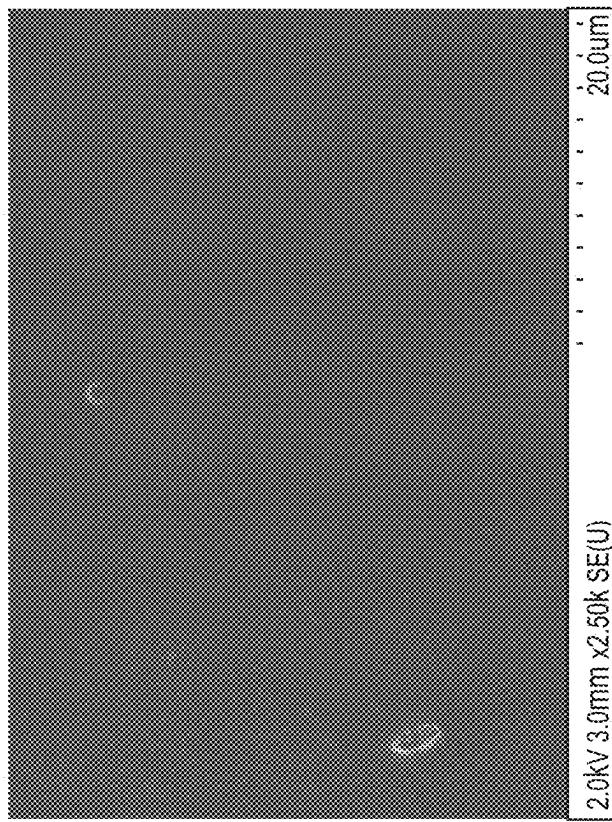


FIG. 207

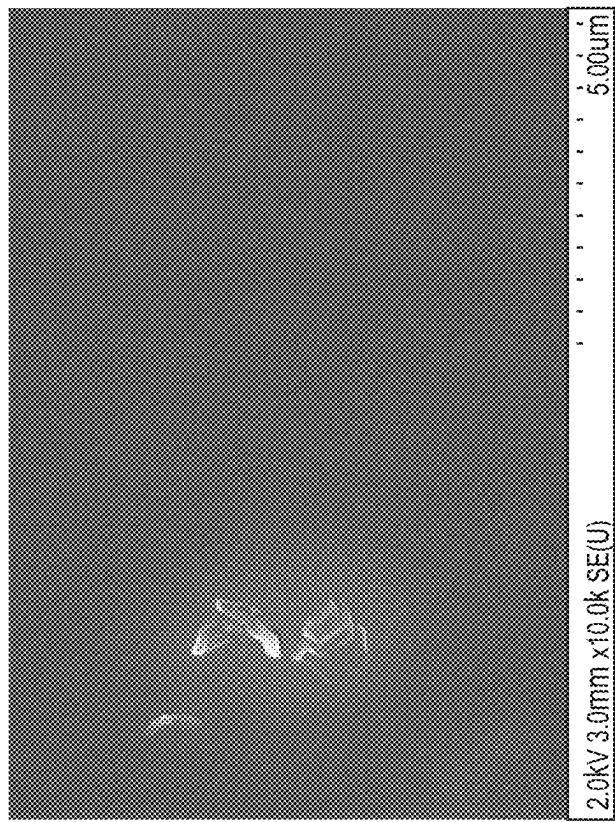


FIG. 208

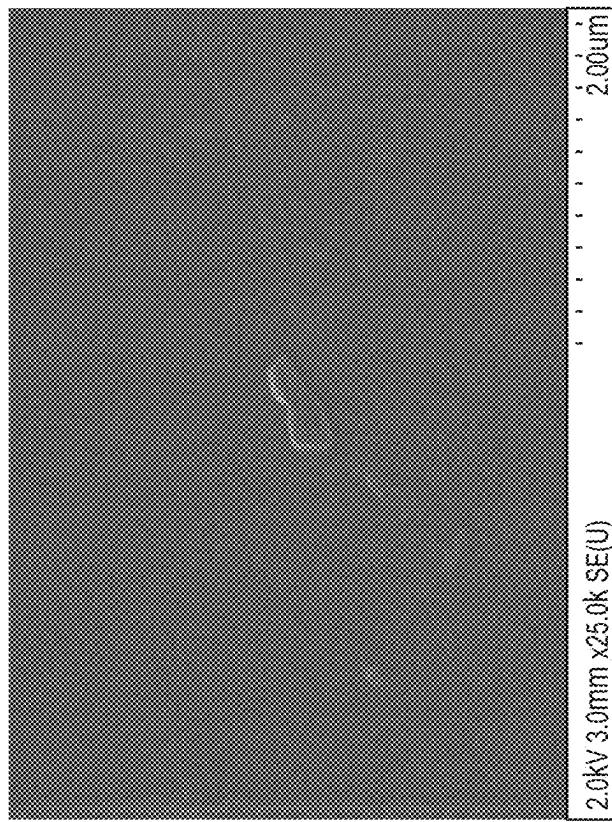


FIG. 209

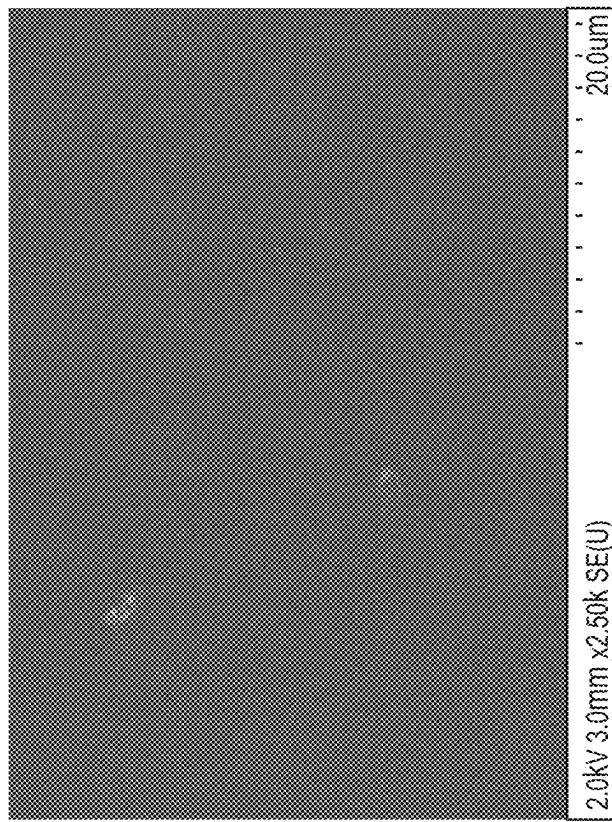


FIG. 210

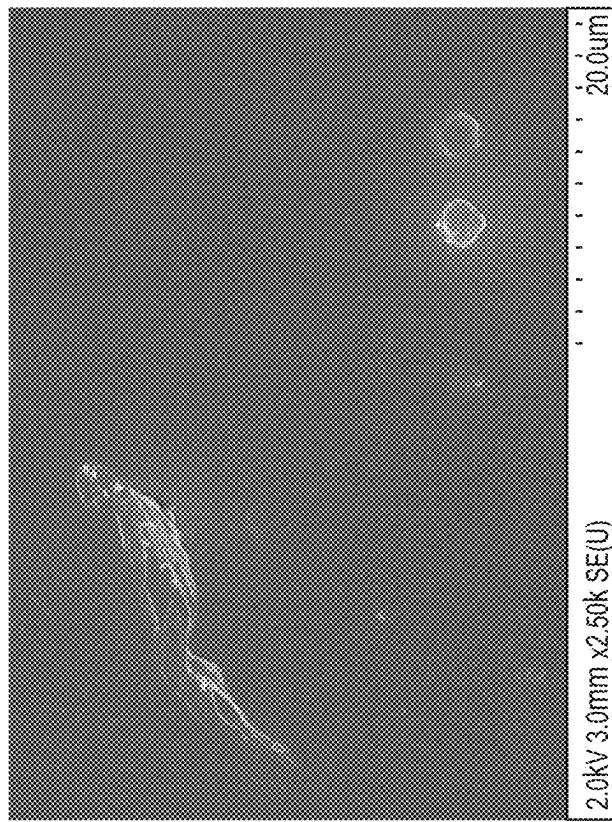


FIG. 211

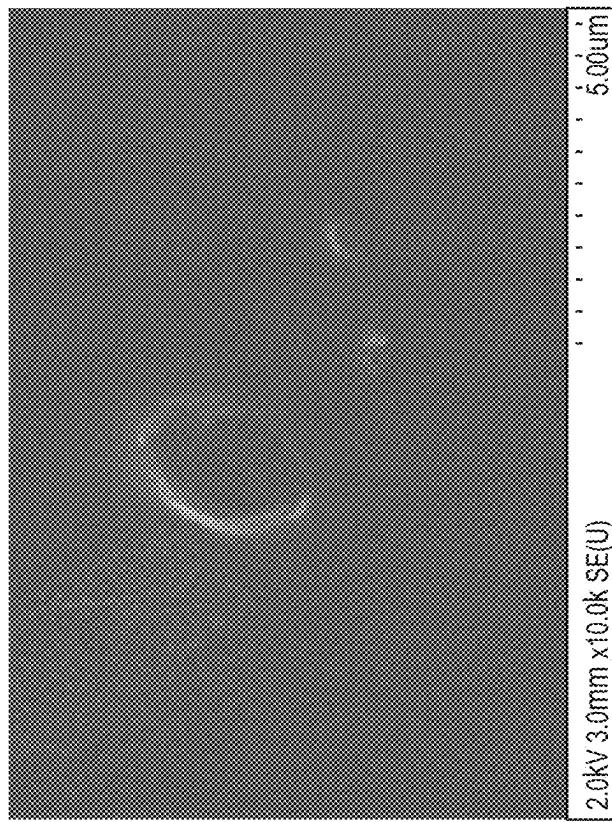


FIG. 212

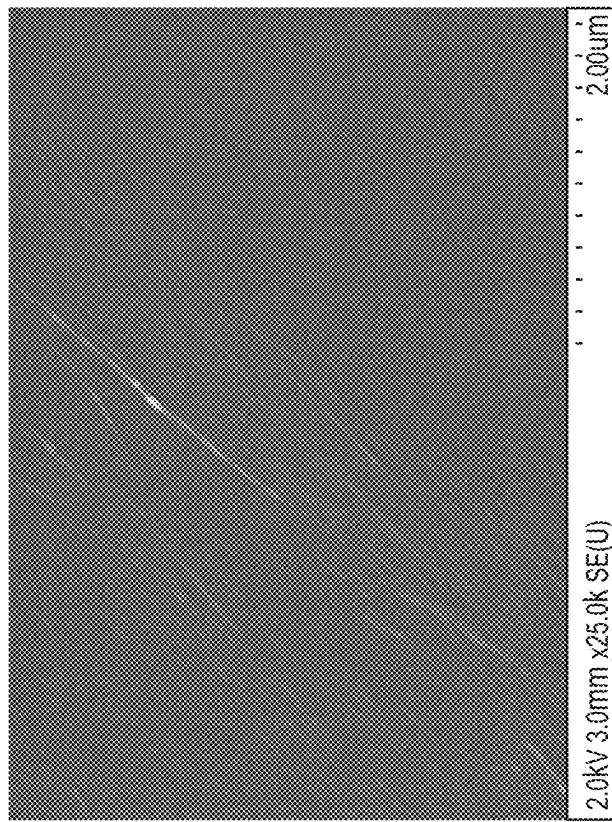


FIG. 213

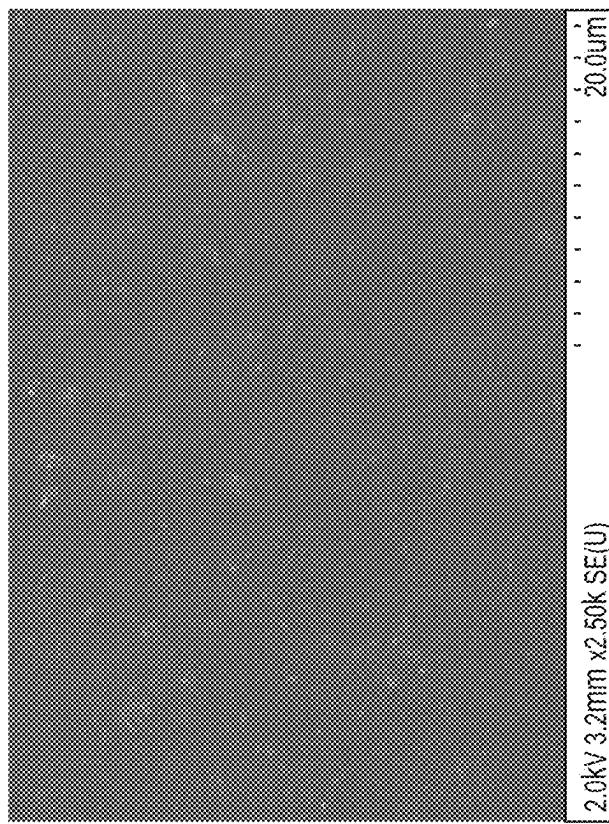


FIG. 214

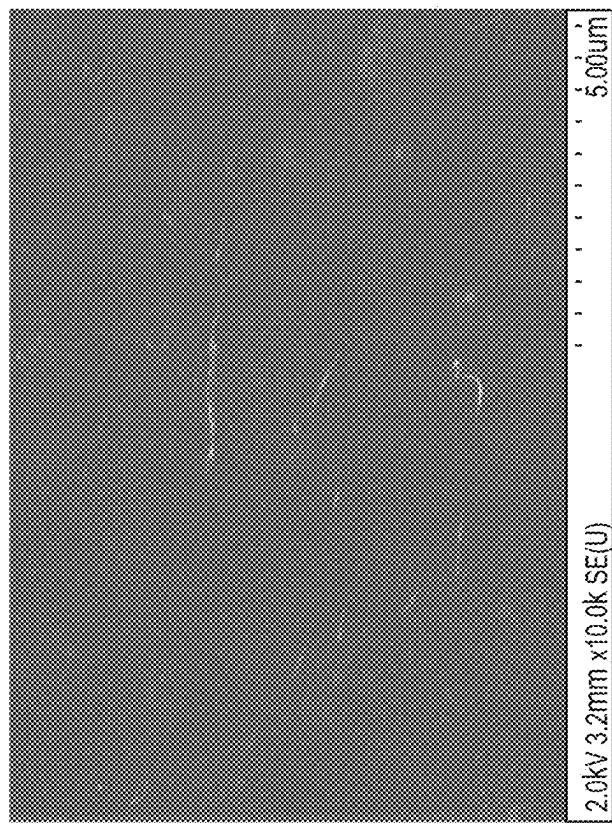


FIG. 215



FIG. 216

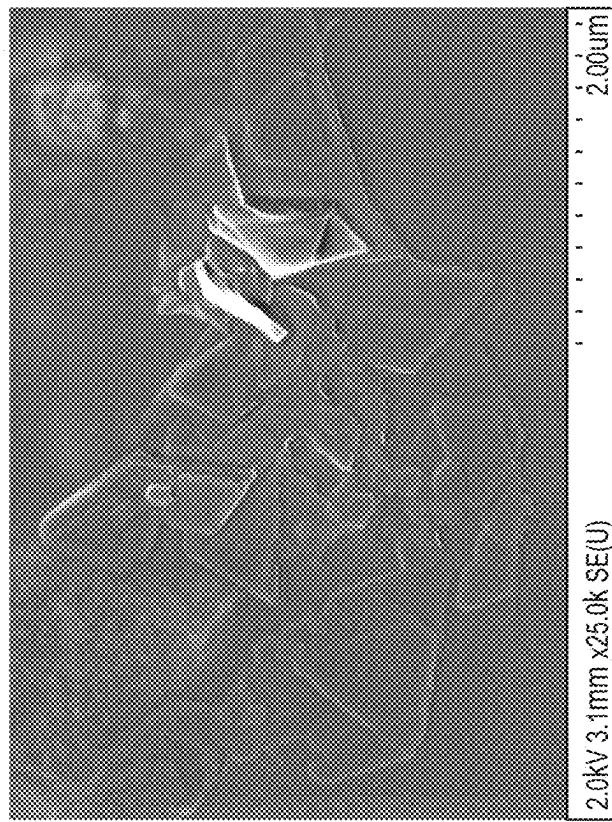


FIG. 217



FIG. 218

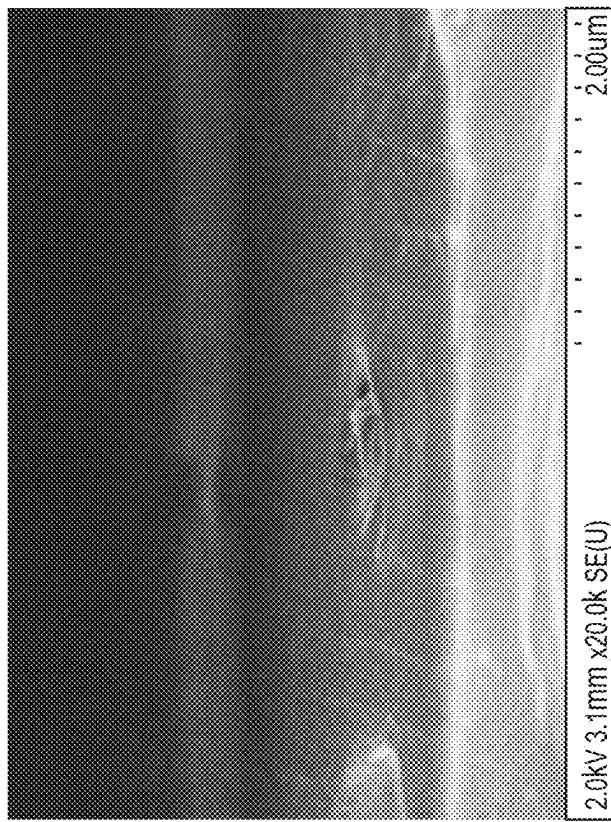


FIG. 219

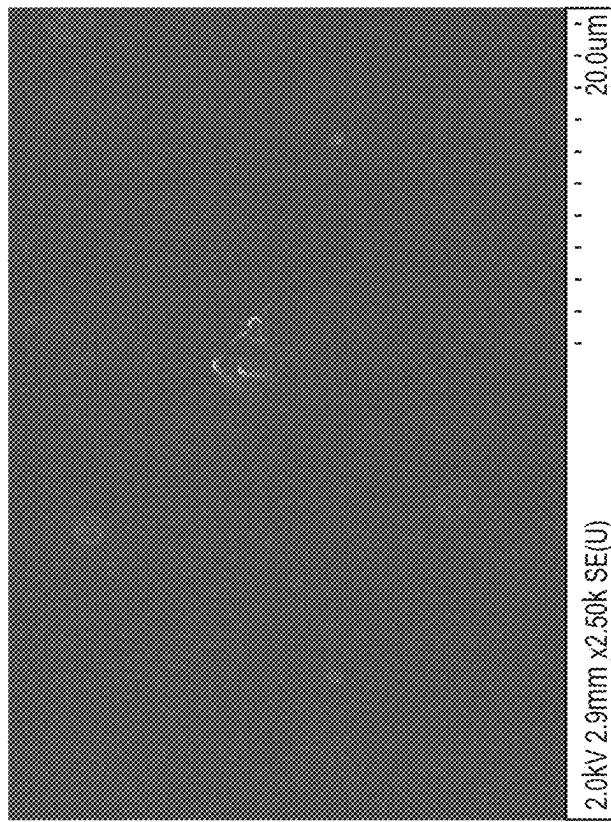


FIG. 220

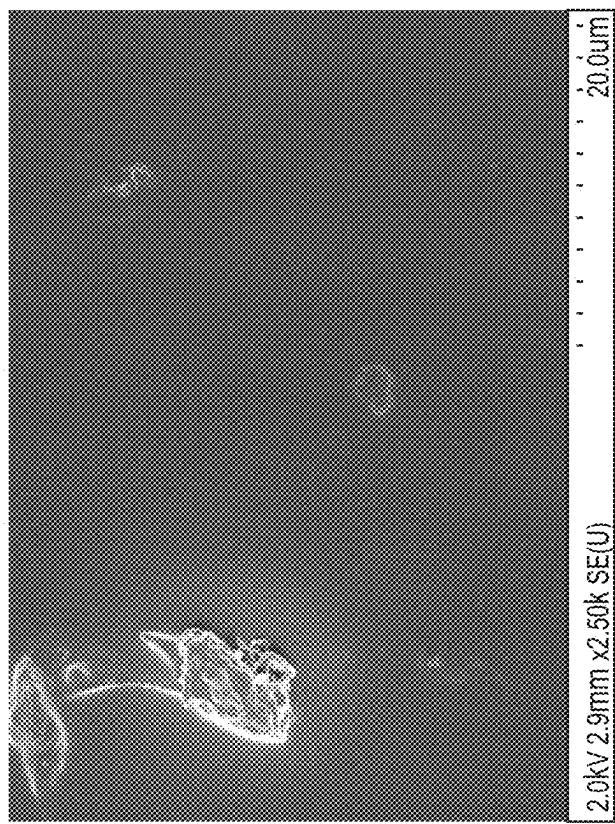


FIG. 221

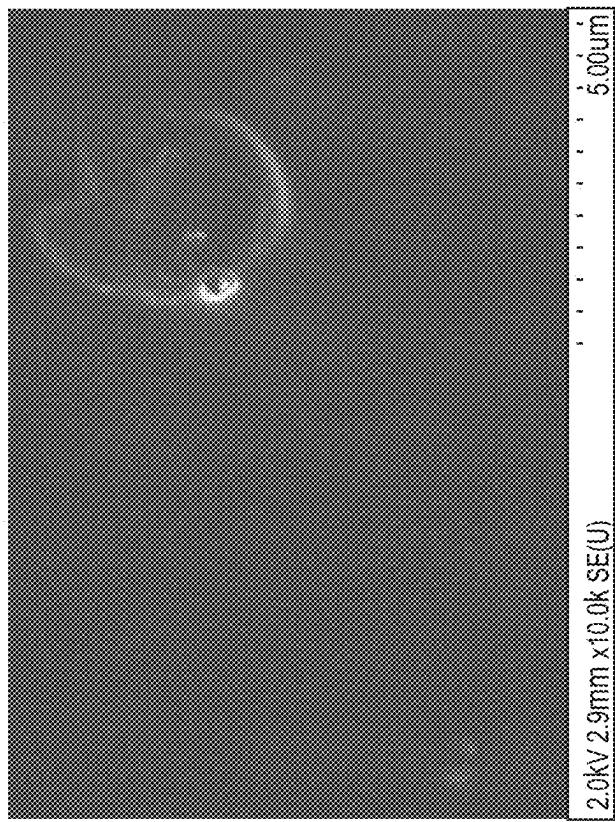


FIG. 222

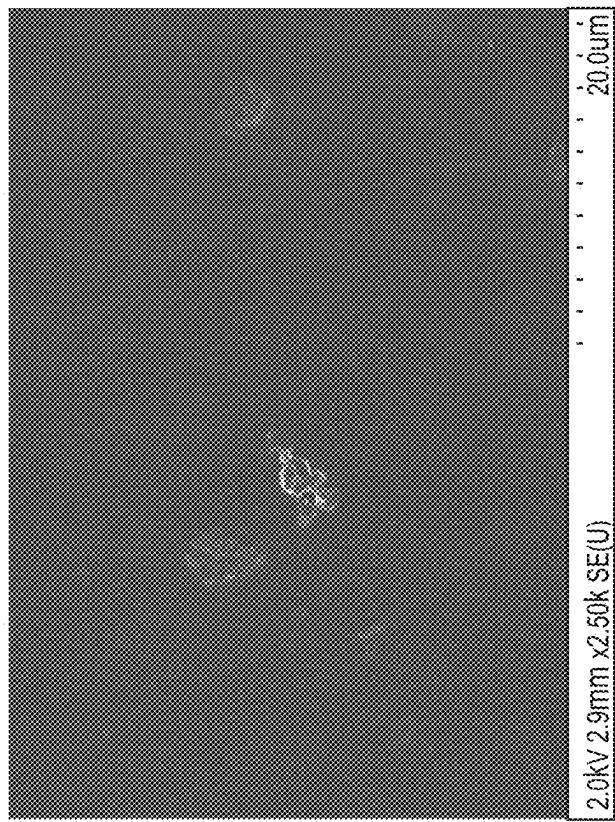


FIG. 223

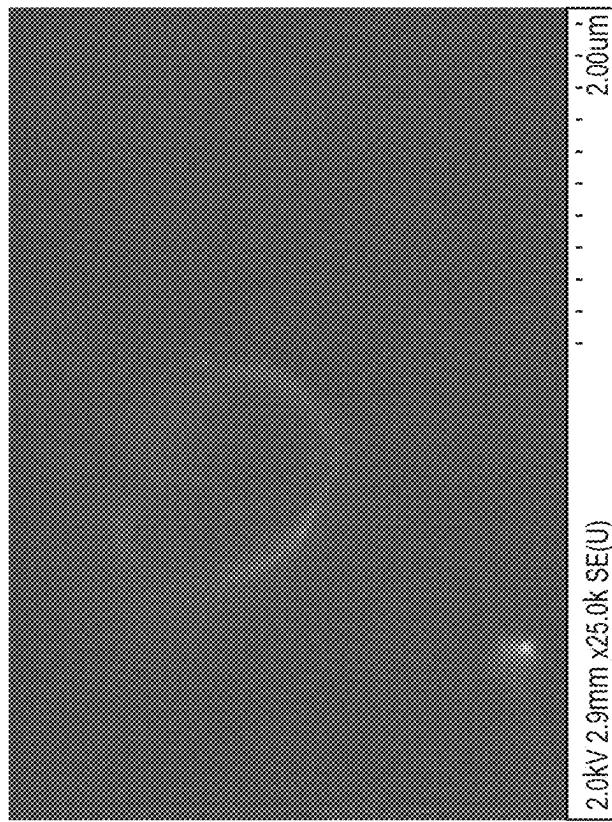


FIG. 224

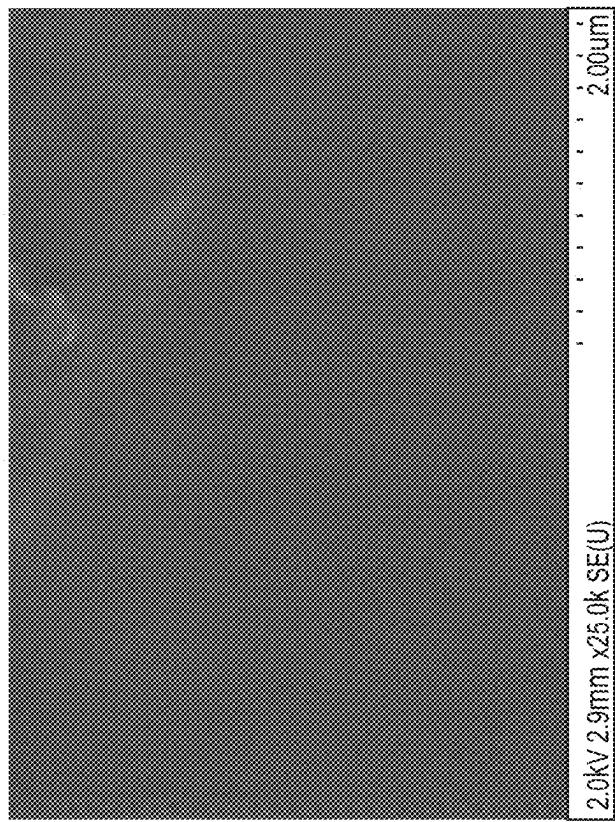


FIG. 225

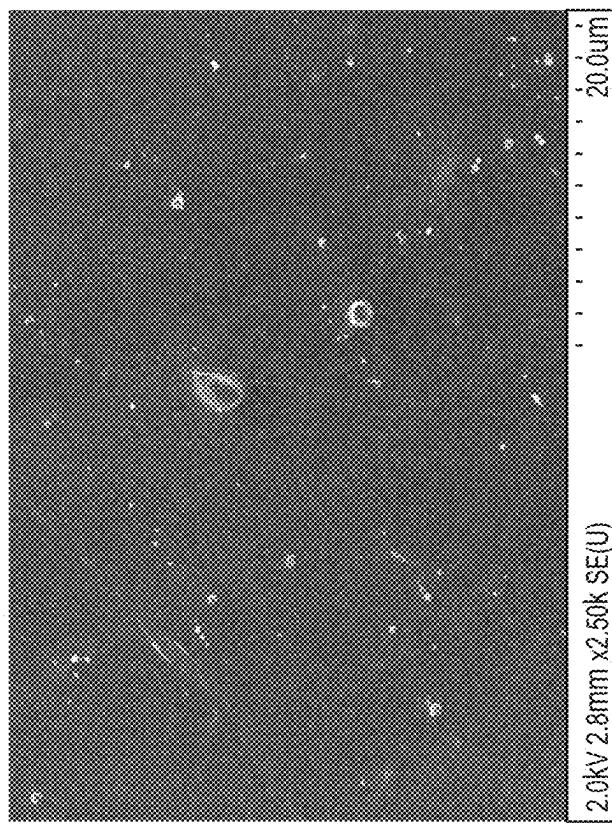


FIG. 226

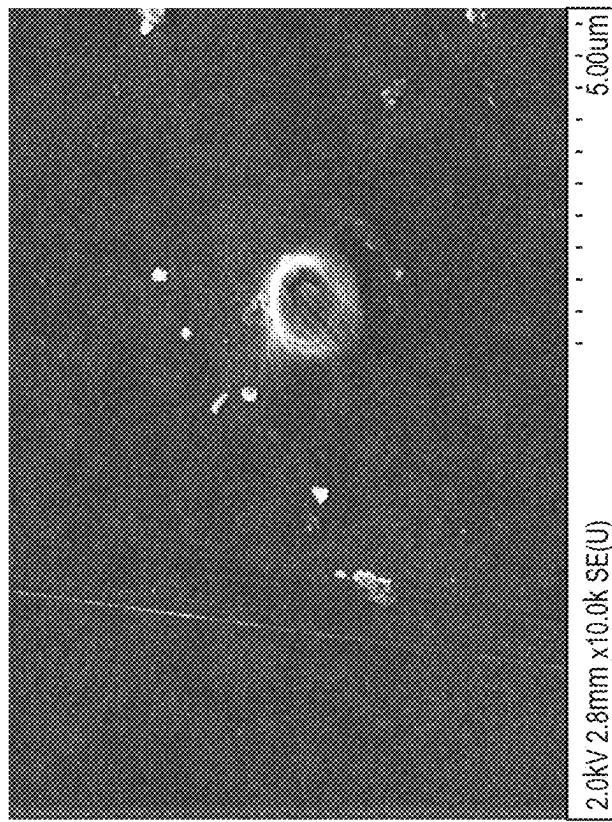


FIG. 227

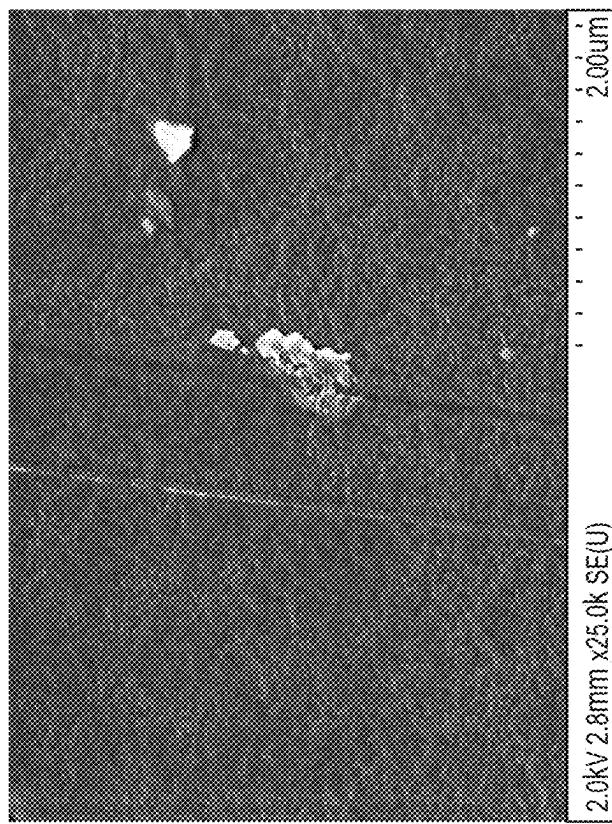


FIG. 228

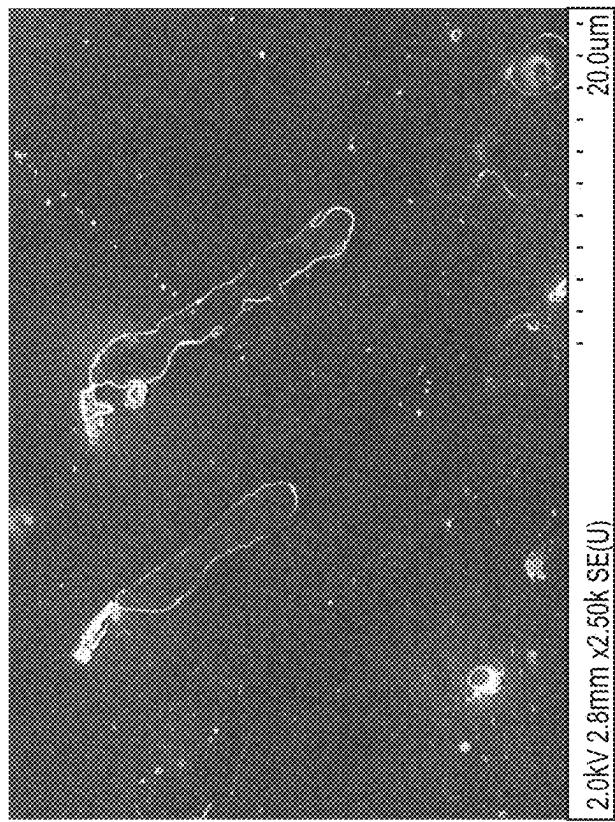


FIG. 229



FIG. 230

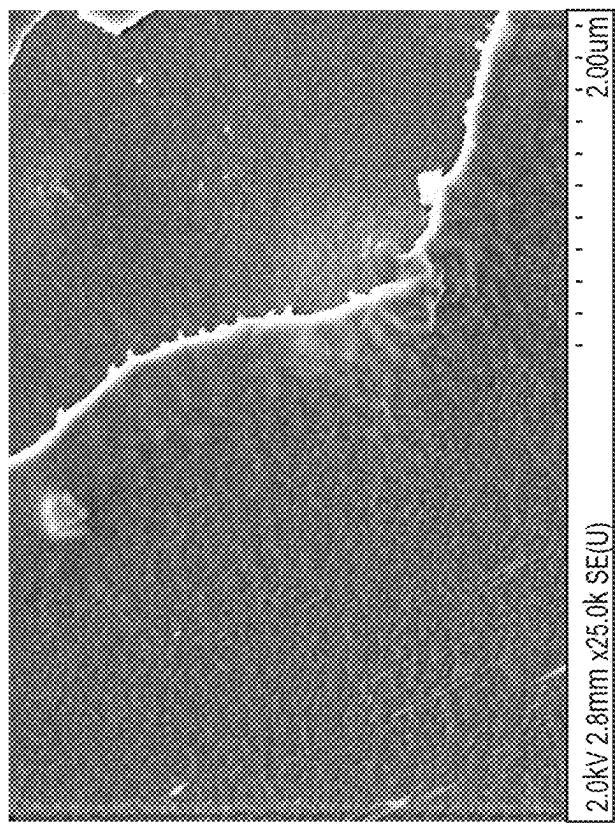


FIG. 231

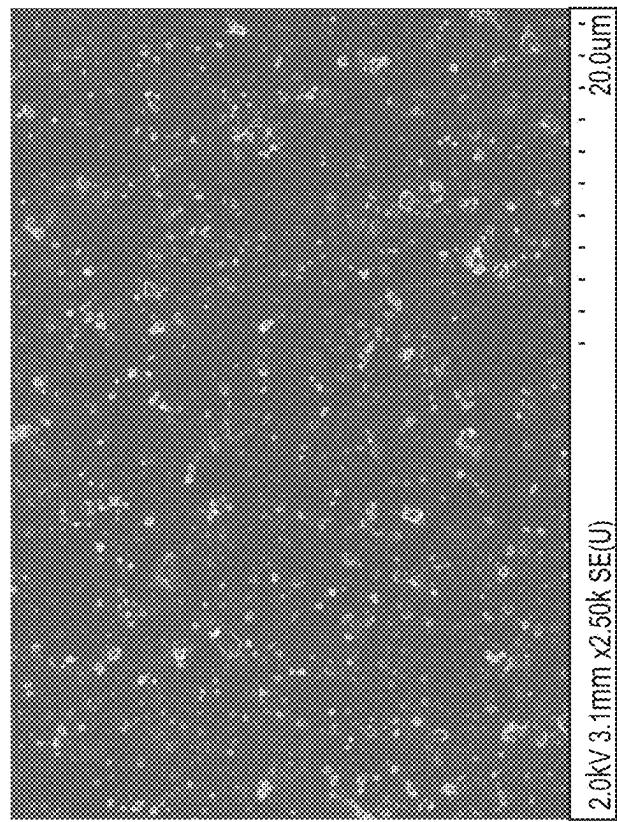


FIG. 232

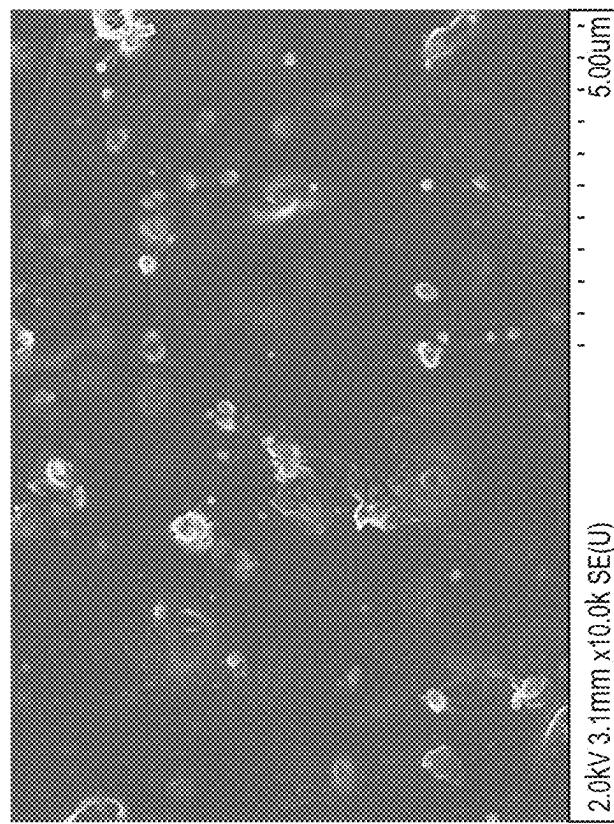


FIG. 233

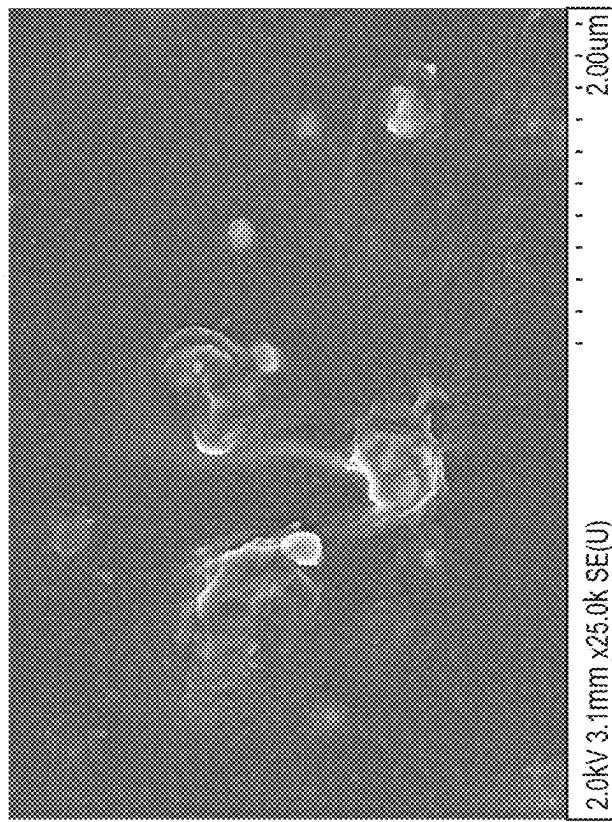


FIG. 234

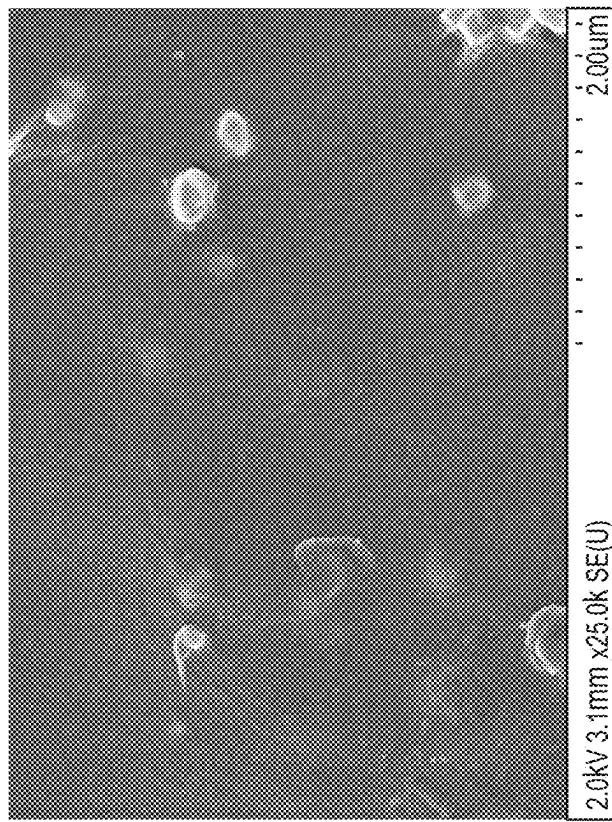


FIG. 235

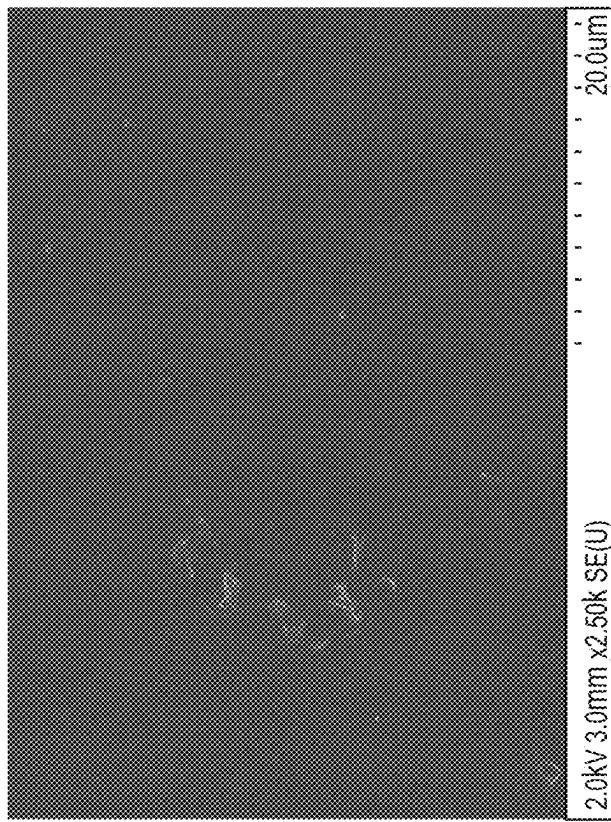


FIG. 236

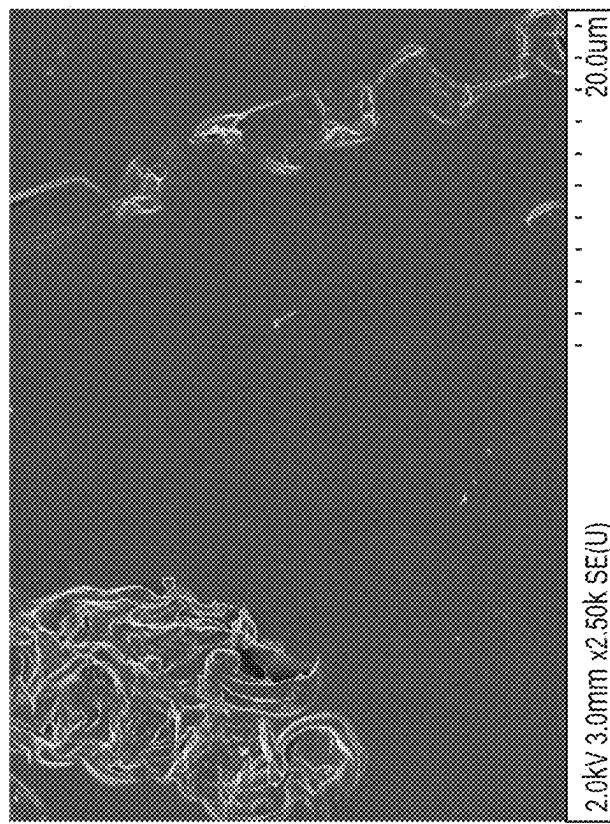


FIG. 237

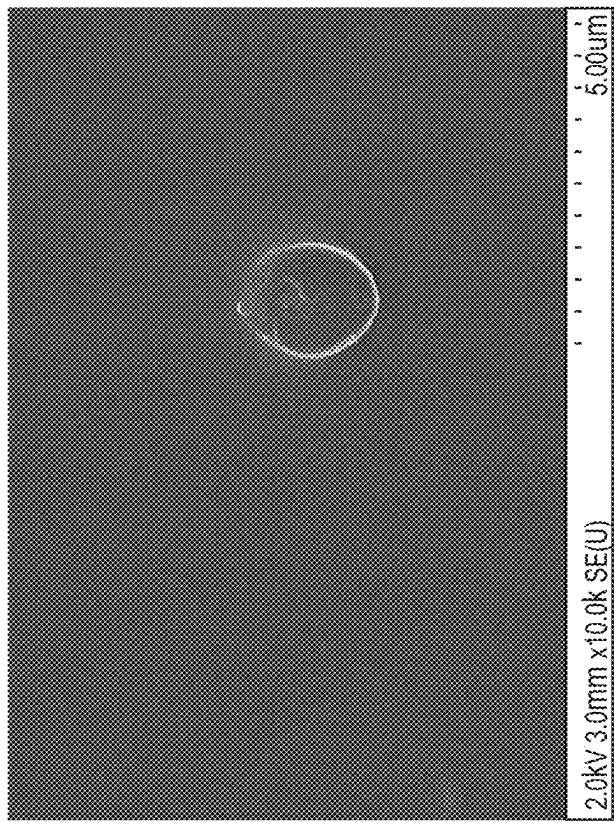


FIG. 238

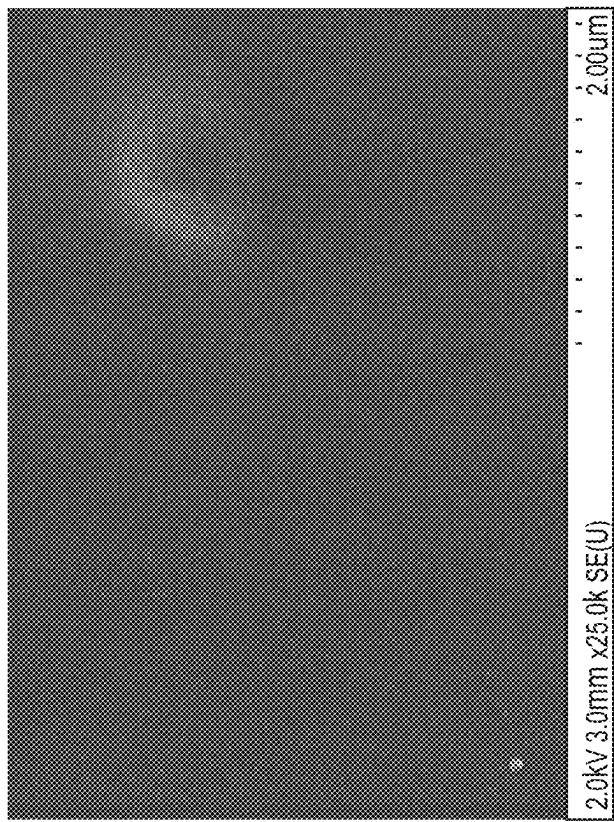


FIG. 239

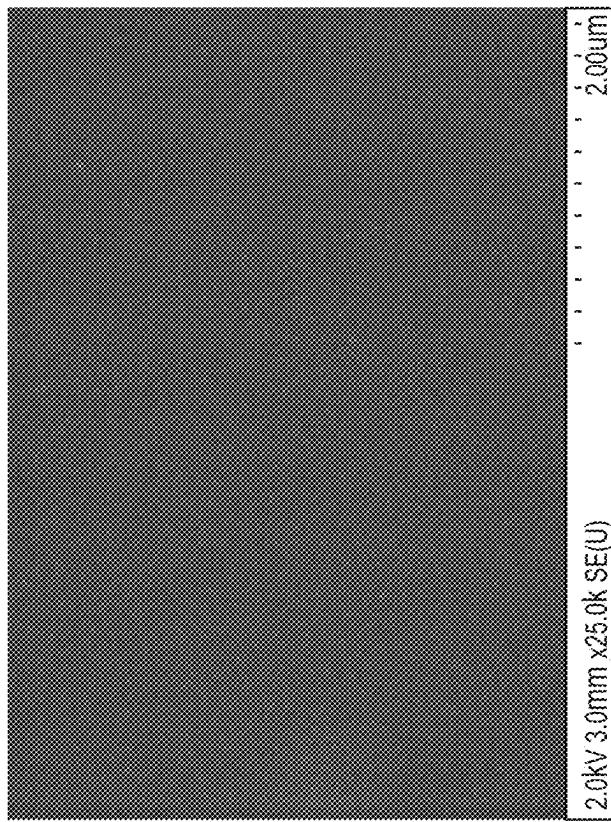


FIG. 240

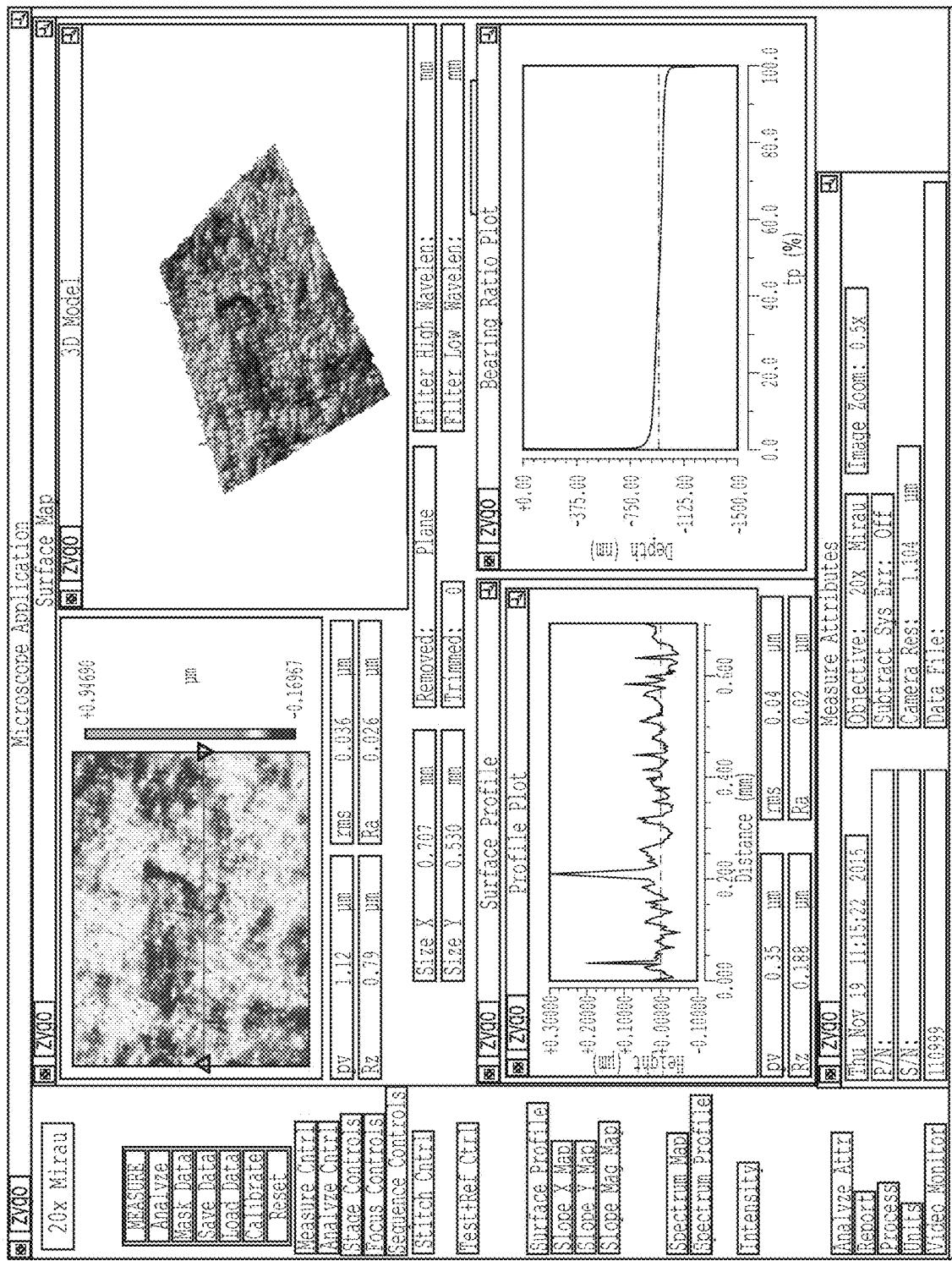


FIG. 241

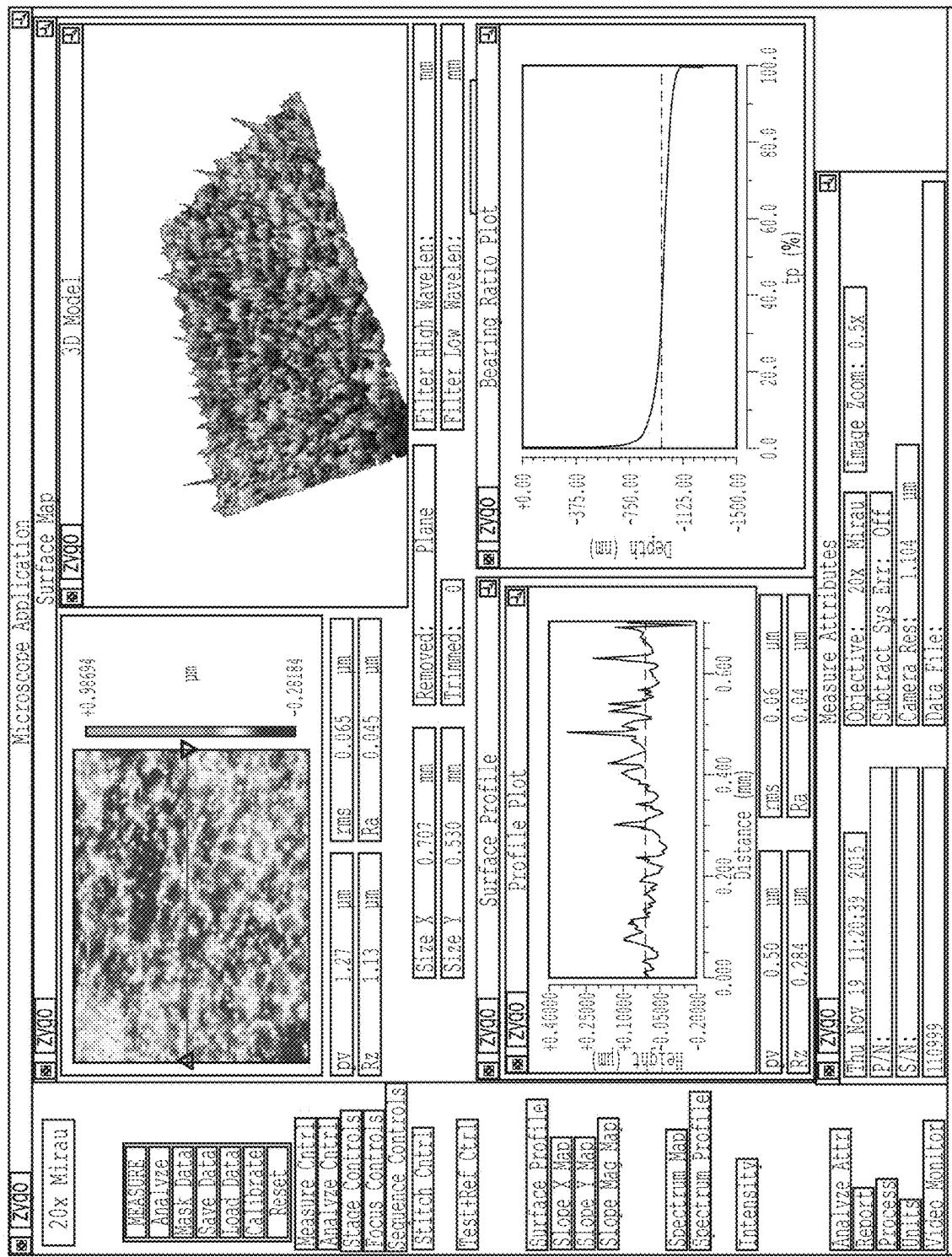


FIG. 242

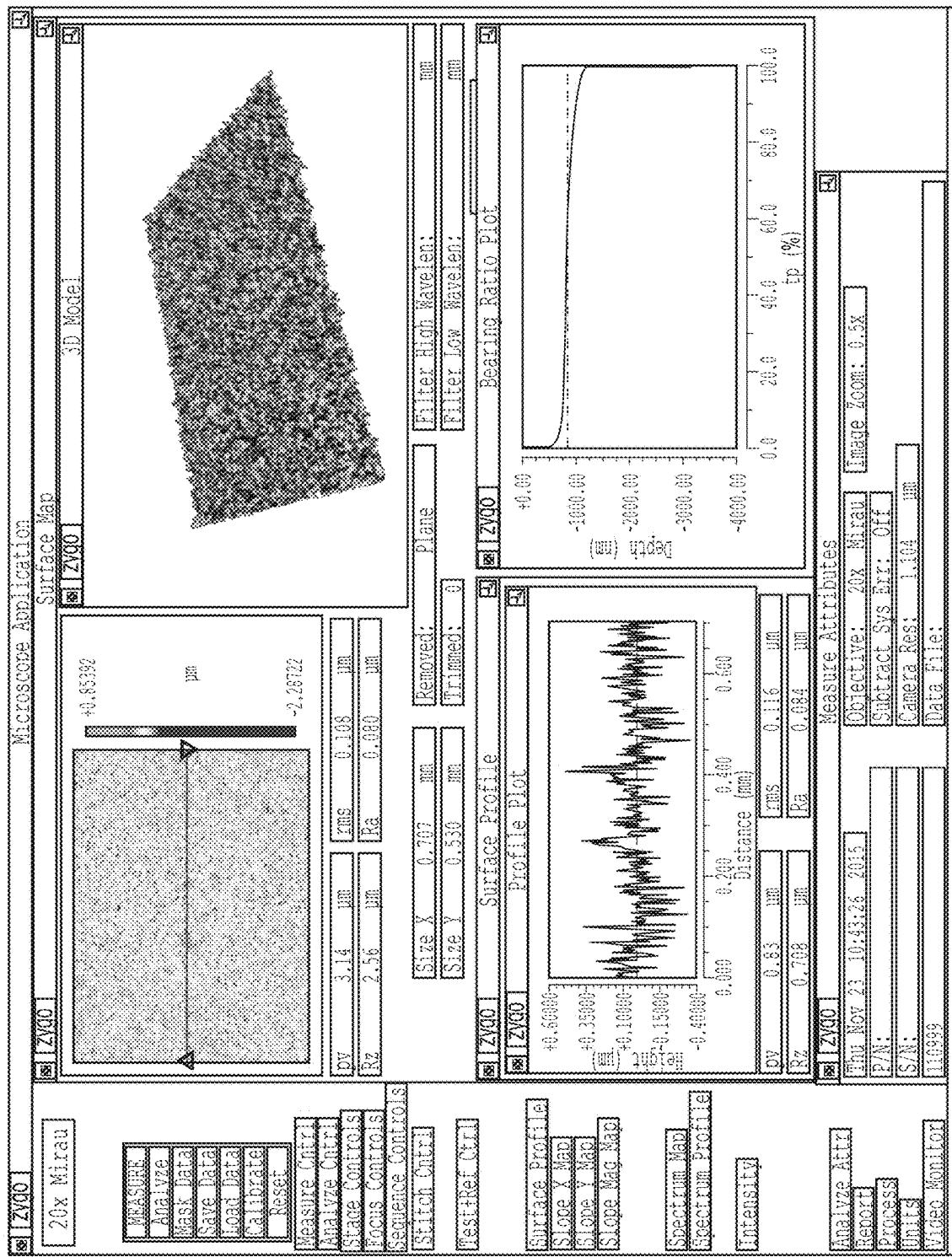


FIG. 243

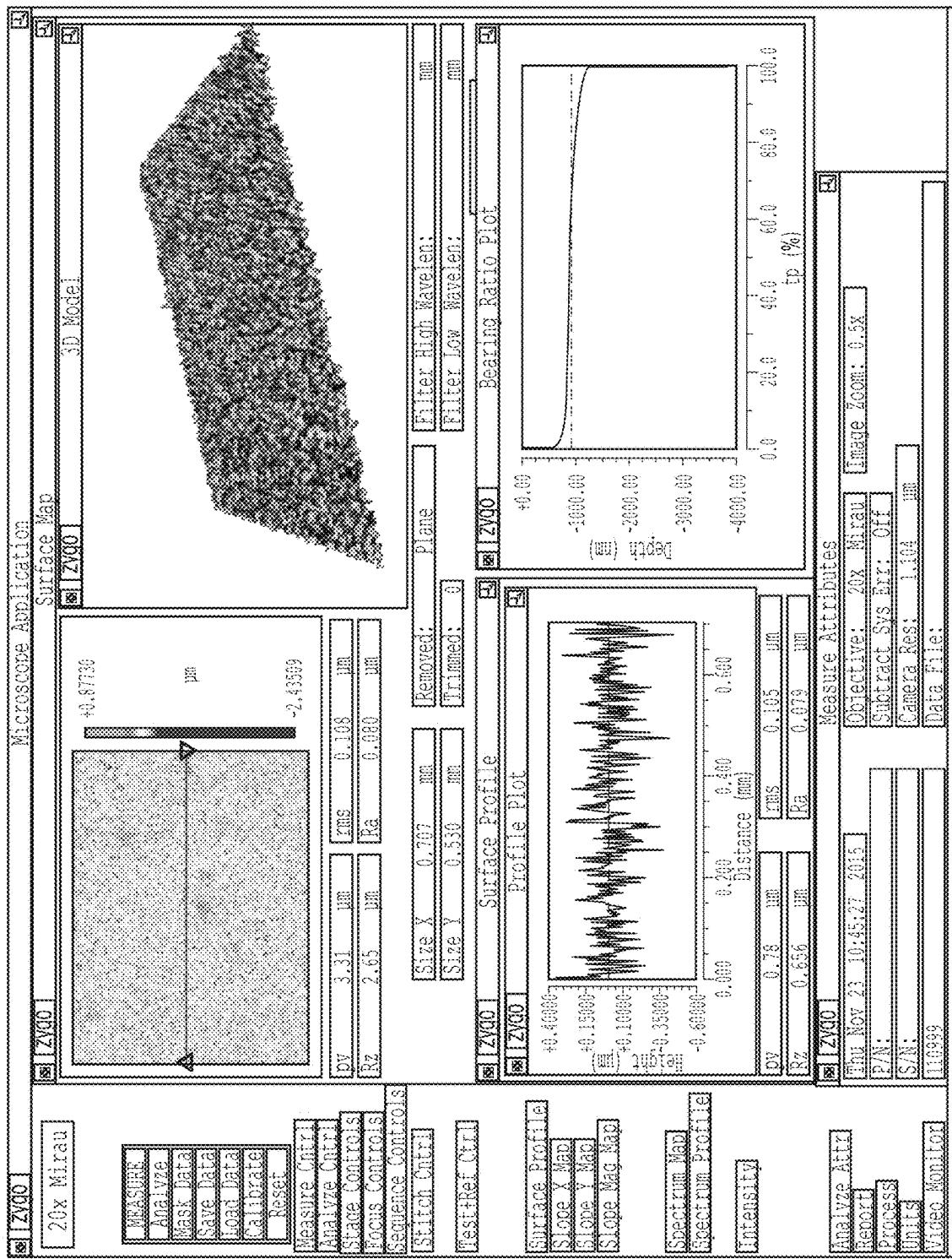


FIG. 244

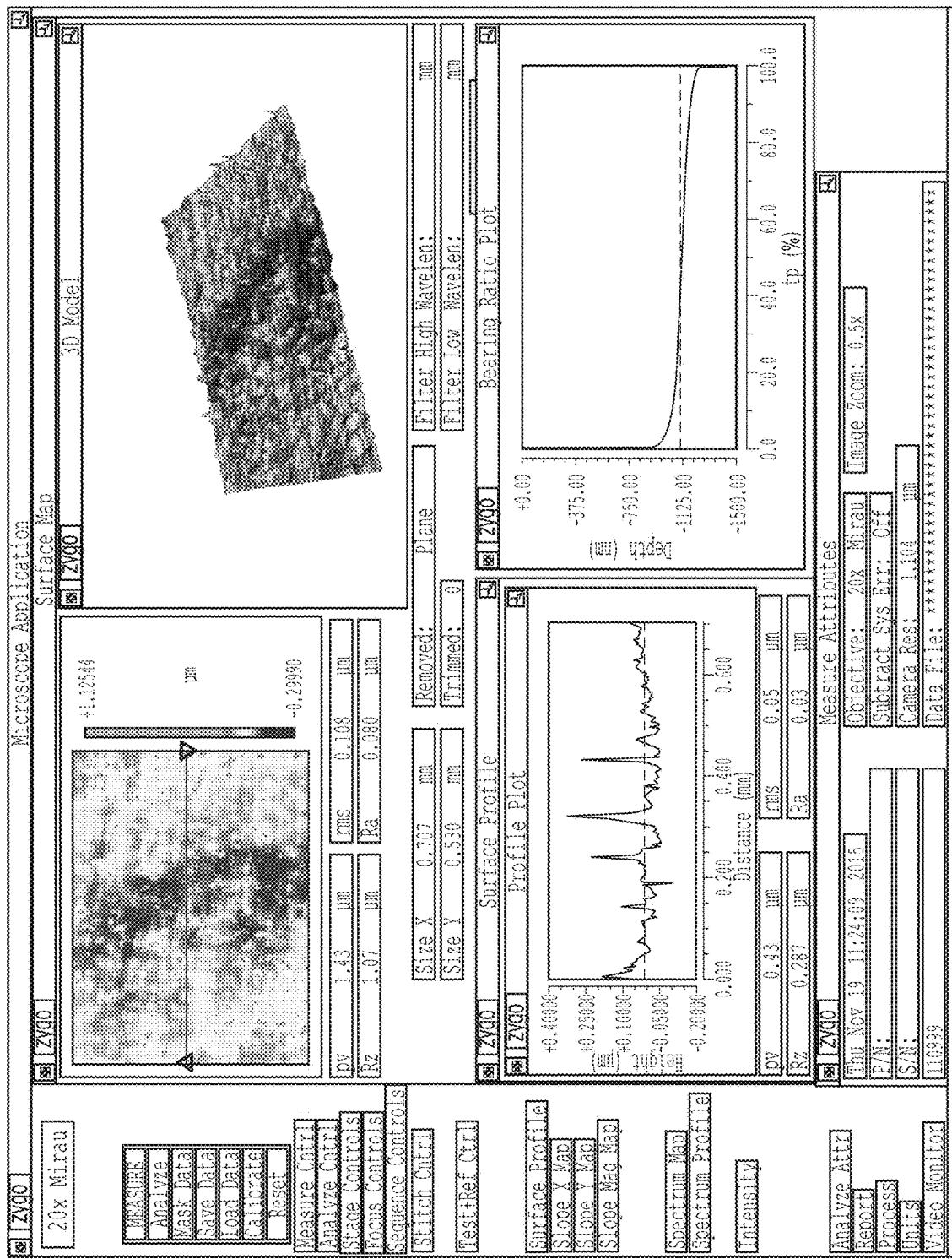


FIG. 245

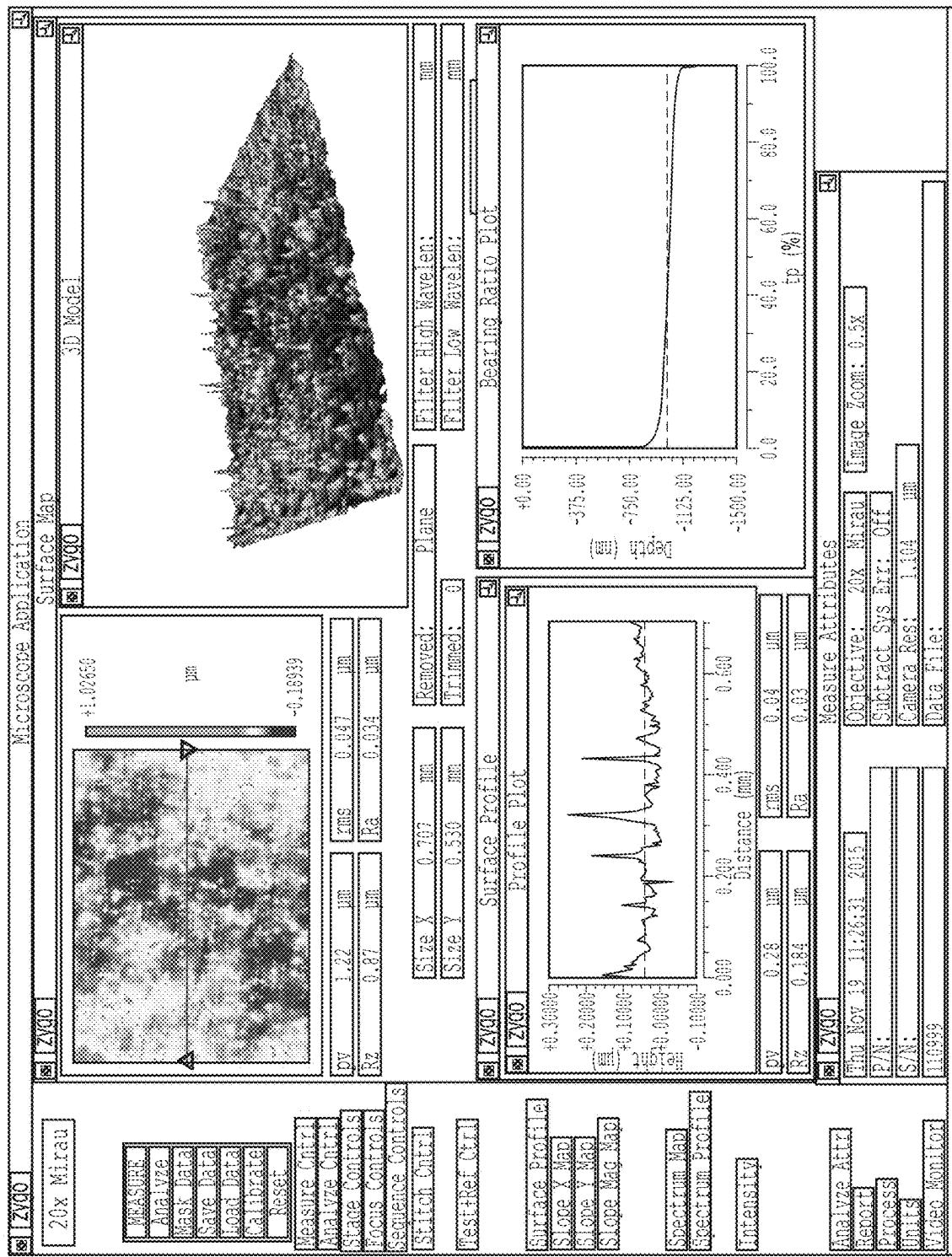


FIG. 246

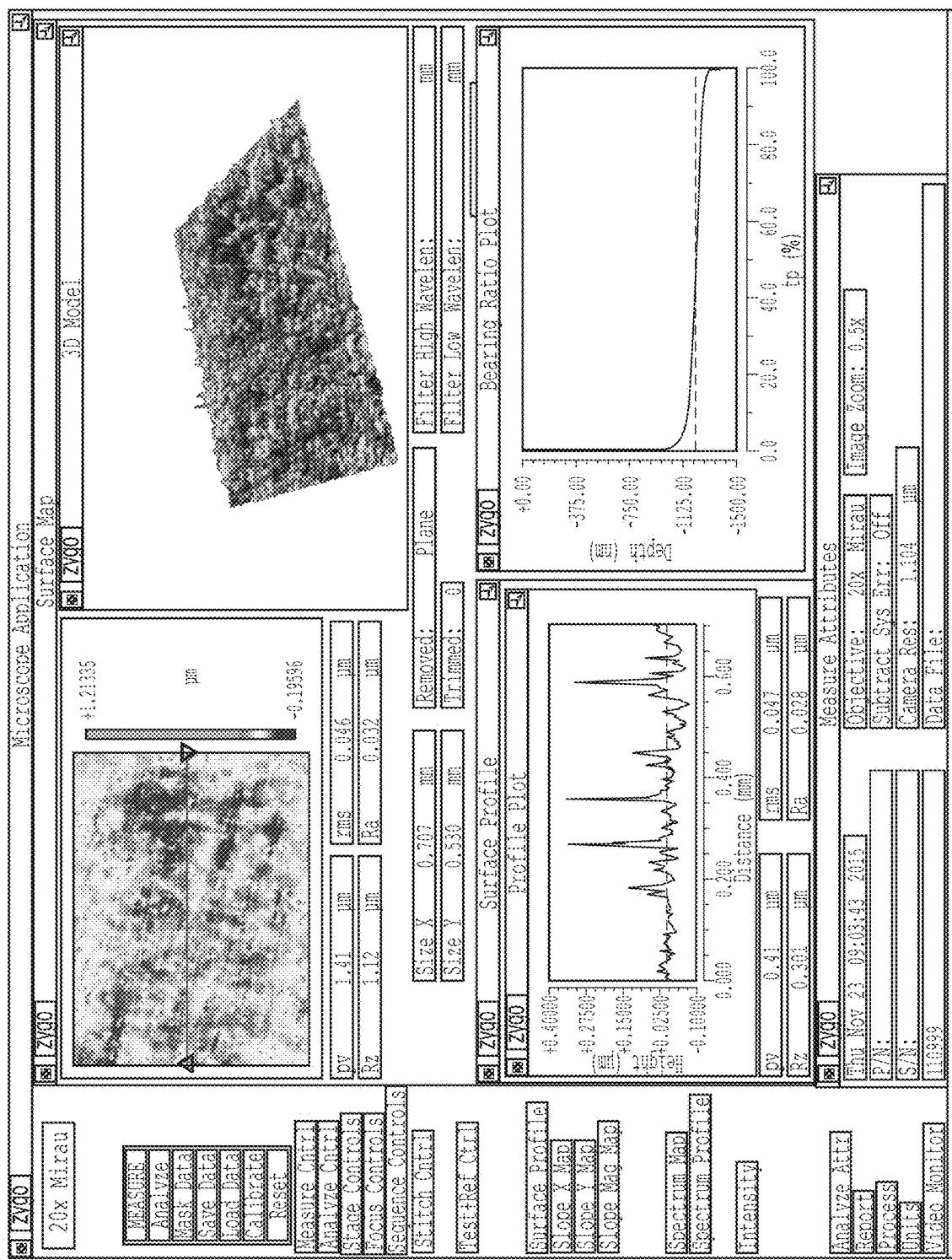


FIG. 247

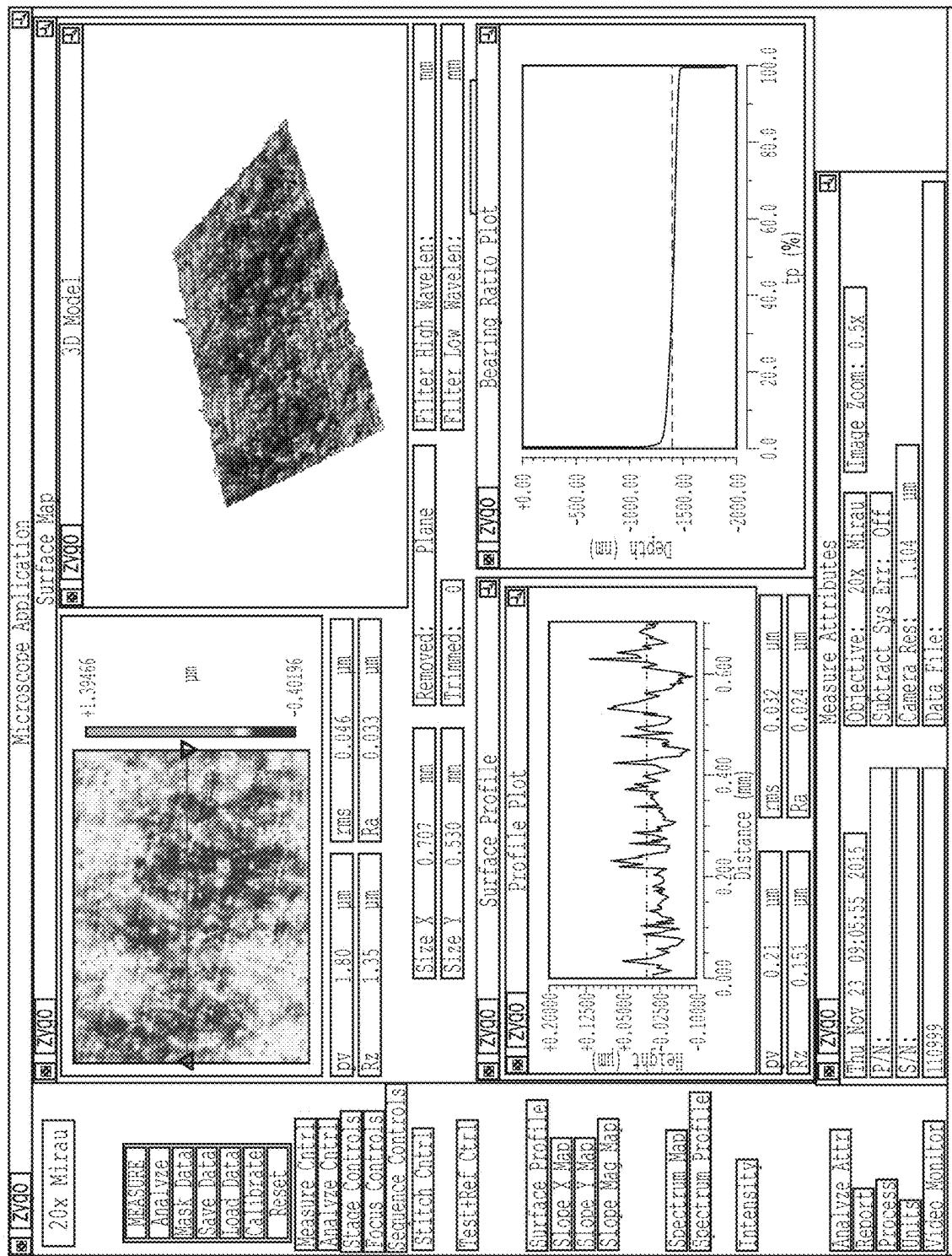


FIG. 248

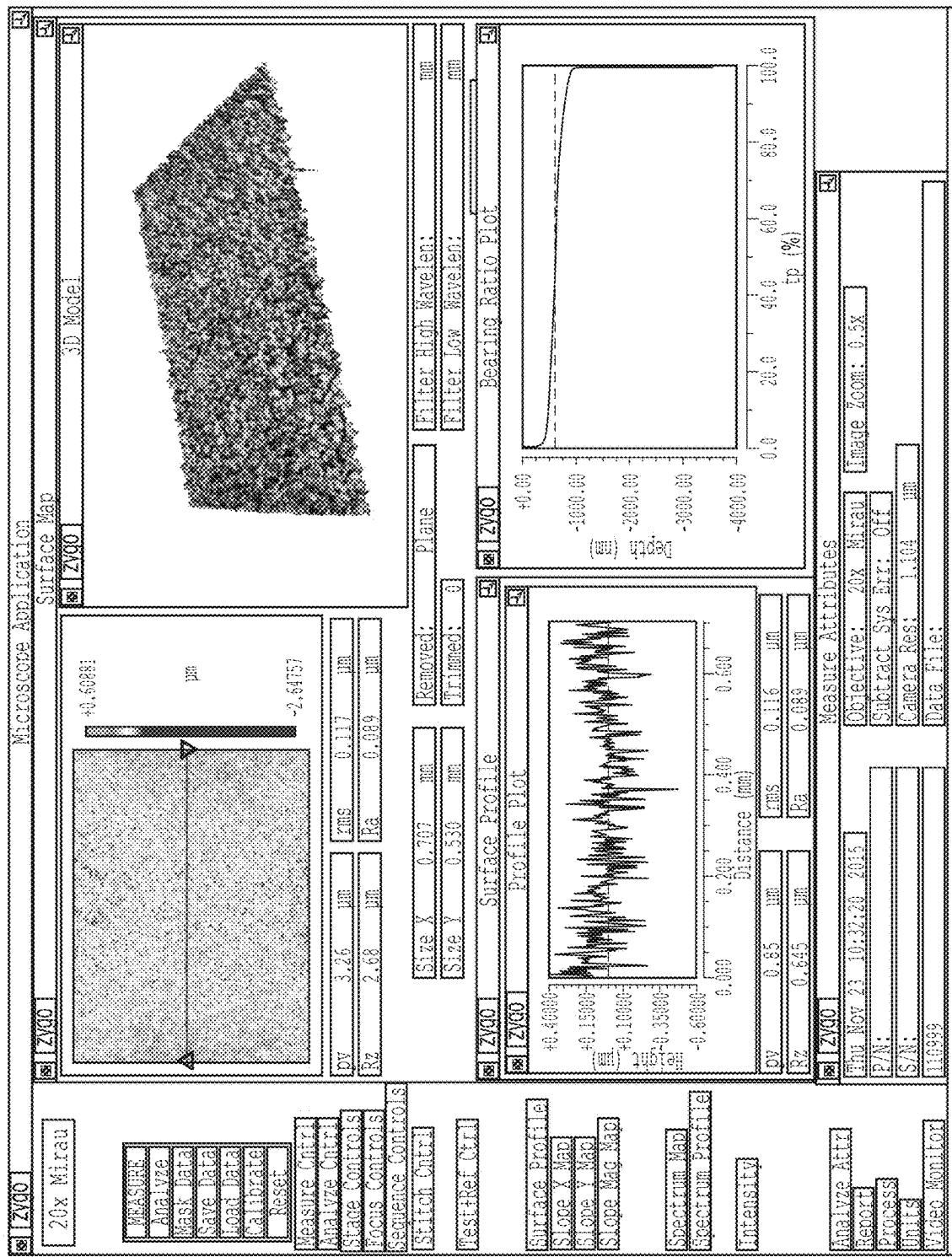


FIG. 249

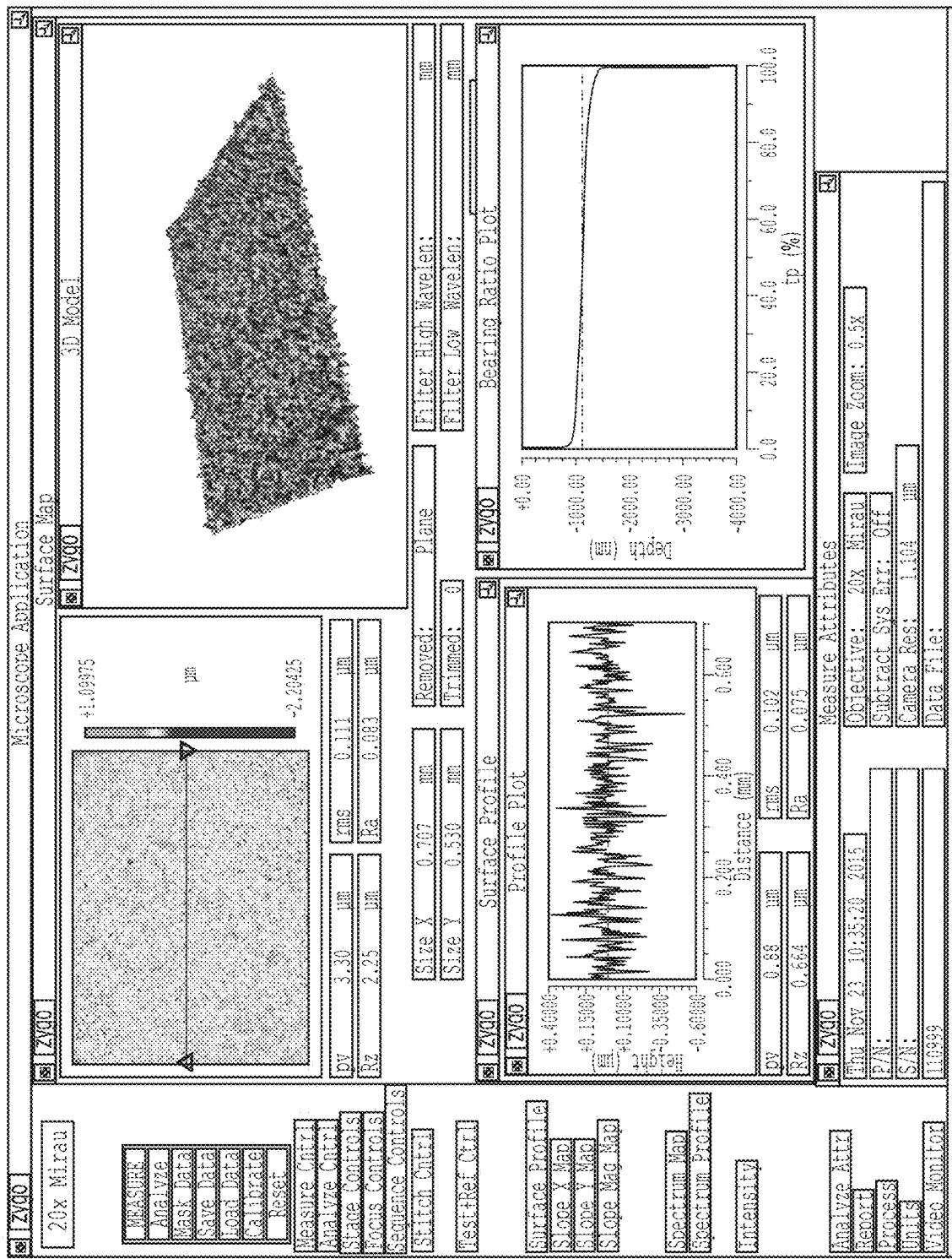


FIG. 250

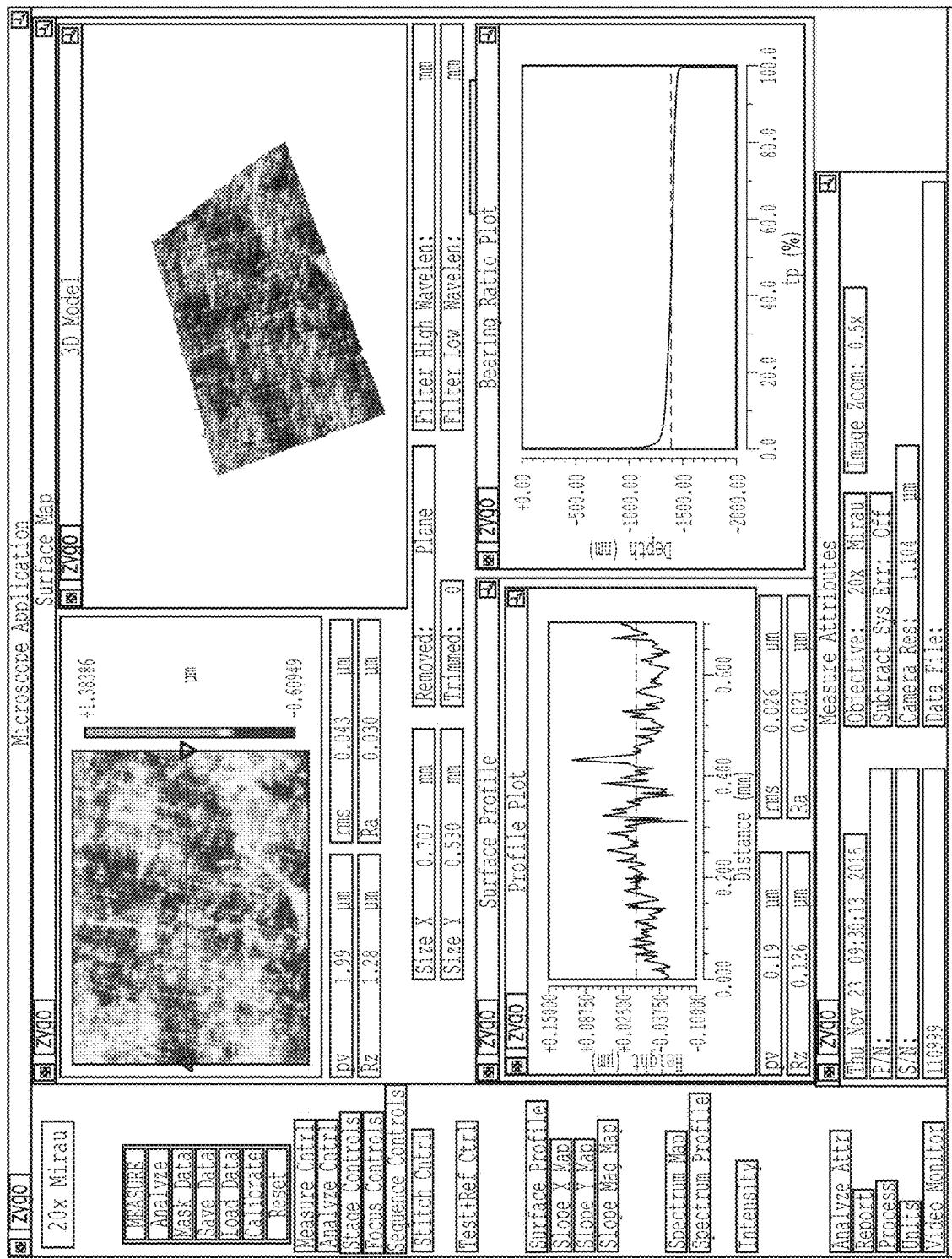


FIG. 251

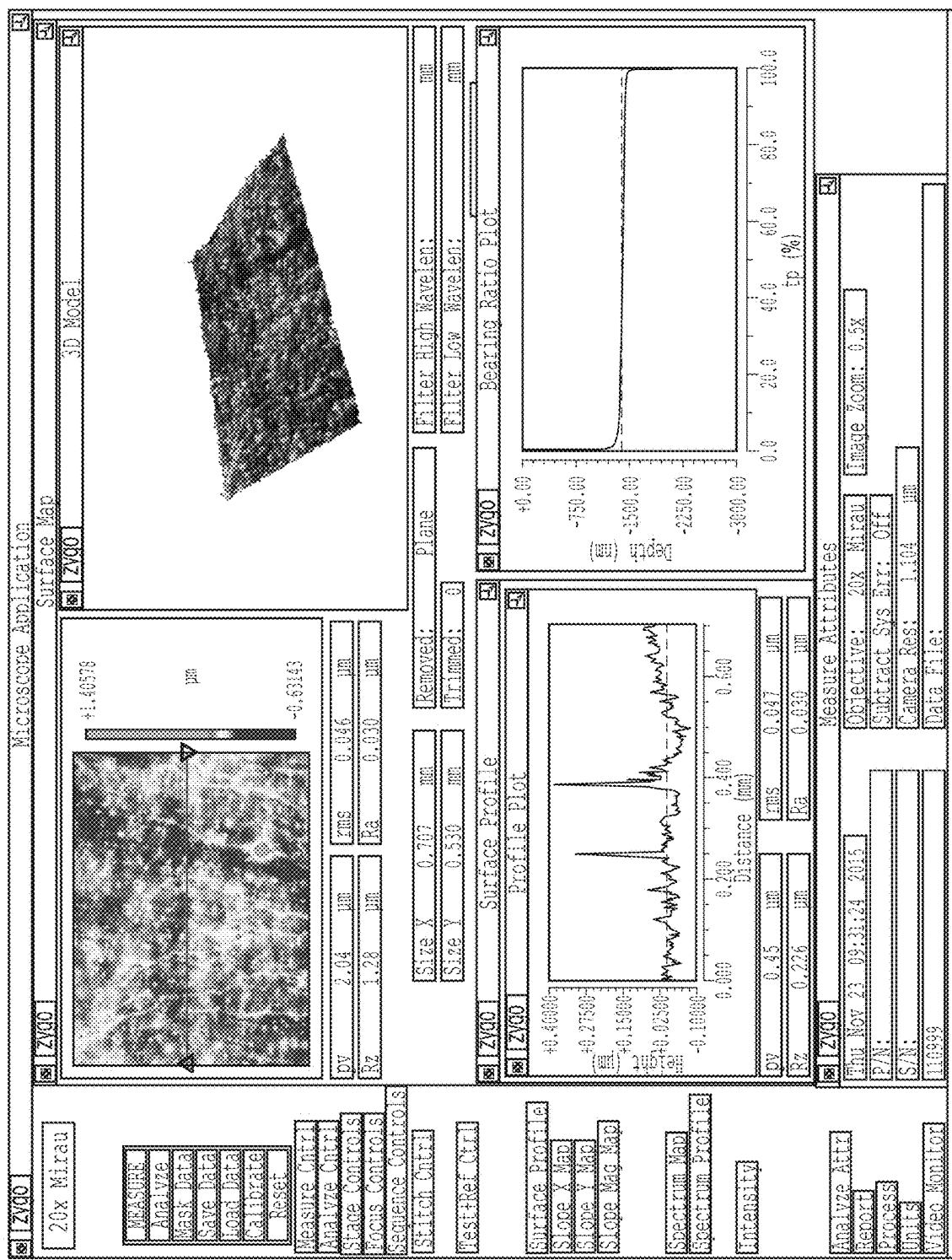


FIG. 252

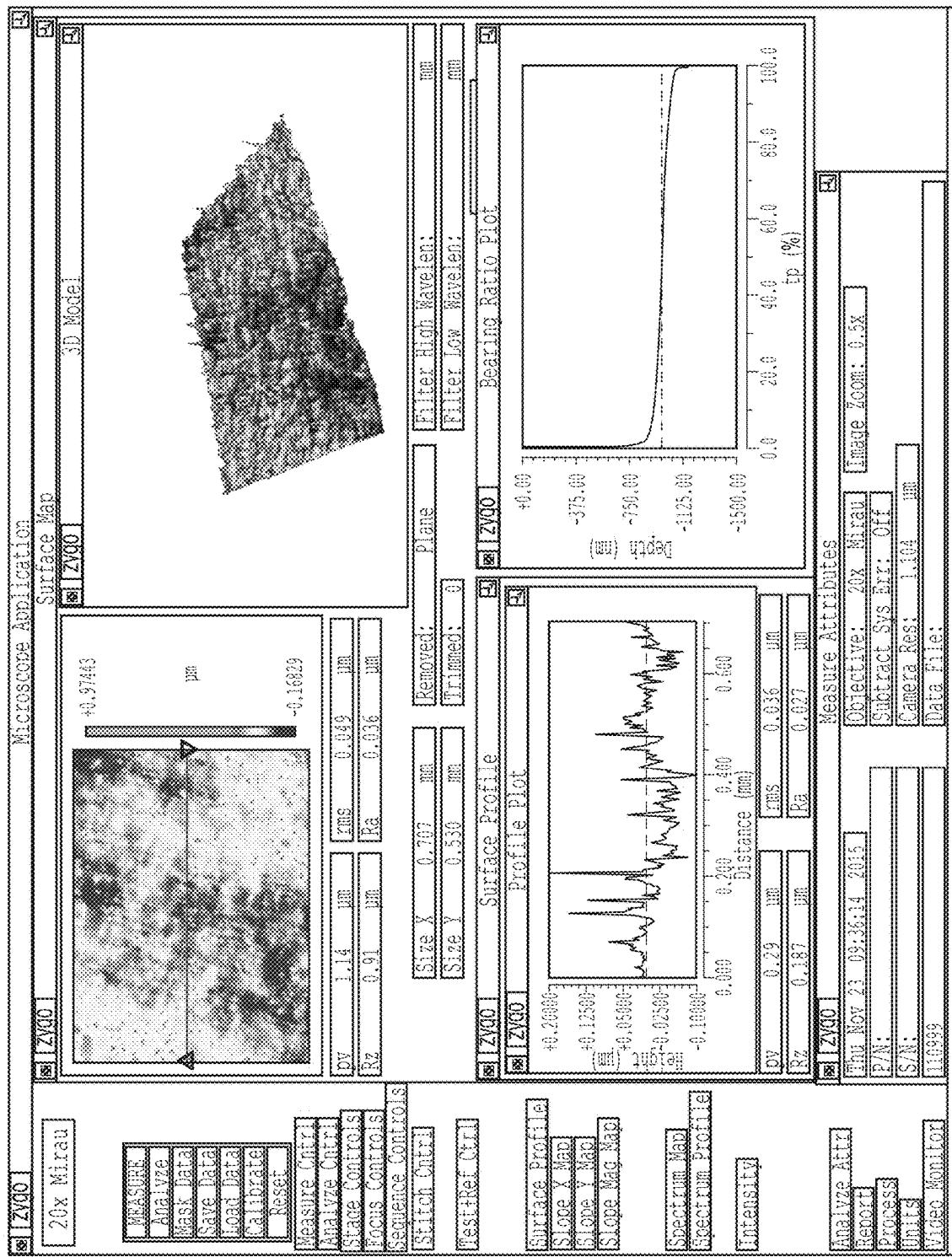


FIG. 253

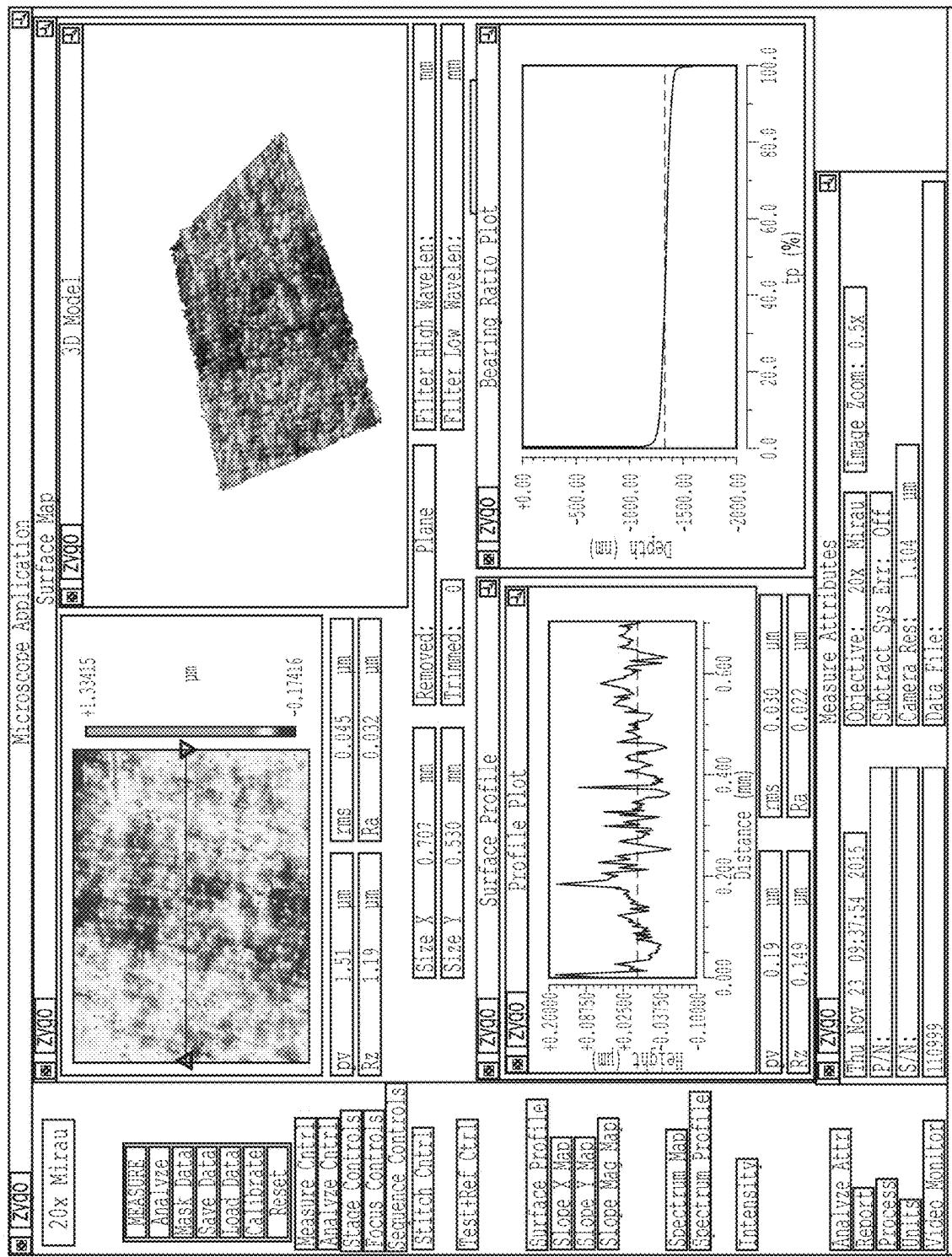


FIG. 254

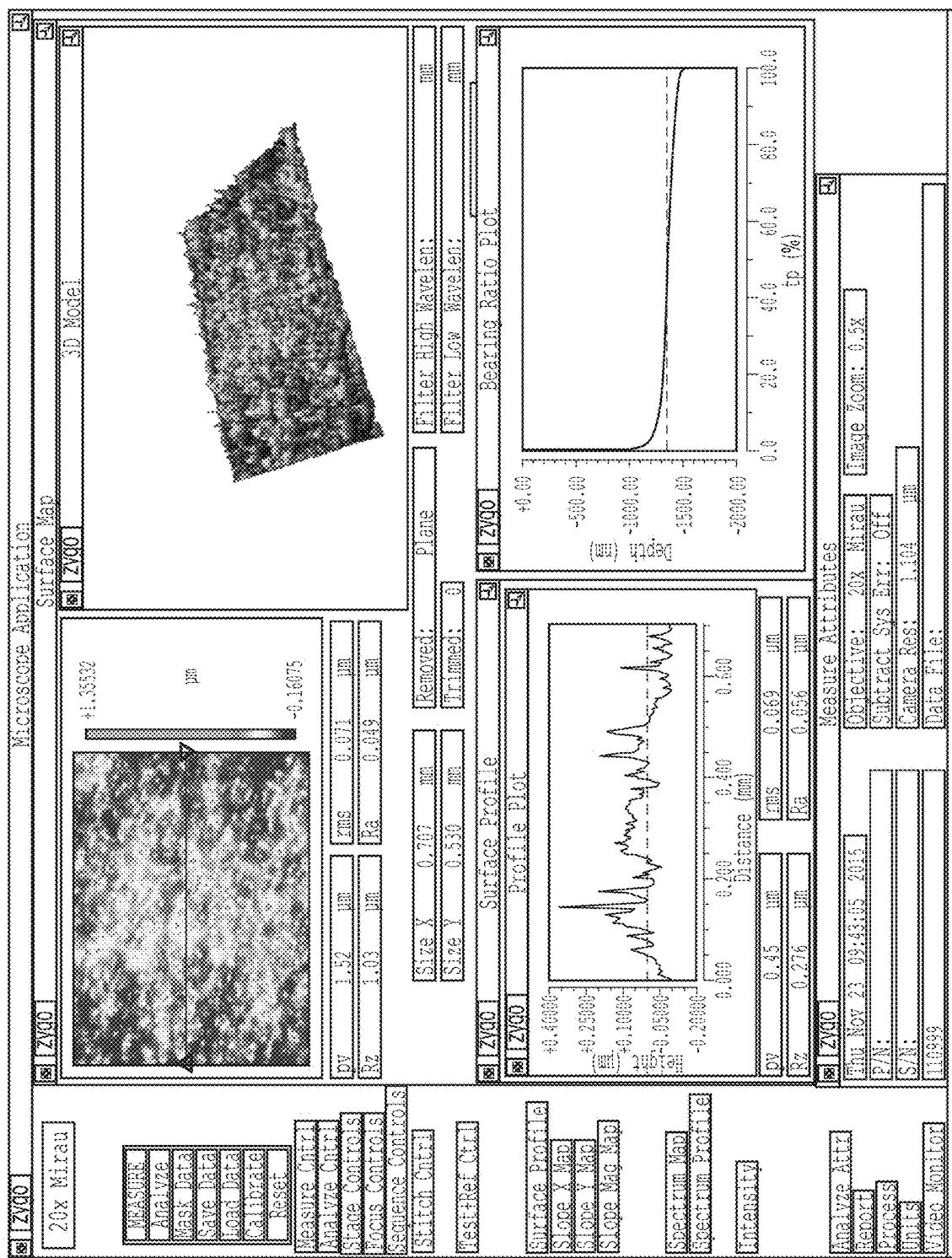


FIG. 255

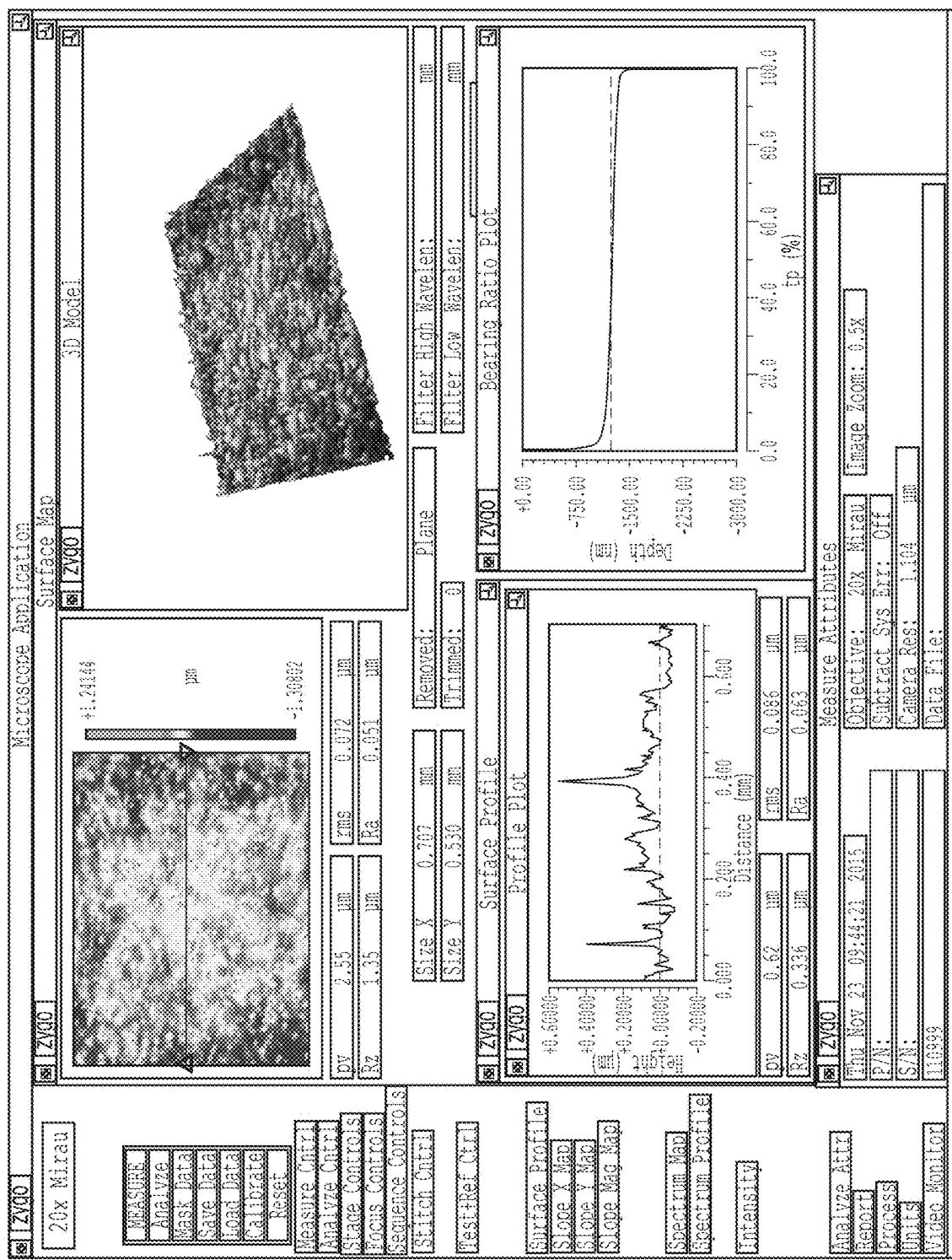


FIG. 256

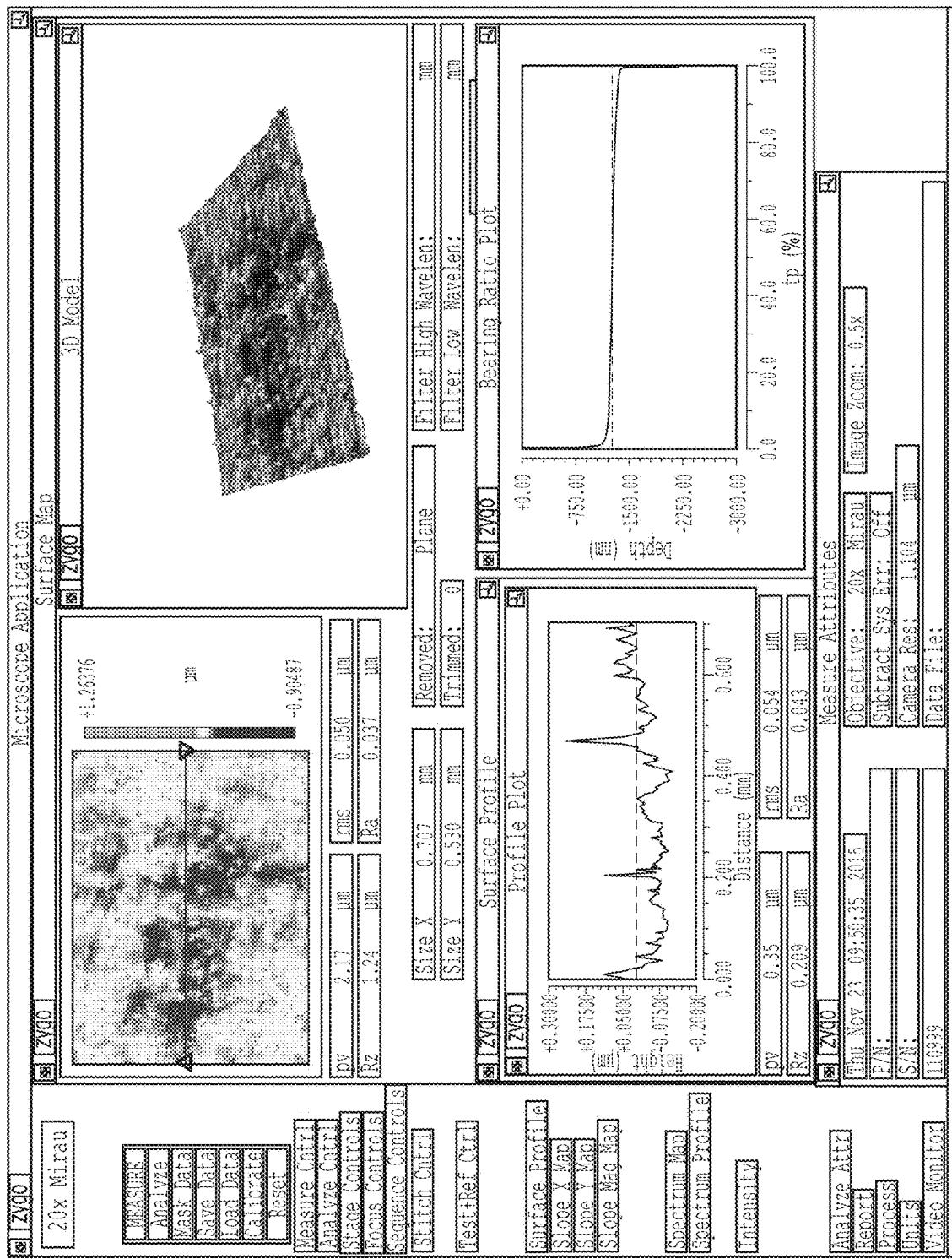


FIG. 257

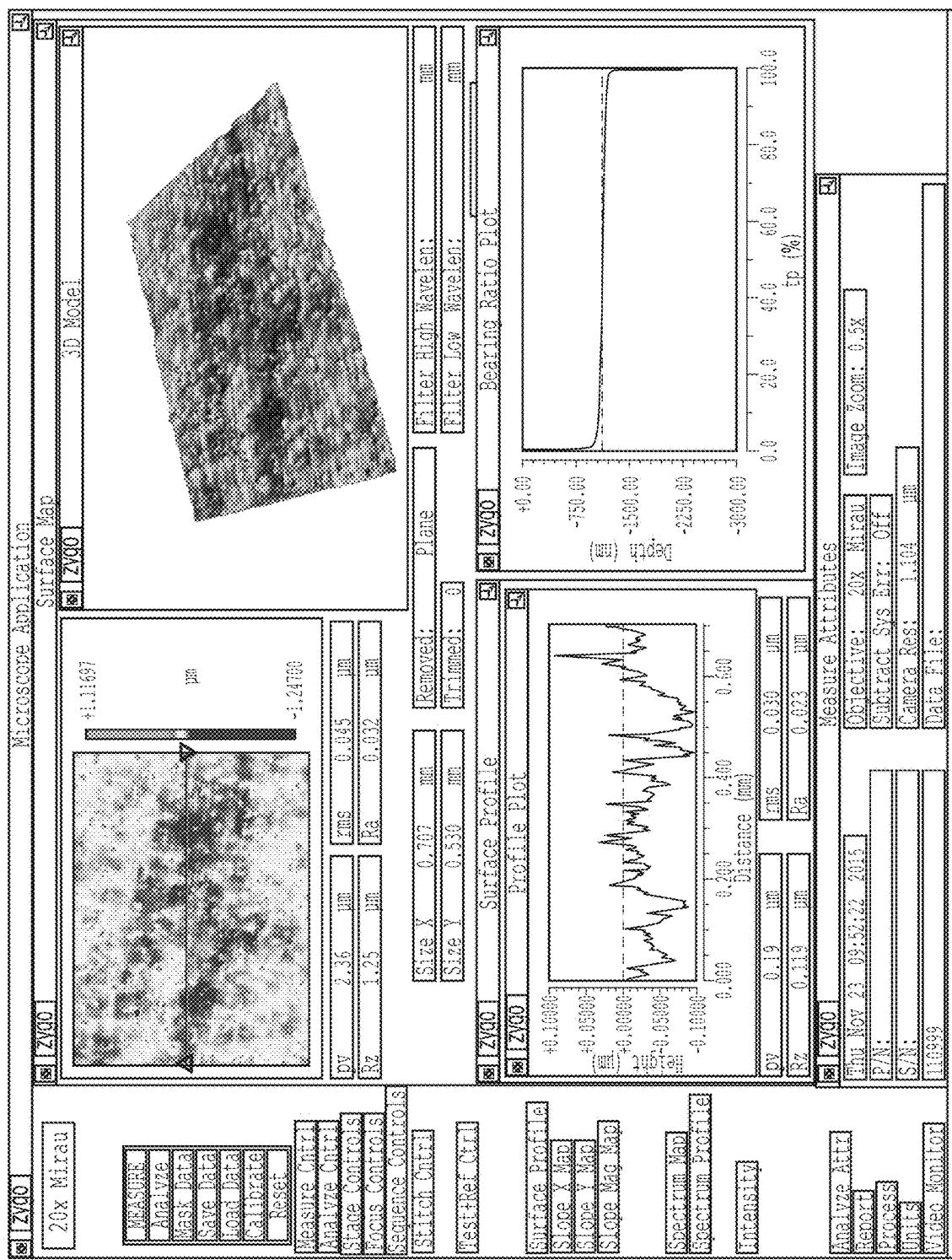


FIG. 258

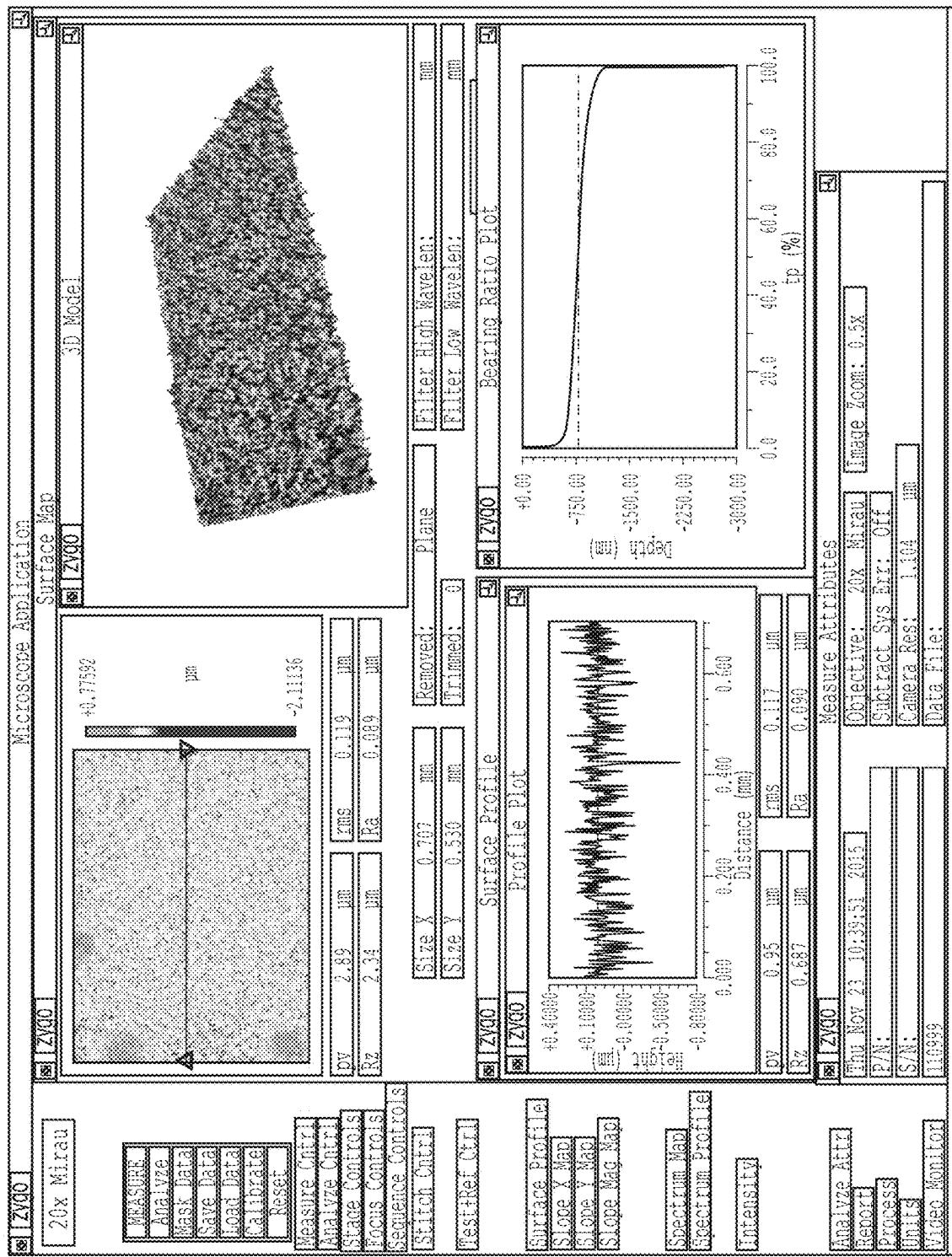


FIG. 259

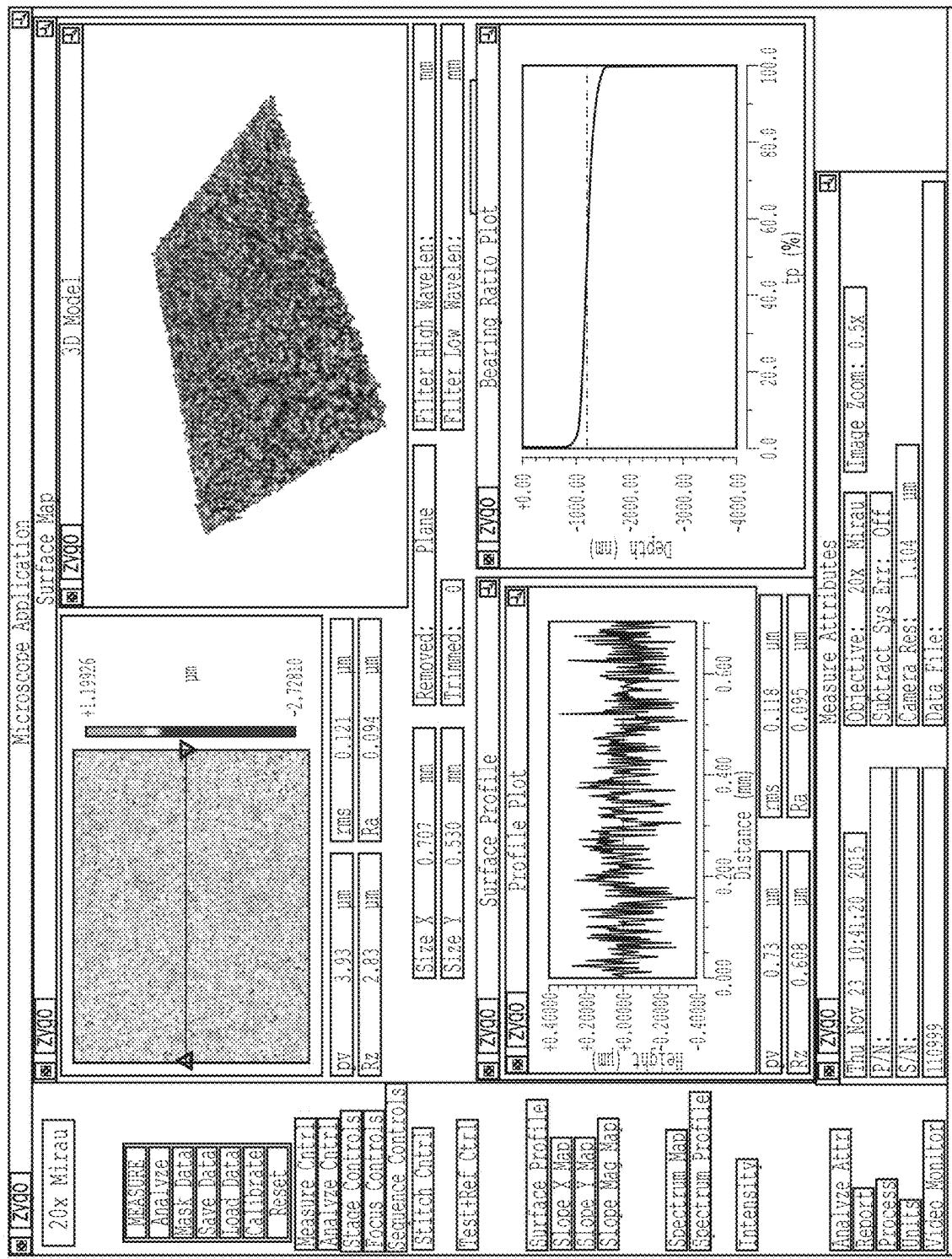


FIG. 260

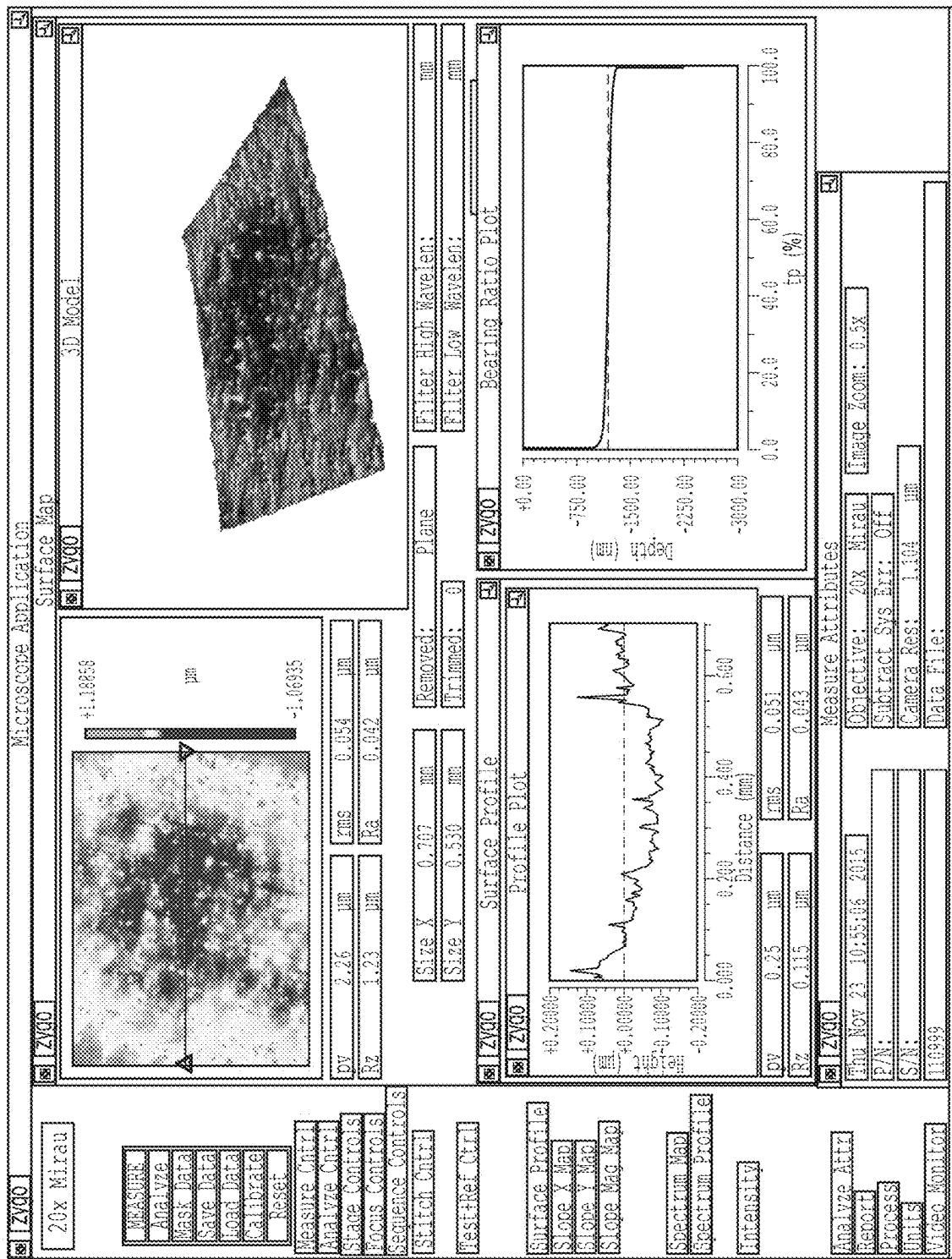


FIG. 261

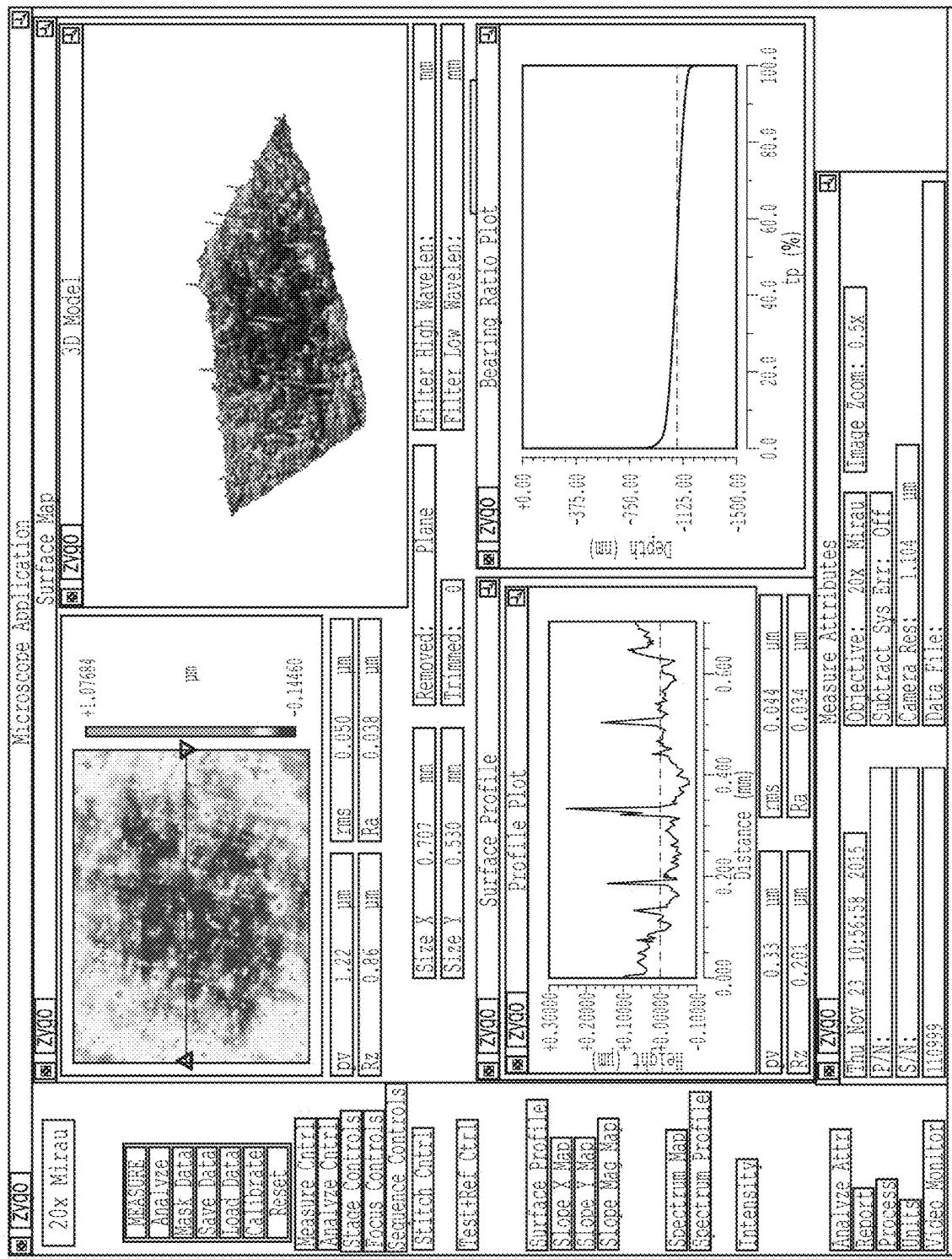


FIG. 262

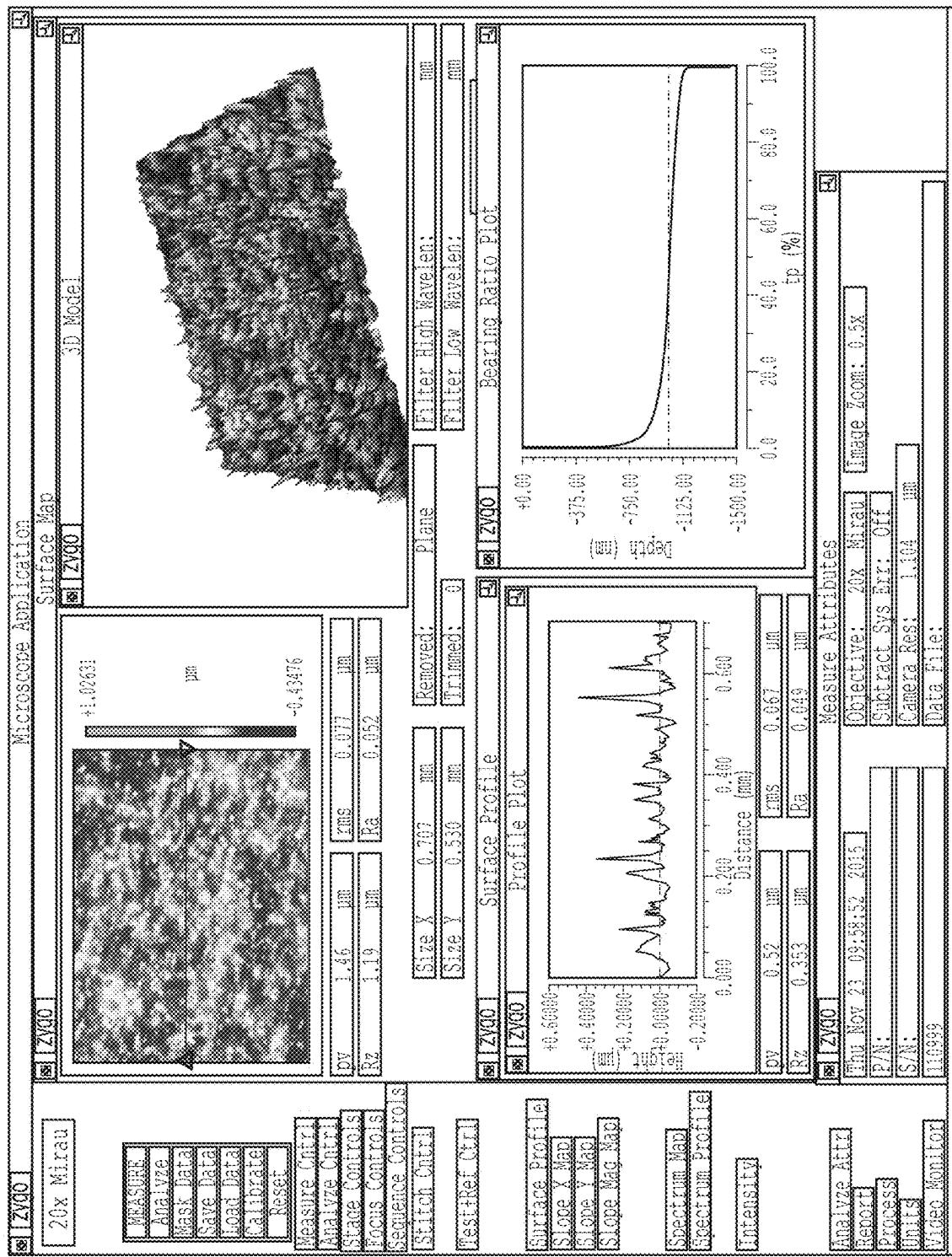


FIG. 263

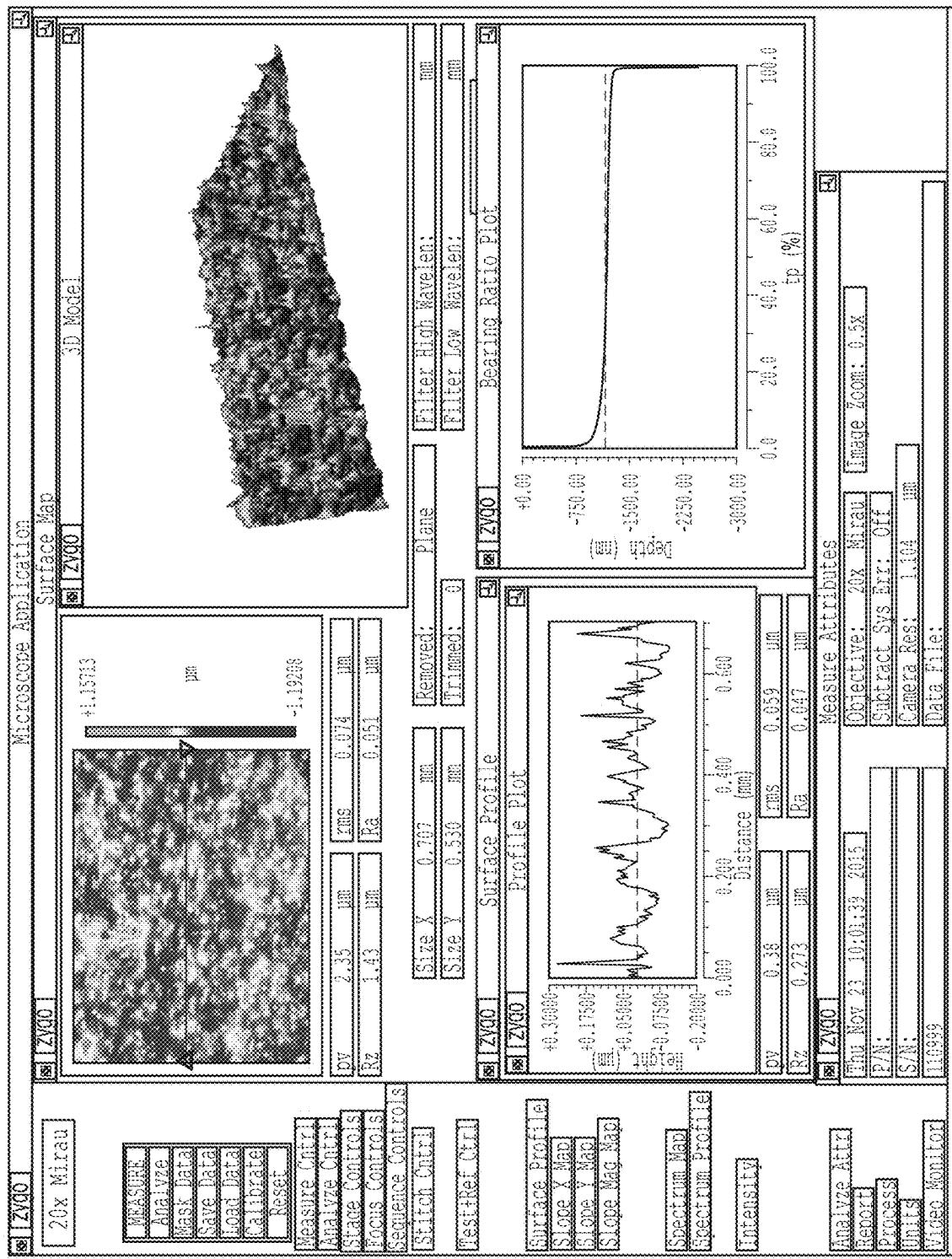


FIG. 264

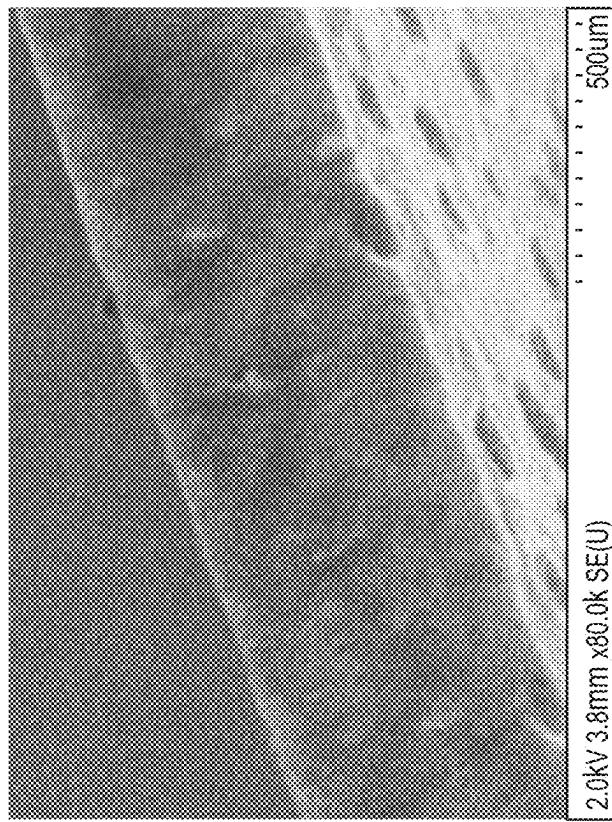


FIG. 265

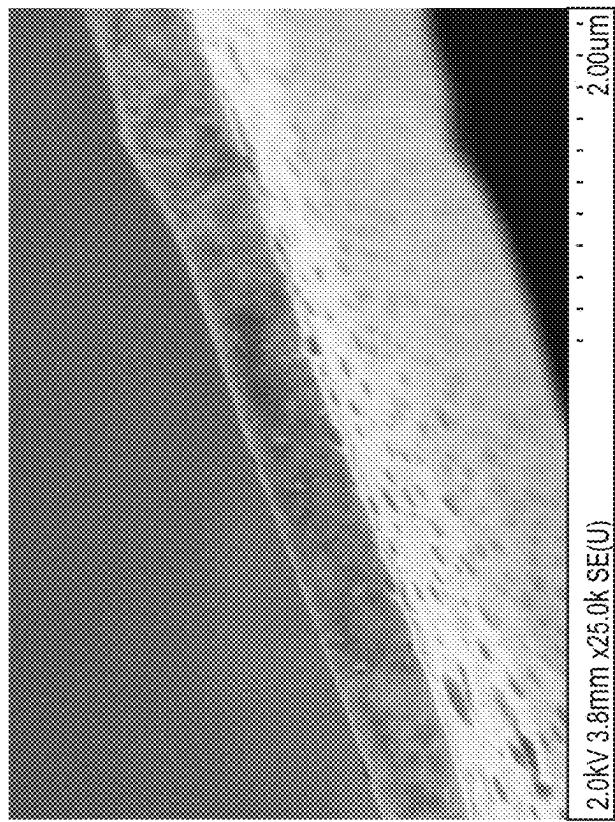


FIG. 266

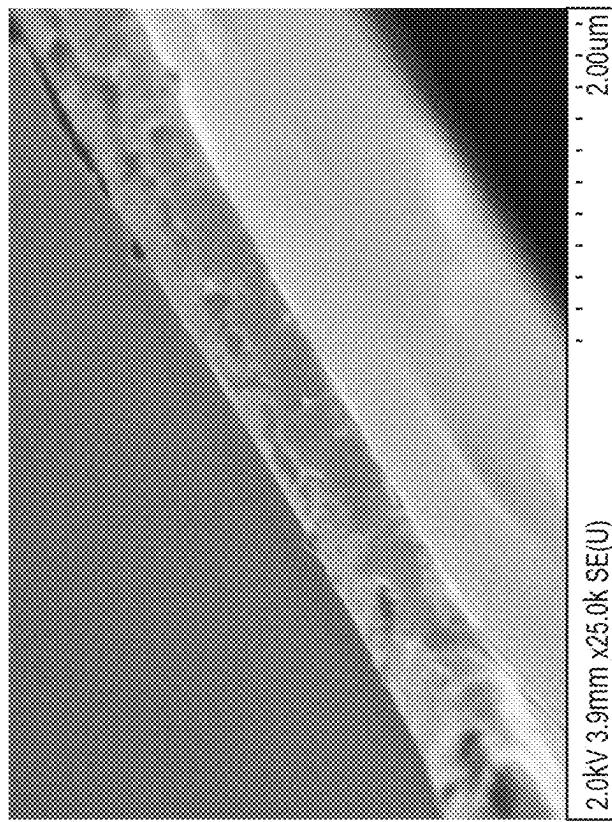


FIG. 267

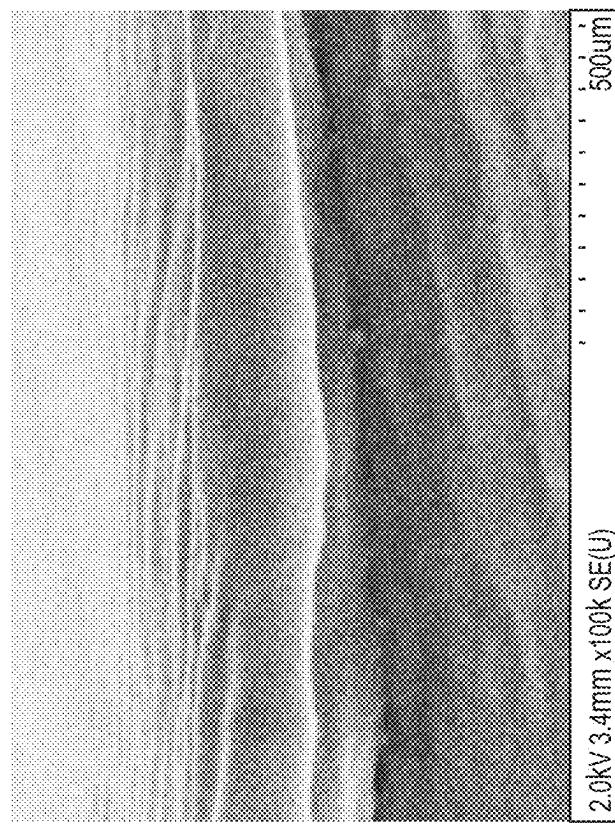


FIG. 268

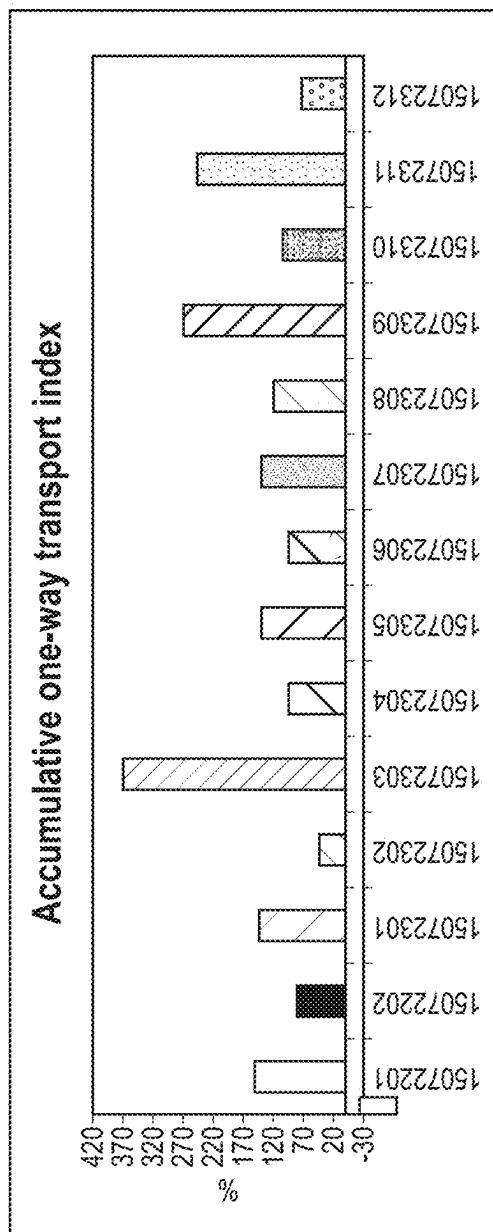


FIG. 269

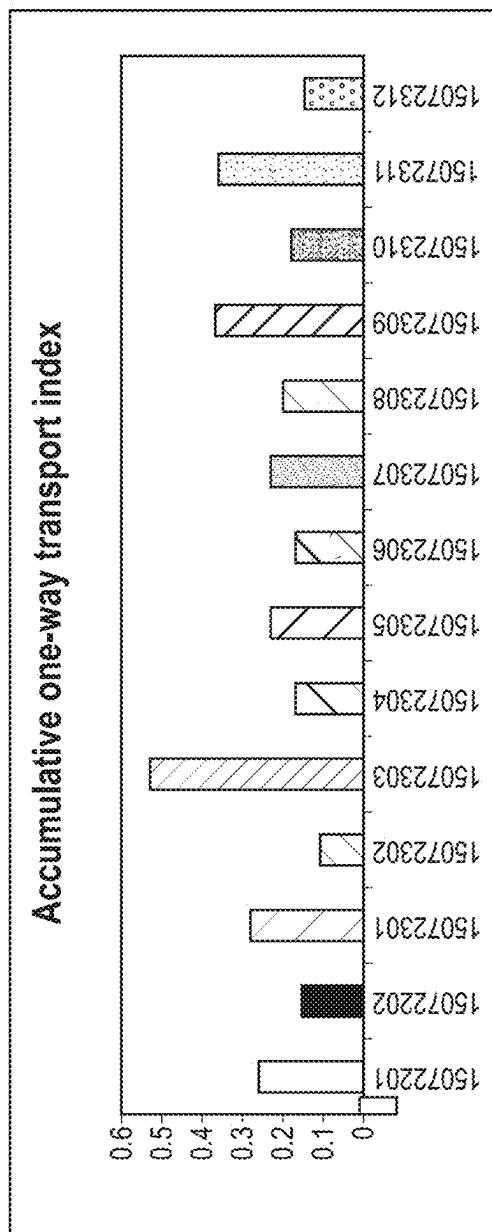


FIG. 270

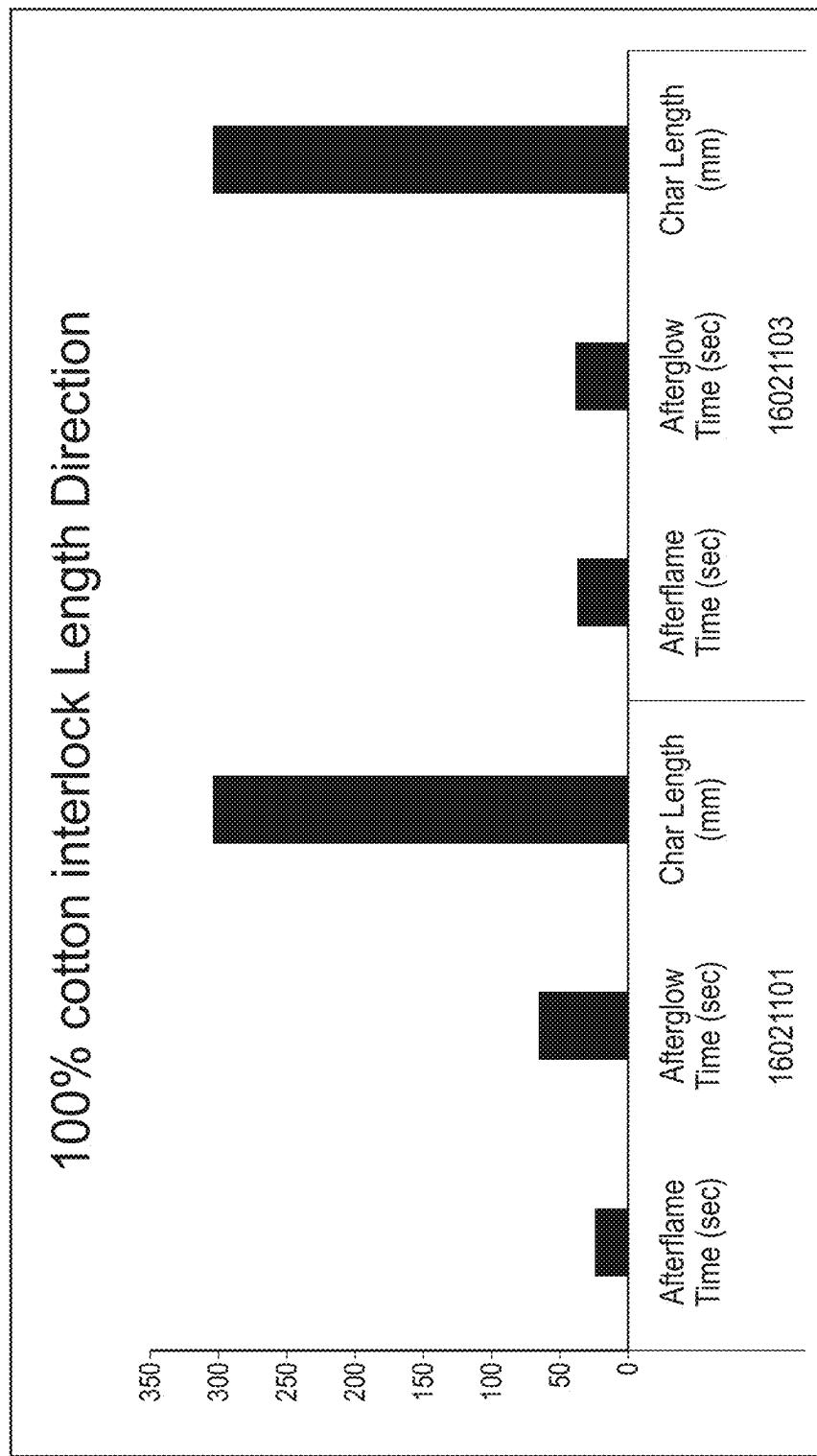


FIG. 271

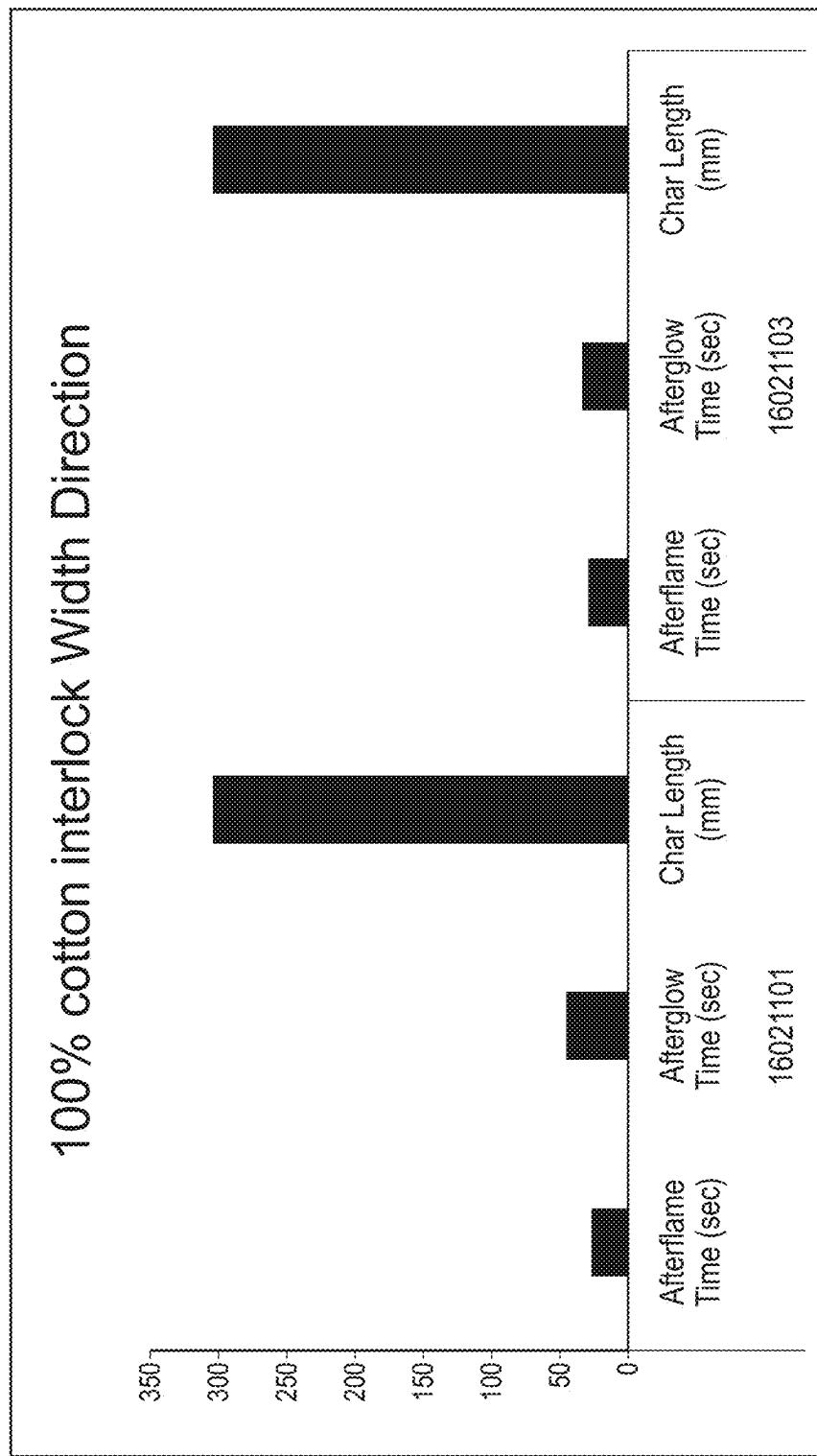


FIG. 272

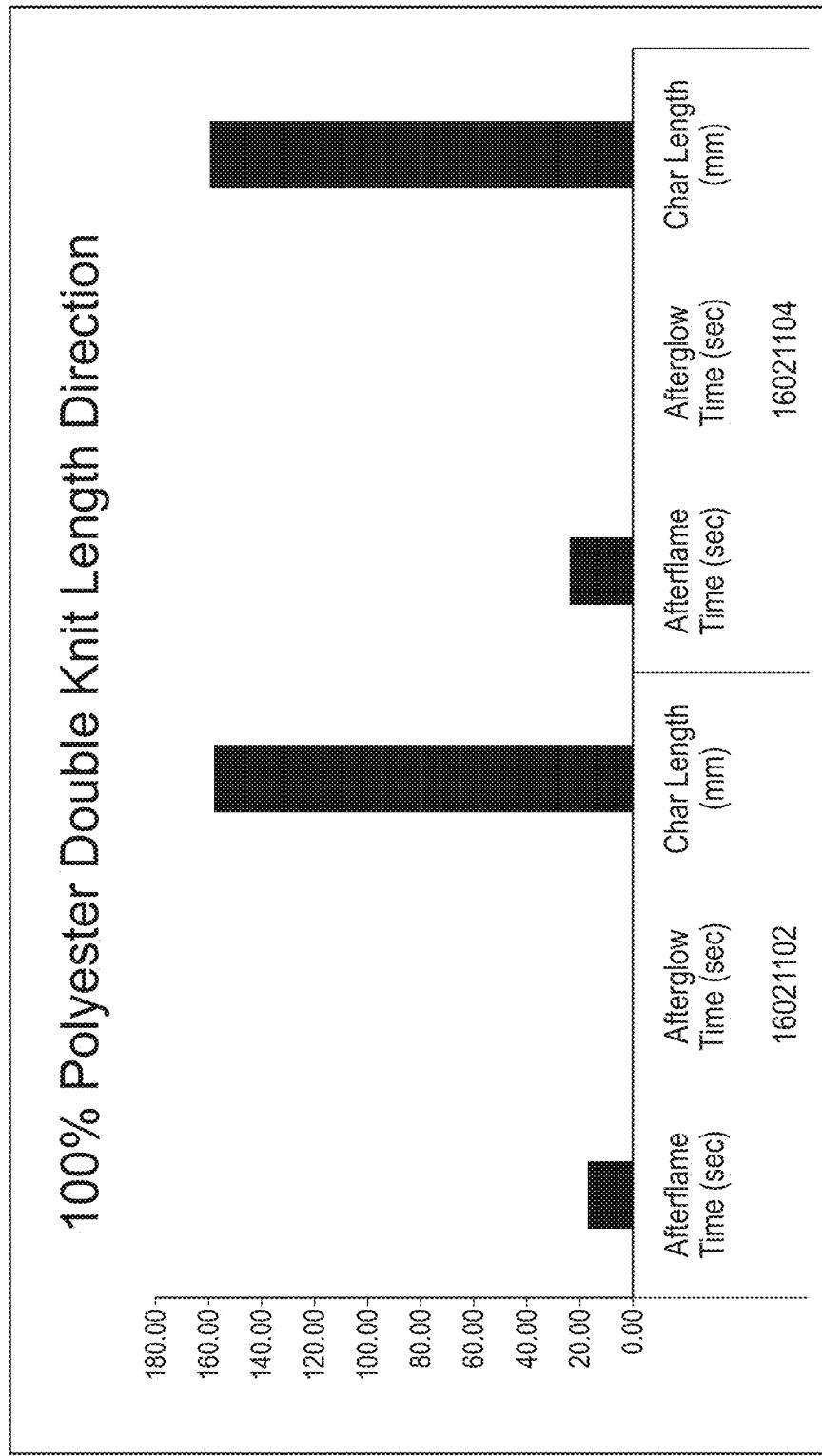


FIG. 273

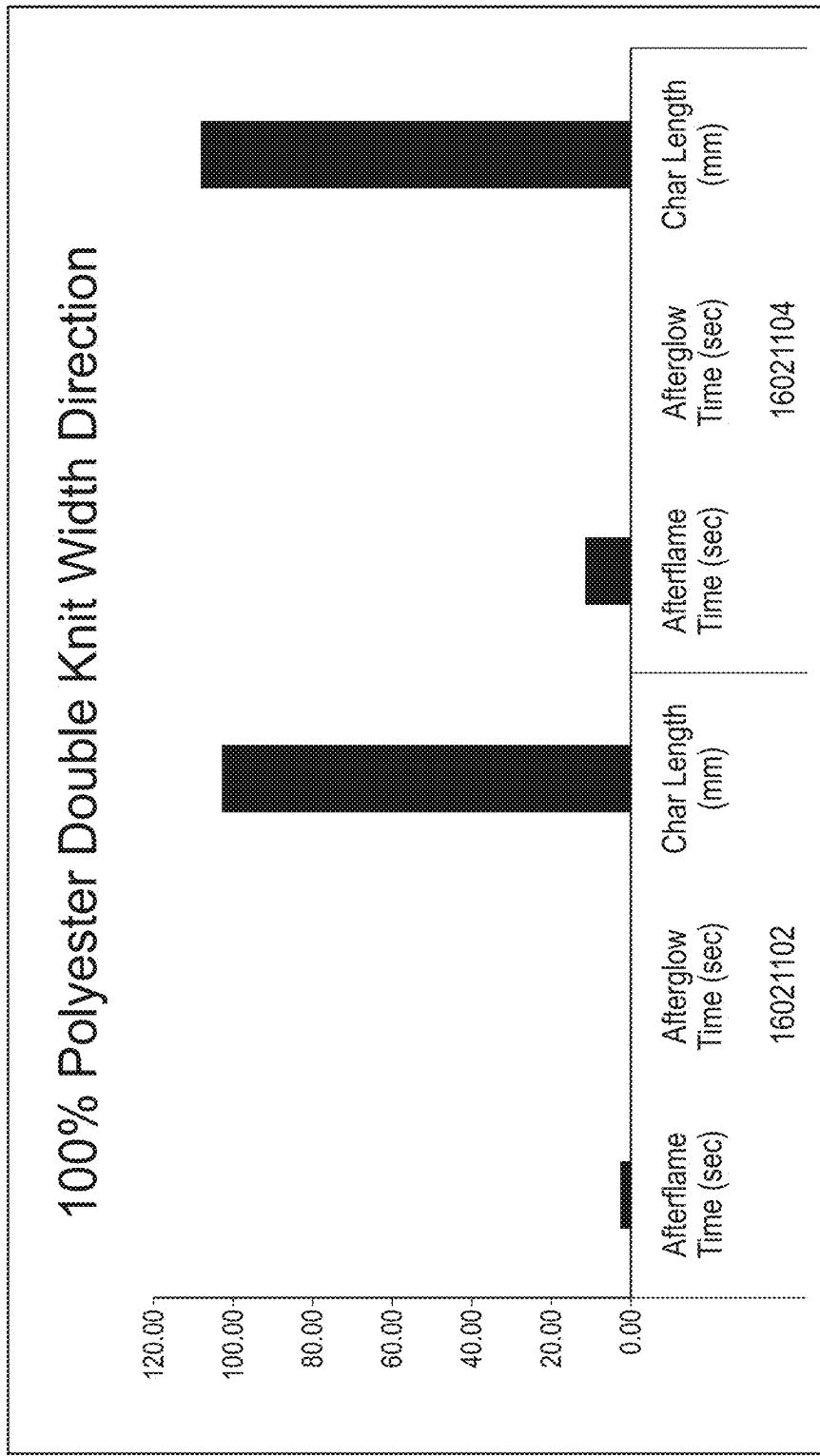


FIG. 274

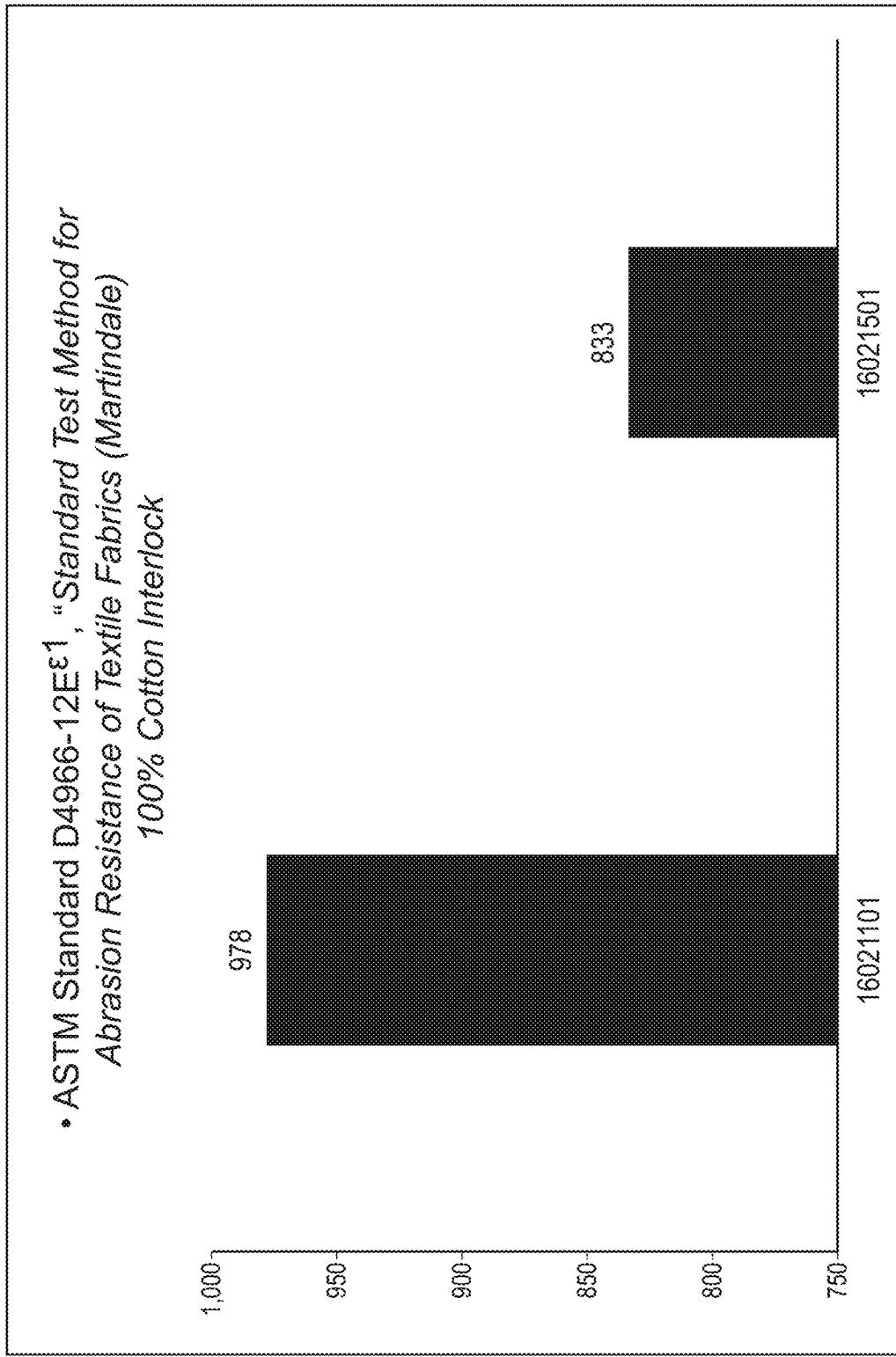


FIG. 275

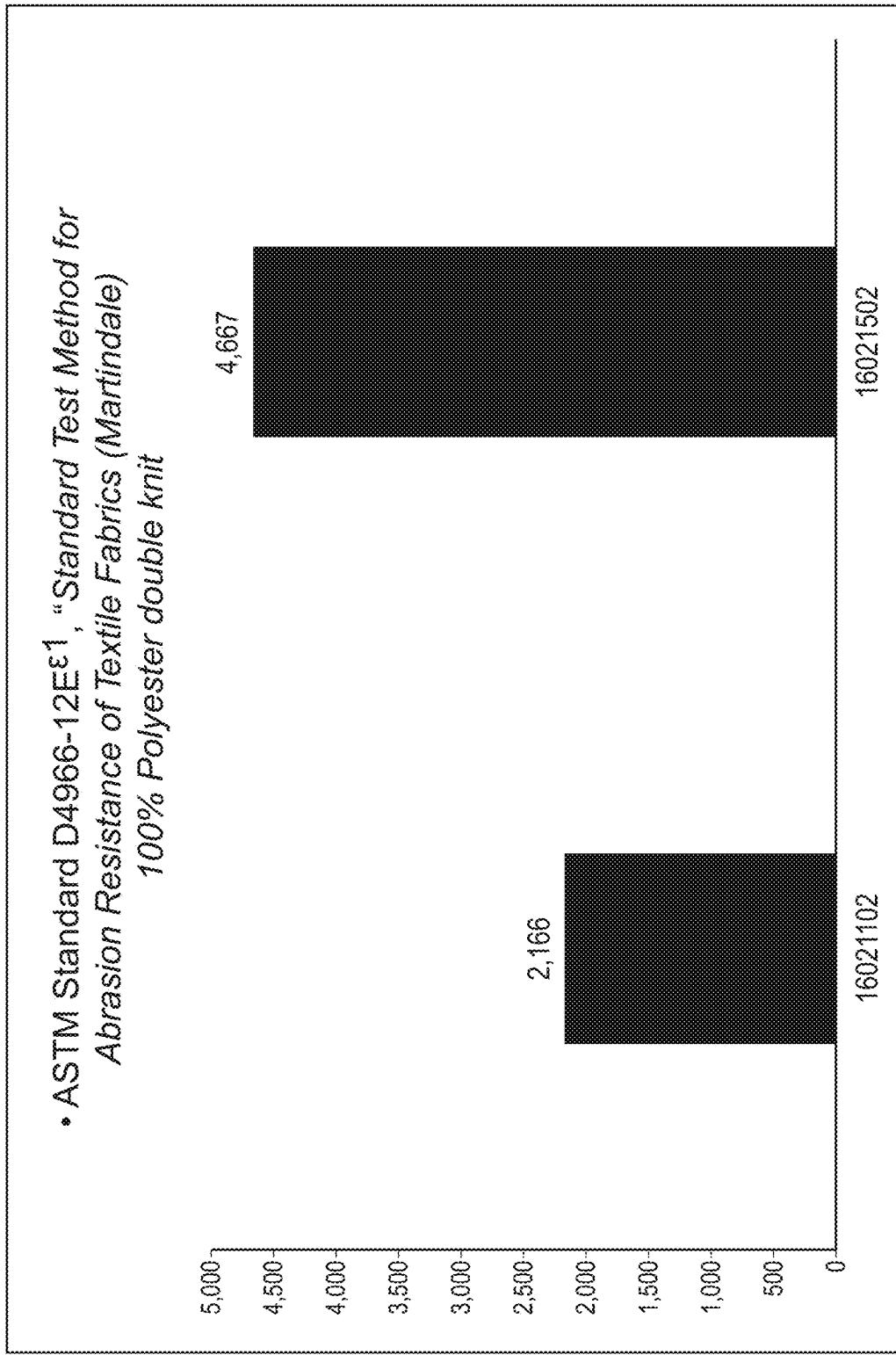


FIG. 276

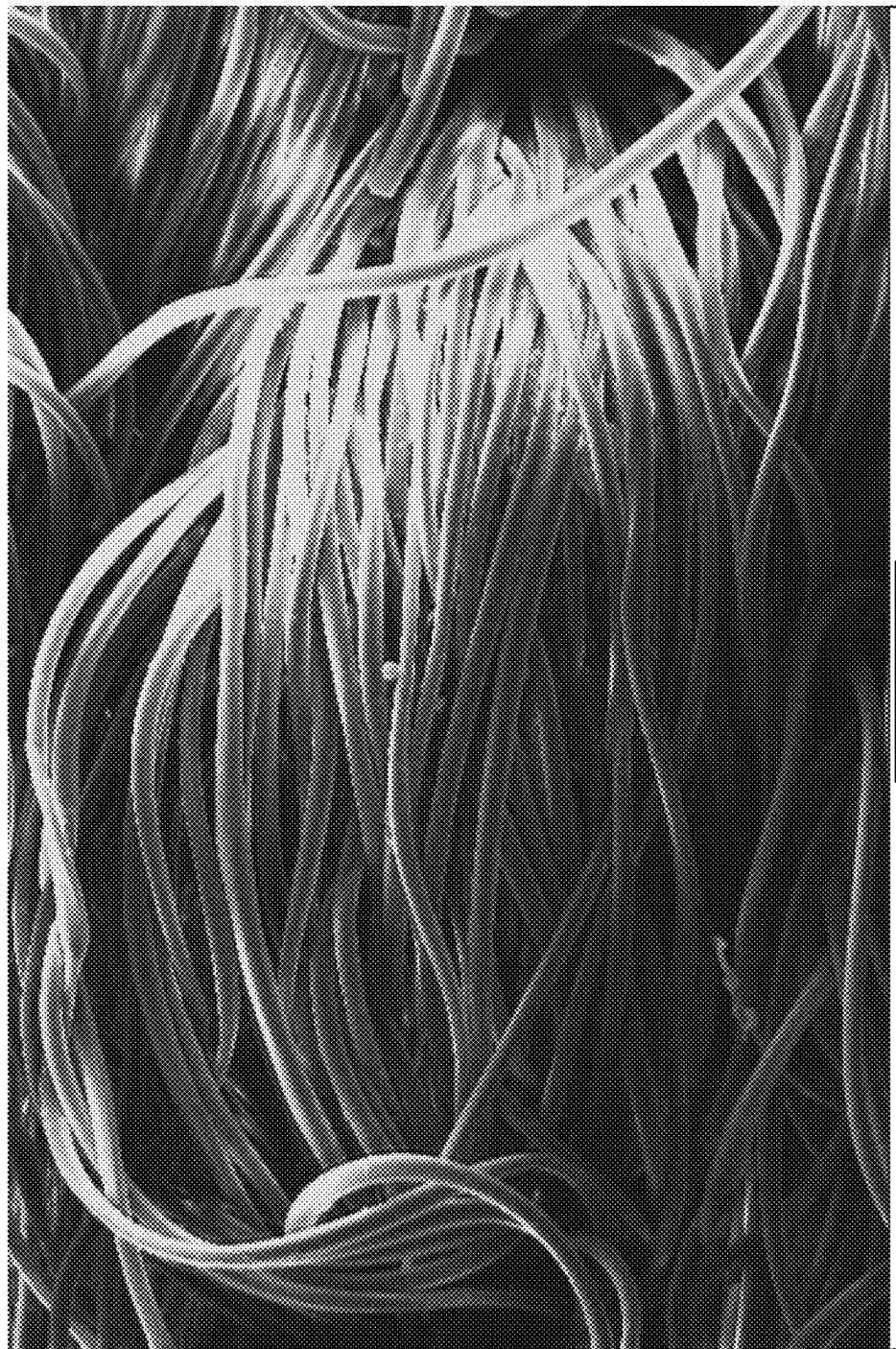


16041301

20.0 kV 100 μ m GASTON TMC

85.0x

FIG. 277



16041301

200 x 20.0 kV 100 μm GASTION TPC

200 x

FIG. 278

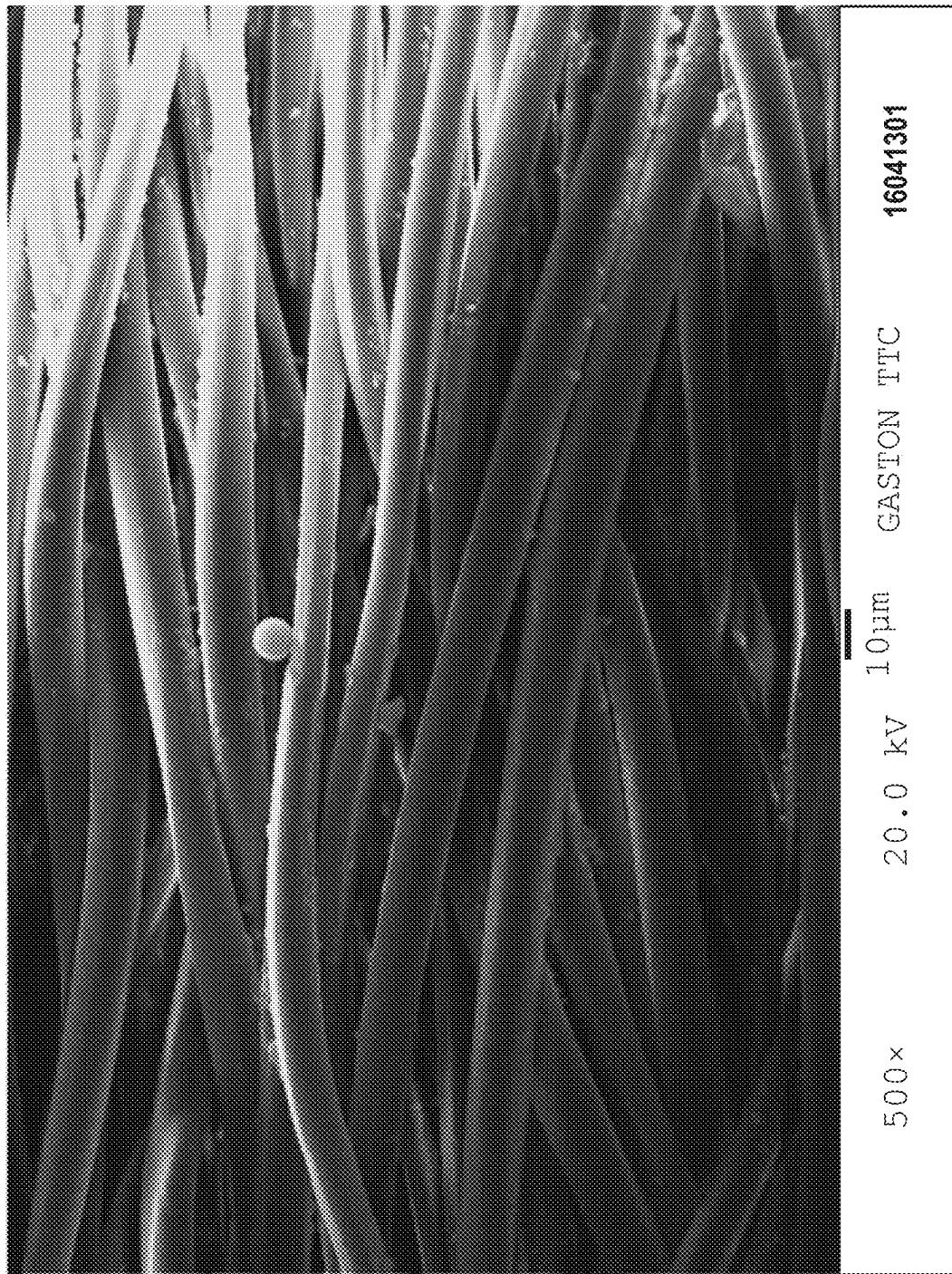
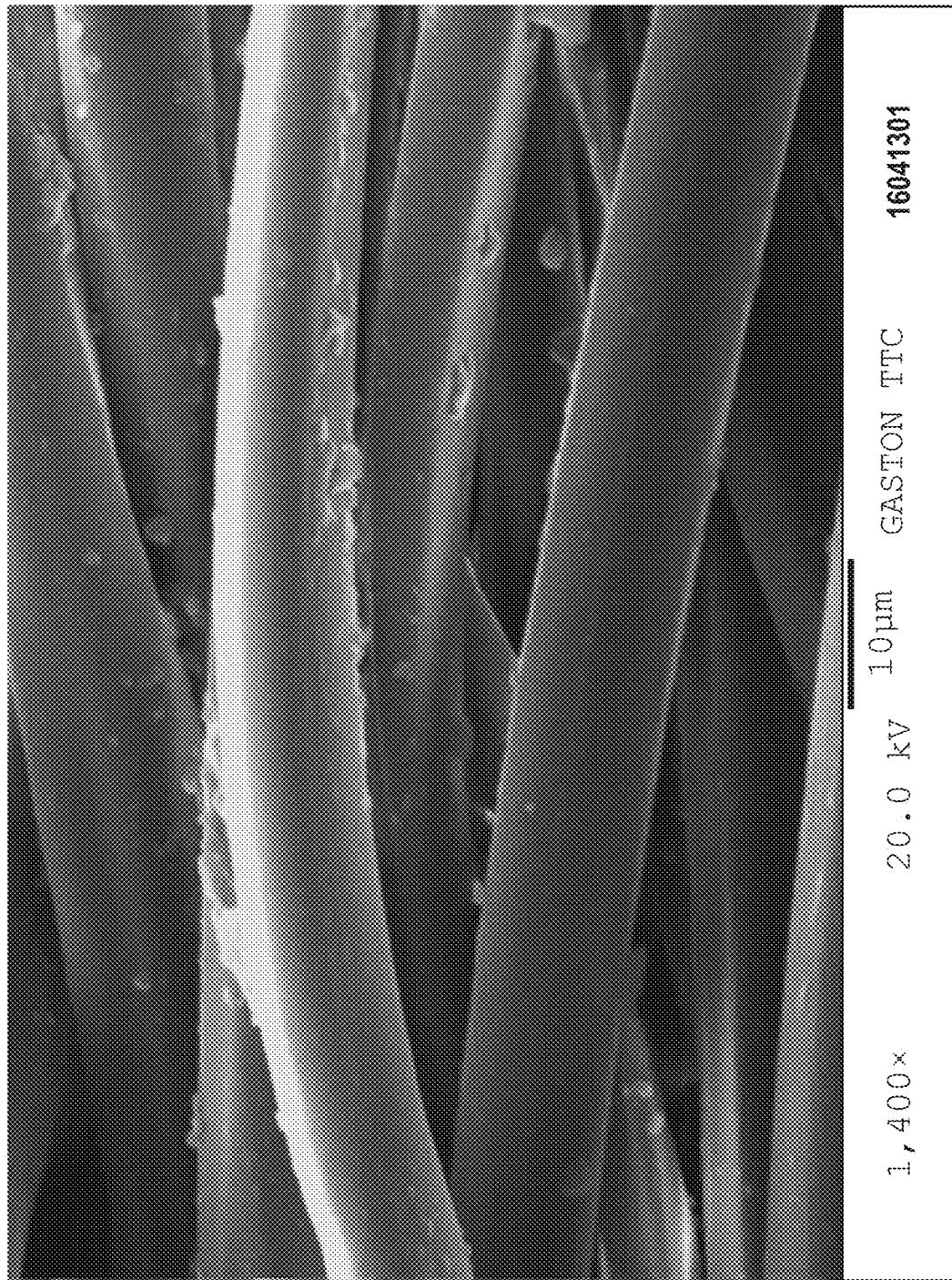


FIG. 279

500 \times 20.0 kV 10 μ m GASEATION TiC
16041301



FIG. 280

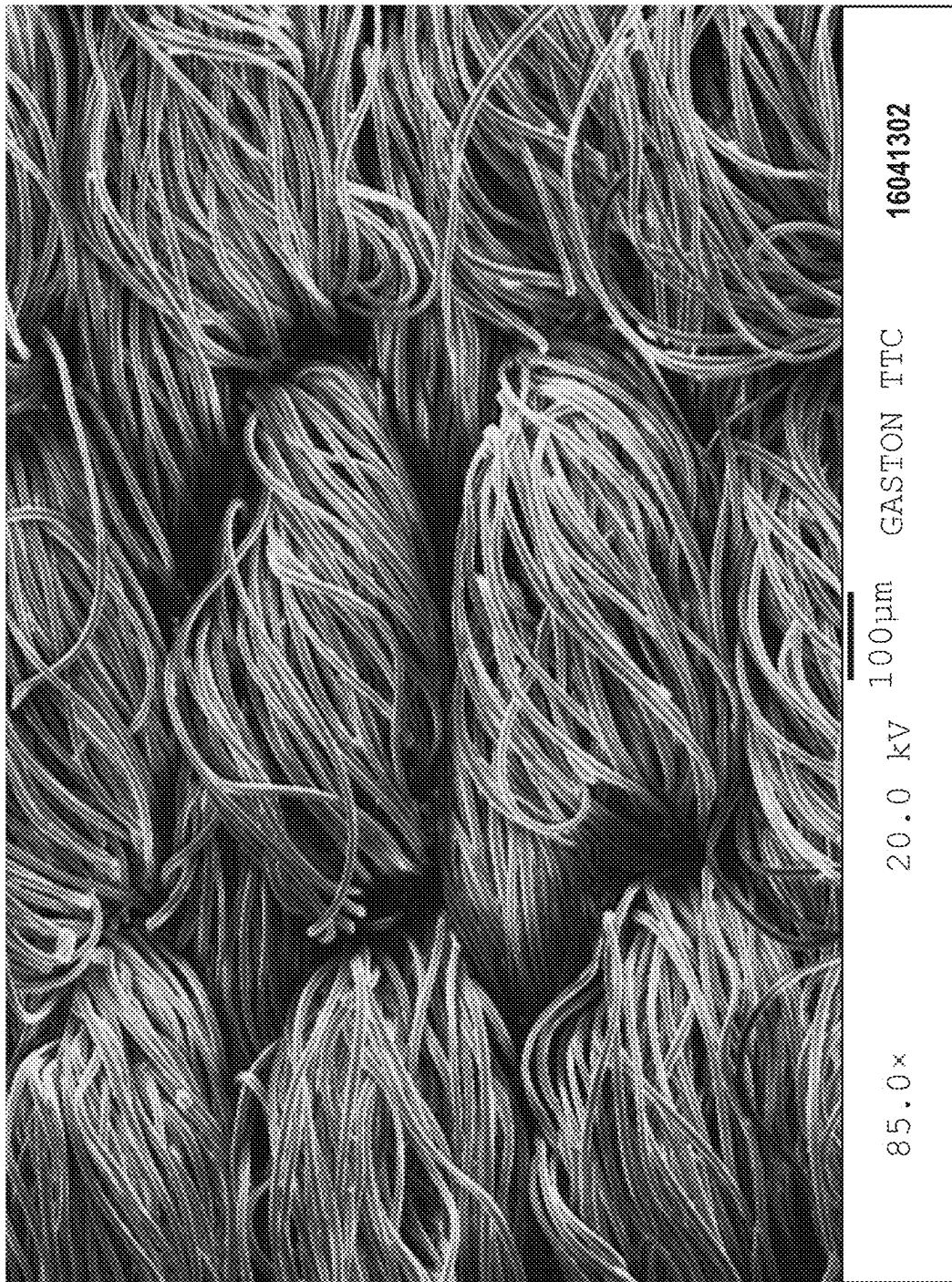


16041301

20.0 kV 10µm GASTON TTC

1,400X

FIG. 281



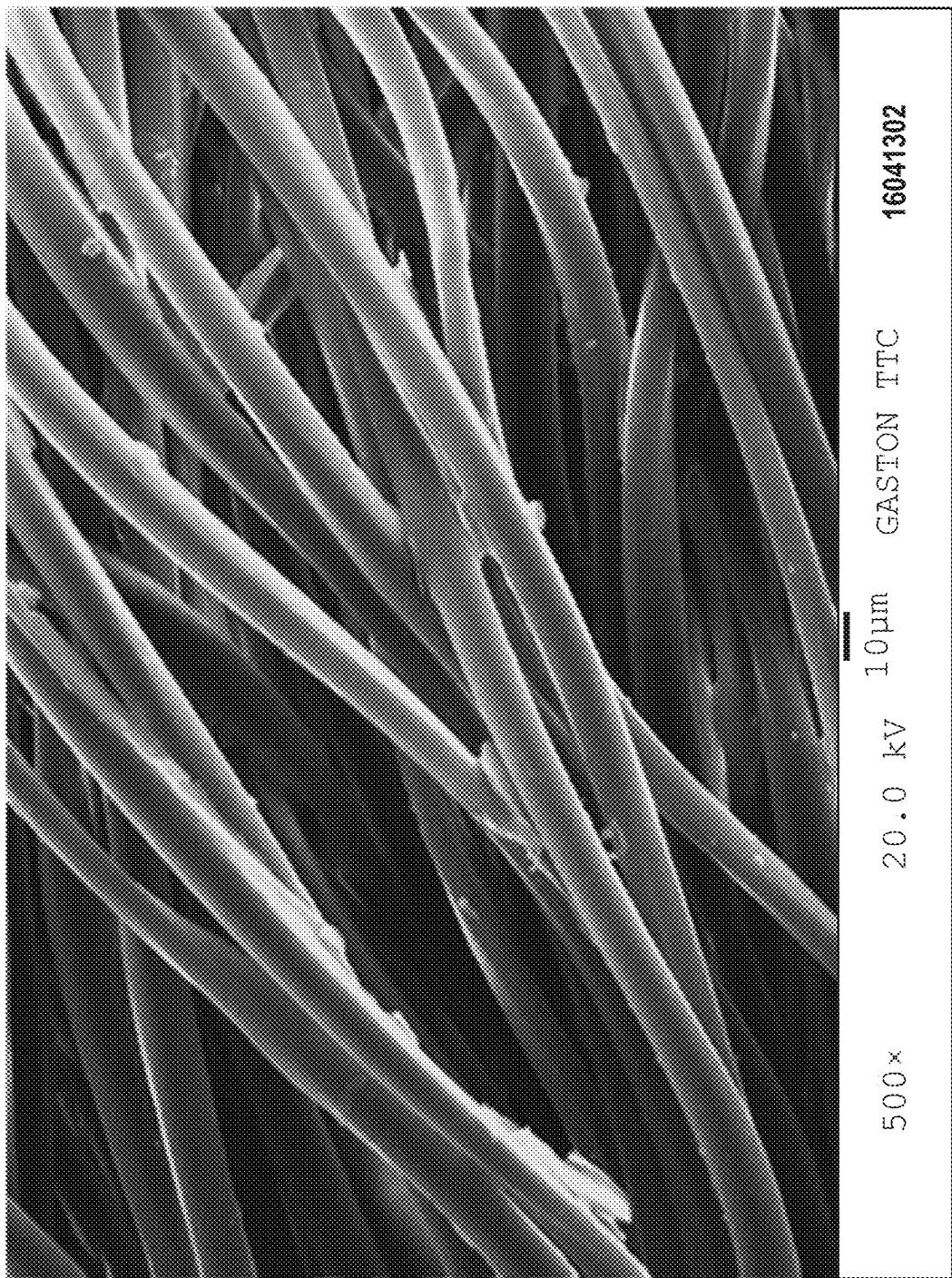


16041302

200.0 kV 100 μm GASTON TMC

200×

FIG. 283



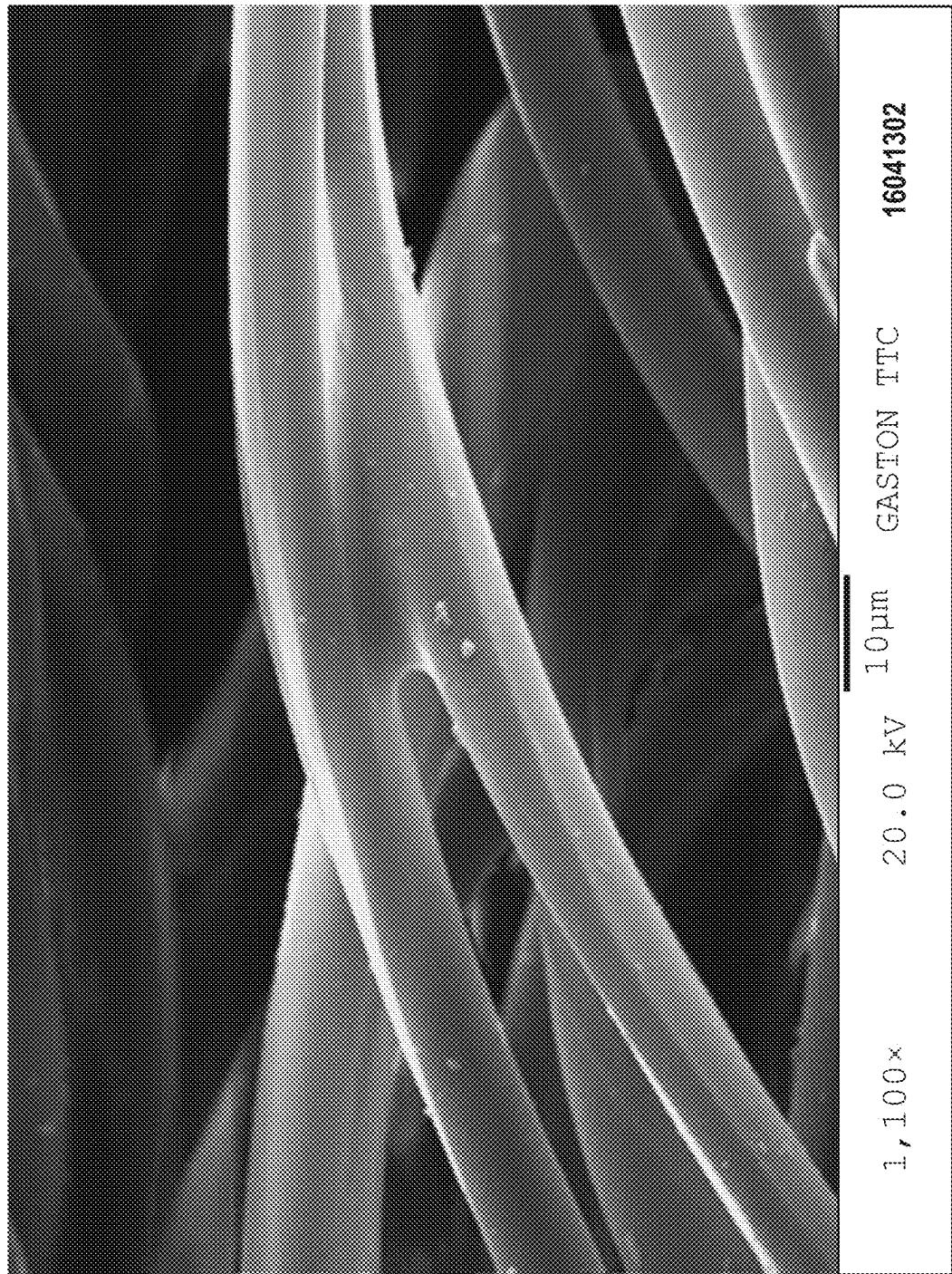


FIG. 285

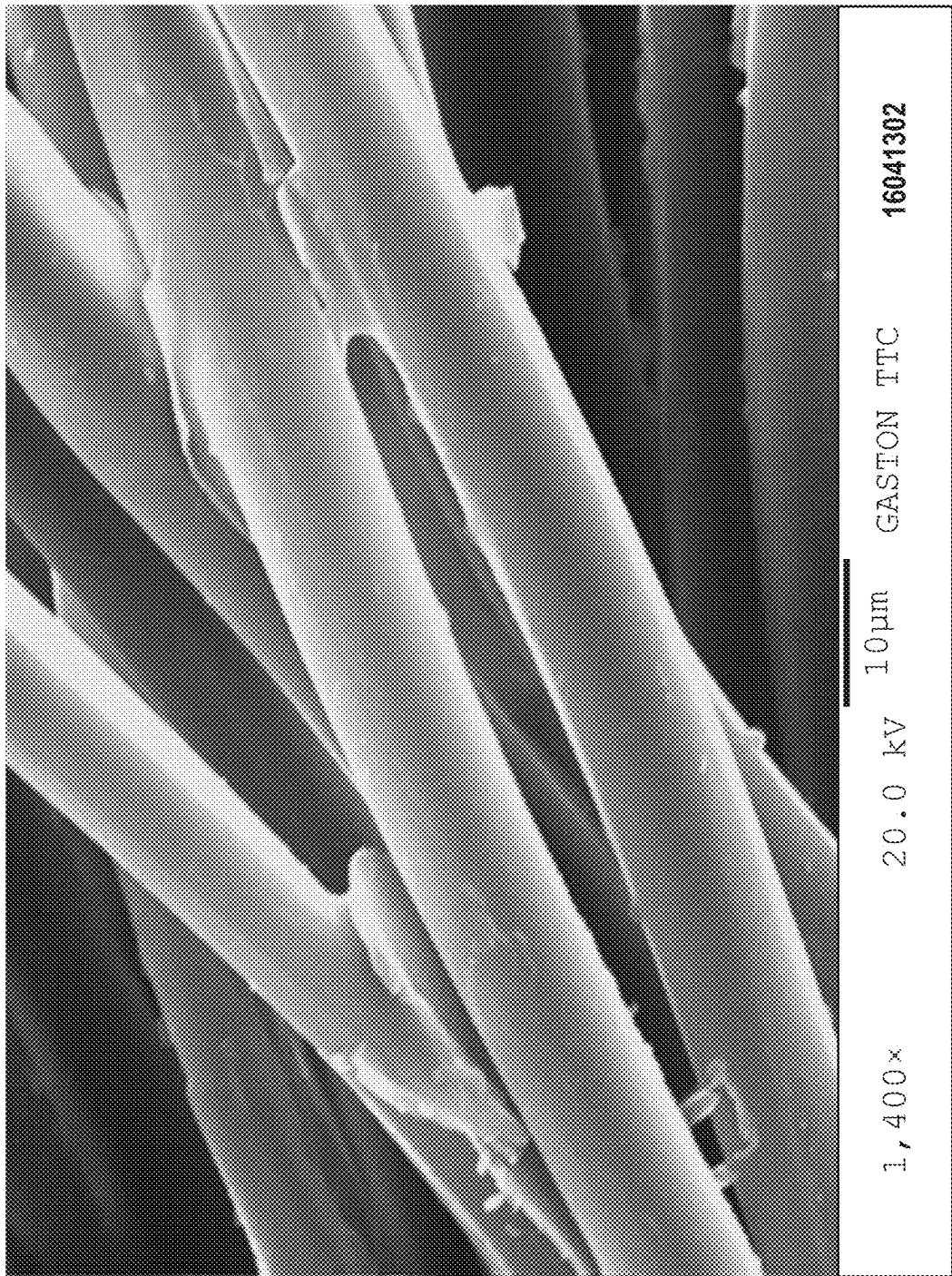


FIG. 286

16041302

20.0 kV 10 μ m GASTON TTC

1,400 \times



16041303

20.0 kV 100 μ m GASTON TMC

85.0 x

FIG. 287



FIG. 288

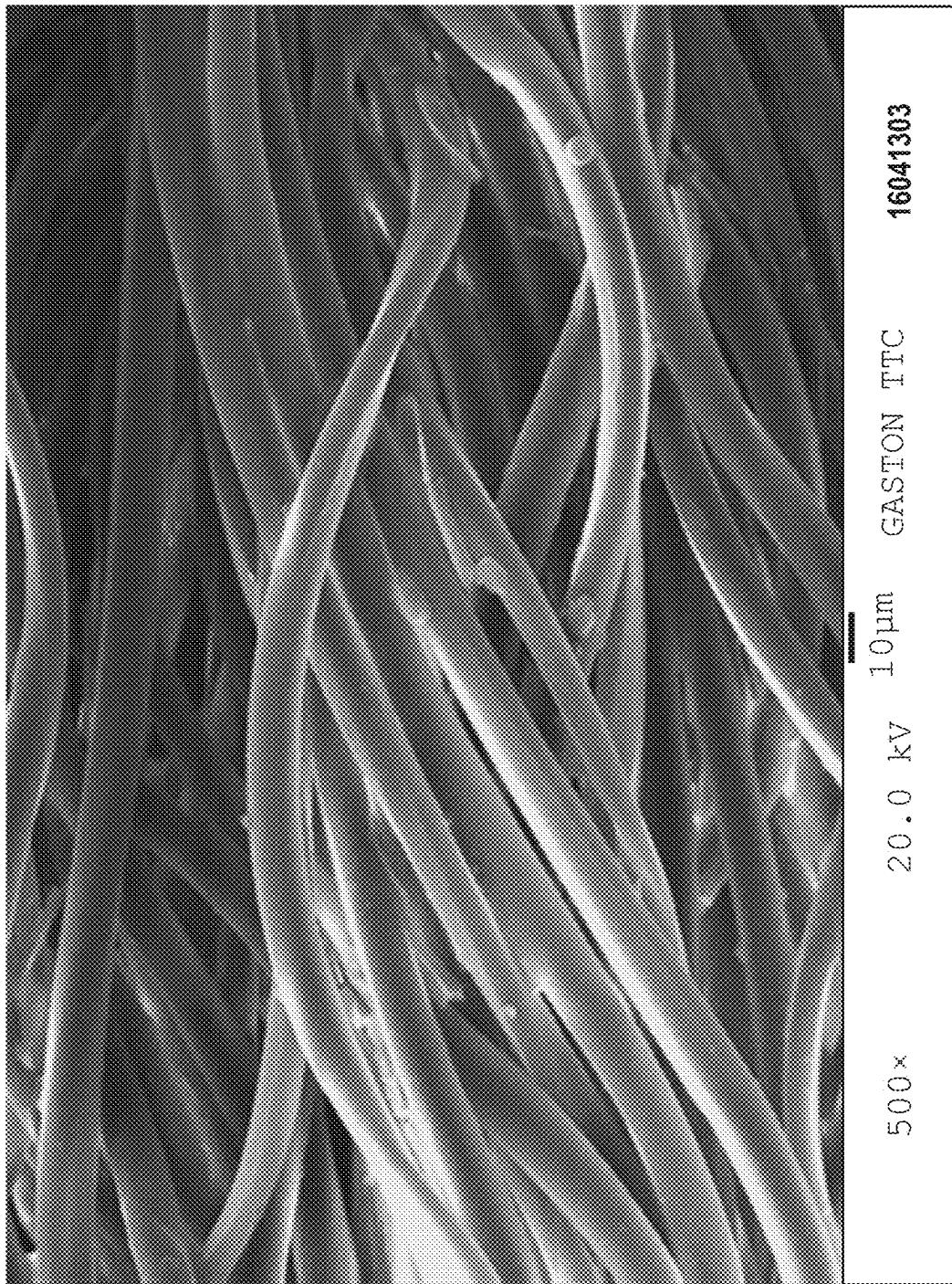
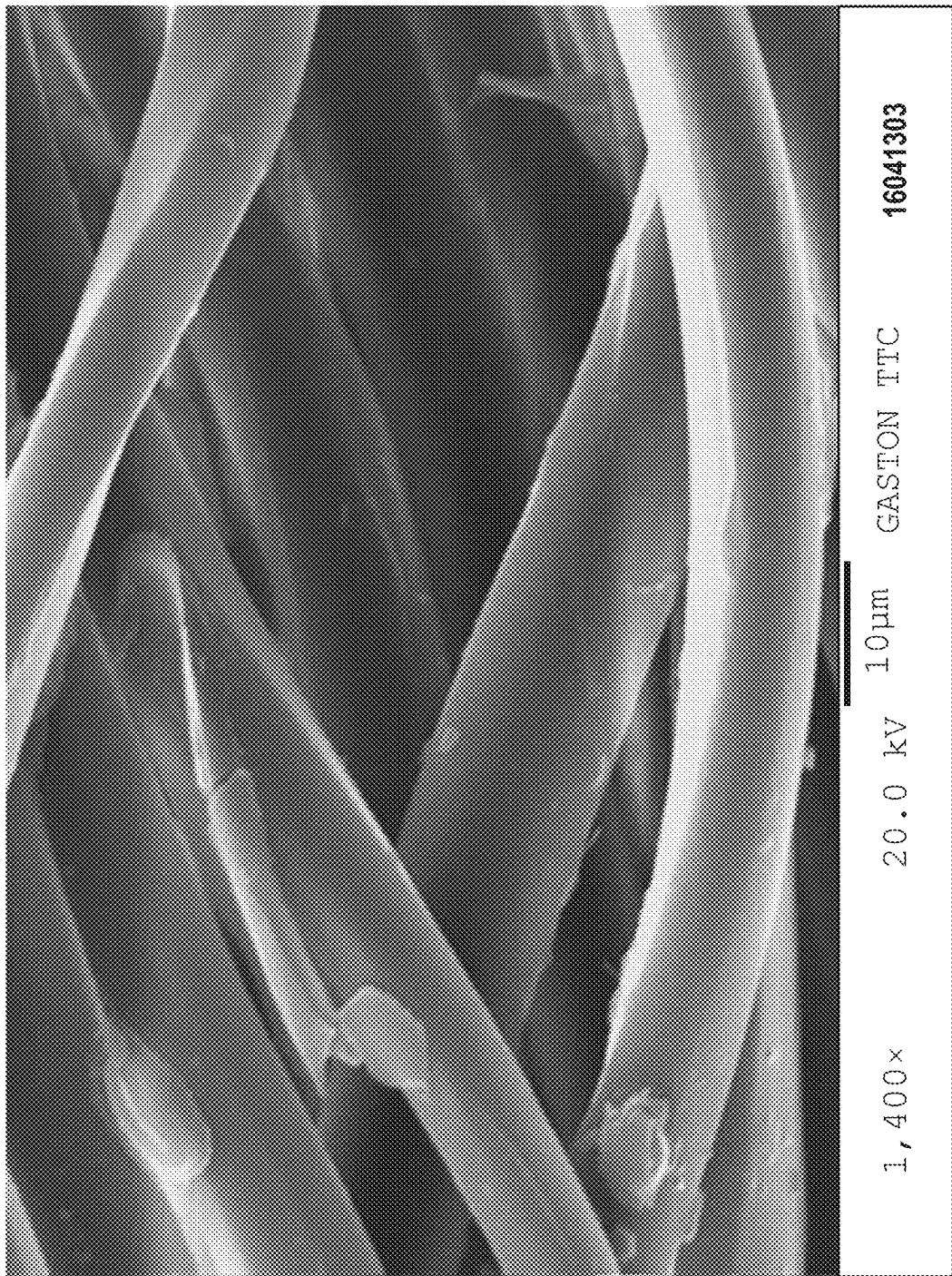


FIG. 289

500 \times 20.0 kV 10 μ m GASTON TTc 16041303







16041304

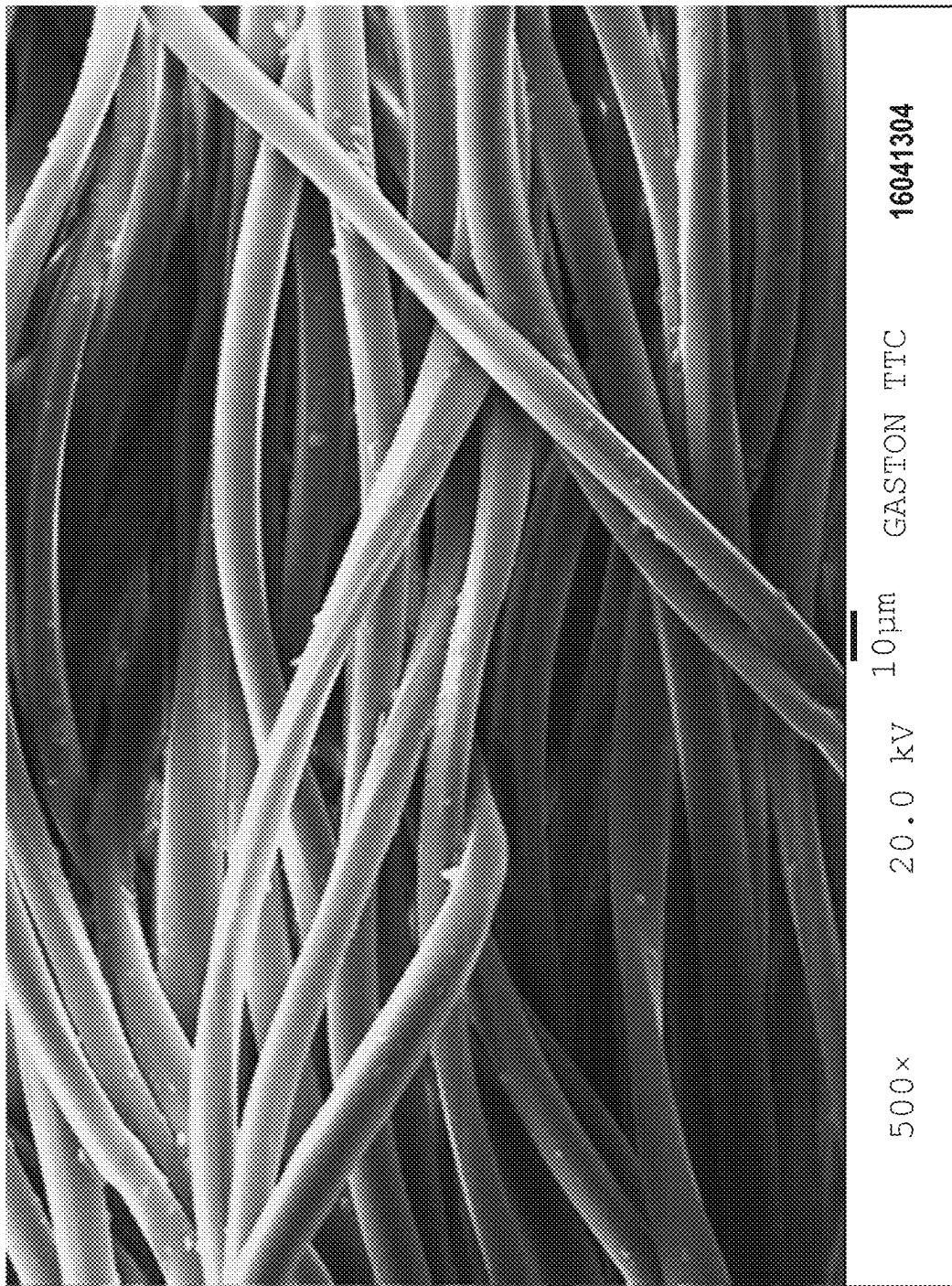
20.0 kV 100 μ m GASTION TIC

85.0 x

FIG. 292



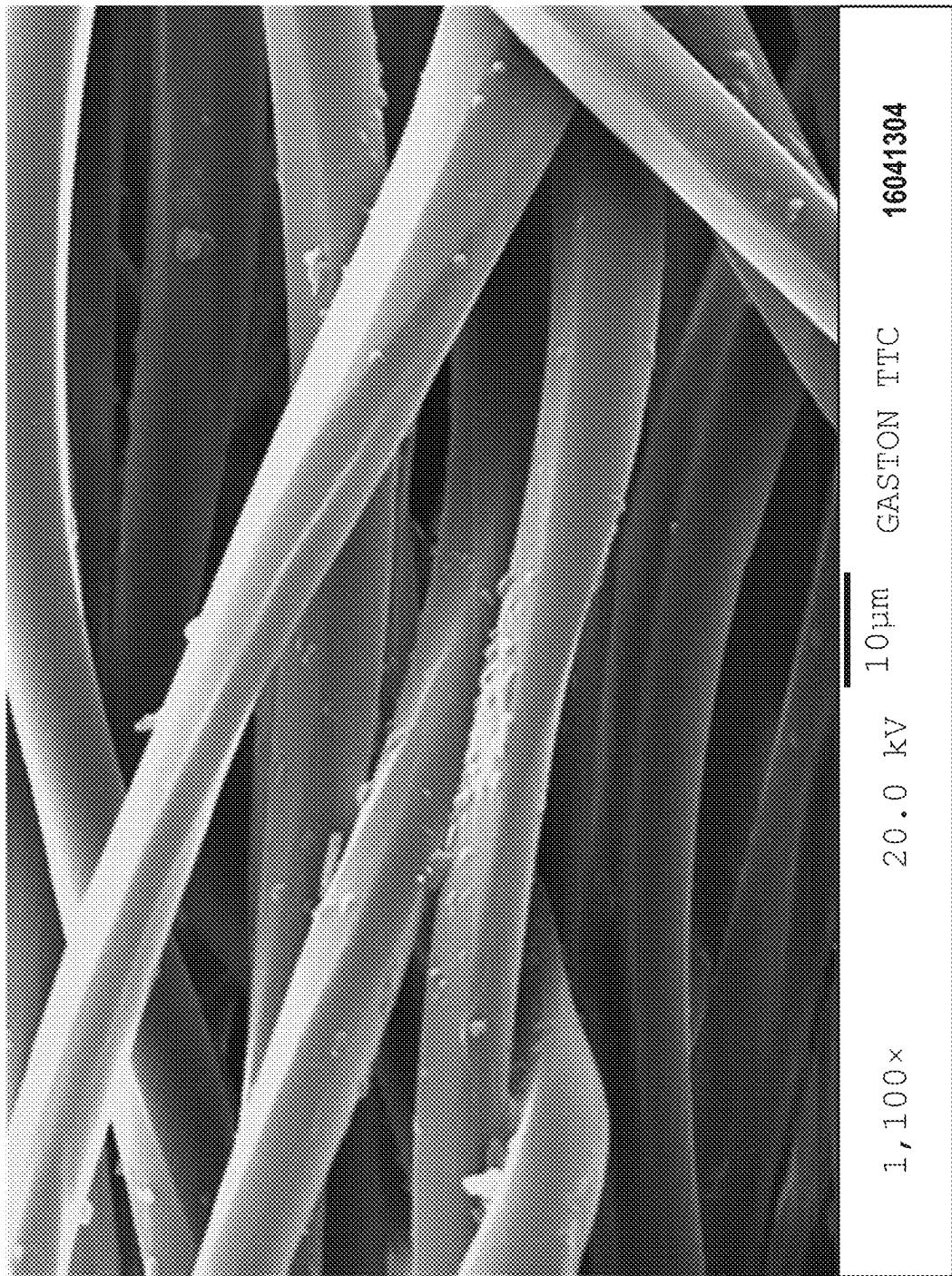
FIG. 293

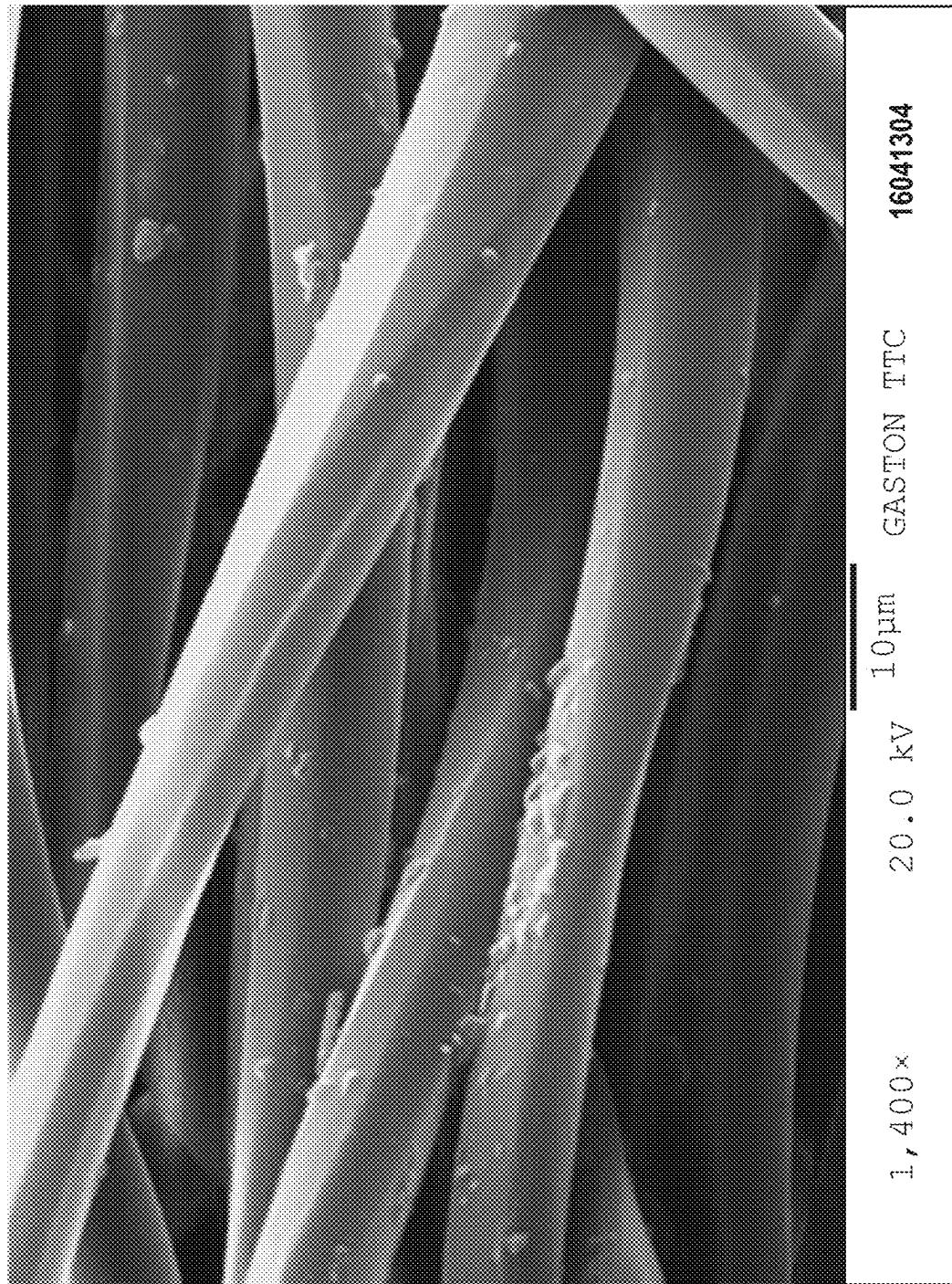


16041304

500 \times 20.0 kV 10 μ m GASTON TIC

FIG. 294





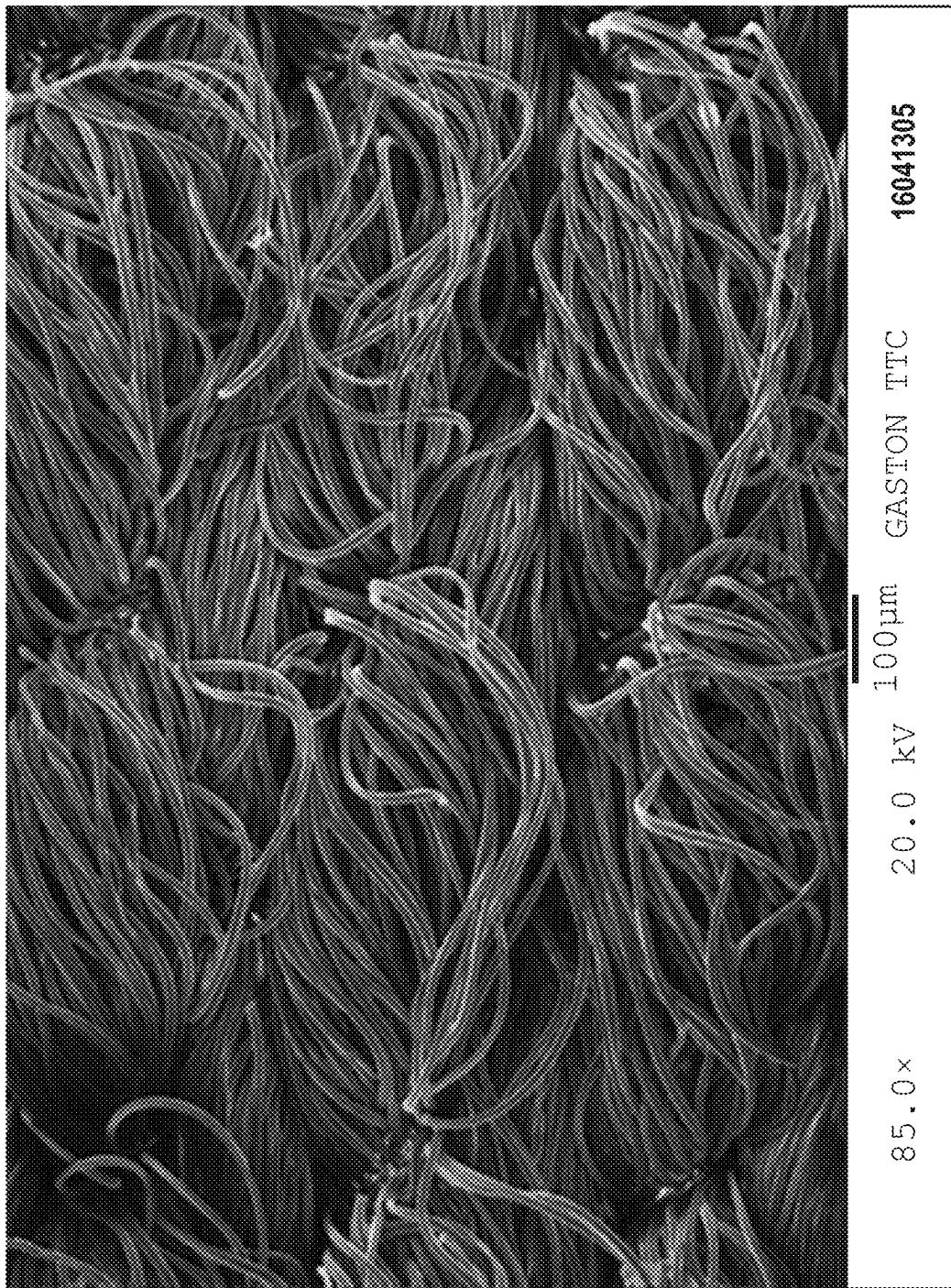


FIG. 297

85.0 x 20.0 kV 100 μm GASTION TT^{MC} 16041305

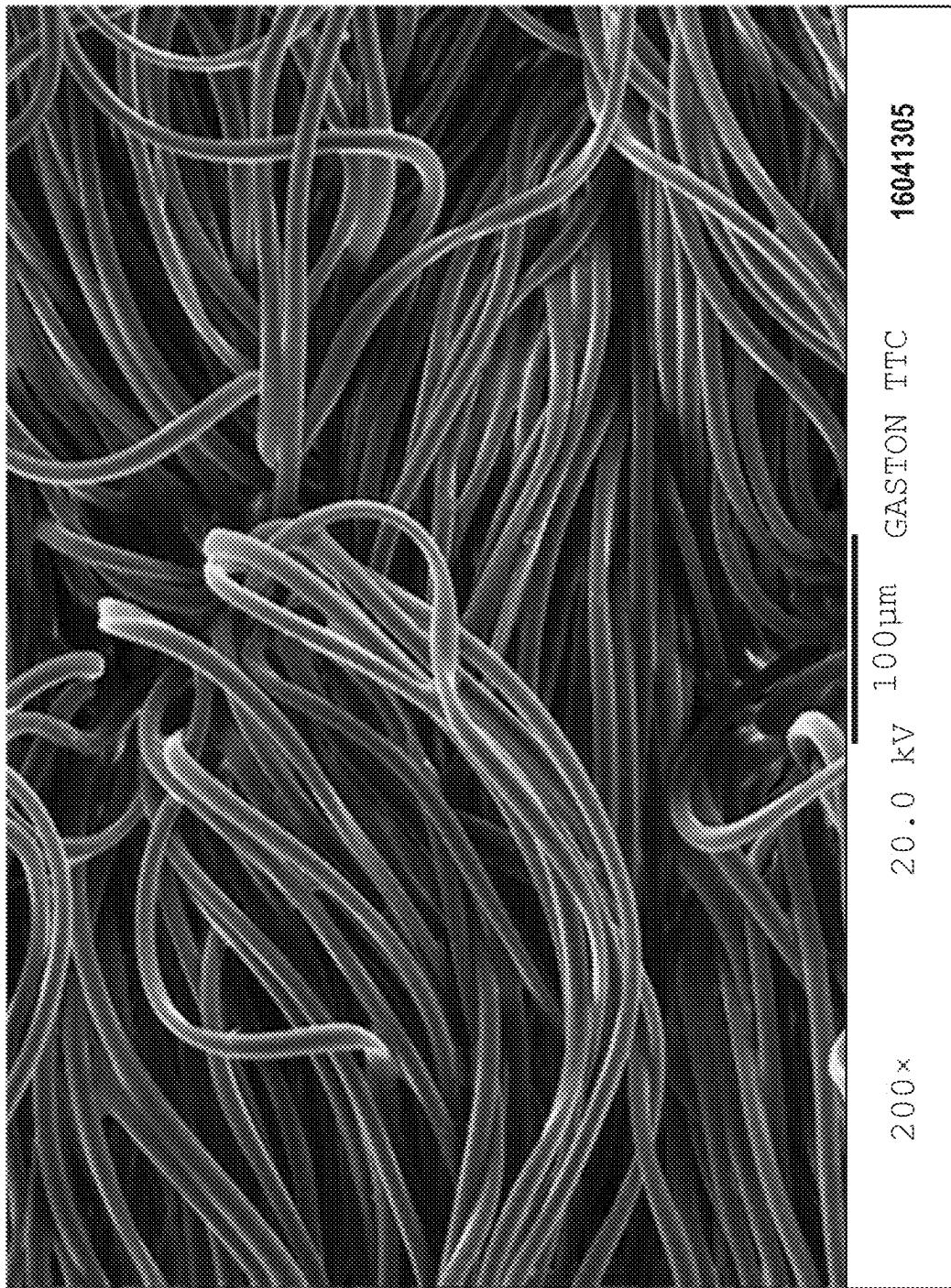


FIG. 298

16041305

20.0 kV 100 µm GASTON TTc

200 X

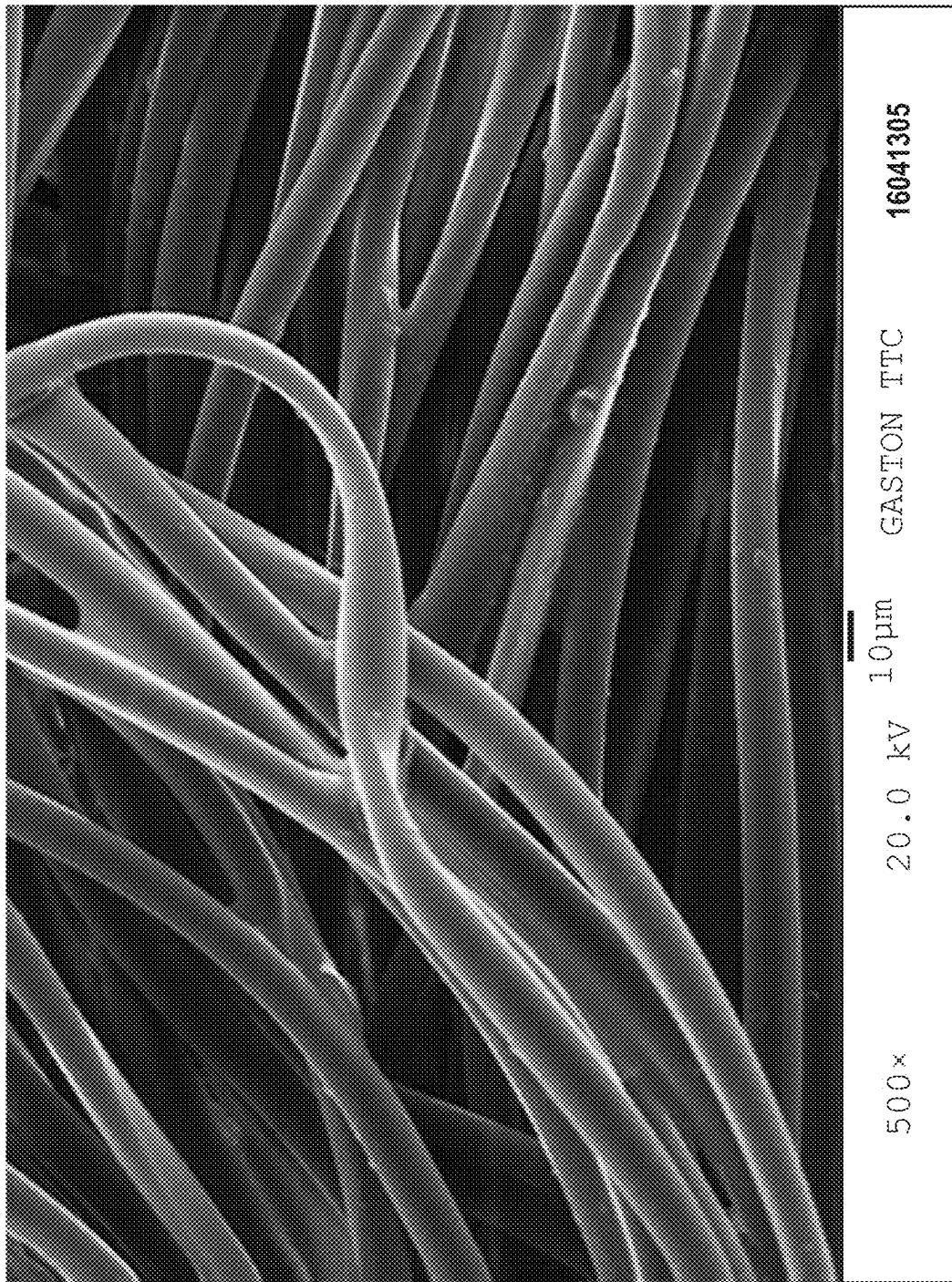
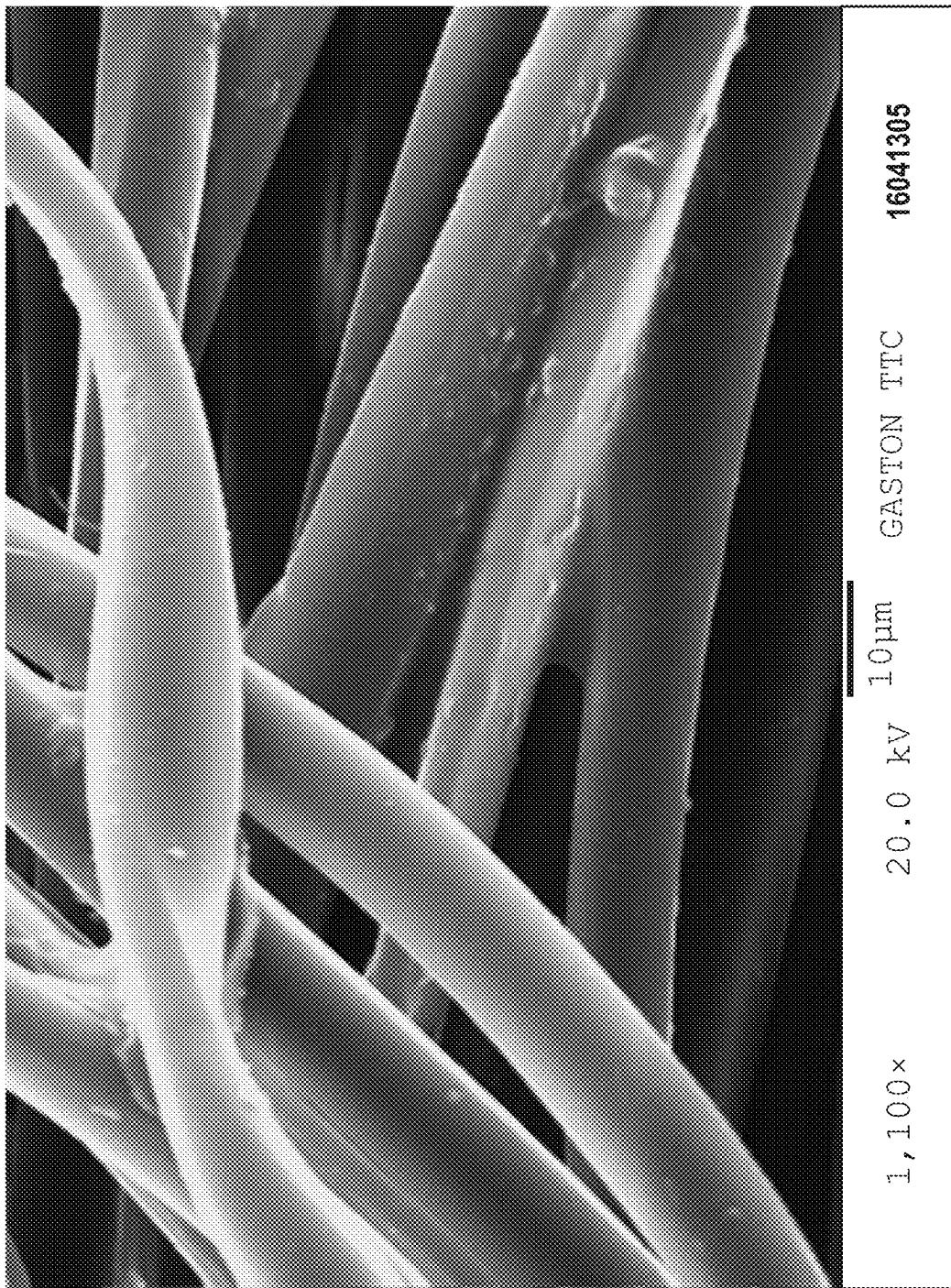
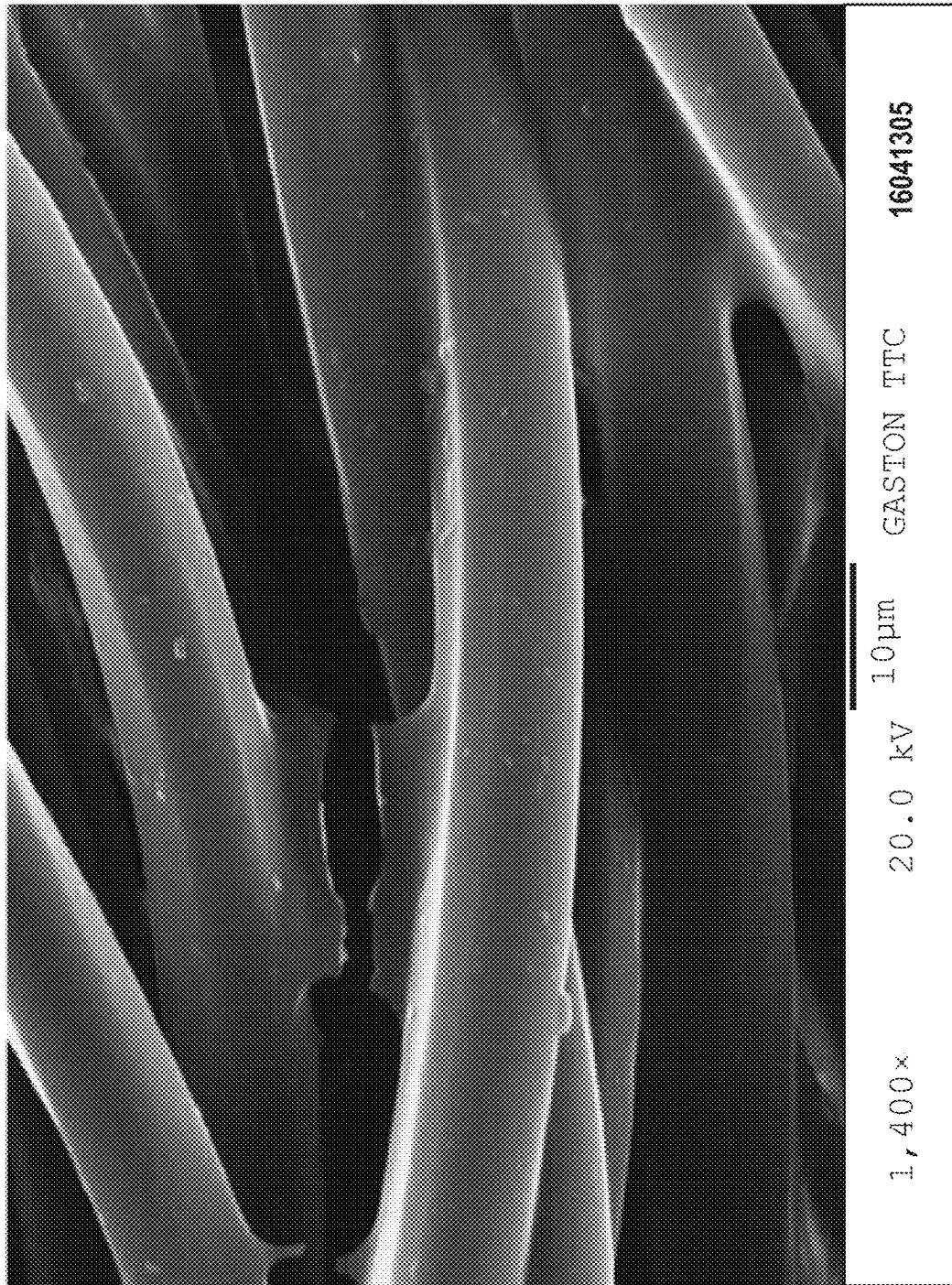


FIG. 299





16041305

20.0 kV 10µm GASTON TTC

1,400X

FIG. 301



FIG. 302





FIG. 304

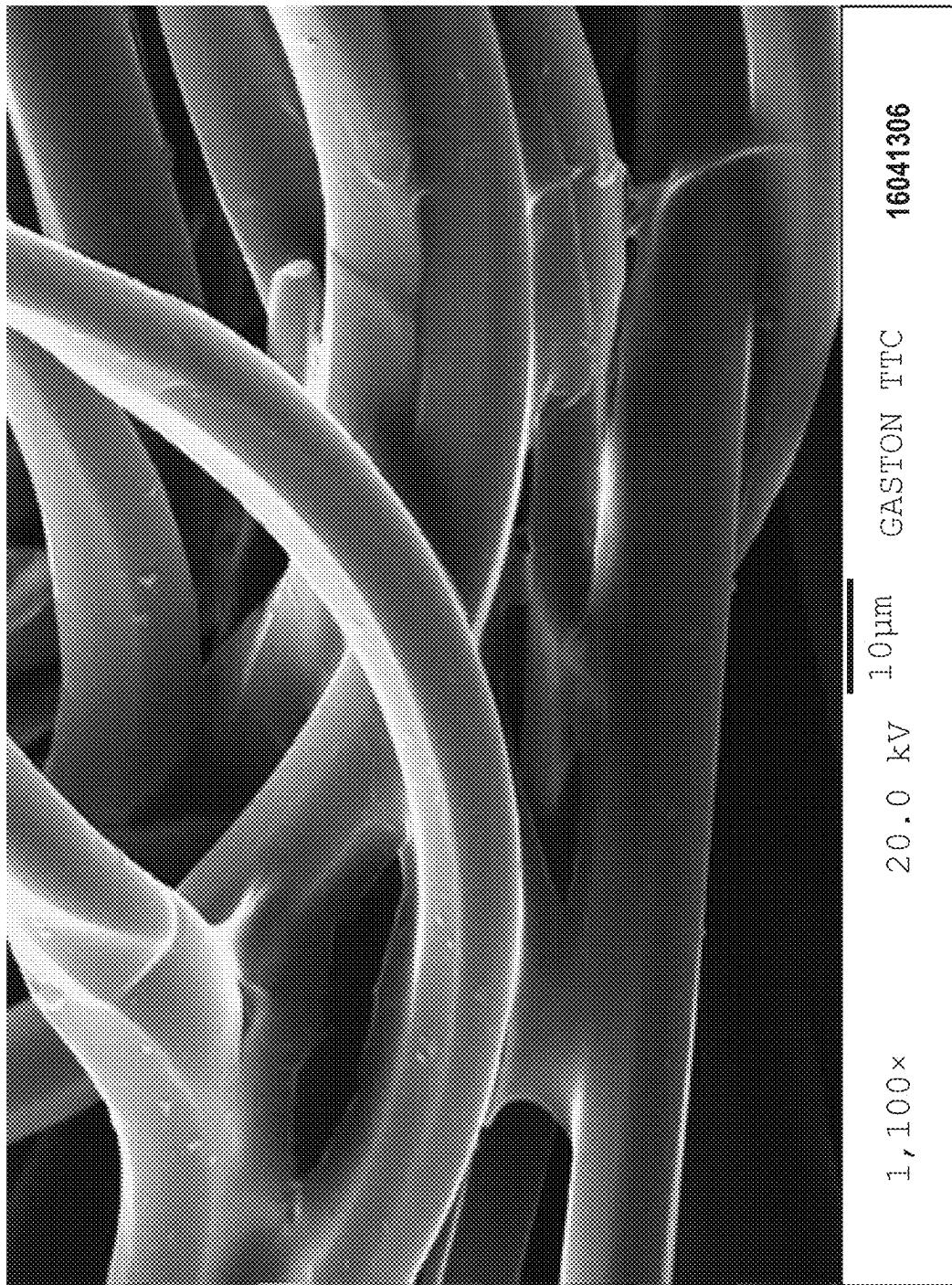


FIG. 305

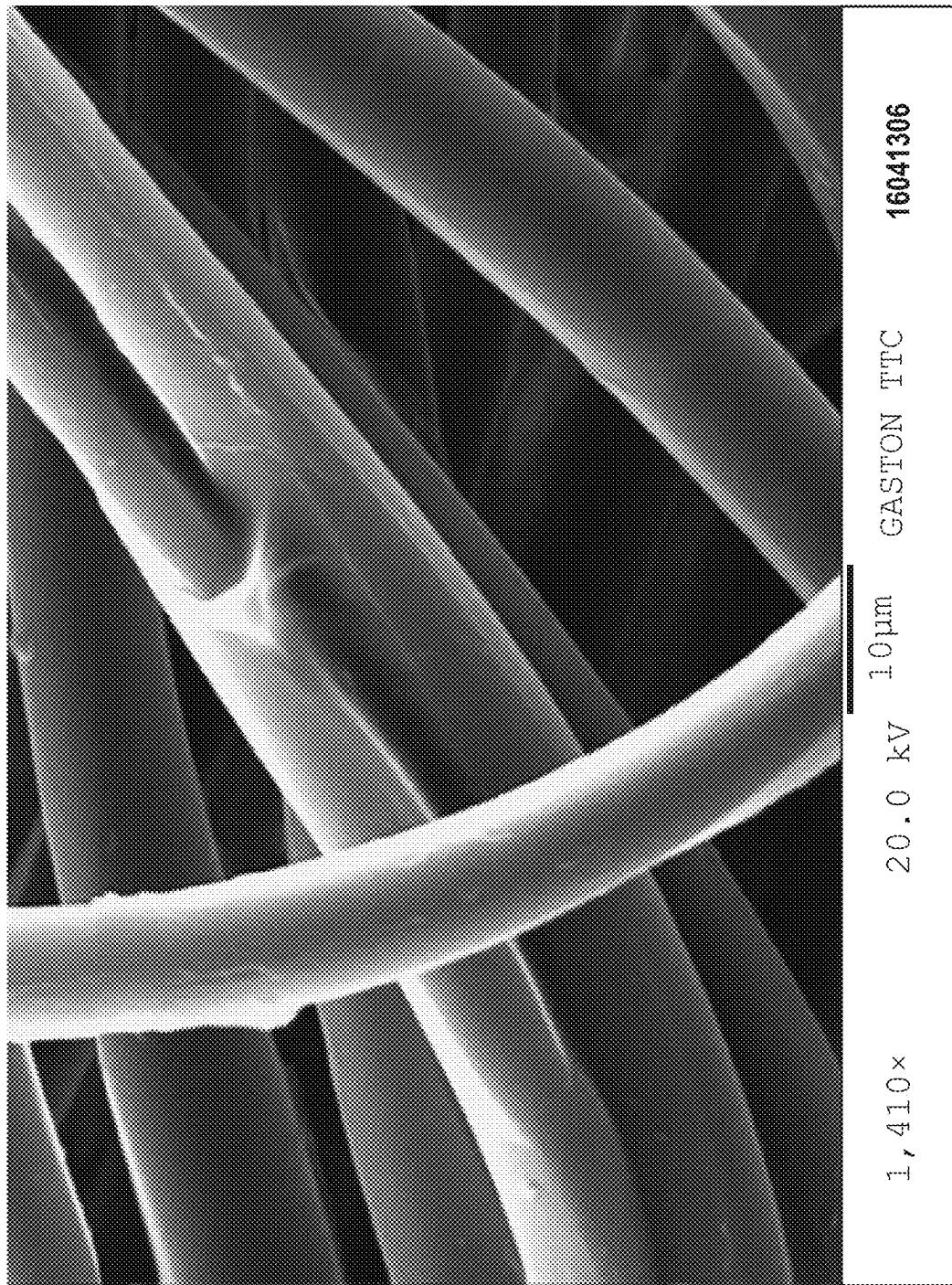


FIG. 306

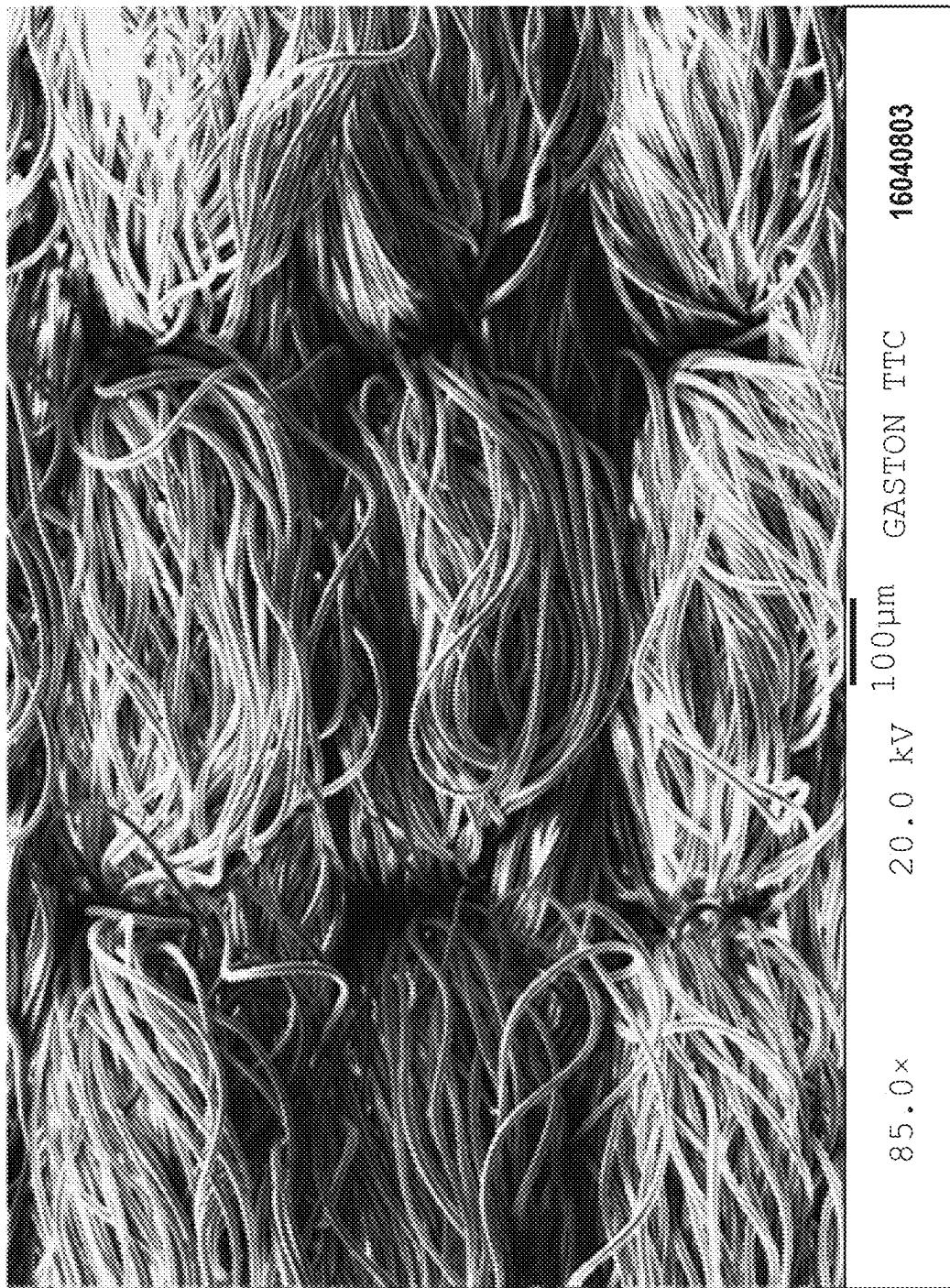


FIG. 307



FIG. 308

200^x 20.0 kV 100^μm GASTON TT C 16040803

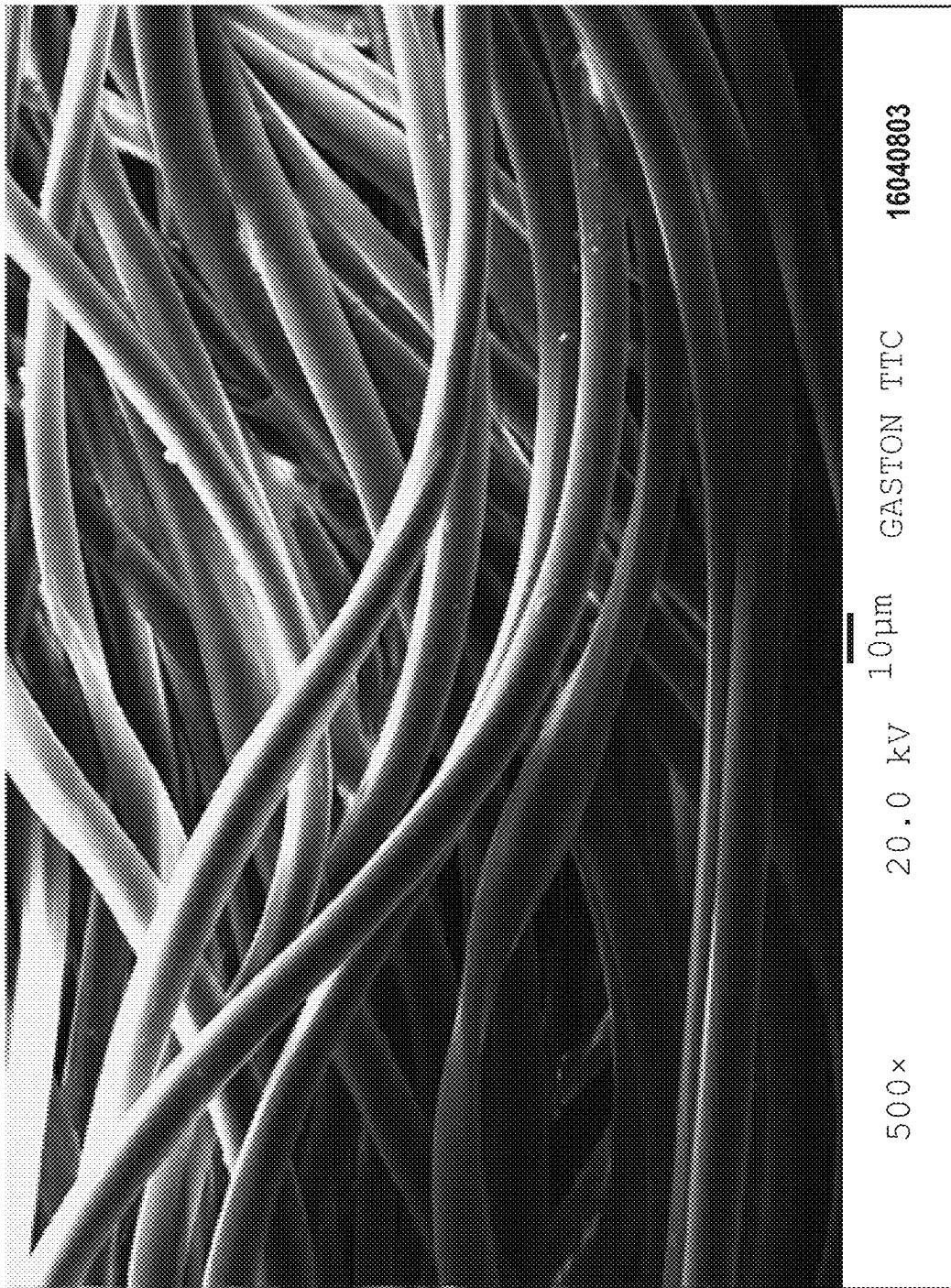


FIG. 309

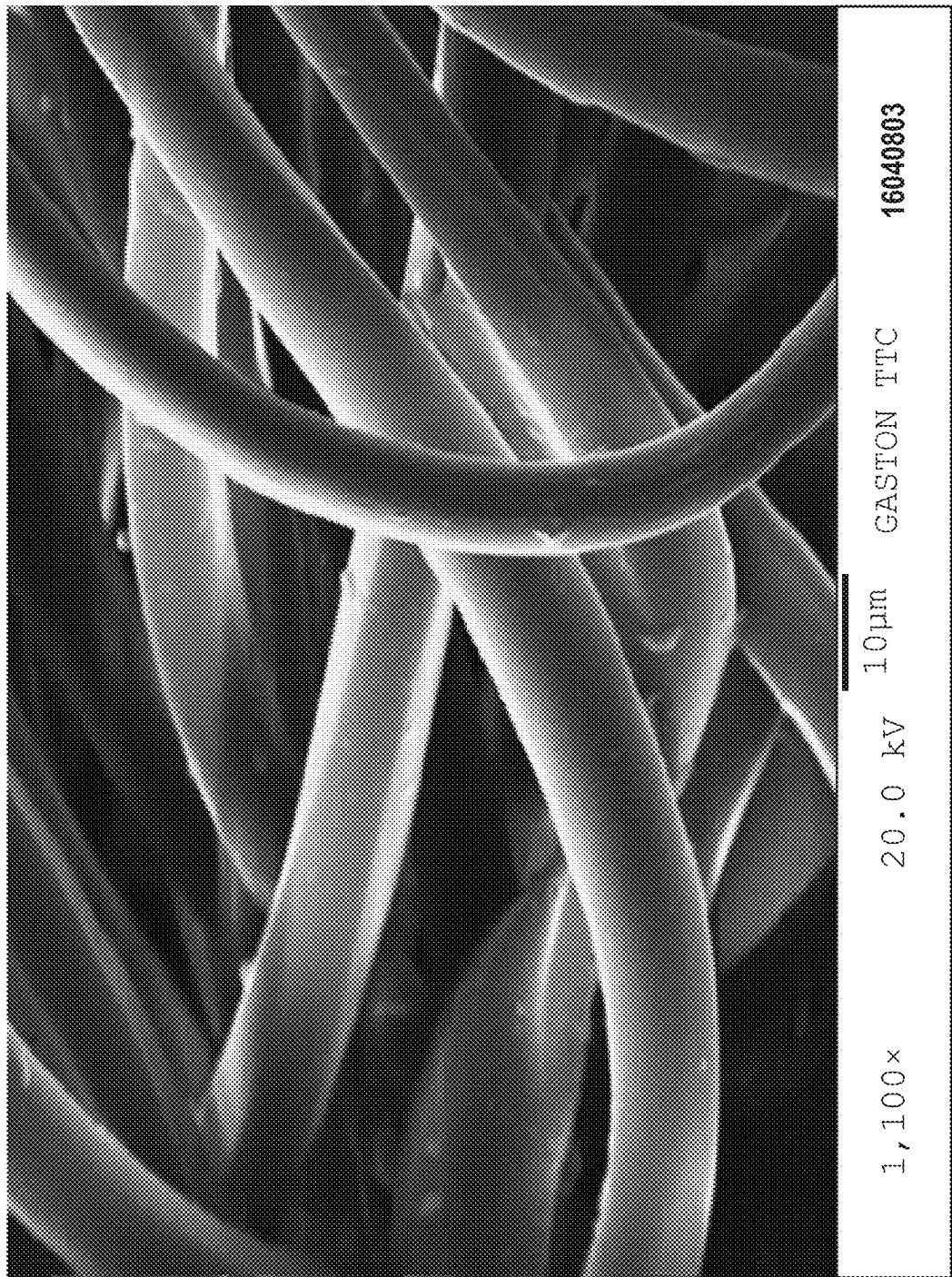
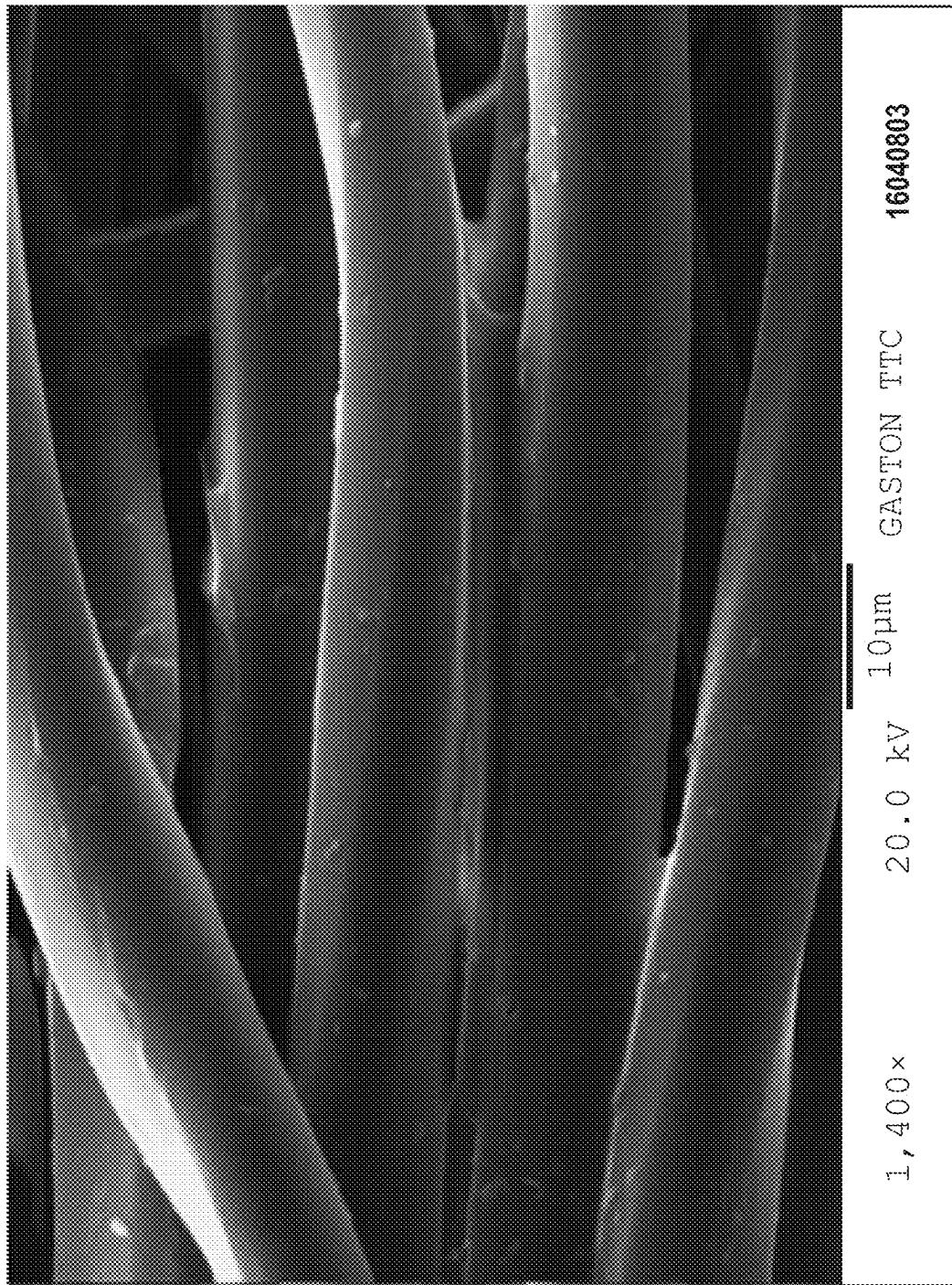


FIG. 310



16040803

20.0 kV 10 μ m GASTON TMC

1,400 \times

FIG. 311



16040808

20.0 kV 100µm GASTON TT C

85.0 x

FIG. 312



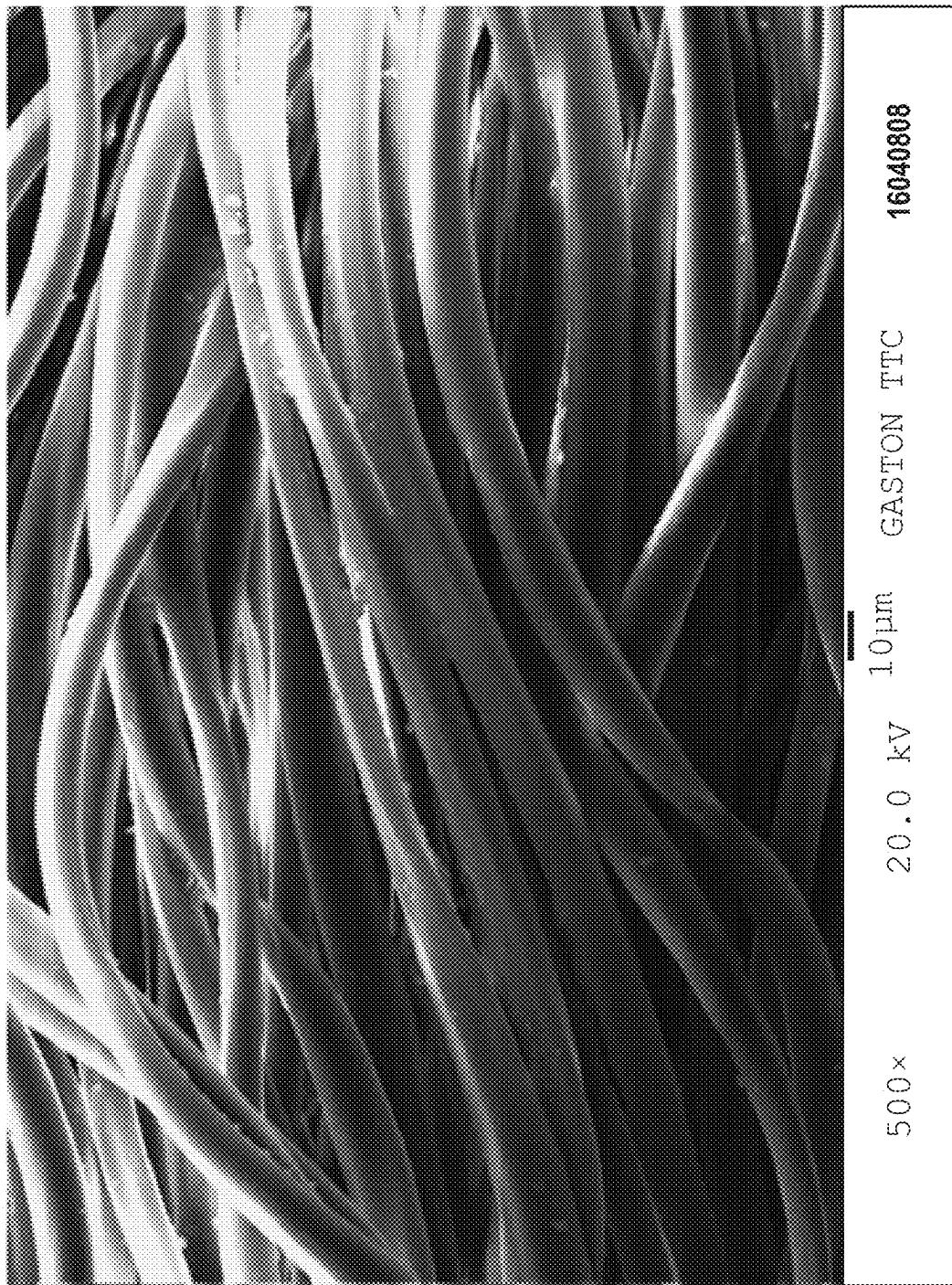
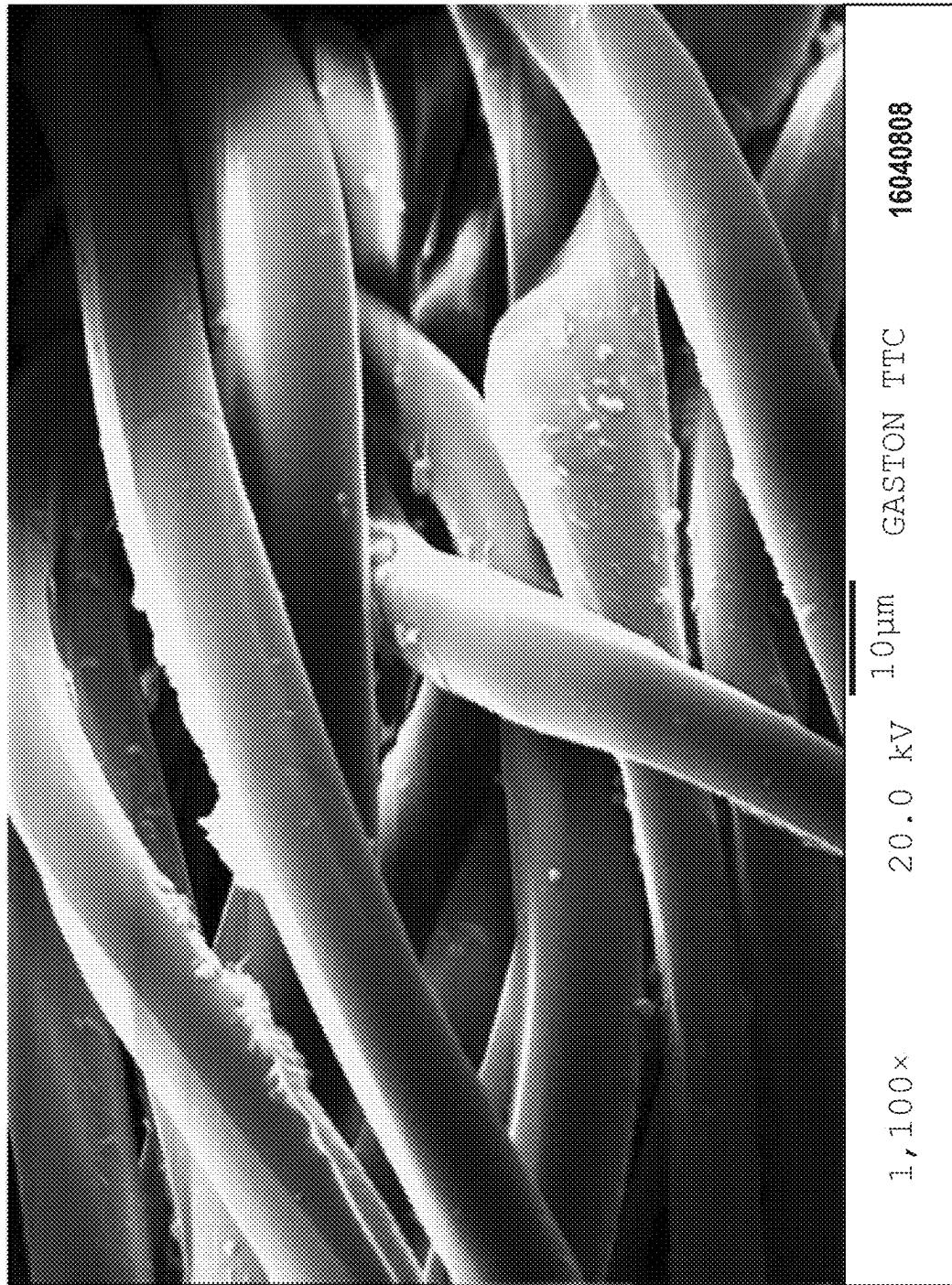


FIG. 314



16040808

20.0 kV 10µm GASTON TRC

1,100×

FIG. 315

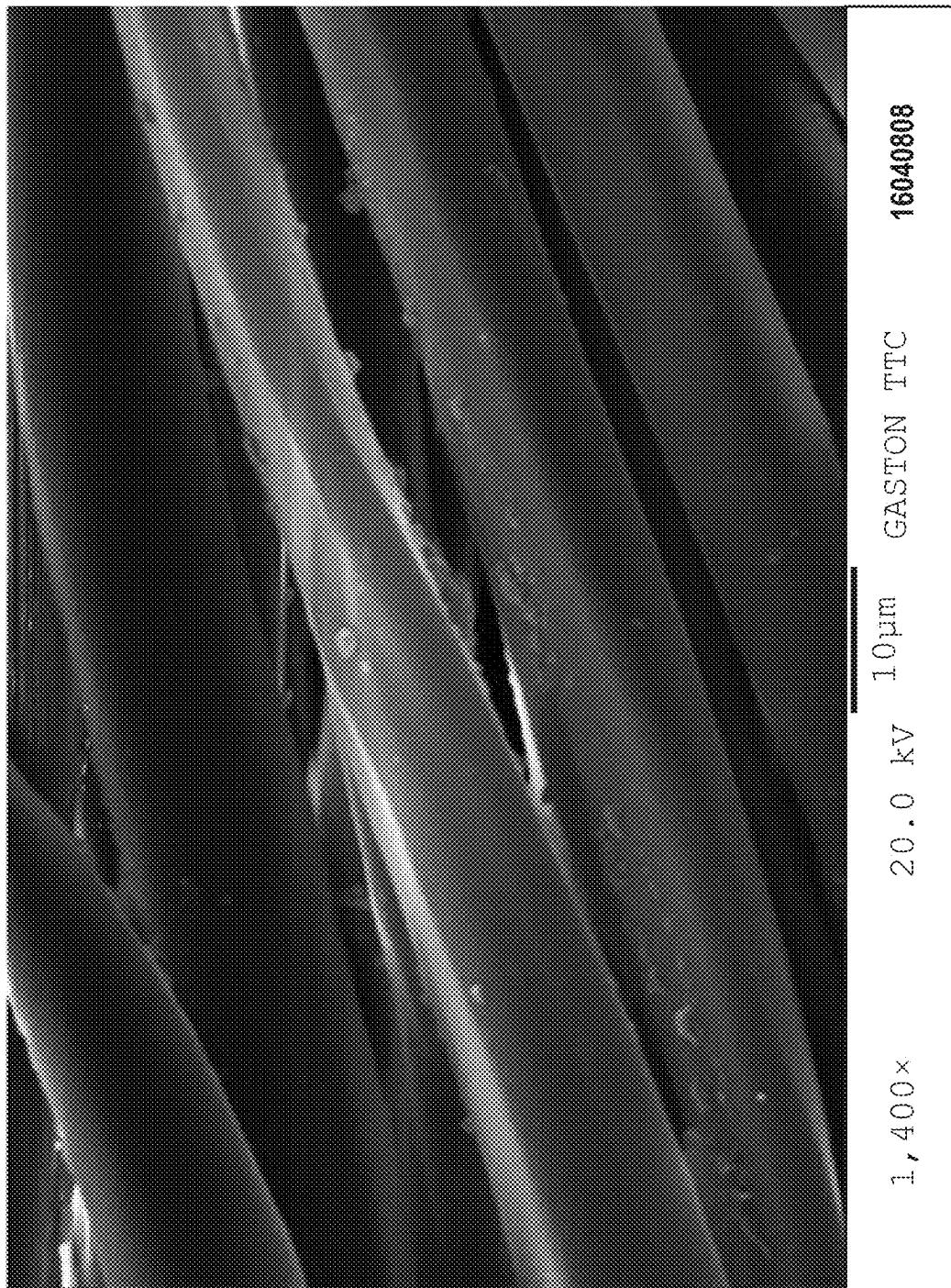


FIG. 316

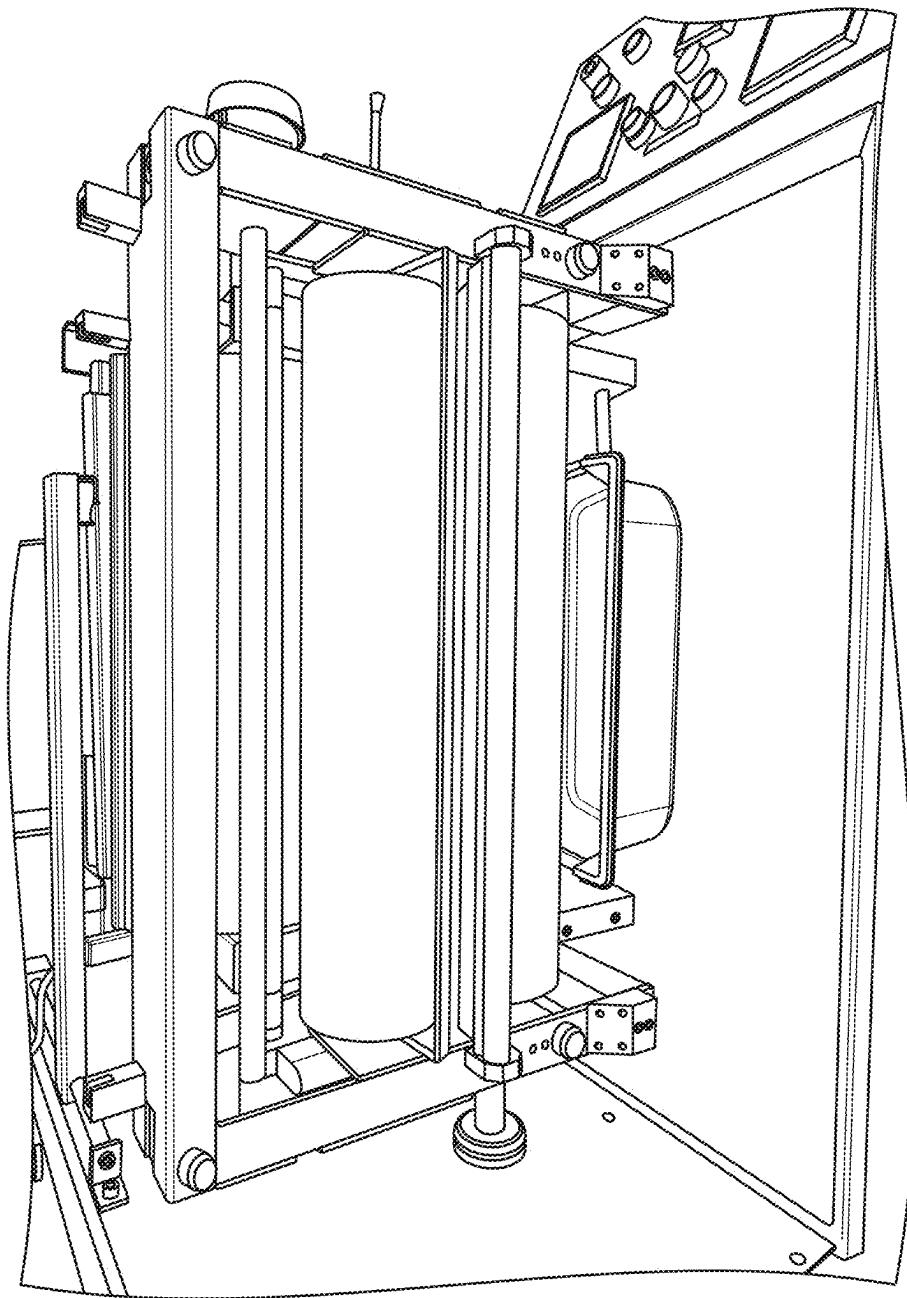


FIG. 317

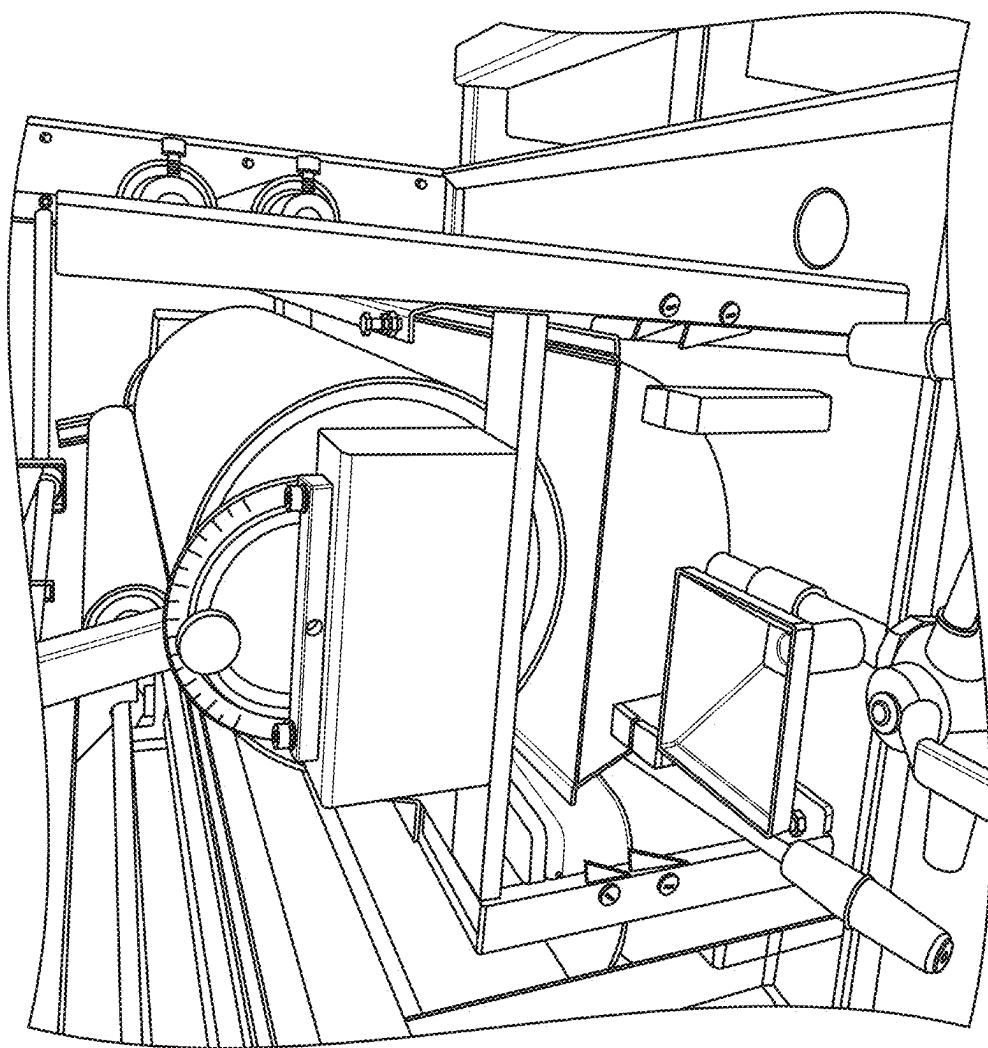


FIG. 318

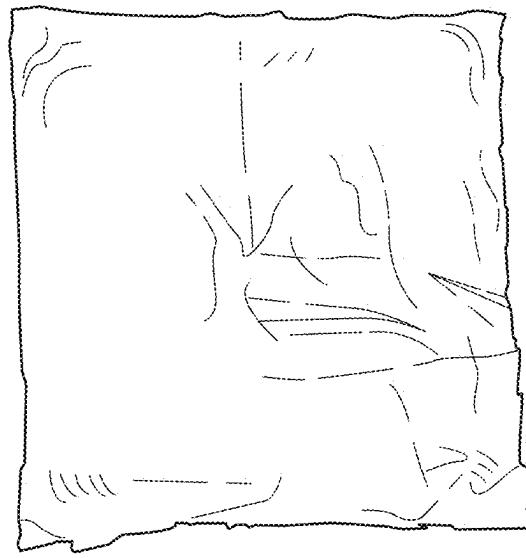


FIG. 320

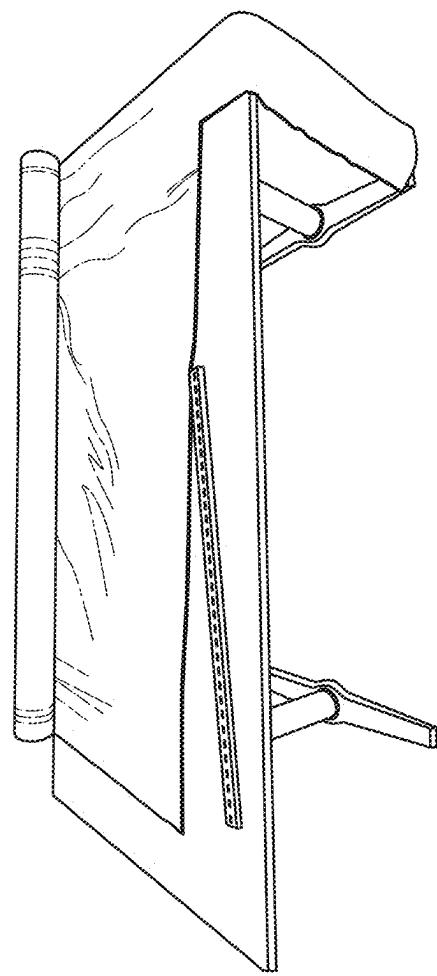


FIG. 319

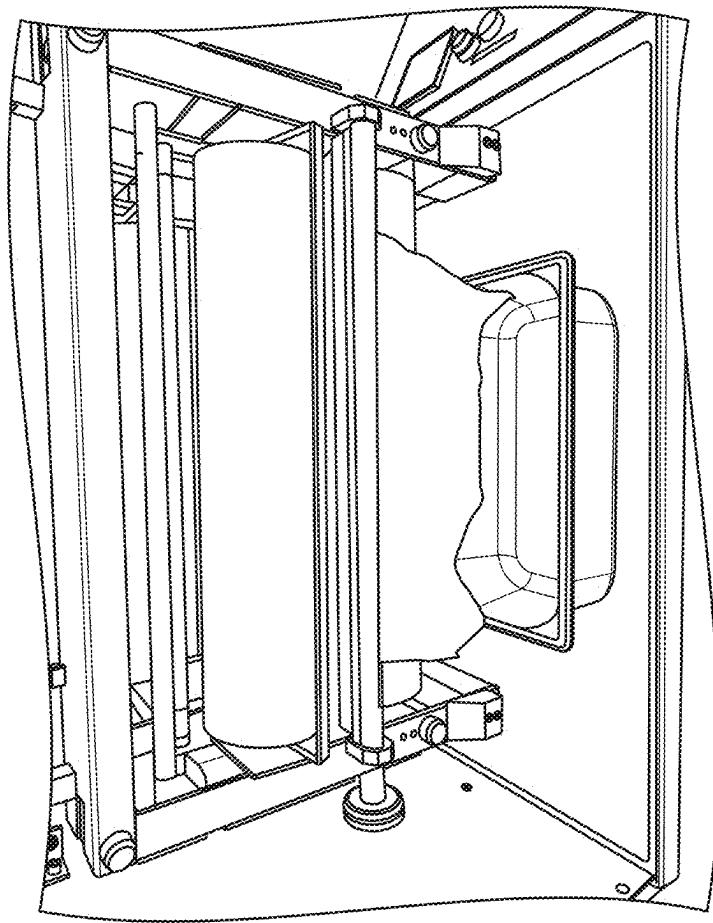


FIG. 322

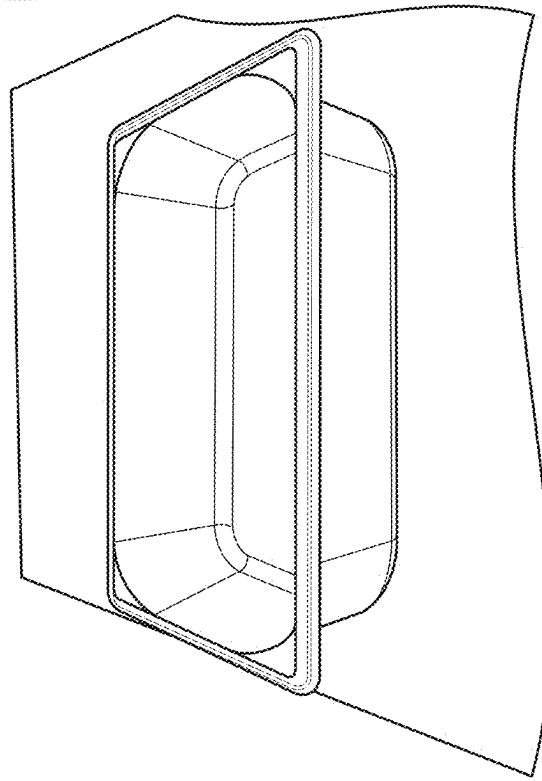


FIG. 321

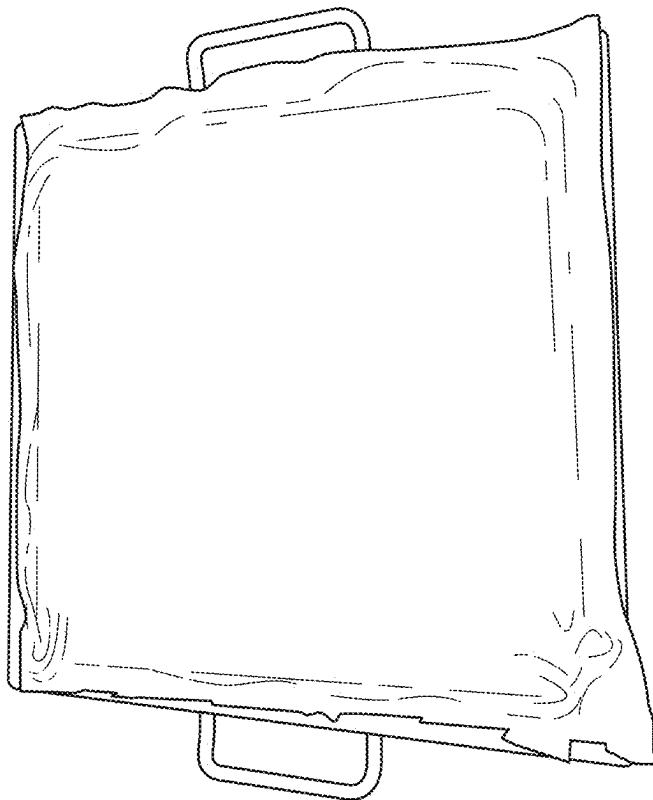


FIG. 324

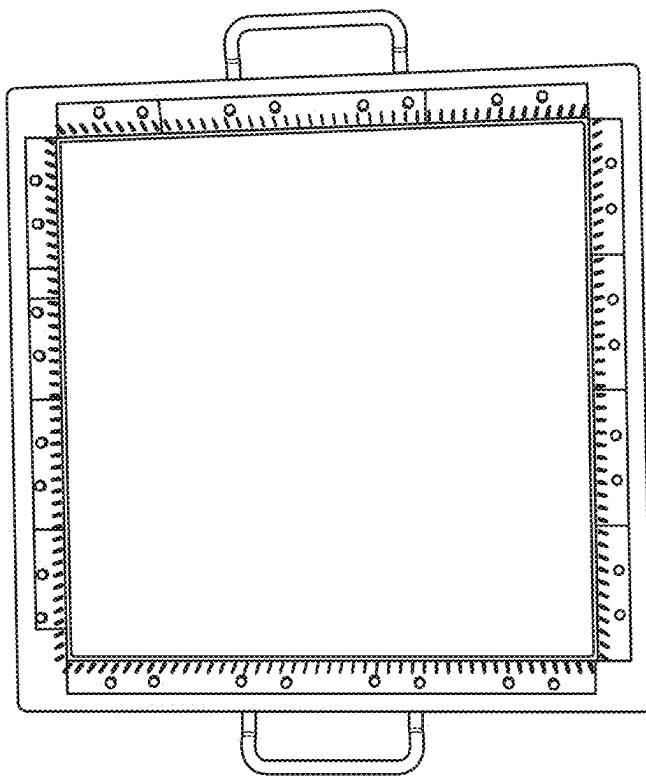


FIG. 323

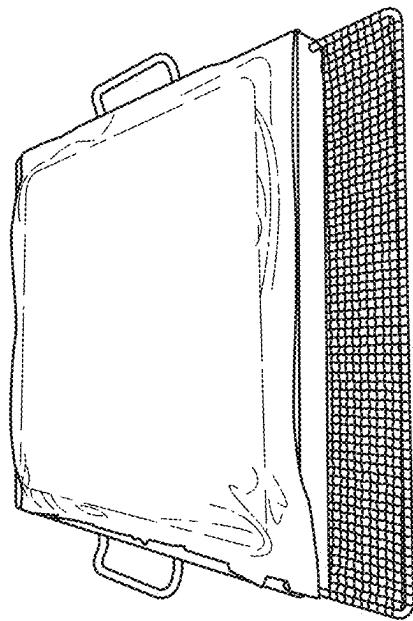


FIG. 326

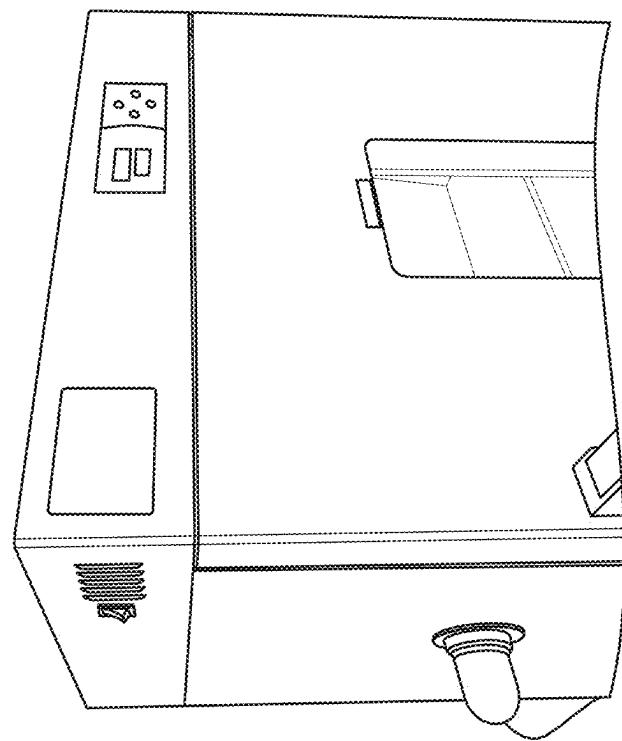


FIG. 325

Testing Results:												
	Wetting Time	Wetting Time	Absorption	Top Bottom	Top Max	Bottom Max	Top	Bottom	Accumulative	Over all	Moisture	Management
	Time	Time	Absorption	Wetted	Wetted	Wetted	Spreading	Spreading	One-Way	Capability		
	Top	Bottom	Rate	Radius	Radius	Radius	Speed	Speed	Transport			
	(sec)	(sec)	(%/sec)	(mm)	(mm)	(mm)	(mm/sec)	(mm/sec)	Index(%)	OMMC		
16040101	Mean	6.2062	7.2188	8.7689	5.1279	5	5	0.8888	0.7830	599.4741	0.5028	
16040102	Mean	4.5005	6.6565	6.4329	5.6507	5	5	1.0684	0.8066	613.2260	0.5019	
16040103	Mean	4.2000	5.4564	12.7828	8.5878	5	5	1.1428	0.9071	374.3193	0.4723	
16040106	Mean	4.3310	4.8936	11.8091	10.4725	5	5	1.1096	0.9923	364.2011	0.4650	
16040105	Mean	4.9498	4.1248	14.0804	17.1970	5	5	1.1247	1.2175	287.8853	0.4207	
16040104	Mean	6.103	4.2124	8.6855	15.8154	5	5	0.8041	1.1509	88.4355	0.1827	
15042001	Mean											

FIG. 327

Testing Results:										Over all Moisture Management Capability
	Wetting Time	Wetting Time	Absorption Rate	Top Bottom (sec)	Top Bottom (sec)	Top Max Radius (mm)	Bottom Radius (mm)	Top Speed (mm/sec)	Bottom Speed (mm/sec)	
								Spreading Index(%)	OMMC	
								Spreading Index(%)	OMMC	
16040101	Grade	3	3	1	1	1	1	1	1	3
16040102										
16040103		4	3	1	1	1	1	2	1	5
16040104		4	4	2	2	1	1	2	2	4
16040105		4	4	2	2	1	1	2	1	4
16040106		4	3	2	1	1	1	2	1	4
15042001		3	4	1	2	1	1	2	2	1

FIG. 328

Testing Results:													
	Wetting Time	Wetting Time	Top Absorption	Bottom Absorption	Top Max Wetted	Bottom Max Wetted	Top Max	Bottom Max	Top	Bottom	Accumulative Spreading Speed	One Way Transport Speed	Over all Moisture Management Capability
	Top (sec)	Bottom (sec)	Rate (%/sec)	Rate (%/sec)	Radius (mm)	Radius (mm)	(mm)	(mm)	(mm/sec)	(mm/sec)	(mm/sec)	Index(%)	OMMC
16040801	Mean	32.5310	6.5620	3.8394	2.8465	5	5	0.1528	0.7407	461.1657	0.5000		
16040802	Mean	4.5652	4.8466	8.201	5.7837	5	5	1.0535	0.9992	437.2409	0.5028		
16040803	Mean	3.9938	4.6312	13.3611	9.2254	5	7	1.1942	1.0736	433.6376	0.5097		
16040804	Mean	4.2	4.5754	12.5656	7.9578	5	5	1.1412	1.0528	432.1879	0.5052		
16040805	Mean	4.3310	4.8936	11.8091	10.4725	5	5	1.1096	0.9923	364.2011	0.4650		
16040806	Mean	4.2936	4.425	10.4676	11.8023	5	5	1.1238	1.0855	443.8888	0.5125		
16040807	Mean	4.406	4.5936	10.4972	8.7678	5	5	1.1101	1.0603	436.9568	0.5097		
16040808	Mean	5.6434	4.256	9.4582	11.9617	5	5	1.0143	1.1318	437.3739	0.5201		
15042001	Mean	6.103	4.2124	8.6855	15.8154	5	5	0.8041	1.1509	88.4355	0.1827		

FIG. 329

Testing Results:													
	Wetting Time	Wetting Time	Absorption	Top Bottom	Top Max	Bottom Max	Top	Bottom	Accumulative	Over all	Moisture	Management	Capability
	Top	Bottom	Rate	Rate	Radius	Radius	Spreading Speed	Spreading Speed	One Way Transport	OMMC			
	(sec)	(sec)	(%/sec)	(%/sec)	(mm)	(mm)	(mm/sec)	(mm/sec)	index(%)				
16040801	Grade	2	1	1	1	1	1	1	1	5	3		
16040802		4	4	1	1	1	2	1	1	5	3		
16040803		4	4	2	1	1	1	2	2	5	3		
16040804		4	4	2	1	1	1	2	2	5	3		
16040805		2	2	1	1	1	1	1	1	5	3		
16040806		4	4	2	4	1	1	2	2	5	3		
16040807		4	4	2	4	1	1	2	2	5	3		
16040808		3	4	1	2	1	1	2	2	5	3		
15042001		3	4	1	2	1	1	1	2	2	1		

FIG. 330

Testing Results:												
	Mean Values	Wetting Time	Wetting Time	Absorption	Bottom Wetted	Top Max	Bottom Max	Top	Bottom	Accumulative	Over all Moisture	Management Capability
		Top (sec)	Bottom (sec)	Rate (%/sec)	Rate (%/sec)	Radius (mm)	Radius (mm)	Speed (mm/sec)	Speed (mm/sec)	Spreading Index(%)	MMC	
16041201	1% low mw, 150C, 10 min	4.9498	5.381	10.1284	7.8688	5	5	0.9978	0.9255	244.6475	0.3296	
16041202	1% low mw, 200C, 10 min	14.6560	15.8747	6.8175	3.3093	5	5	0.3982	0.3609	256.3562	0.3404	
16041302	1% low mw, 150C, 5 min	4.9594	4.65	8.9505	12.7455	5	5	1.117	1.1924	170.7486	0.2834	
16041303	1% low mw, 200C, 3 min	4.822	5.1782	11.3758	6.8097	5	5	1.0106	0.9397	250.1812	0.3364	
16041203	1% medium mw, 200C, 10 min	36.4377	48.9377	4.4255	3.0289	5	5	0.1758	0.1077	163.9531	0.2377	
16041204	1% medium mw, 150C, 10 min	7.0122	6.8058	12.668	12.0749	5	5	0.8715	0.9216	90.3758	0.1858	
16041305	1% medium mw, 200C, 3 min	6.469	63.703	7.32785	3.18745	5	2.5	0.87815	0.2614	561.1452	0.5	
16041306	1% medium mw, 150C, 5 min	15.1498	11.2872	12.8199	5.54318	10	6	0.67668	0.782	151.81352	0.23198	
16041301	no coating, 150C, 5 min	4.1906	4.0594	13.16422	9.1083	5	5	1.1456	0.9716	219.342	0.30542	
16041304	no coating, 200C, 3 min	5.4375	2.64825	7.775525	10.8061	5	5	0.922975	1.021225	219.26975	0.391575	

FIG. 331

Testing Results:														
		Wetting Time	Wetting Time	Absorption Rate	Absorption Rate	Bottom Top Max	Bottom Max	Top	Bottom	Accumulative	Over all	Moisture	Management	Capability
		Top	Bottom	Radius	Radius	Wetted Radius	Wetted Radius	Spreading Speed	Spreading Speed	One-Way Transport	OMMC	Speed	Speed	Transport
		(sec)	(sec)	(%/sec)	(%/sec)	(mm)	(mm)	(mm/sec)	(mm/sec)	index(%)	OMMC			
16041201	Grade	3	3	2	1	1	1	1	1	4	2			
16041202		3	3	1	1	1	1	1	1	4	2			
16041302		4	4	1	2	1	1	2	2	3	2			
16041303		4	3	2	1	1	1	2	1	4	2			
16041203		2	2	1	1	1	1	1	1	3	2			
16041204		3	3	2	2	1	1	1	1	4	2			
16041305		3	2	1	1	1	1	1	1	3	2			
16041306		3	3	2	1	2	1	1	1	4	2			
16041301		4	4	2	1	1	1	2	1	4	2			
16041304		3	5	1	2	1	1	1	1	4	2			

FIG. 332

Testing Results:												
	Wetting Time	Wetting Time	Top Absorption	Bottom Absorption	Top Max Wetted	Bottom Max Wetted	Top Radius	Bottom Radius	Spreading Speed	Spreading Speed	One Way Transport	Over all Moisture Management Capability
	Top (sec)	Bottom (sec)	Rate (%/sec)	Rate (%/sec)	(mm)	(mm)	(mm)	(mm)	(mm/sec)	(mm/sec)	index(%)	OMMC
16041301	Mean	4.1906	4.0594	13.16422	9.1083	5	5	1.1456	0.9716	219.342	0.30542	
16041302	Mean	4.9594	4.65	8.9505	12.7455	5	5	1.117	1.1924	170.7486	0.2834	
16041303	Mean	4.822	5.1782	11.3758	6.8097	5	5	1.0106	0.9397	250.1812	0.3364	
16041304	Mean	5.4375	2.6483	7.7755	10.8061	5	5	0.9230	1.0212	291.2698	0.3916	
16041305	Mean	6.4690	63.7030	7.3279	3.1875	5	3	0.8782	0.2614	561.1452	0.5000	
16041306	Mean	15.1498	11.2872	12.8199	5.5432	10	6	0.6767	0.7820	151.8135	0.2320	
15042001	Mean	6.103	4.2124	8.6855	15.8154	5	5	0.8041	1.1509	88.4355	0.1827	
16040101	Mean	6.2062	7.2188	8.7689	5.1279	5	5	0.8888	0.7830	599.4741	0.5028	
16040106	Mean	4.2	5.4564	12.7828	8.5878	5	5	1.1428	0.9071	374.3193	0.4723	

FIG. 333

Testing Results:		Wetting Time	Absorption	Top Max	Bottom Max	Top	Bottom	Accumulative	Over all
		Time	Wetted	Top	Bottom	Spreading	Spreading	One-Way	Moisture Management Capability
		Top	Bottom	Rate	Rate	Radius	Speed	Speed	Transport
		(sec)	(sec)	(%/sec)	(%/sec)	(mm)	(mm/sec)	(mm/sec)	OMMC
16041301	Grade	4	4	2	1	1	2	1	4
16041302		4	4	1	2	1	2	2	3
16041303		4	3	2	1	1	2	1	4
16041304		3	5	1	2	1	1	1	4
16041305		3	2	1	1	1	1	1	5
16041306		3	3	2	1	2	1	1	4
15042001		3	4	1	2	1	1	2	2
16040101		3	3	1	1	1	1	1	5
16040106		4	3	2	1	1	2	1	4

FIG. 334

Silk conc (%)	Low Molecular Weight (MW) Silk					Medium Molecular Weight (MW) Silk				
	65C	150C	200C (385F = 196C)	65C	150C	200C (385F = 196C)	5	10	3	5
1.000	599.5, 0.5028	151.8, 0.2319	90.4, 0.1858	613.2, 0.5019	250.2, 0.3364	374.3, 0.4723	364.2, 0.4650	244.6, 0.3296	287.9, 0.4207	256.4, 0.3404
0.750		461.2, 0.5000								
0.500							364.2, 0.4650			
0.250	40.6, 0.1327	437.3, 0.5028		188.0, 0.2805		97.0, 0.1635		106.3, 0.1778		141.6, 0.2236
0.100	138.0, 0.2532	112.9, 0.2116		63.4, 0.1260		134.9, 0.2250		443.9, 0.5125		91.2, 0.1599
0.075		456.3, 0.5032								
0.050								436.9, 0.5097		
0.025		432.2, 0.5052								
0.001								437.4, 0.5201		
Fabric Controls (no heat setting)	non-finished	88.4, 0.1827	semi-finished	(-) 6.8, 0.1038	finished	62.4, 0.2854				

FIG. 335

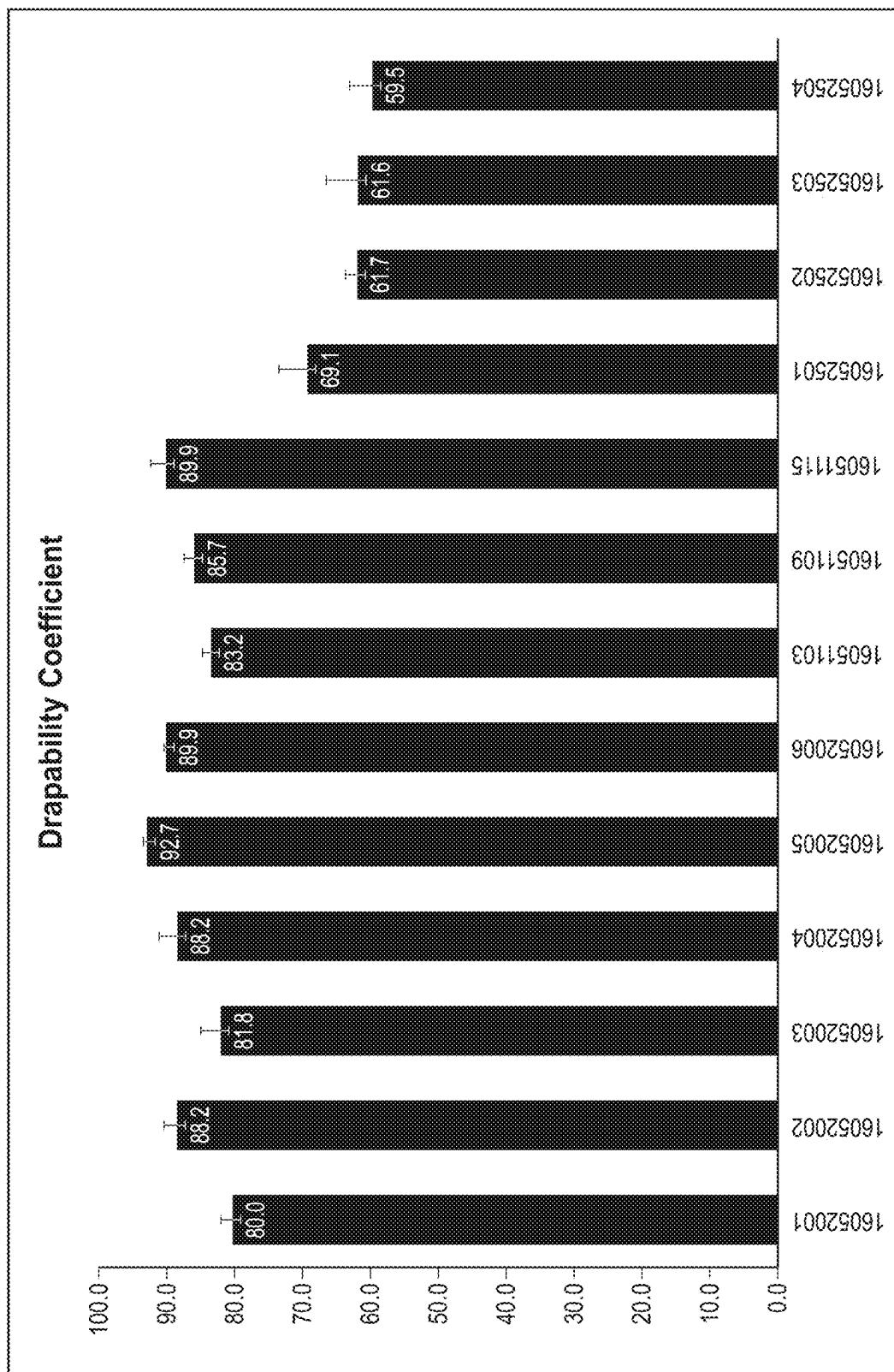


FIG. 336

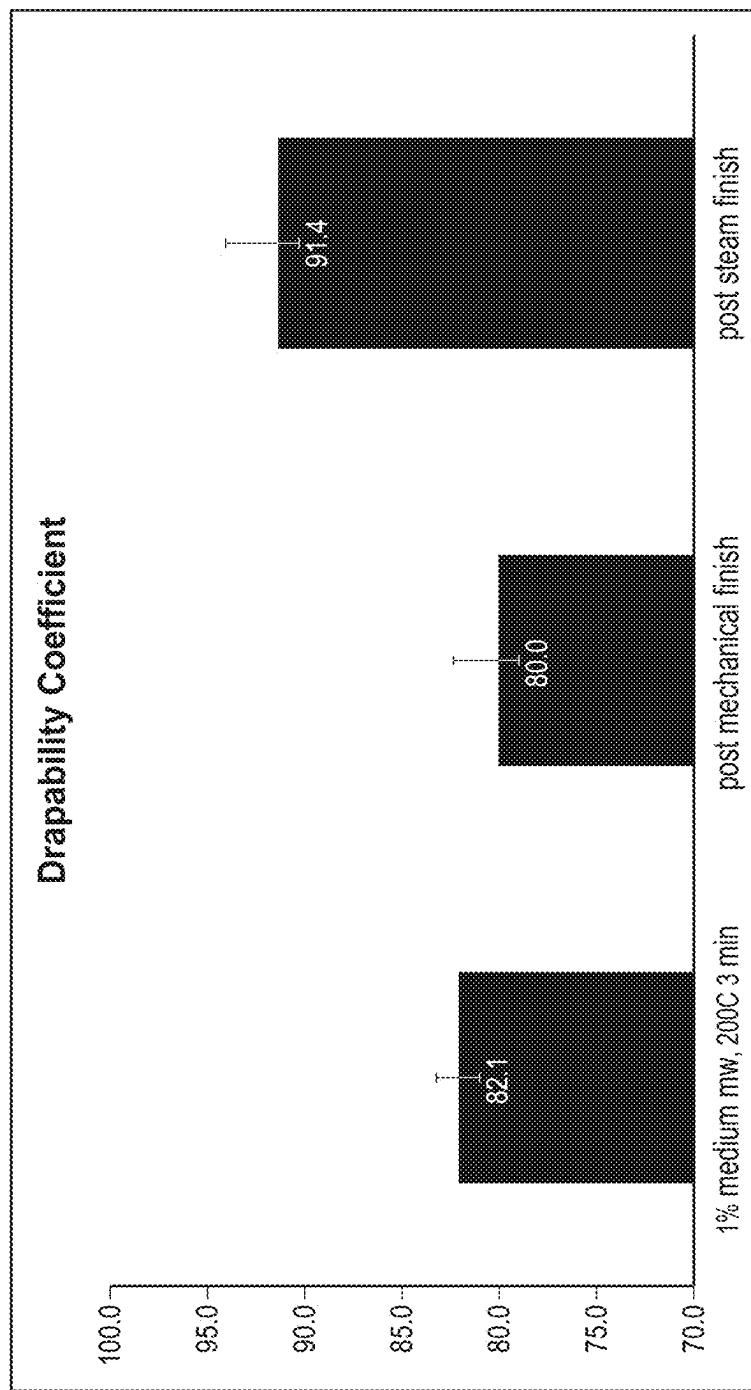


FIG. 337

test group	description	percentage change
160511	medium mw 0.1%	-0.29%
	medium mw 0.25%	-0.21%
	low mw 0.1%	-0.23%
	low mw 0.25%	-0.42%
160520	medium mw 1% - SI 2.2%	-0.36%
	medium mw 1% - SI 2.2% - acetic acid 0.05%	0.16%
	medium mw 1% - CSP 5% - acetic acid 0.1%	-0.24%
	medium mw 1% - CSP 5% - acetic acid 0.1%	-0.29%
160525	medium mw 1% - citric acid 0.1%	-1.88%
	medium mw 15% - citric acid 0.05%	0.61%
	2.2% SI	-0.34%
	2.2% SI - 0.05% acetic acid	-0.20%
5% CSP	5% CSP	-0.51%
	5% CSP - 0.1% acetic acid	-0.38%

FIG. 338

sample #	variables	mass before coating	mass post coating 24hrs coating	mass post coating 24hrs coating	coating mass %
16050401	0.1%, medium mw, 65C 10min	27.8998	27.8441	27.8797	-0.07%
16050402	0.1%, medium mw, 150C 5min	27.4518	27.3692	27.4133	-0.14%
16050403	0.1%, medium mw, 200C 3min	27.4786	27.3371	27.3965	-0.30%
16050404	0.25%, medium mw, 65C 10min	27.4948	27.3842	27.4556	-0.14%
16050405	0.25%, medium mw, 150C 5min	27.3981	27.3046	27.3693	-0.11%
16050406	0.25%, medium mw, 200C 3min	27.5101	27.4633	27.5152	0.02%
16050407	0.1%, low mw, 65C 10min	27.4390	27.3486	27.3890	-0.18%
16050408	0.1%, low mw, 150C 5min	27.7413	27.6189	27.6738	-0.24%
16050409	0.1%, low mw, 200C 3min	28.4868	28.2885	28.3568	-0.46%
16050410	0.25%, low mw, 65C 10min	27.7291	27.6048	27.6583	-0.26%
16050411	0.25%, low mw, 150C 5min	27.7296	27.6167	27.6878	-0.15%
16050412	0.25%, low mw, 200C 3min	27.6659	27.6153	27.6237	-0.15%
15042001	no coating				

FIG. 339

	Wetting Time	Wetting Time	Top Absorption	Bottom Absorption	Top Max Wetted	Bottom Max Wetted	Top Spreading Speed	Bottom Spreading Speed	One-Way Transport Speed	Accumulative Index(%)	Overall Moisture Management Capability
mean	Top (sec)	Bottom (sec)	Rate (%/sec)	Rate (%/sec)	Radius (mm)	Radius (mm)	(mm/sec)	(mm/sec)	(mm/sec)	index(%)	
16050401	3.6562	3.9002	21.1783	19.132	5	5	1.3021	1.226	138.0962	0.2532	
16050402	3.7876	3.994	19.1555	15.0486	5	5	1.2542	1.1981	112.9818	0.2116	
16050403	4.5562	5.4936	7.5662	6.5758	5	5	1.0592	0.8944	63.4438	0.126	
16050404	4.7814	5.2688	9.5862	13.4556	5	5	1.0693	1.0128	40.5577	0.1327	
16050405	4.1436	4.7154	14.1859	9.356	5	5	1.1598	1.033	171.9273	0.2539	
16050406	4.0502	4.481	15.0691	11.1372	5	5	1.1817	1.0909	188.01	0.2805	
16050407	4.03876	4.51684	15.431	12.24992	5	5	1.1914	1.08848	134.89182	0.22504	
16050408	4.05	4.8188	14.7362	11.2181	5	5	1.2453	1.1026	119.3349	0.2133	
16050409	4.6122	5.625	14.8515	9.1391	5	5	1.0401	0.8718	91.2189	0.1599	
16050410	4.3312	6.45	9.3714	7.5046	5	5	1.1074	0.7927	97.0366	0.1635	
16050411	4.2002	5.0626	13.4135	8.2152	5	5	1.1403	0.9616	106.3481	0.1778	
16050412	4.1436	4.6874	14.1363	11.1217	5	5	1.1583	1.0408	141.6139	0.2236	
15042001	6.103	4.2124	8.6855	15.8154	5	5	0.8041	1.1509	88.4355	0.1827	

FIG. 340

sample #	variables	mass before coating	mass post coating	mass post 24hrs coating	coating mass %
16051101	no coating, 65C, 10min	27.7559	27.7209	27.7958	0.00%
16051102	no coating, 150C, 5min	27.5591	27.4186	27.5361	-0.08%
16051103	no coating, 200C, 3min	27.5610	27.3764	27.5184	-0.15%
16051104	0.1%, medium mw, 200C 3min	27.6831	27.5328	27.6529	-0.11%
16051105	0.1%, medium mw, 150C 5min	27.5614	27.4813	27.5808	0.07%
16051106	0.1%, medium mw, 65C 10min	27.7428	27.6970	27.7638	0.08%
16051107	0.25%, medium mw, 65C 10min	27.4758	27.4524	27.5281	0.19%
16051108	0.25%, medium mw, 150C 5min	28.0202	27.9299	28.0444	0.09%
16051109	0.25%, medium mw, 200C 3min	26.8532	26.7314	26.8612	0.03%
16051110	0.1%, low mw, 200C 3min	27.2731	27.1462	27.2458	-0.10%
16051111	0.1%, low mw, 150C 5min	27.2532	27.1622	27.2574	0.02%
16051112	0.1%, low mw, 65C 10min	27.9193	27.8521	27.9375	0.07%
16051113	0.25%, low mw, 65C 10min	27.5451	27.5295	27.5999	0.20%
16051114	0.25%, low mw, 150C 5min	27.5025	27.4405	27.5743	0.26%
16051115	0.25%, low mw, 200C 3min	27.6829	27.5671	27.6922	0.03%

FIG. 341

Wetting Time Top (sec)	Wetting Time Bottom (sec)	Top Absorption Rate (%/sec)	Bottom Absorption Rate (%/sec)	Top Max Wetted Radius (mm)	Bottom Max Wetted Radius (mm)	Spreading Speed (mm/sec)	Top Spreading Speed (mm/sec)	Bottom Spreading Speed (mm/sec)	One-Way Transport Index(%)	Accumulative Over all Moisture Management Capability OMMC
16051101	3.9376	4.2564	13.2112	18.2272	5	5	1.2169	1.1411	103.023	0.2051
16051102	4.1526	4.5748	14.7715	16.11604	5	5	1.17186	1.0658	59.44466	0.14638
16051103	4.5128	5.7314	12.3379	10.5193	5	5	1.0869	0.8947	83.235	0.156
16051104	7.444	28.8754	6.5736	6.9355	5	5	0.8685	0.4821	72.883	0.1365
16051105	4.6498	4.6312	10.4792	11.2174	5	5	1.0467	1.0495	47.9845	0.1206
16051106	4.0688	4.5376	16.2767	17.2449	5	5	1.1941	1.1597	52.839	0.1533
16051107	19.6124	13.8564	6.996	7.9745	5	7	0.82	0.7765	127.3957	0.201
16051108	11.9688	26.2188	7.1779	5.1517	5	5	0.7964	0.8926	242.7475	0.3466
16051109	5.3816	10.425	8.4204	4.1142	5	5	0.9135	0.5415	223.8266	0.3043
16051110	4.4628	8.4376	7.849	4.4341	5	5	1.0764	0.6062	226.5862	0.3073
16051111	3.9752	5.2502	15.2155	11.2055	5	5	1.2513	1.1286	115.8167	0.2153
16051112	4.3346	4.5596	11.2951	12.7915	5	5	1.111	1.0635	123.1502	0.207
16051113	4.2938	4.5376	10.8059	8.5425	5	5	1.1225	1.0614	107.2899	0.1815
16051114	4.5408	4.8404	8.6481	12.9761	5	8	1.0668	1.0496	124.2615	0.2094
16051115	5.328	7.6656	7.5532	4.8861	5	5	0.9082	0.6484	113.2722	0.1814

FIG. 342

sample number	description	mass before coating	mass 24hrs after coating	coating mass %
16052001	1% medium mw, + 2.2% SI	16.7936	16.9149	0.72%
16052002	1% medium mw, + 2.2% SI + acetic acid 0.5%	16.0038	16.1727	1.06%
16052003	1% medium mw, + 5% CSP	17.2366	17.4209	1.07%
16052004	1%, medium mw, + 5% CSP + acetic acid 1%	16.0087	16.1993	1.19%
16052005	1% medium mw, + 0.1% citric acid	17.3912	17.5276	0.78%
16052006	1% medium mw, + 0.05% citric acid	15.4389	15.5261	0.56%
16052501	2.2% SI	16.5019	16.5885	0.52%
16052502	2.2% SI + acetic acid 0.5%	18.6291	18.7321	0.55%
16052503	5% CSP	17.0946	17.1797	0.50%
16052504	5% CSP + acetic acid 1%	15.2729	15.336	0.41%

FIG. 343

Raw Data:	Wetting Time	Wetting Time	Top Absorption	Bottom Absorption	Top Max Wetted Radius	Bottom Max Wetted Radius	Top Spreading Speed (mm/sec)	Bottom Spreading Speed (mm/sec)	Accumulative One-Way Transport Index(%)	Overall Moisture Management Capability OMMC
	Top (sec)	Bottom (sec)	(%/sec)	(%/sec)	(mm)	(mm)	(mm/sec)	(mm/sec)		
16052001	120	32.6251	0	11.4019	0	4.375	0	1.4944	396.8843	0.4432
16052002	120	25.0664	0	9.5604	0	6.875	0	2.5826	1084.6953	0.6414
16052003	120	20.5548	0	11.5085	0	6.25	0	2.4735	1157.5399	0.6303
16052004	120	6.4103	0	12.6385	0	5.625	0	2.1531	1182.457	0.6057
16052005	66.0589	34.5352	2.8804	5.0824	3.75	3.75	0.1023	1.7183	1165.2373	0.5832
16052006	107.4843	75.8671	1.0243	1.3469	1.25	1.875	0.0323	0.5417	1121.1284	0.5243
16052501	120	17.5666	0	12.0892	0	3.75	0	1.2849	639.587	0.56
16052502	120	17.1211	0	25.1403	0	5.625	0	2.1137	709.6938	0.6477
16052503	120	105.3281	0	3.6746	0	0.625	0	0.2222	845.16	0.5148
16052504	120	90.7149	0	3.4472	0	1.25	0	0.4365	865.4872	0.5198

FIG. 344

sample #	variables	mass before coating (gr)	mass post coating (gr)	mass post coating 24 hrs (gr)	coating mass variation (%)
16050301	1% low mw, 200C 3min	27.3448	27.3546	27.4811	0.50%
16050302	0.1% low mw, 200C, 3min	27.2618	27.0759	27.2113	-0.19%
16050303	1% medium mw, 200C 3min	27.6729	27.7292	27.8732	0.72%
16050304	1% medium mw, 200C 3min	27.3121	27.3775	27.5029	0.70%
16050305	1% medium mw, 200C 3min	27.5503	27.6099	27.7419	0.70%
16050306	0.1% medium mw, 200C, 3min	27.8158	27.6649	27.7825	-0.12%
16050307	15042001 non wicking finished, 200C, 3 min	27.7029	27.5171	27.6341	-0.25%
16050308	15042001 non wicking finished, 200C, 3 min	27.5277	27.3671	27.4566	-0.26%
16050309	15042001 non wicking finished, 200C, 3 min	27.5404	27.4003	27.4746	-0.24%
16050310	15042001 non wicking finished, 150C, 5 min	27.5235	27.3960	27.4786	-0.16%
16050311	15042001 non wicking finished, 150C, 5 min	27.6228	27.5090	27.5840	-0.14%
16050312	15042001 non wicking finished, 150C, 5 min	27.8506	27.7355	27.8059	-0.16%

FIG. 345

Sample #	bacteria	Results: cfu/sample			
		Zero Contact Time	24 hr Contact Time	Percent Reduction	
16050301	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
1% low mw, 200C, 3min	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
0.1% low mw, 200C, 3min	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
0.1% low mw, 200C, 3min	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050303	Staphylococcus aureus ATCC 6538	1.10E+05	3.10E+06	-2718.18%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050304	Staphylococcus aureus ATCC 6538	1.10E+05	3.50E+06	-3081.82%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050305	Staphylococcus aureus ATCC 6538	1.10E+05	2.90E+06	-2536.37%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
1% medium mw, 200C, 3min	Staphylococcus aureus ATCC 6538	1.10E+05	3.17E+06	-2778.8%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050306	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
0.1% medium mw, 200C, 3min	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050307	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050308	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050309	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
15042001 non wicking finished, 200C, 3min	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050310	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050311	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
16050312	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	
15042001 non wicking finished, 150C, 5min	Staphylococcus aureus ATCC 6538	1.10E+05	5.00E+06	-4445.45%	
	Klebsiella pneumoniae ATCC 4352	2.20E+05	5.00E+06	-2172.73%	

FIG. 346

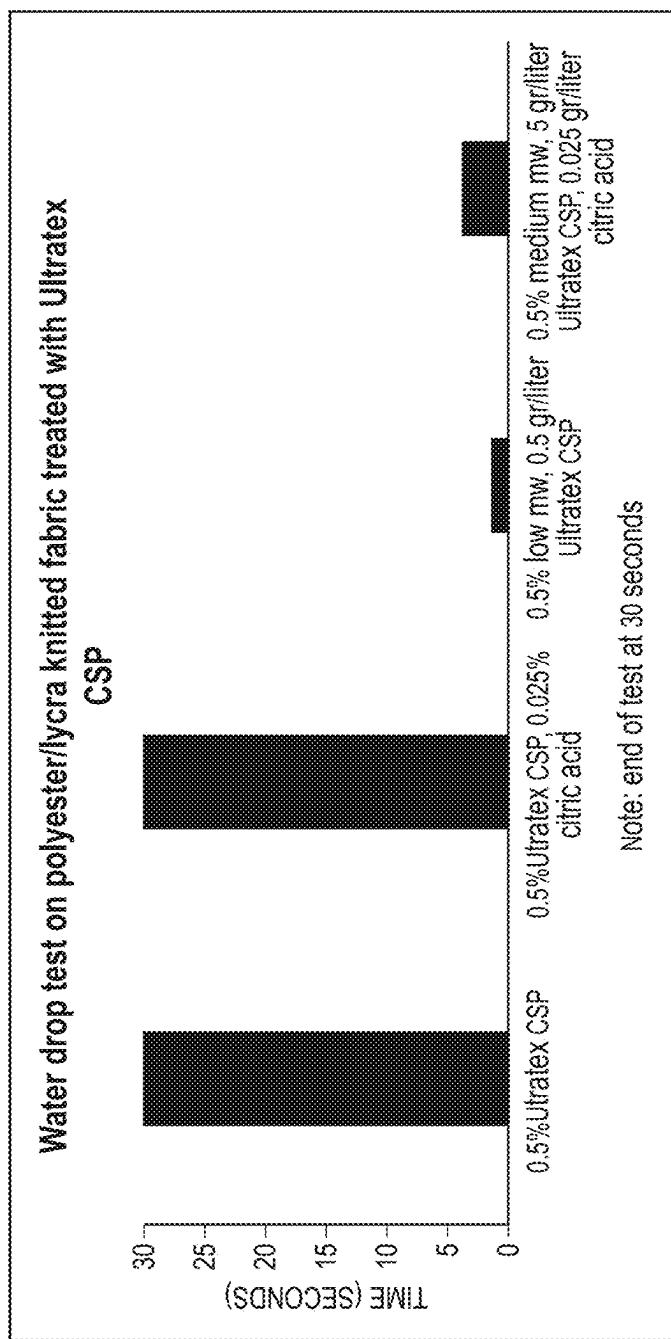


FIG. 347

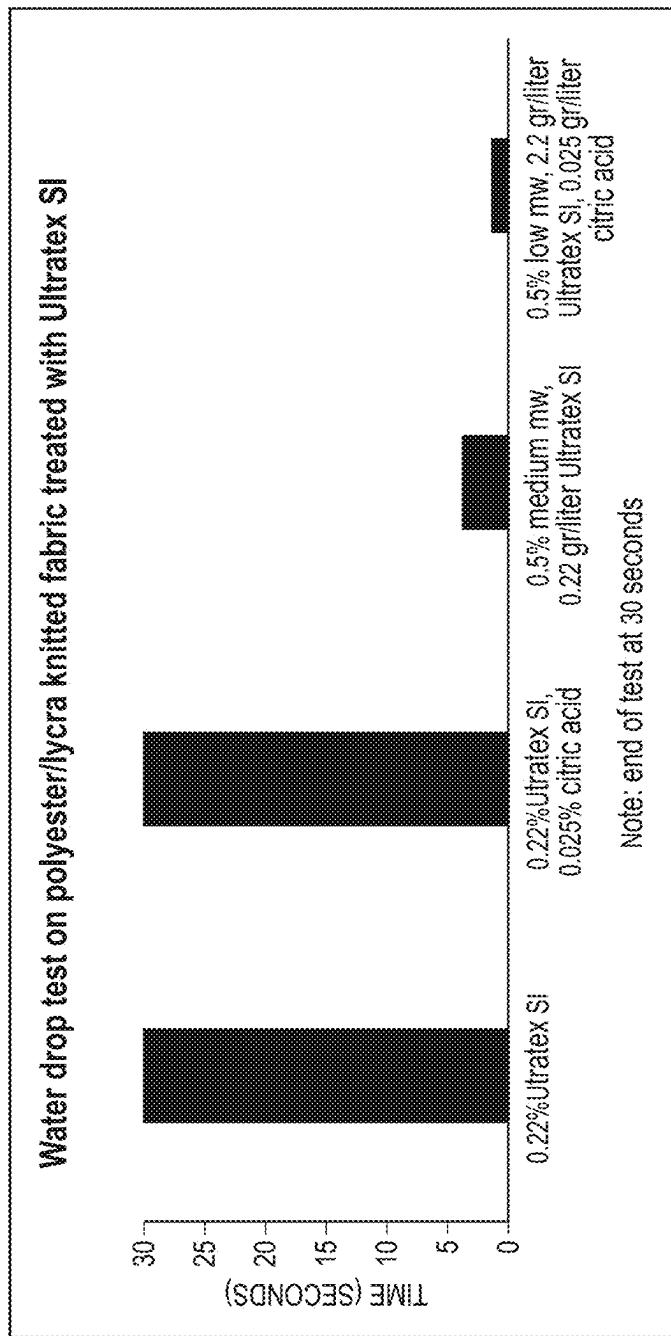


FIG. 348

Sample #	Coating Silk Solution Concentration	Bacteria Inoculation	Washing Cycle	Bacteria Enumeration
16060903	0.5%	yes	Yes	Yes (at 0, 1 and 10 washing cycle)
16060901	no	yes	Yes	Yes (at 0, 1 and 10 washing cycle)
16060904	0.5%	no	Yes	Yes (at 0, 1 and 10 washing cycle)
16060902	no	no	Yes	Yes (at 0, 1 and 10 washing cycle)

FIG. 349

Washing cycle #	Bacteria load per area group 1	Areas	Total bacteria load group 1	Bacteria load per area group 2	Areas	Total bacteria load	Bacteria enumeration	Tested samples per group
	1.00E+07	8	8.00E+07	1.00E+07	8	8.00E+07	Yes	2
0	1.00E+07	6	6.00E+07	1.00E+07	6	6.00E+07	Yes	2
1	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
2	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
3	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
4	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
5	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
6	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
7	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
8	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
9	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	No	
10	1.00E+07	4	4.00E+07	1.00E+07	4	4.00E+07	Yes	2
11	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
12	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
13	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
14	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
15	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
16	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
17	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
18	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
19	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
20	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
21	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
22	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
23	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
24	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	No	
25	1.00E+07	2	2.00E+07	1.00E+07	2	2.00E+07	Yes	2

FIG. 350

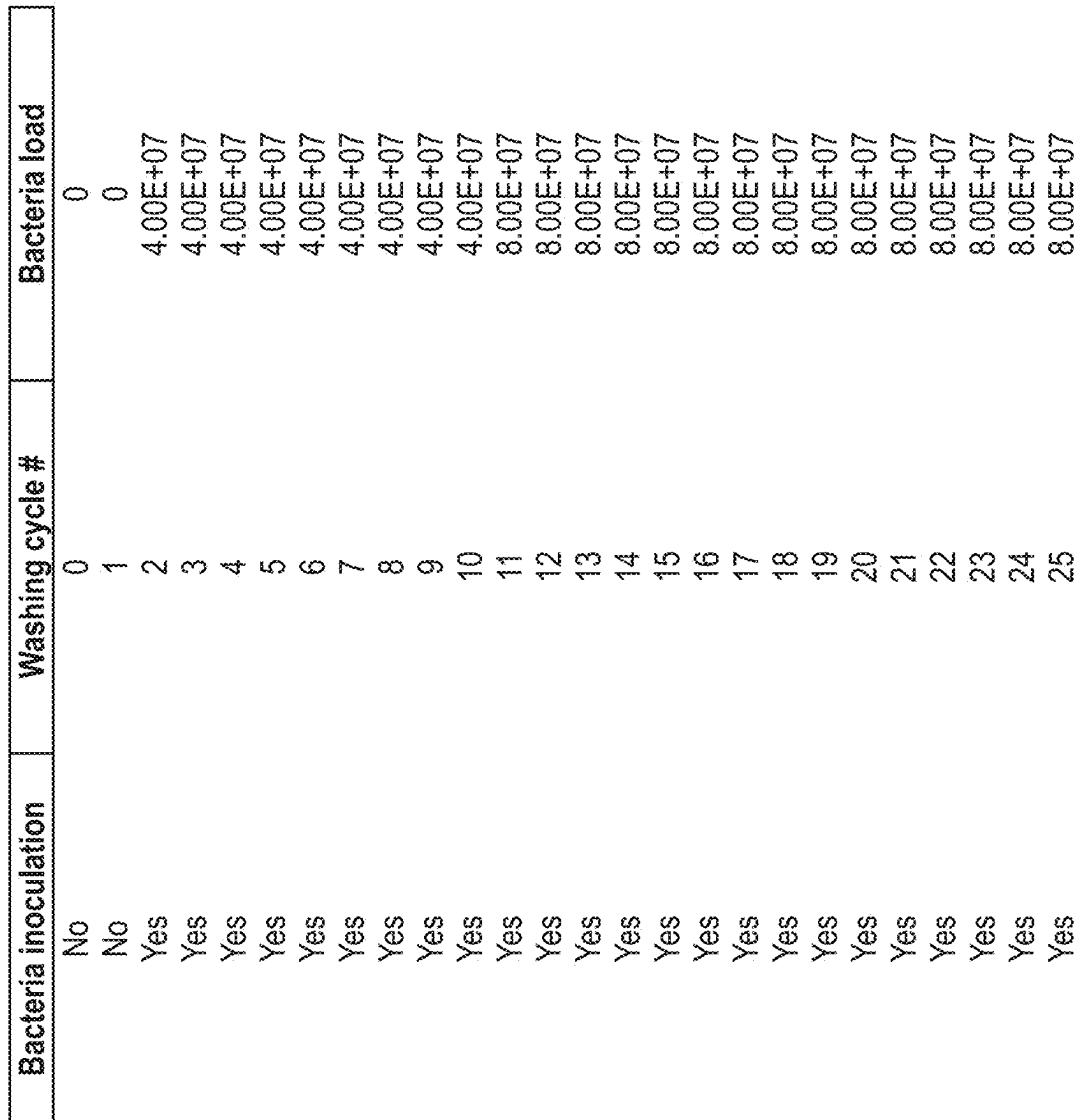


FIG. 351

Number of Wash	Total Inoculation per Wash Cycle	Swatches Enumeration 16060901	Swatches Enumeration 16060902	Swatches Enumeration 16060903	Swatches Enumeration 16060904
0	2.48E+07	2.55E+07	1.00E+03	1.80E+07	1.00E+03
1	4.30E+07	1.00E+03	2.10E+03	2.70E+03	1.55E+03
2	2.35E+07				
3	2.60E+07				
4	1.85E+07				
5	2.75E+07				
6	1.85E+07				
7	3.00E+07				
8	4.60E+07				
9	3.05E+07				
10	1.21E+07	9.99E+02	1.00E+03	9.99E+02	9.99E+02

FIG. 352A

Sample #	Odor Test at t=0	Comments	Odor Test After 1 Wash	Comments2	Odor Test After 10 Washes	Comments3
16060903	1	very weak scent of dye product	1	very weak scent of detergent	1	very weak scent of detergent
16060901	1	very weak scent of dye product	1	very weak scent of detergent	1	very weak scent of detergent
16060904	1	very weak scent of dye product	1	very weak scent of detergent	1	very weak scent of detergent
16060902	1	very weak scent of dye product	1	very weak scent of detergent	1	very weak scent of detergent

Scale	Comments
0	no odor
1	very weak (odor threshold)
2	weak
3	distinct
4	strong
5	very strong
6	intolerable

FIG. 352B

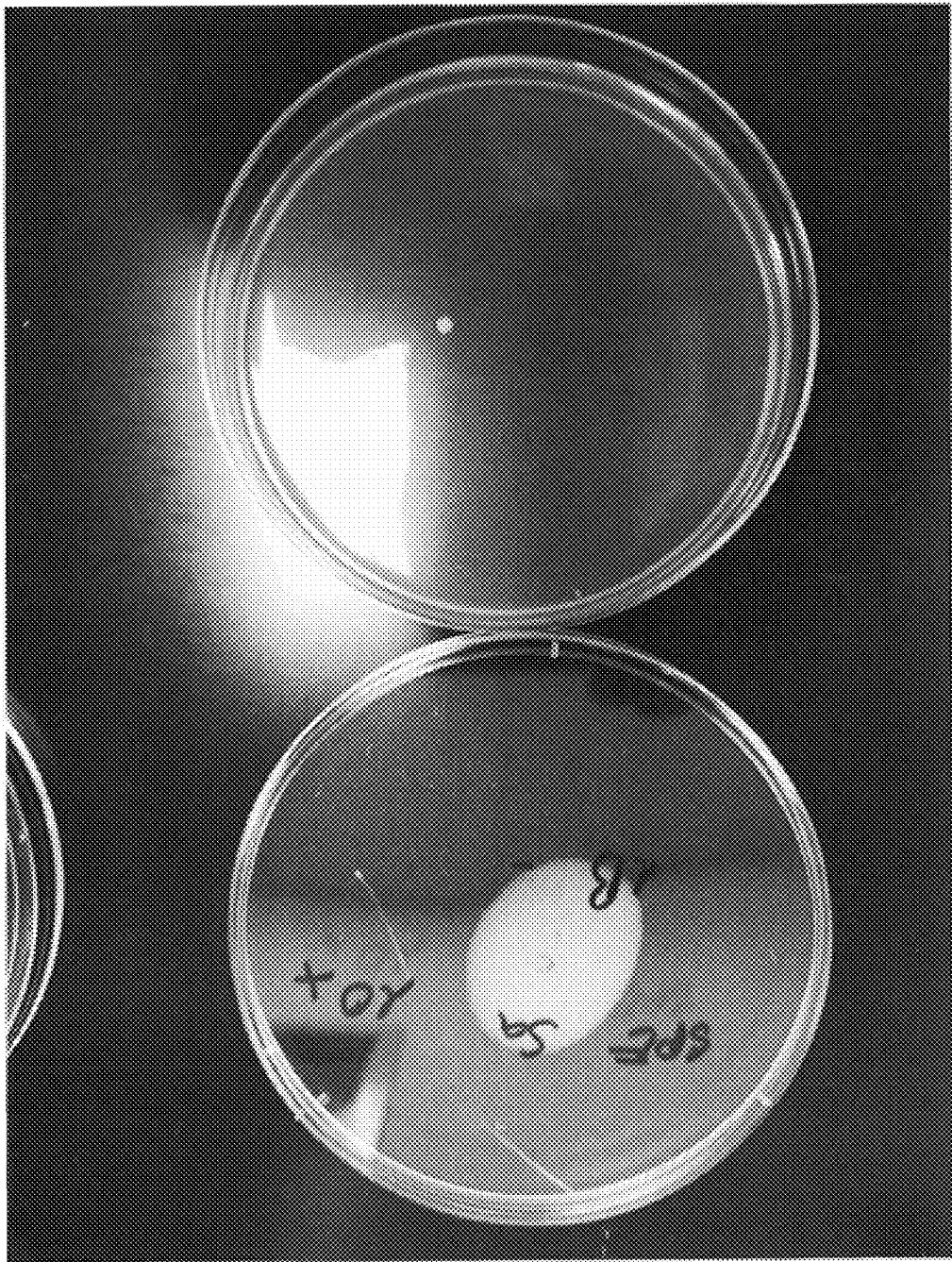


FIG. 353

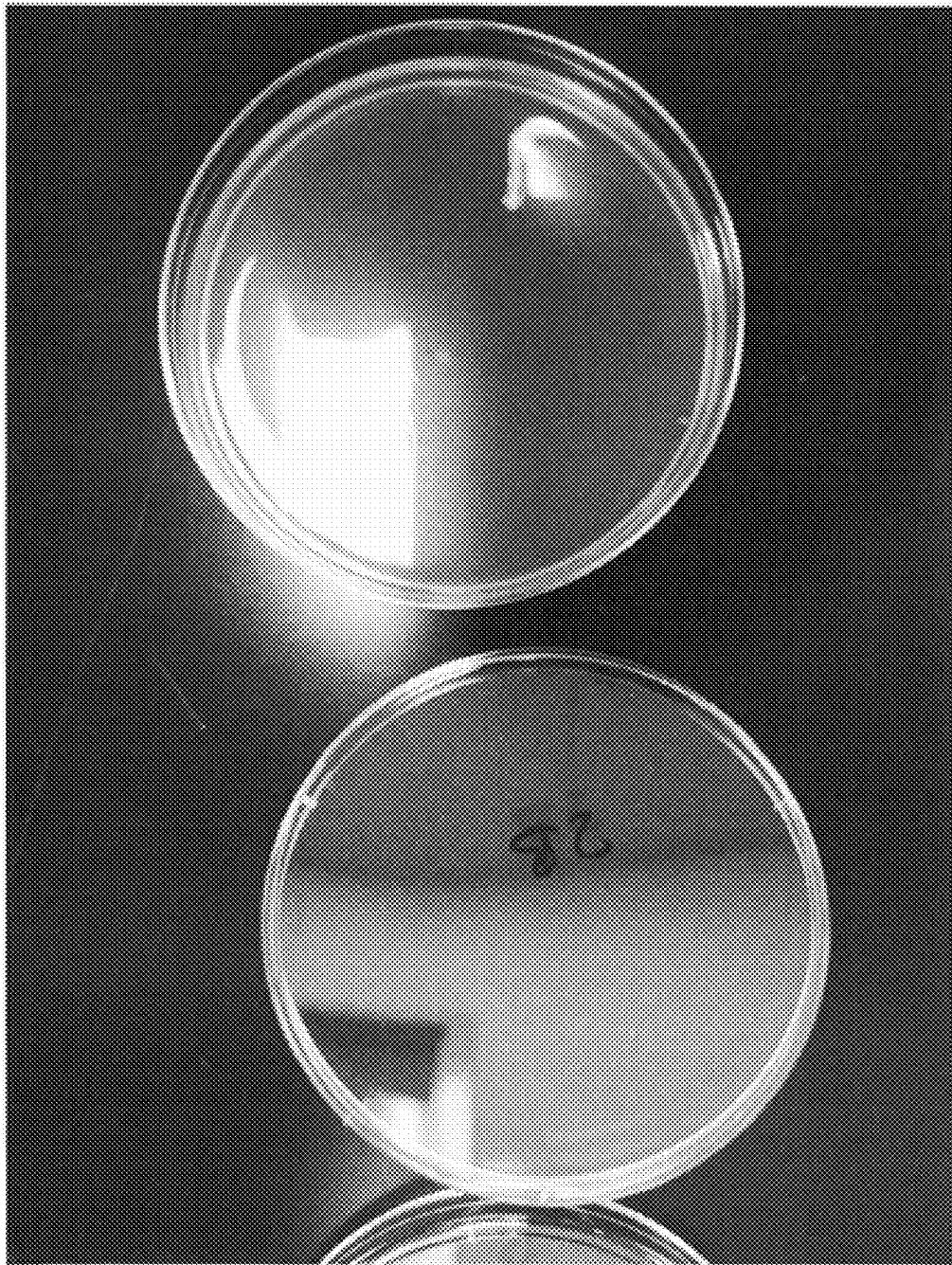


FIG. 354

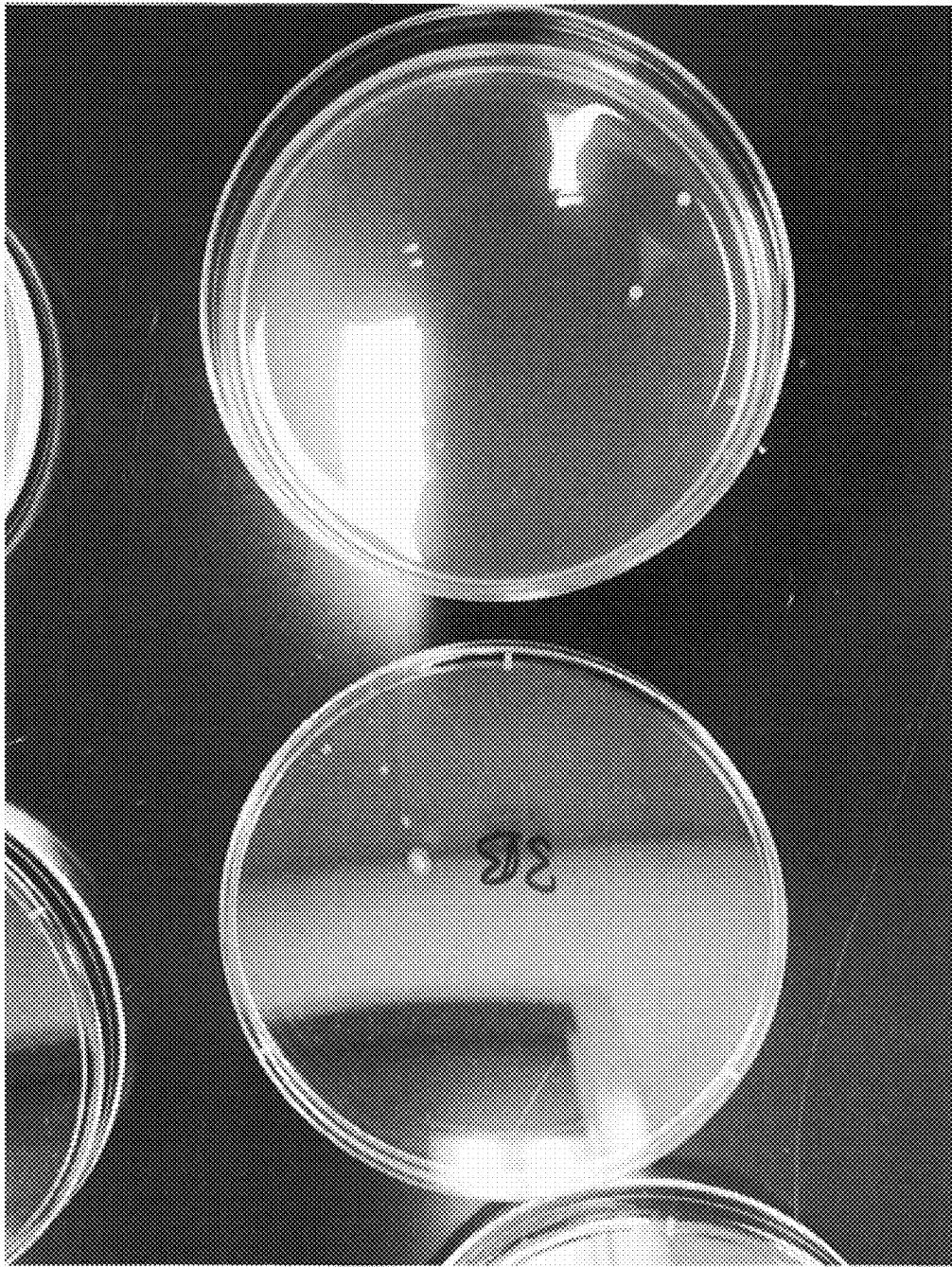


FIG. 355



FIG. 356



FIG. 357

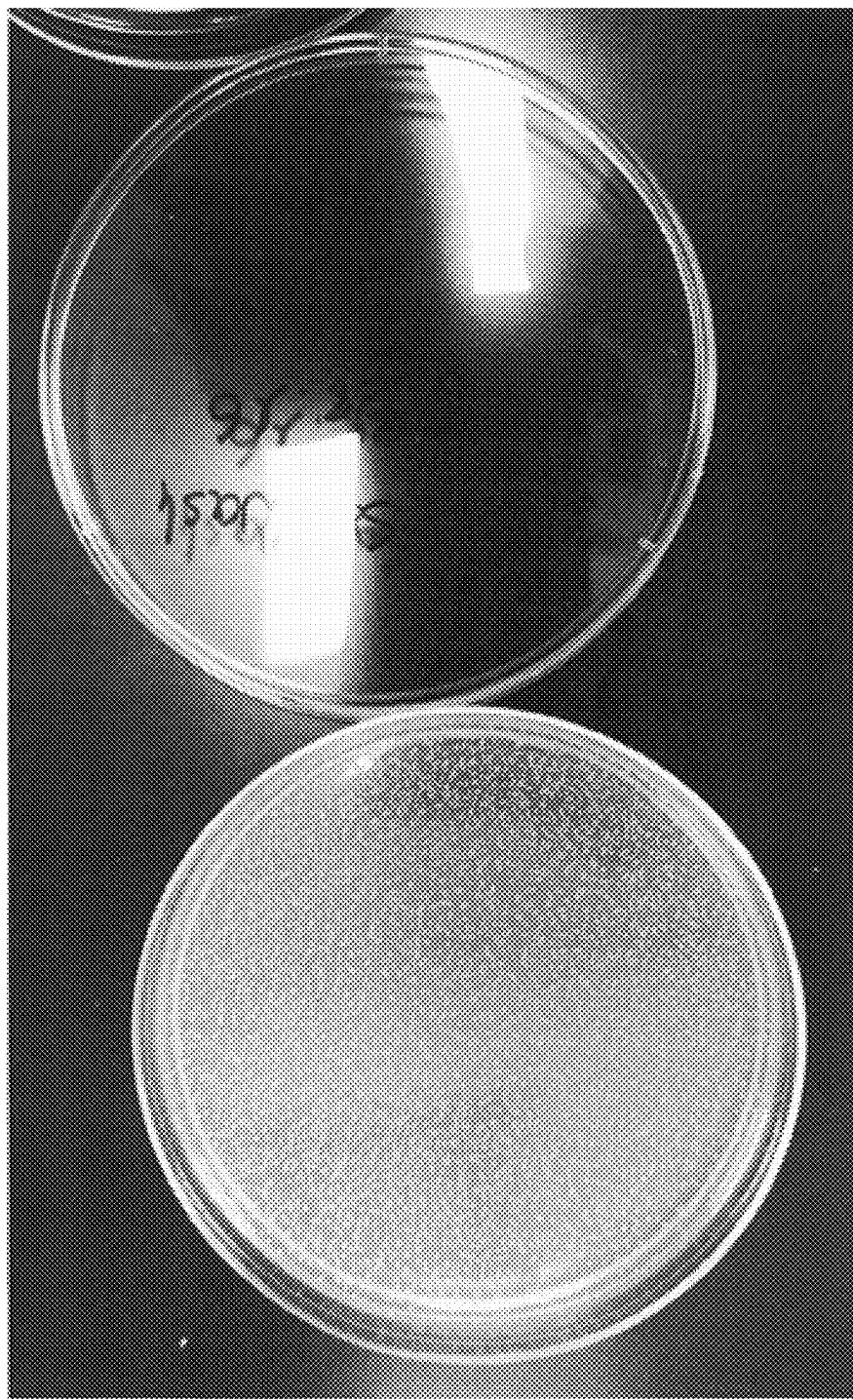


FIG. 358

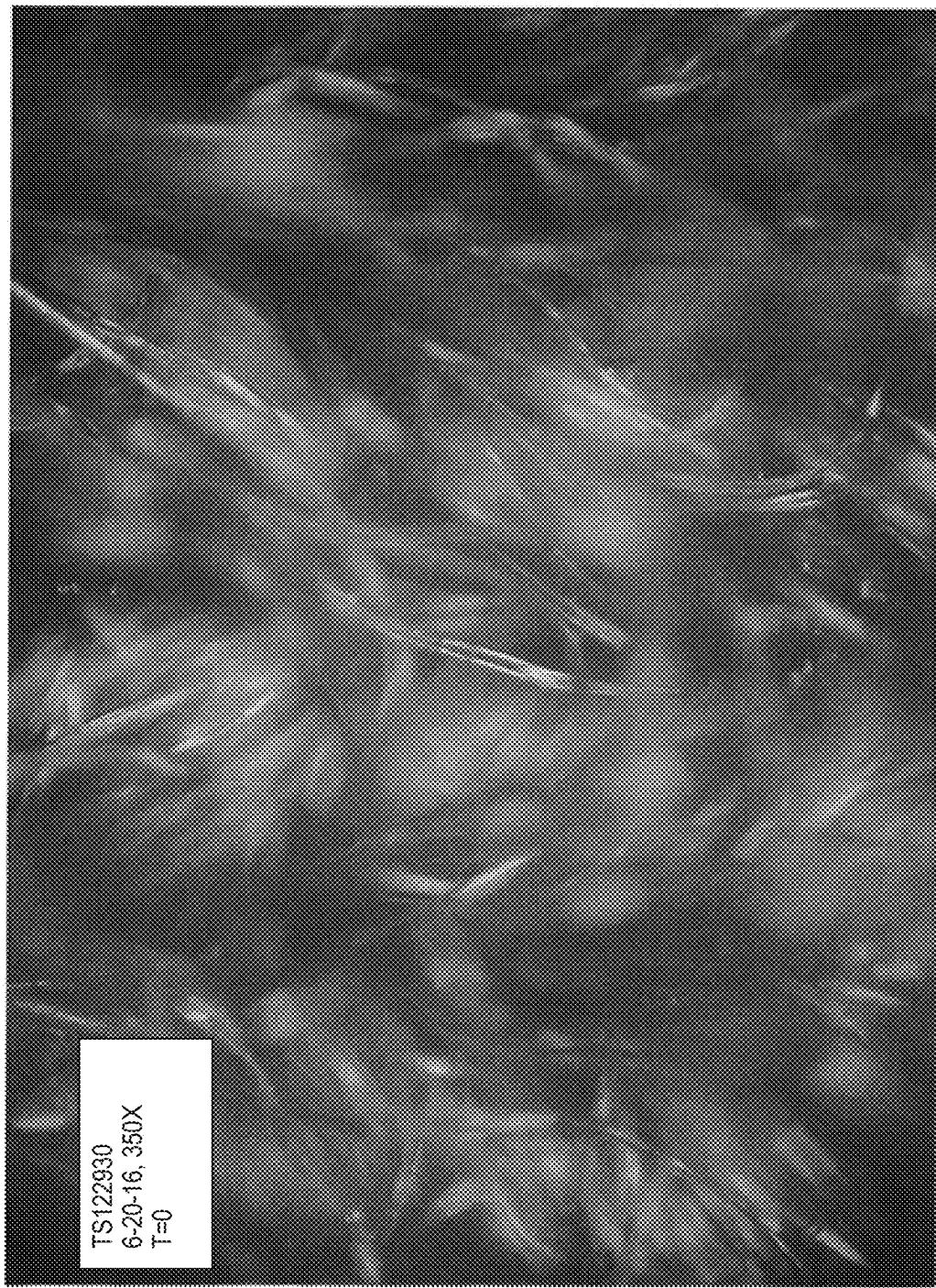


FIG. 359A

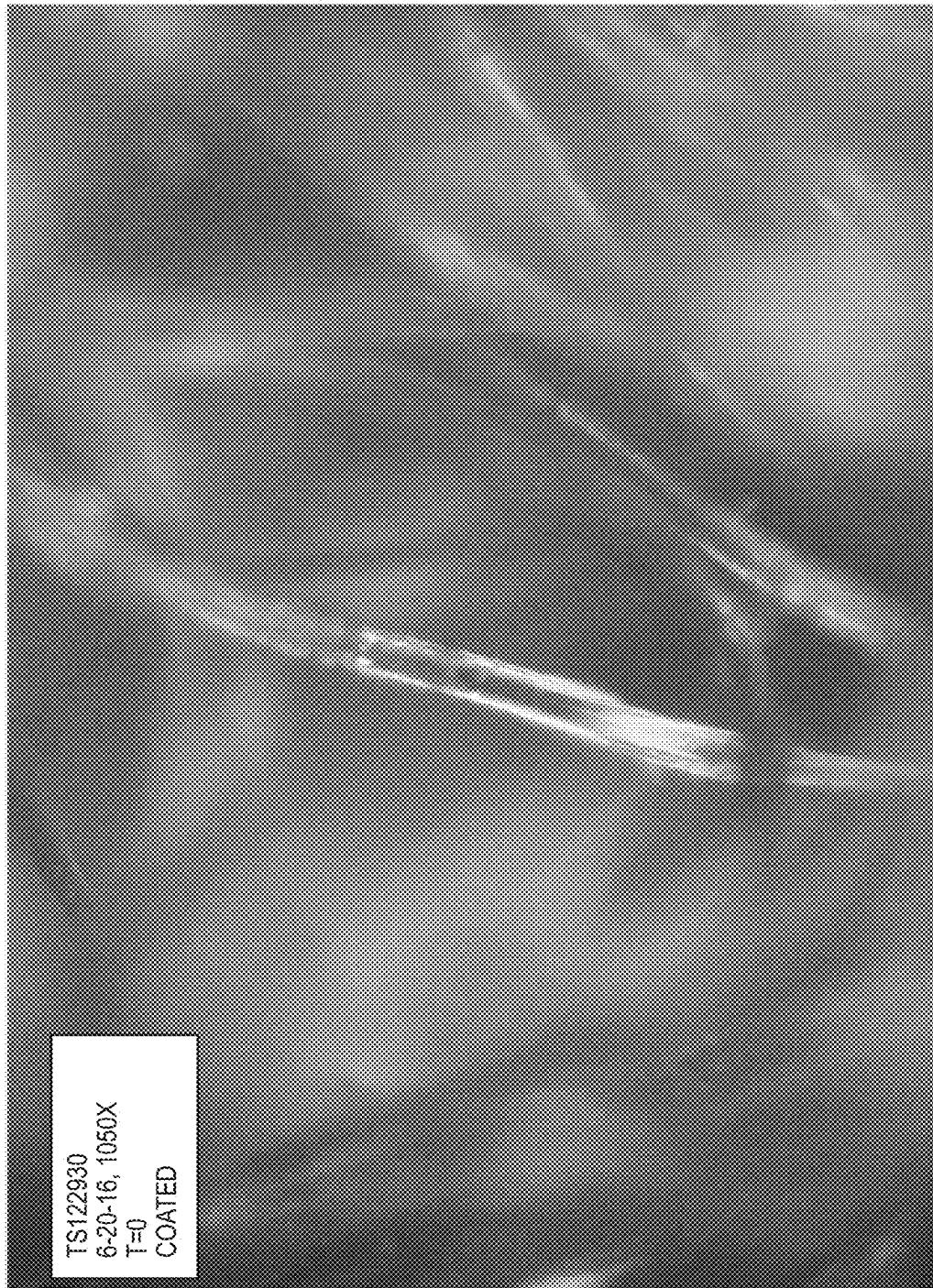


FIG. 359B



FIG. 359C

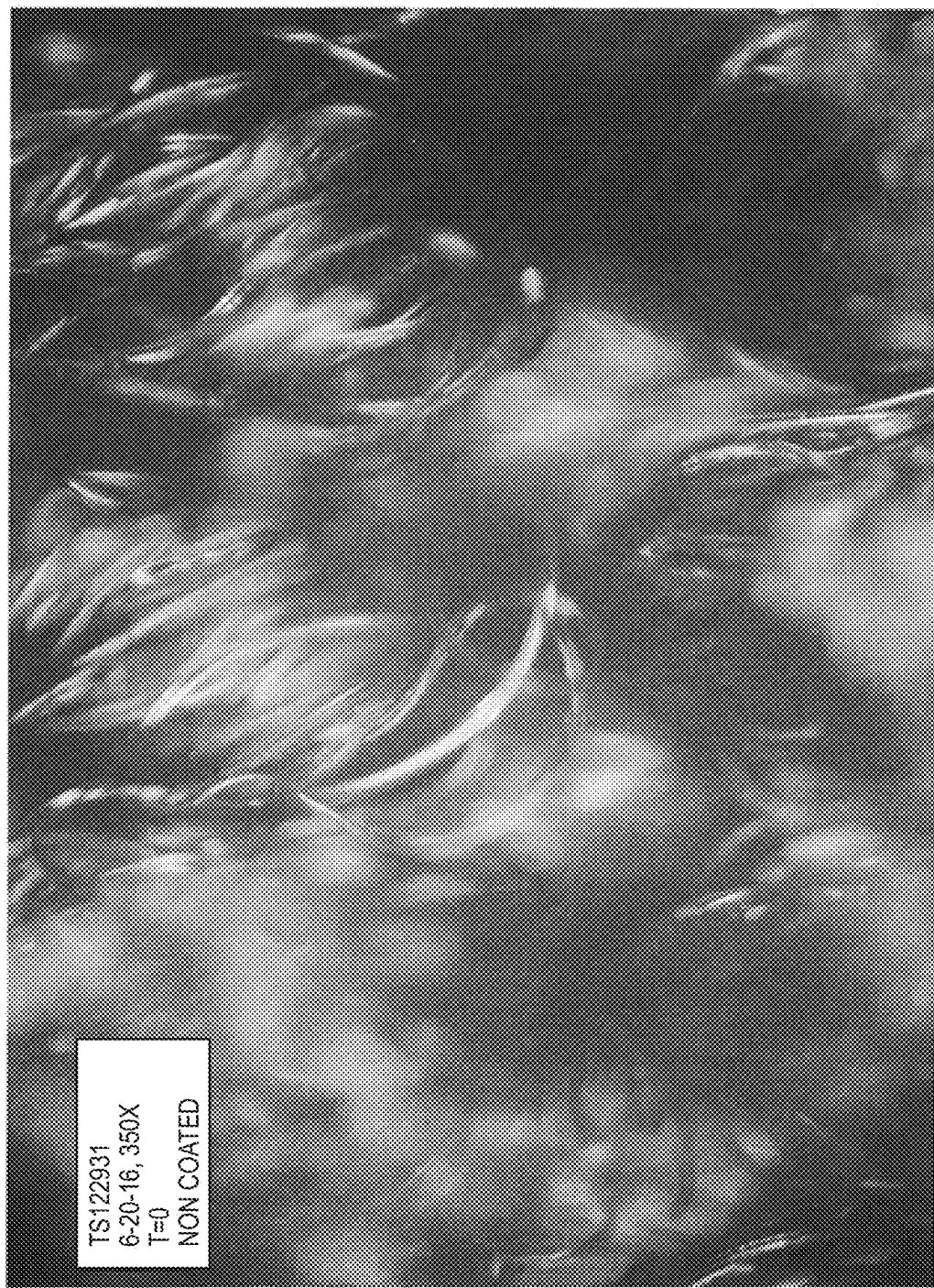


FIG. 360A

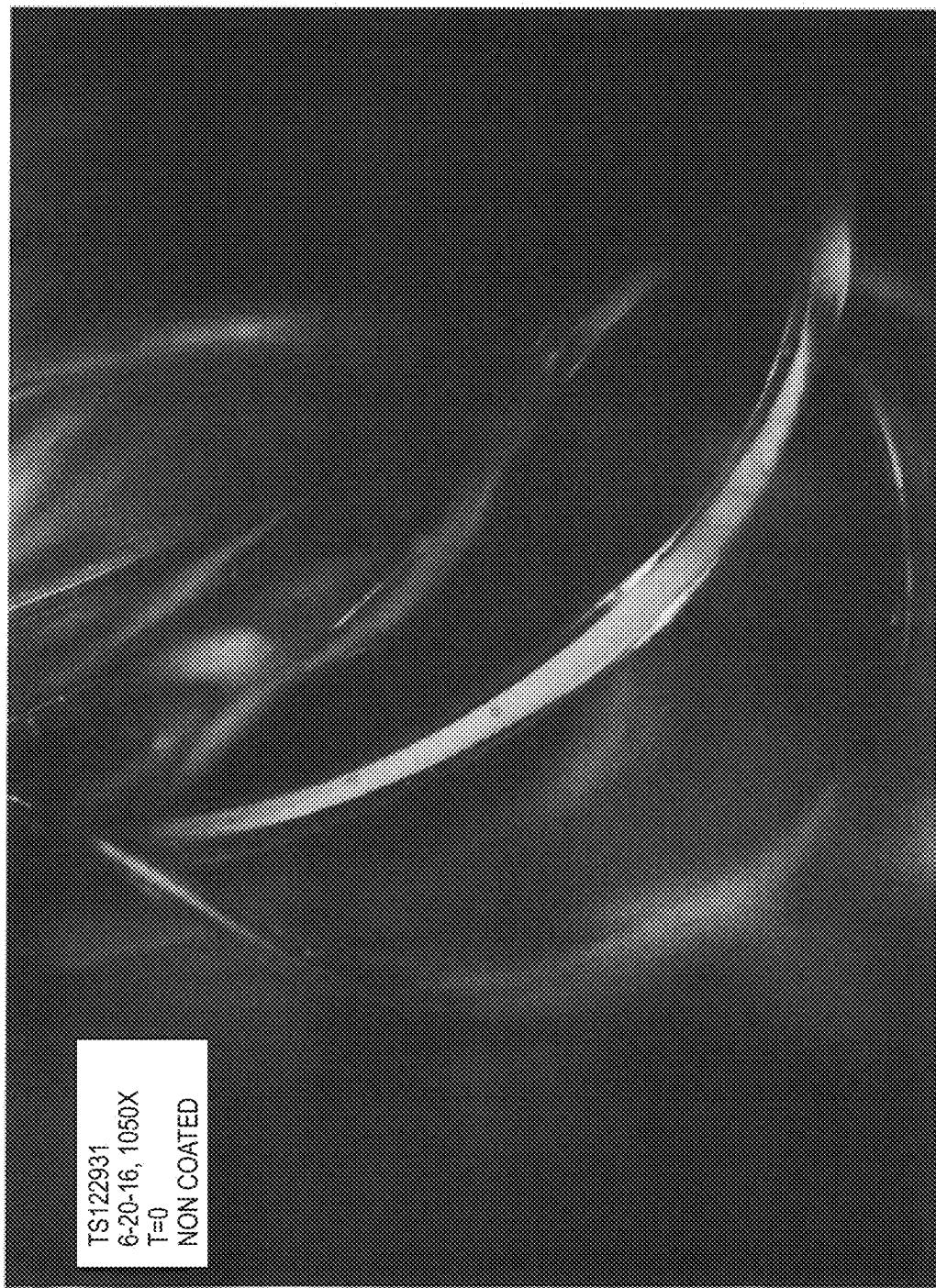


FIG. 360B

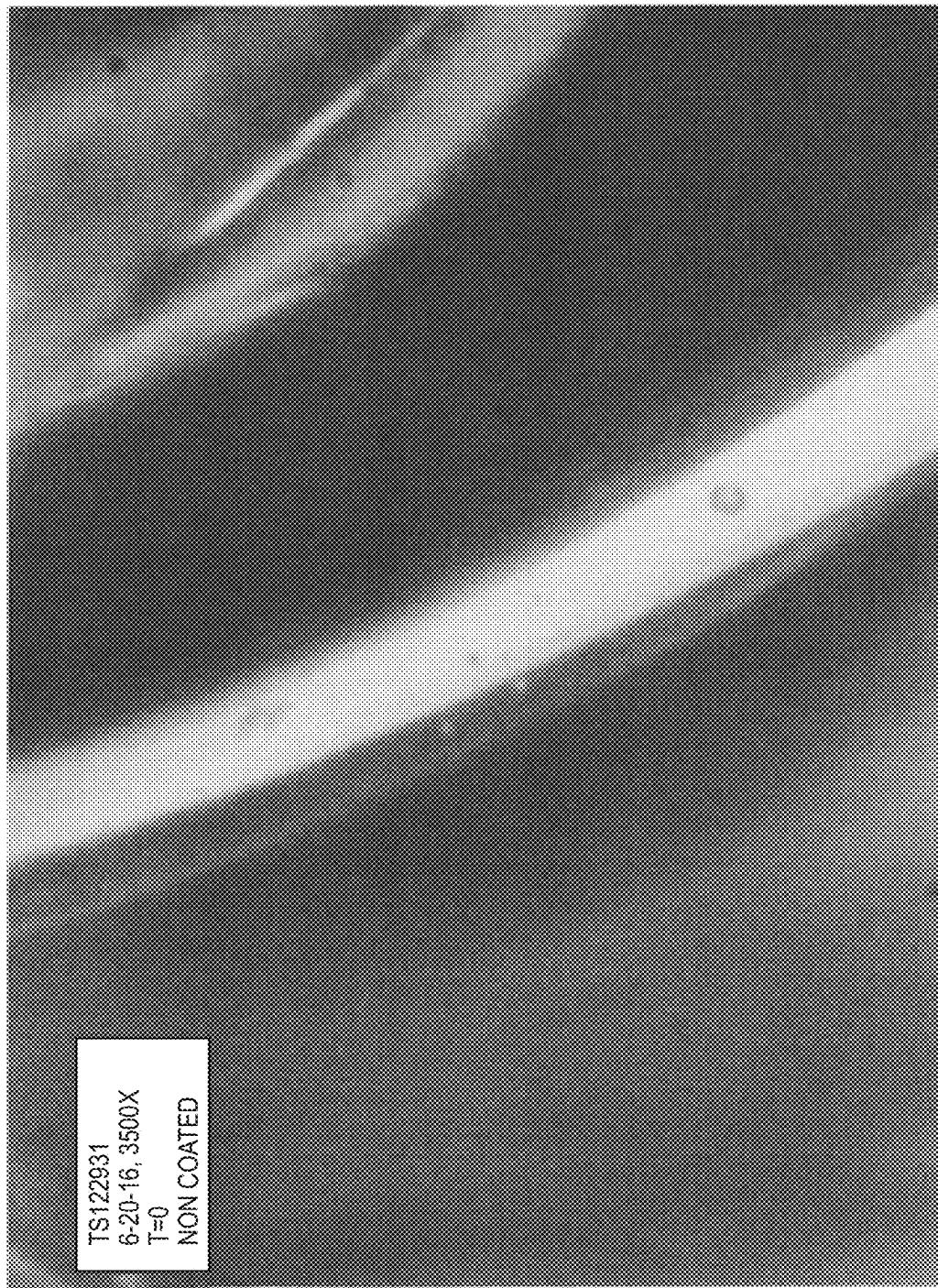


FIG. 360C

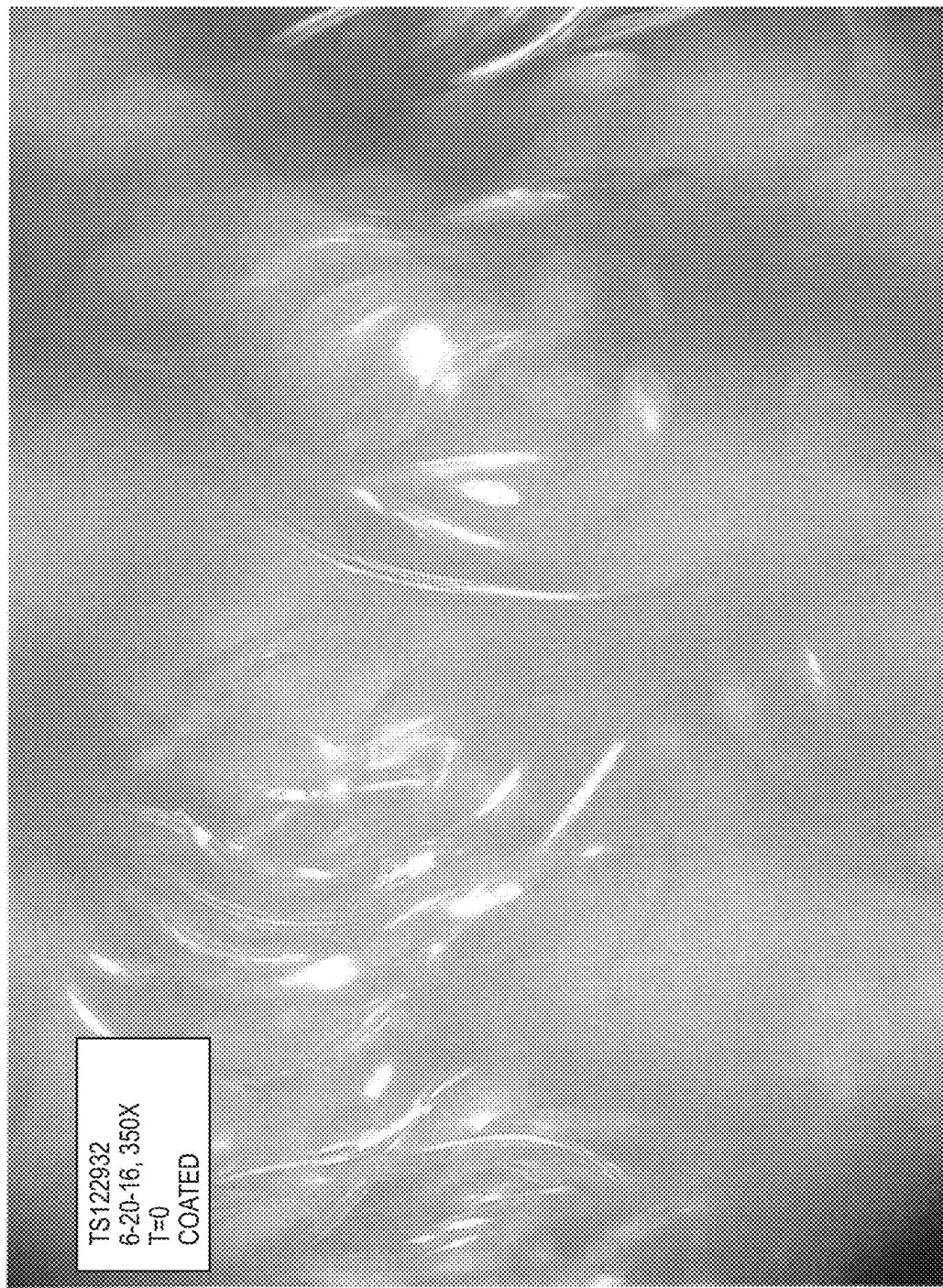


FIG. 361A



FIG. 361B

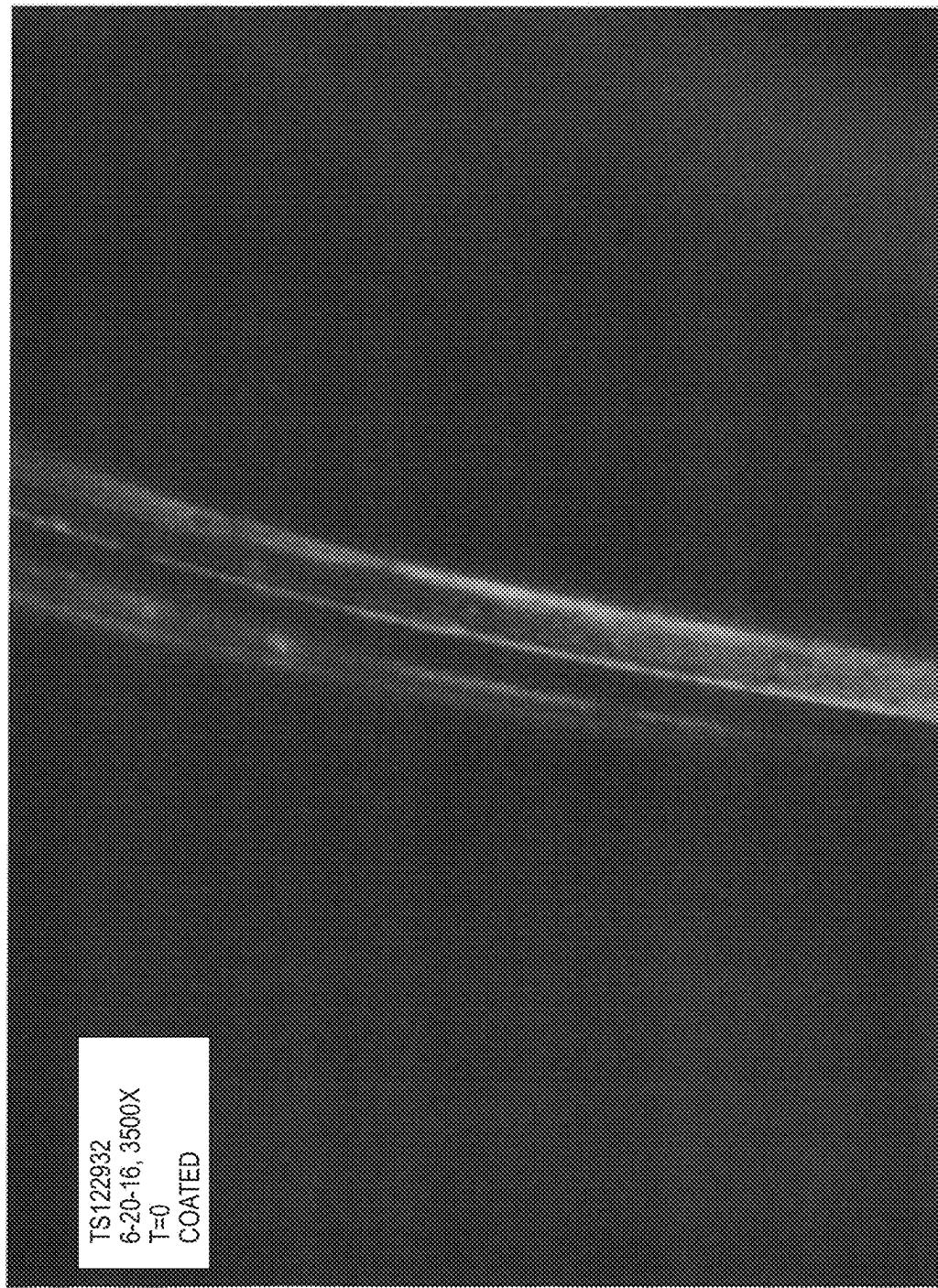


FIG. 361C

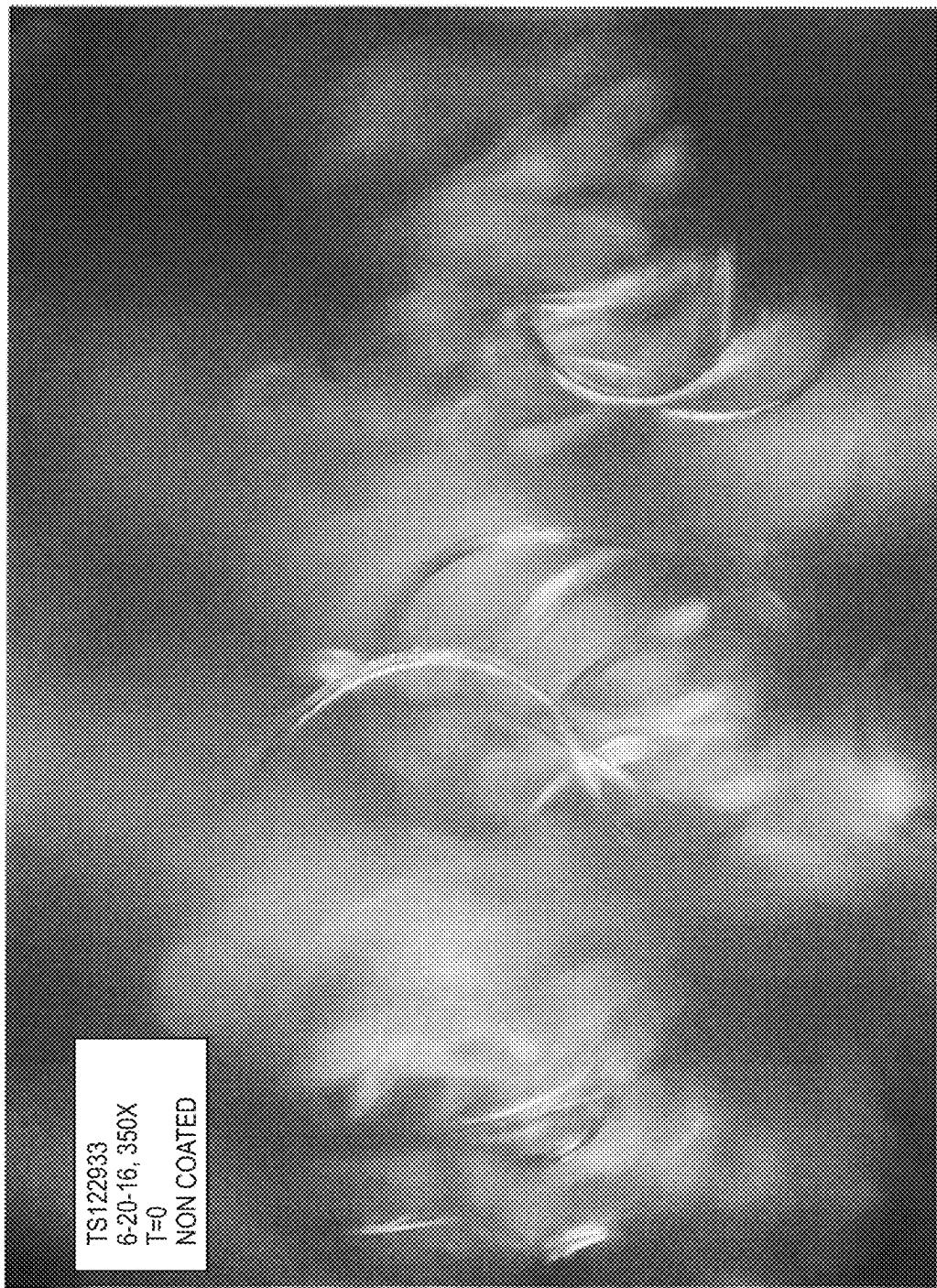


FIG. 362A

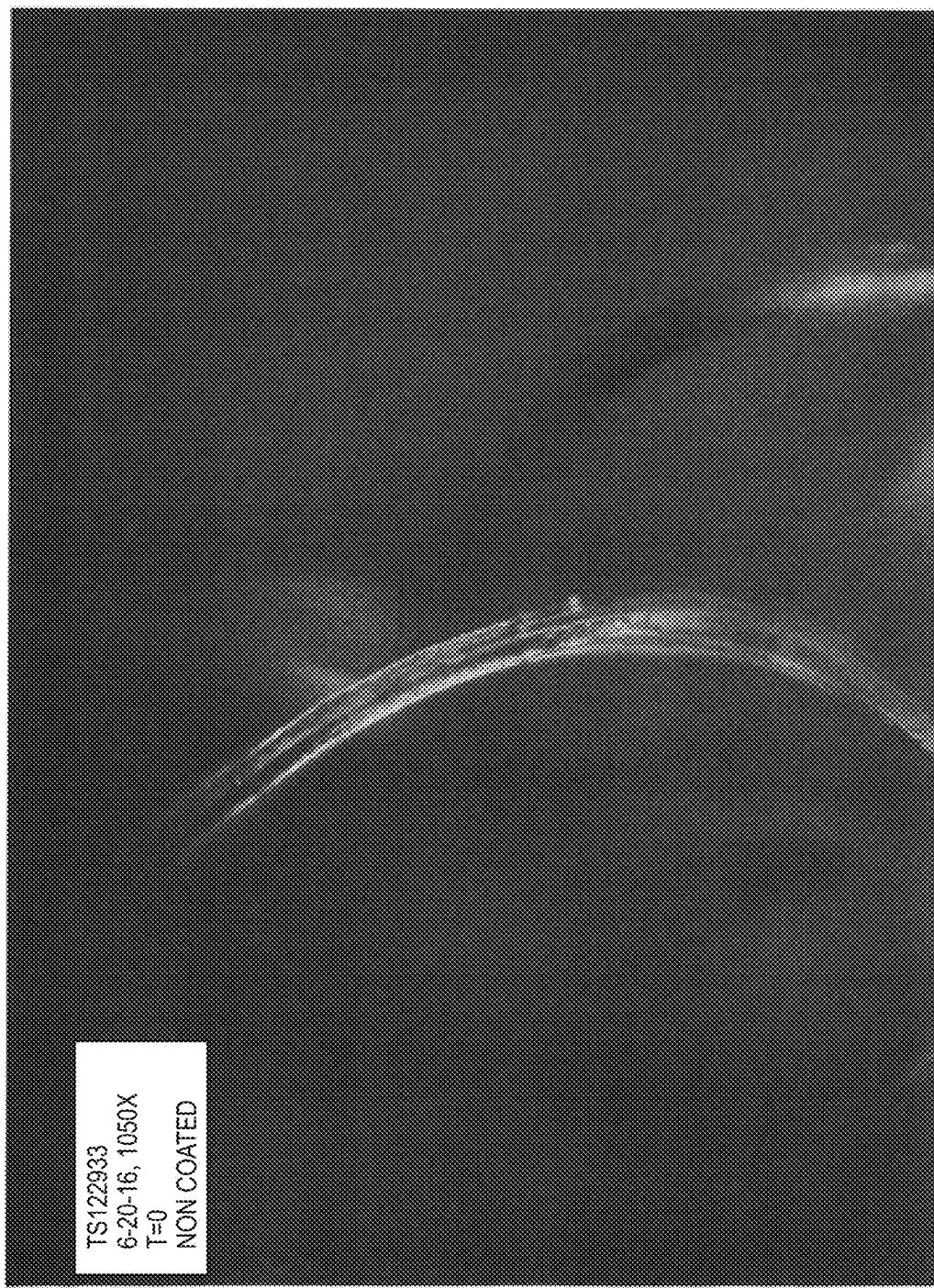


FIG. 362B

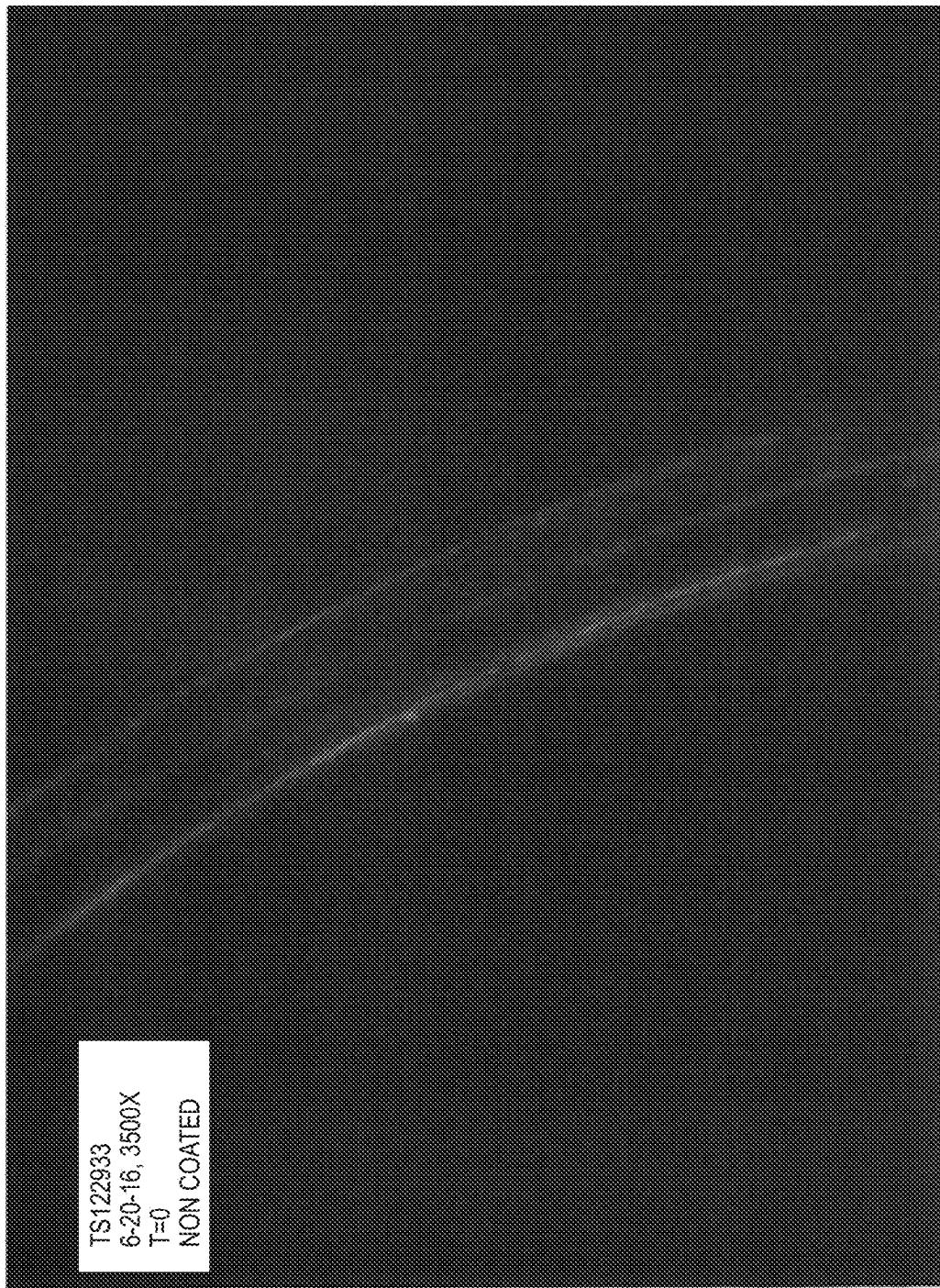


FIG. 362C

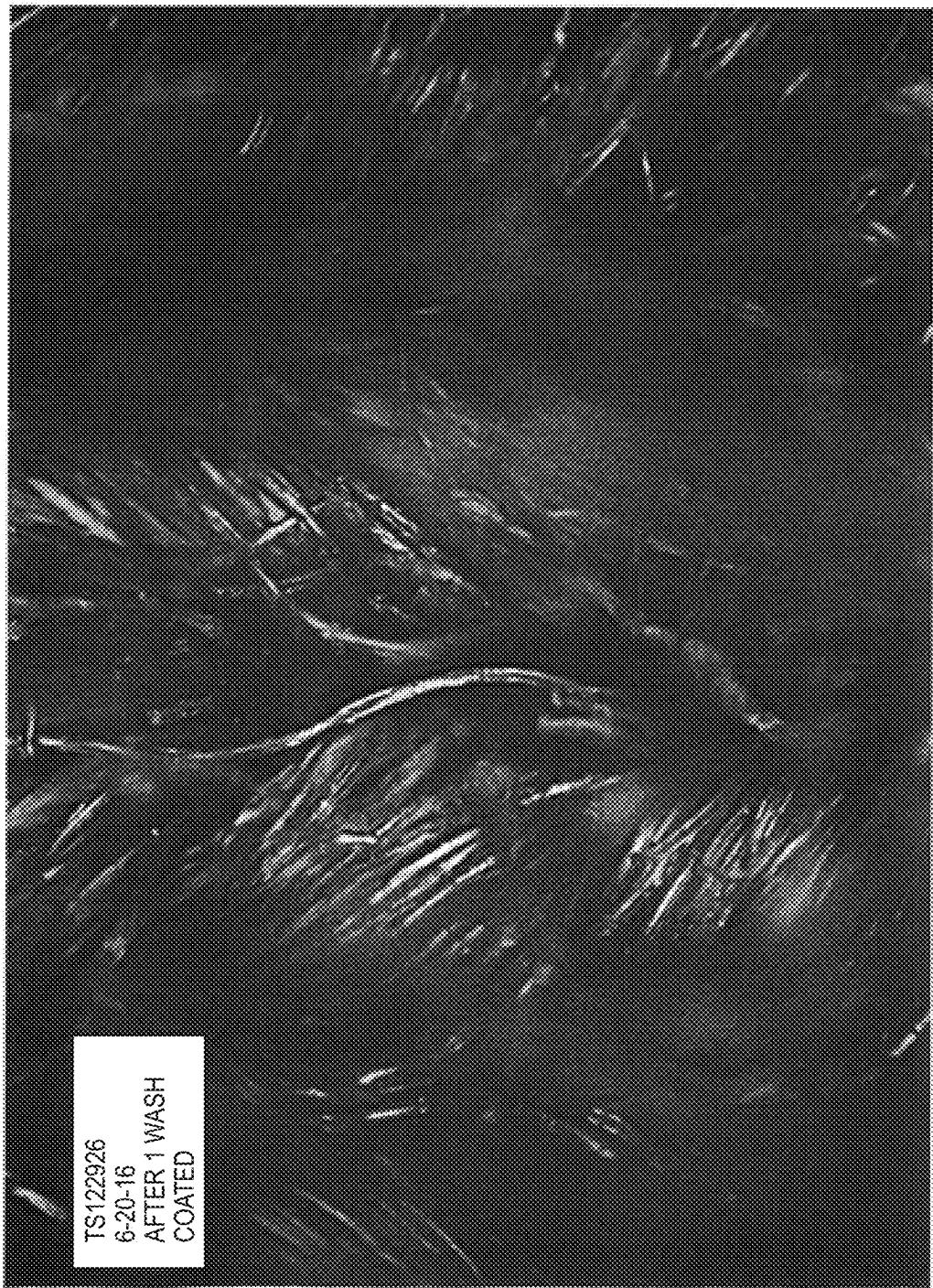


FIG. 363A

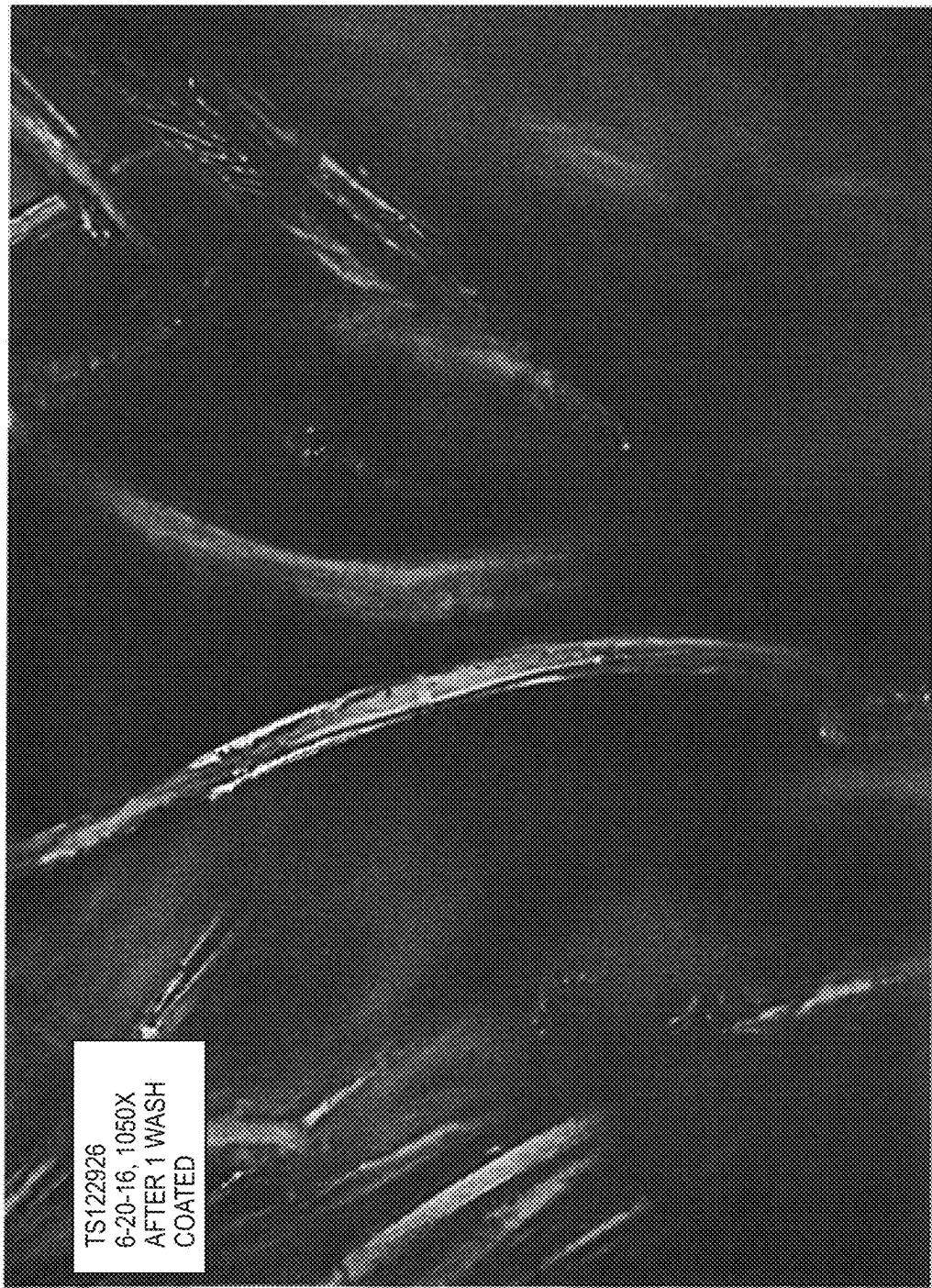


FIG. 363B

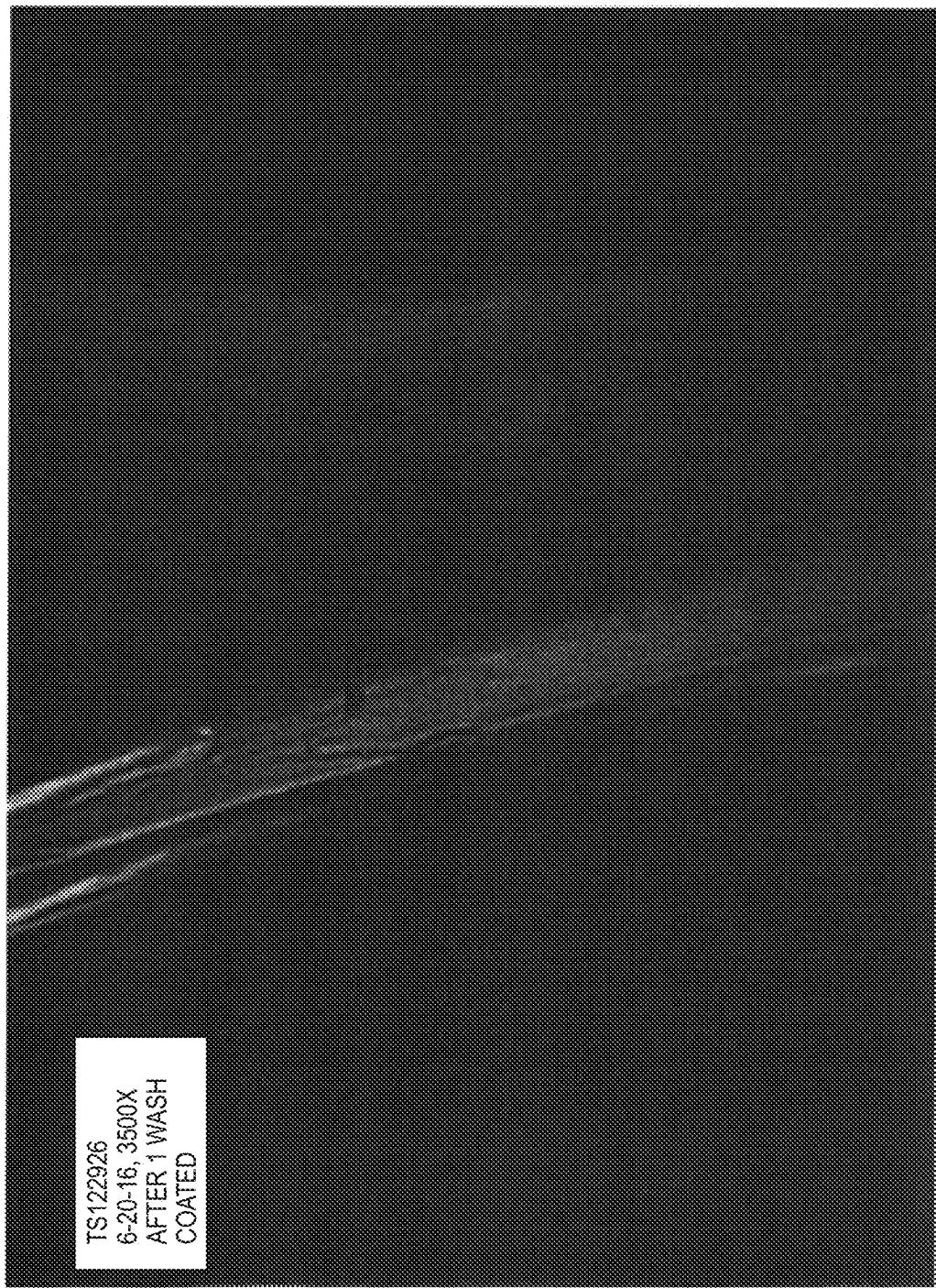


FIG. 363C

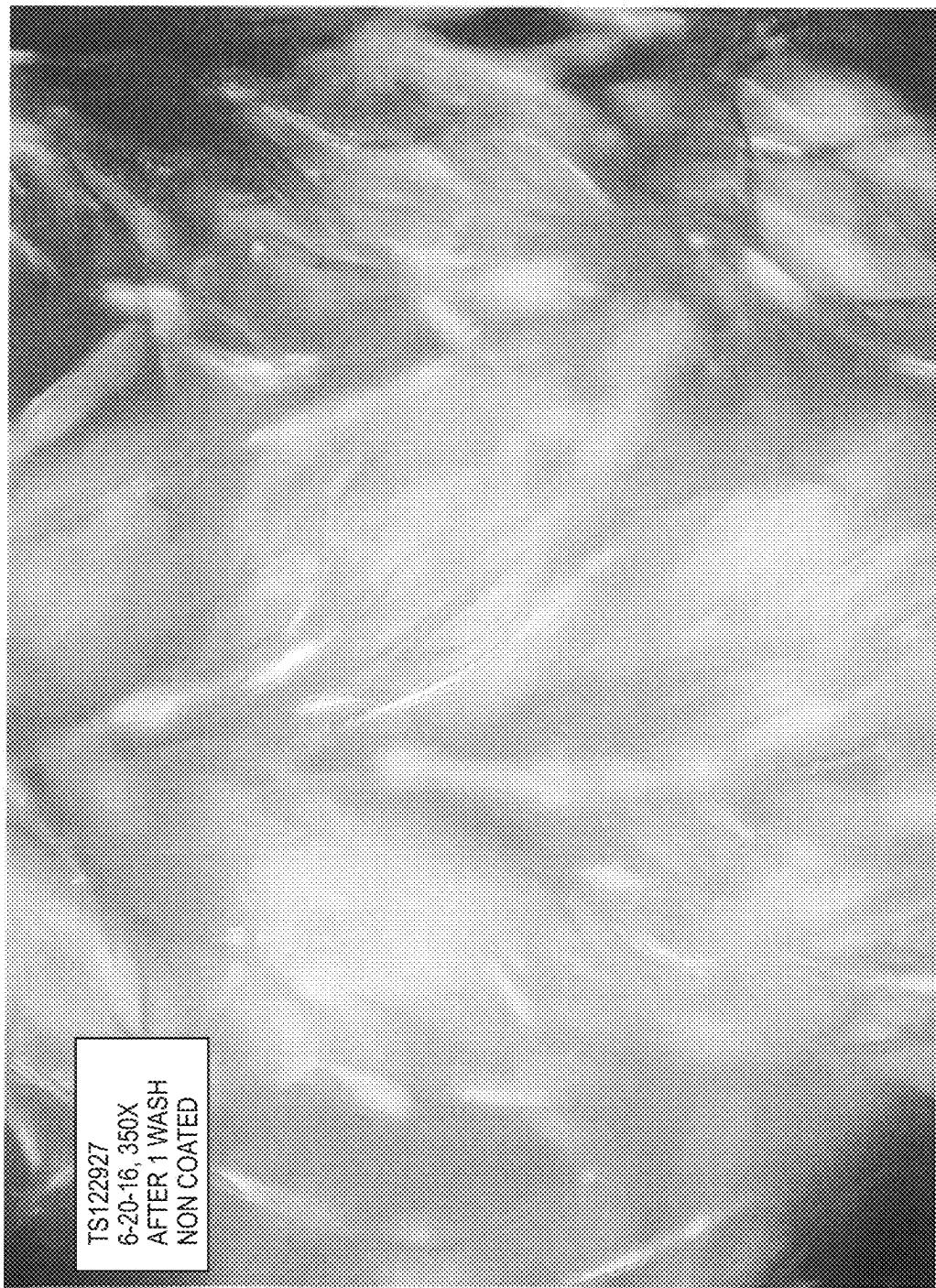


FIG. 364A



FIG. 364B

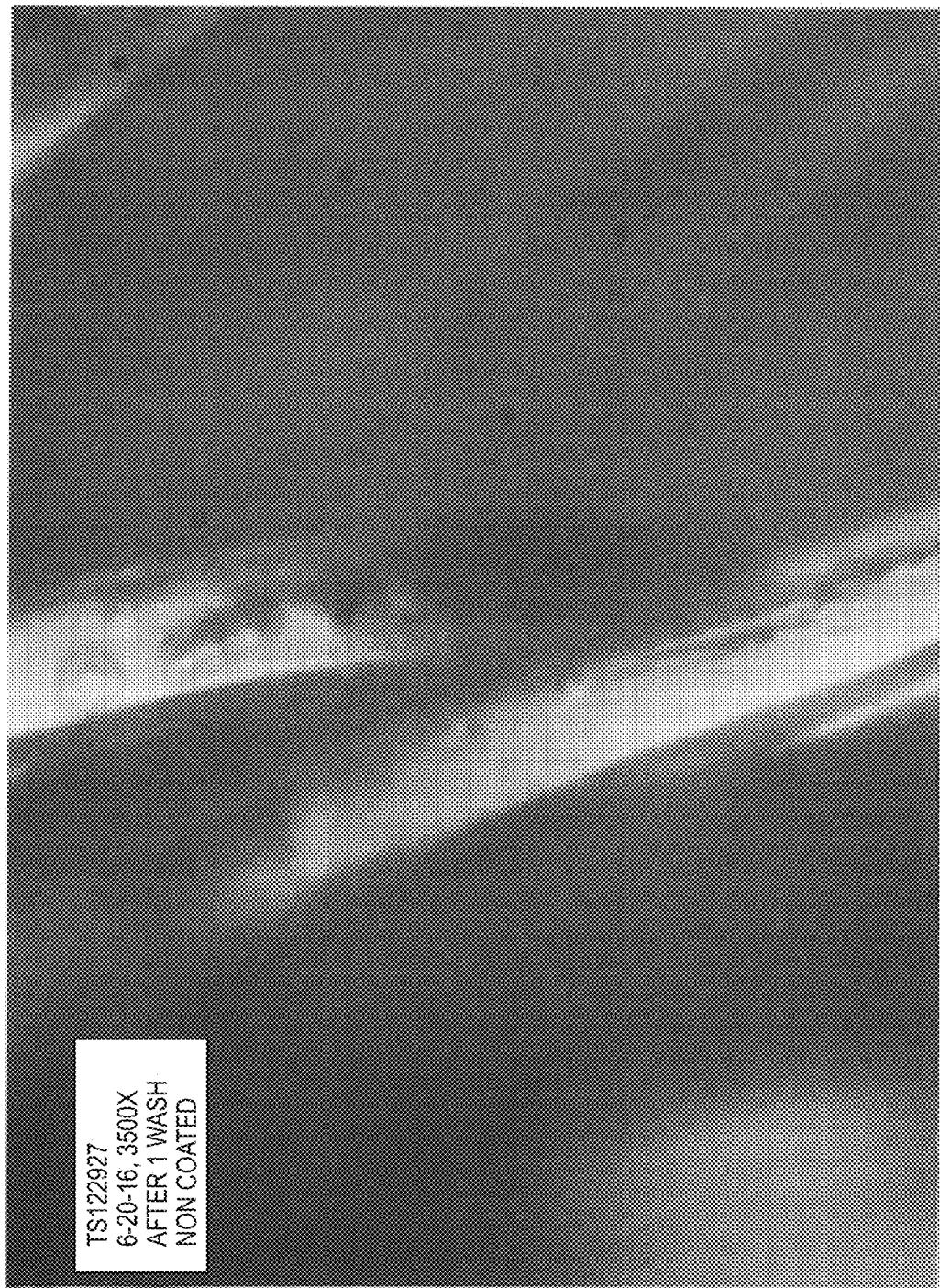


FIG. 364C

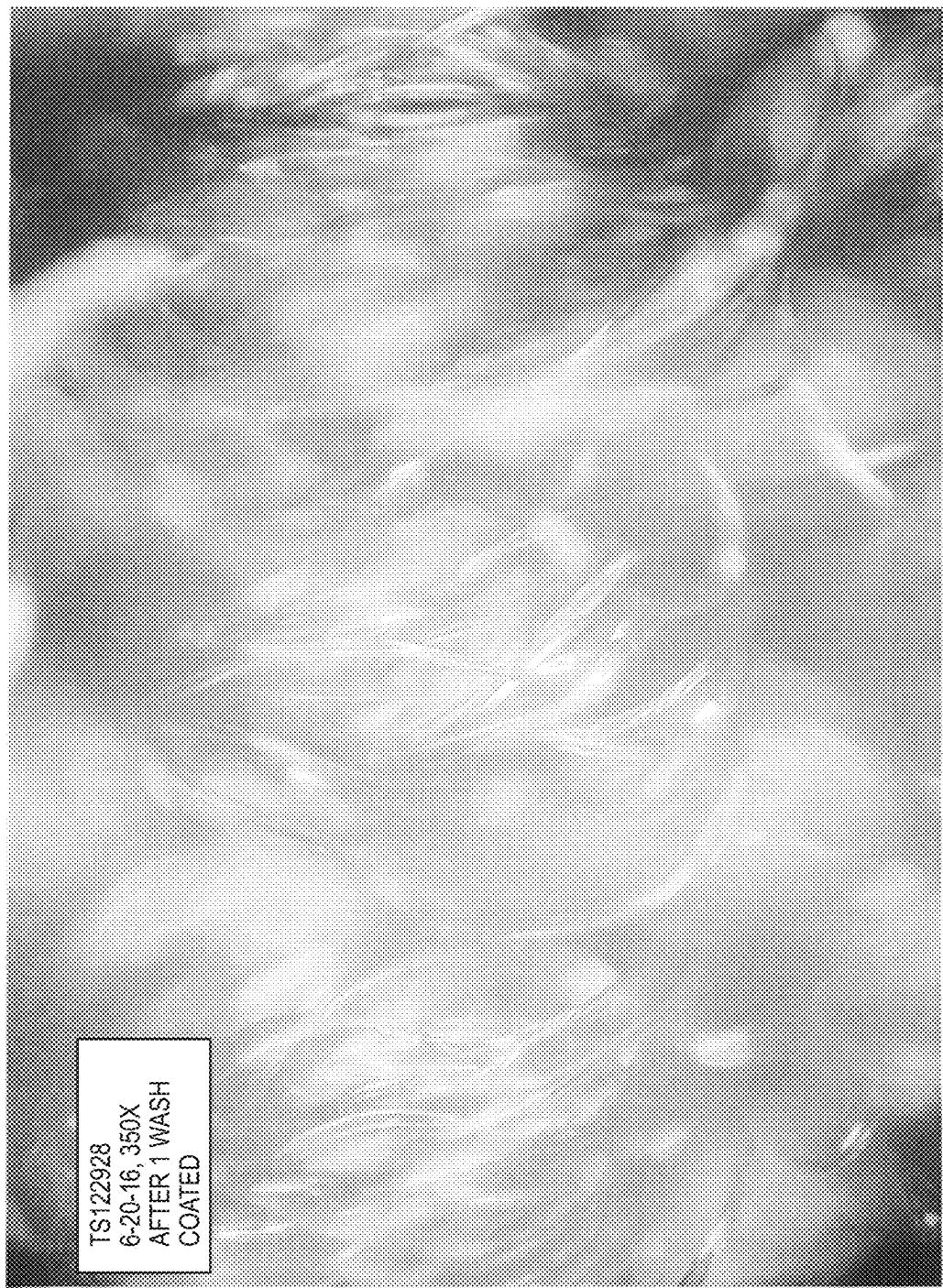


FIG. 365A

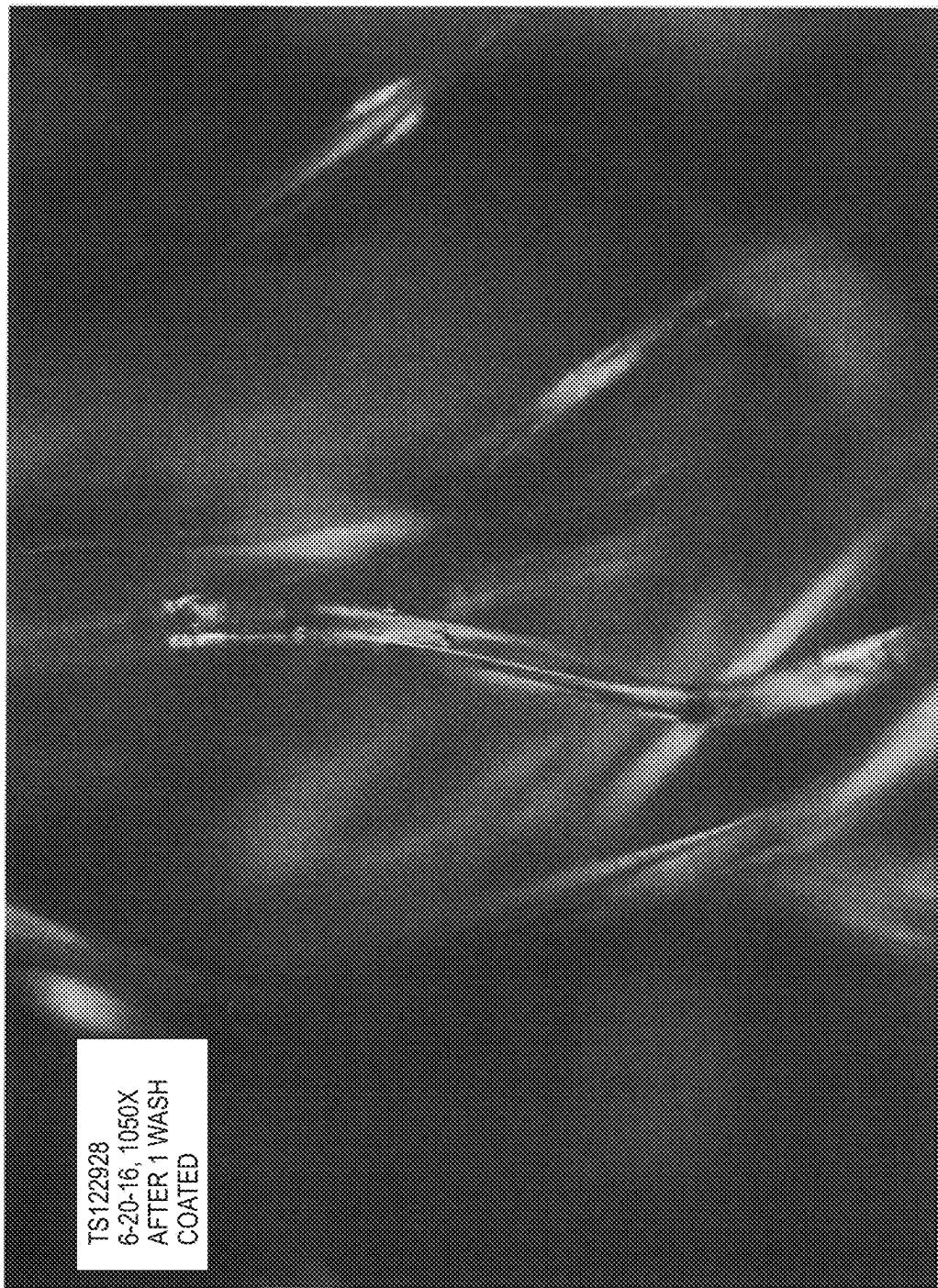


FIG. 365B

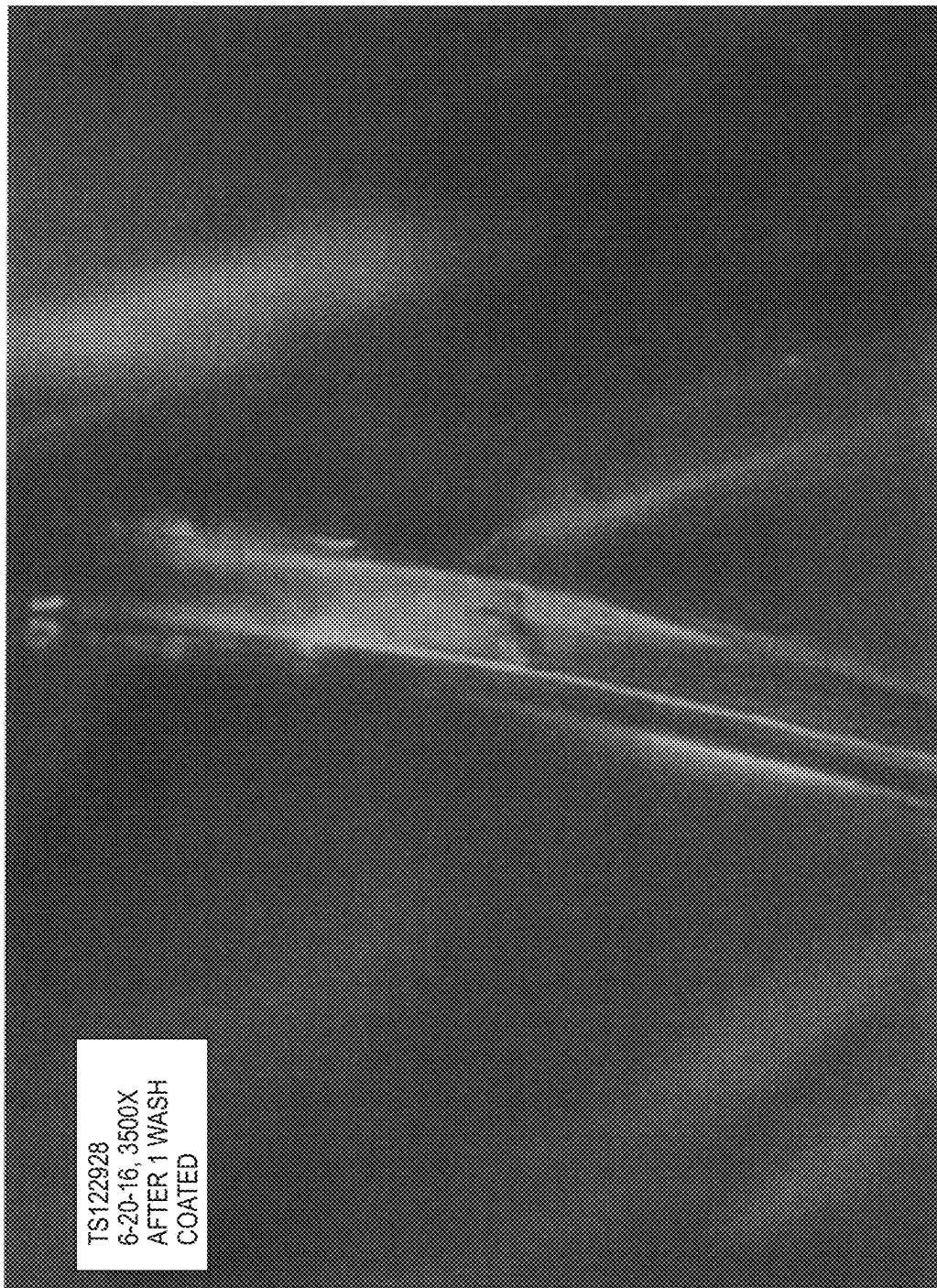


FIG. 365C

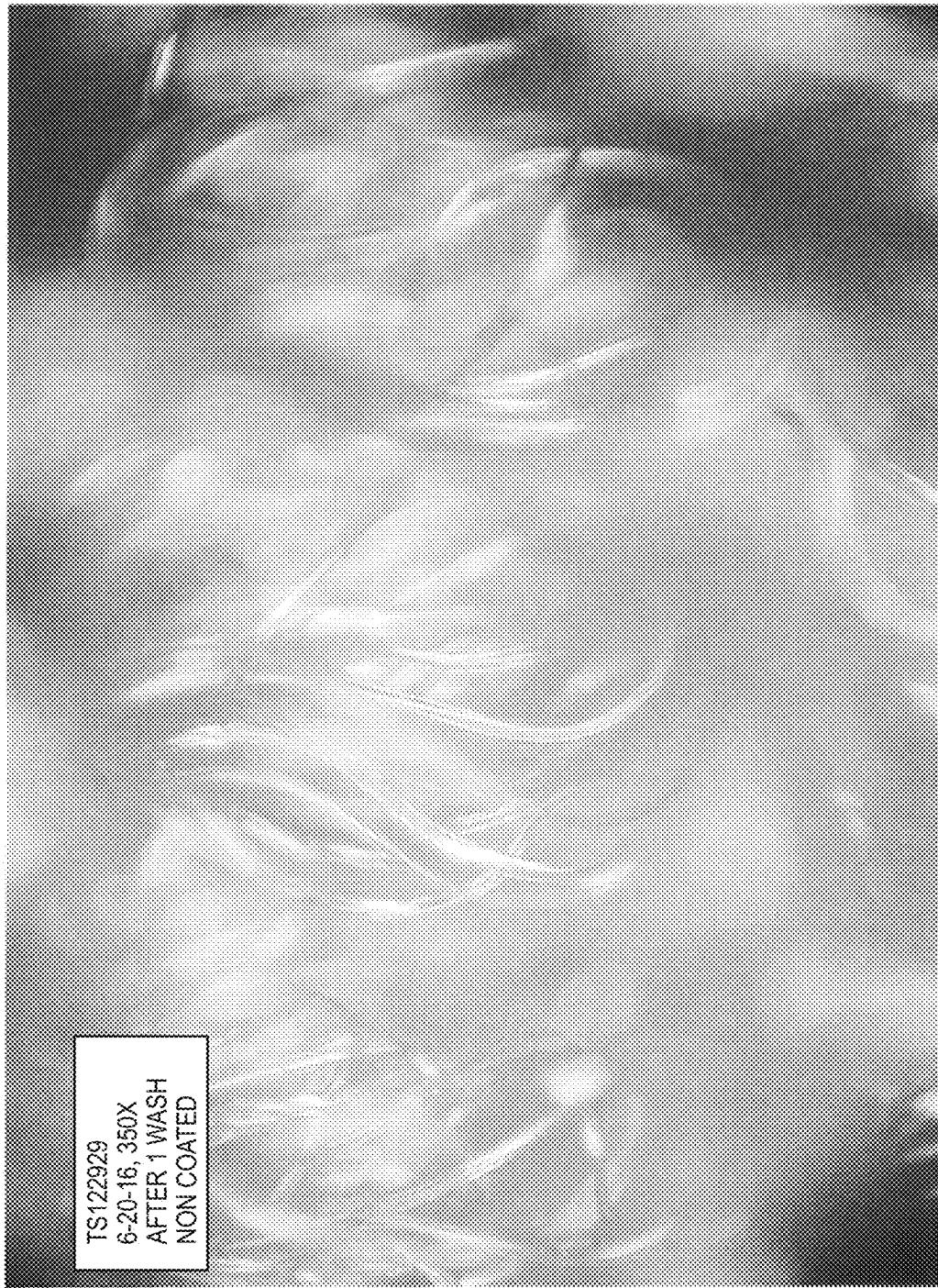


FIG. 366A

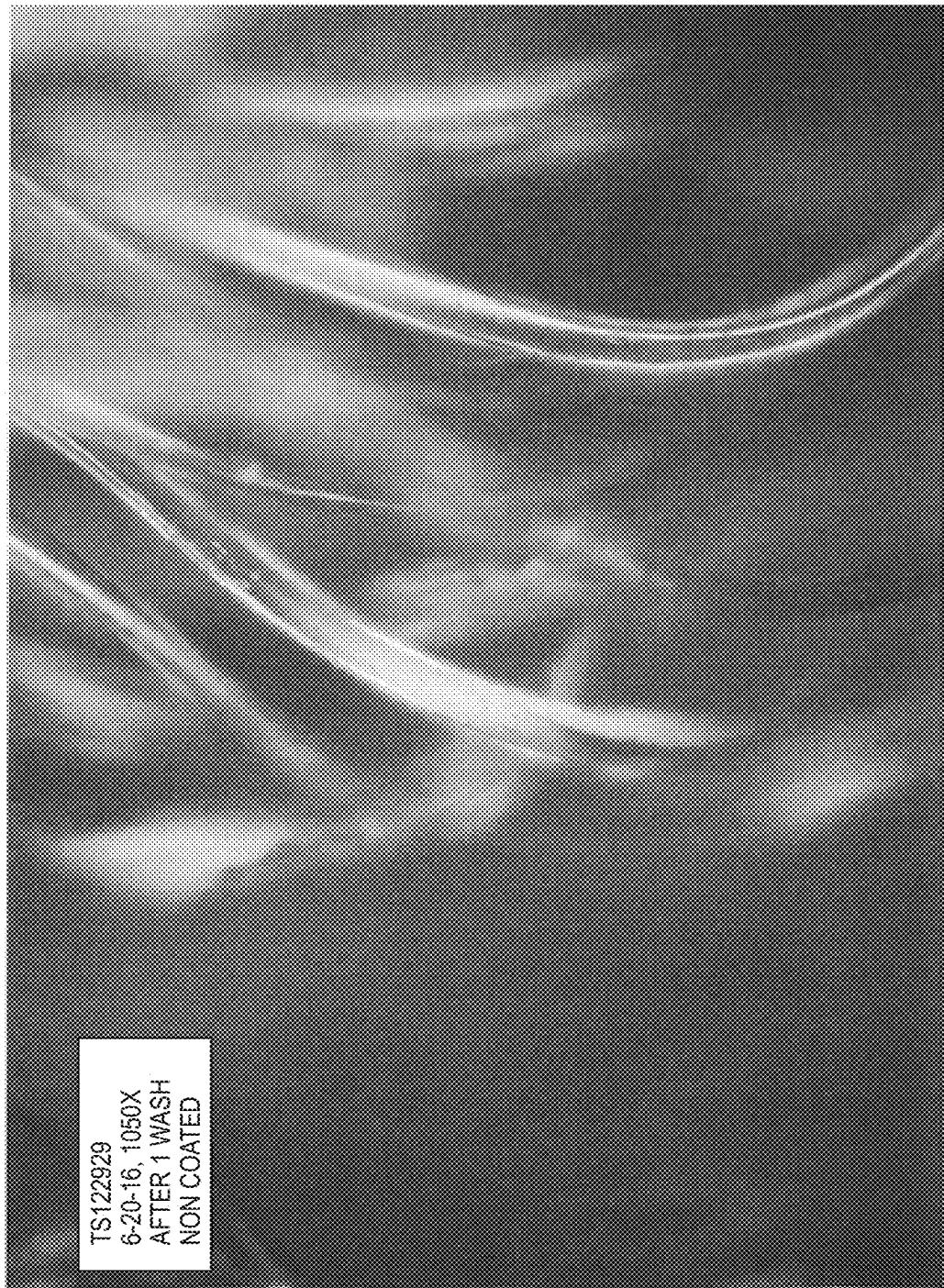


FIG. 366B

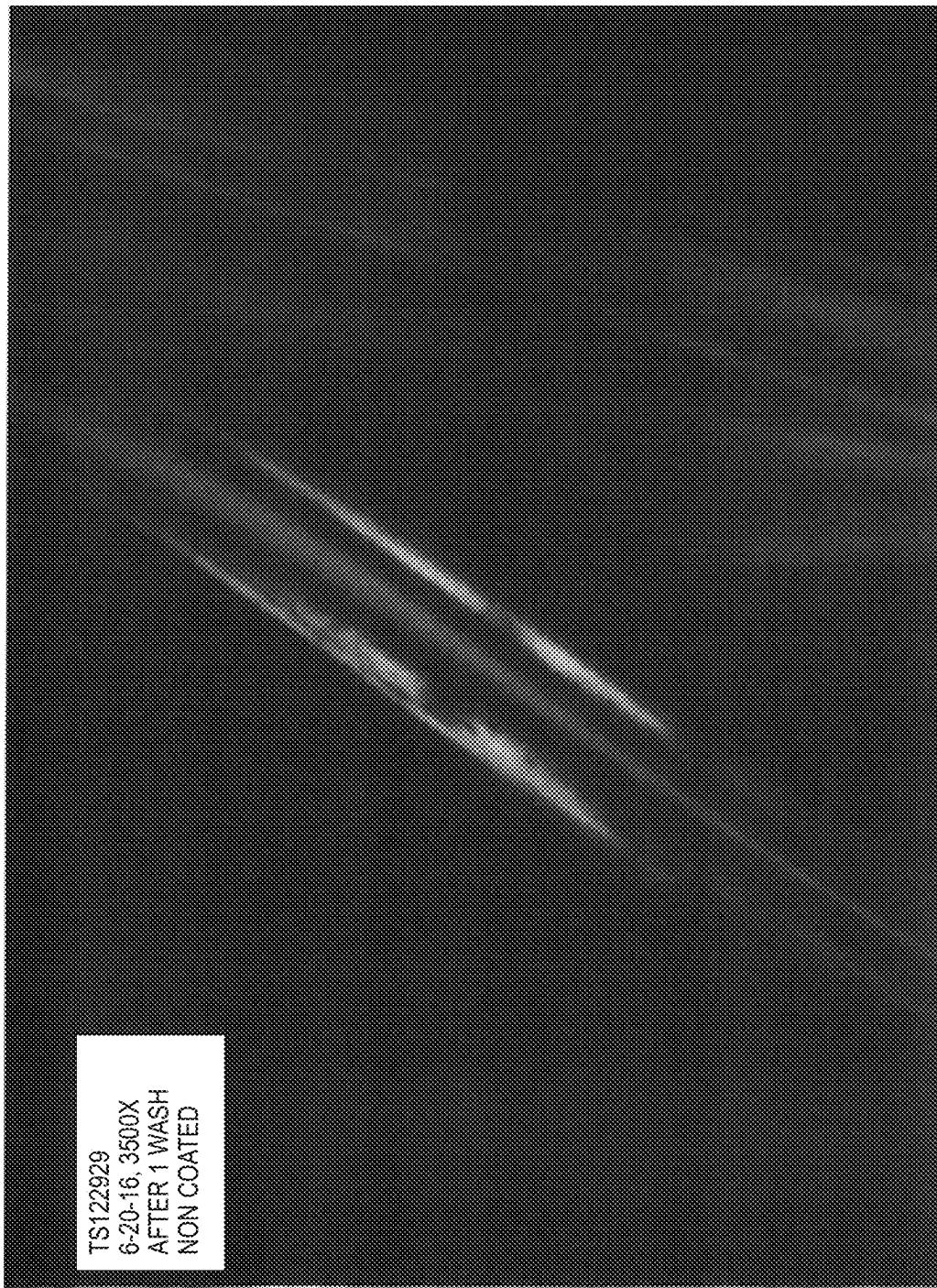


FIG. 366C

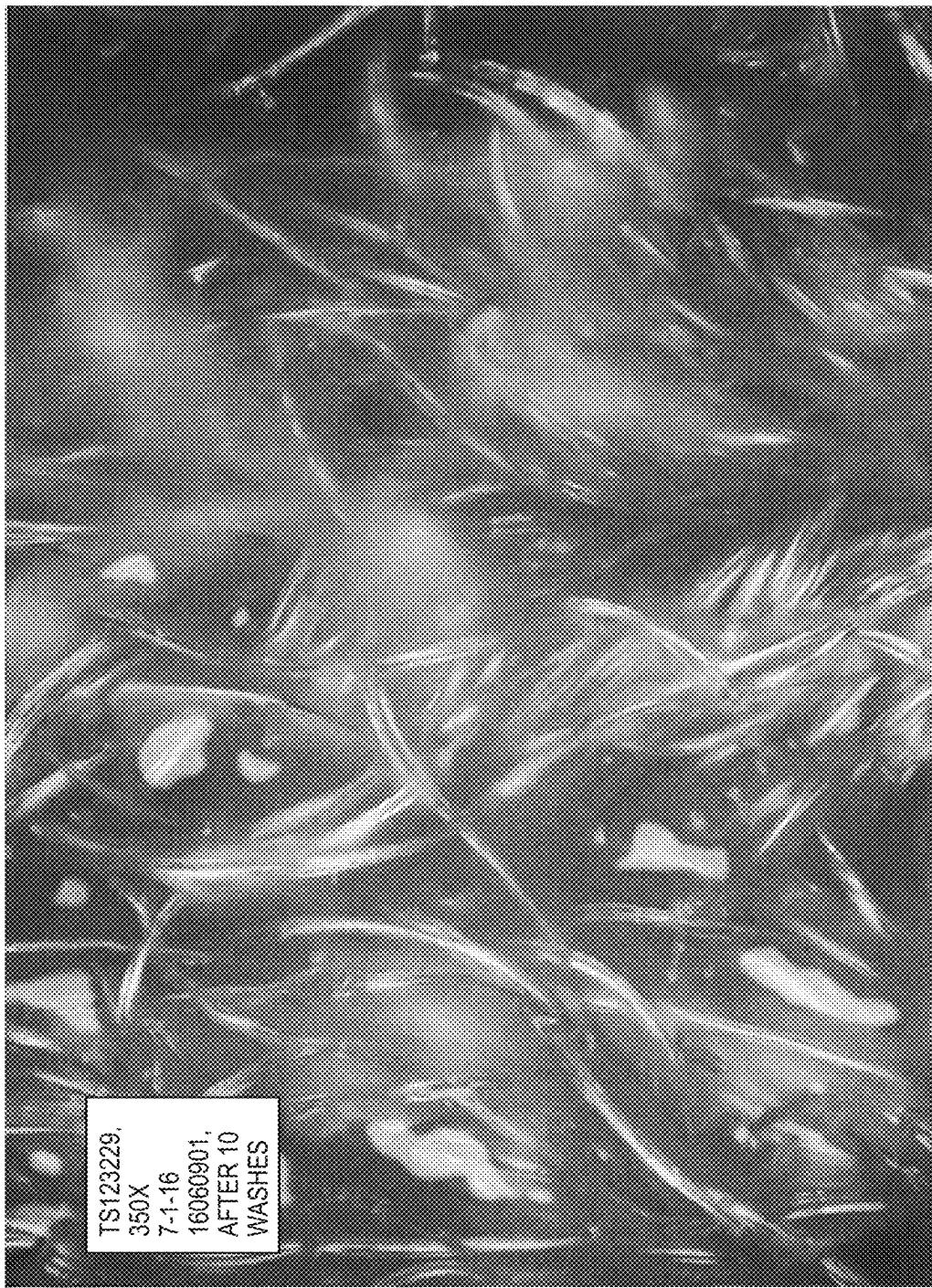


FIG. 367A



FIG. 367B

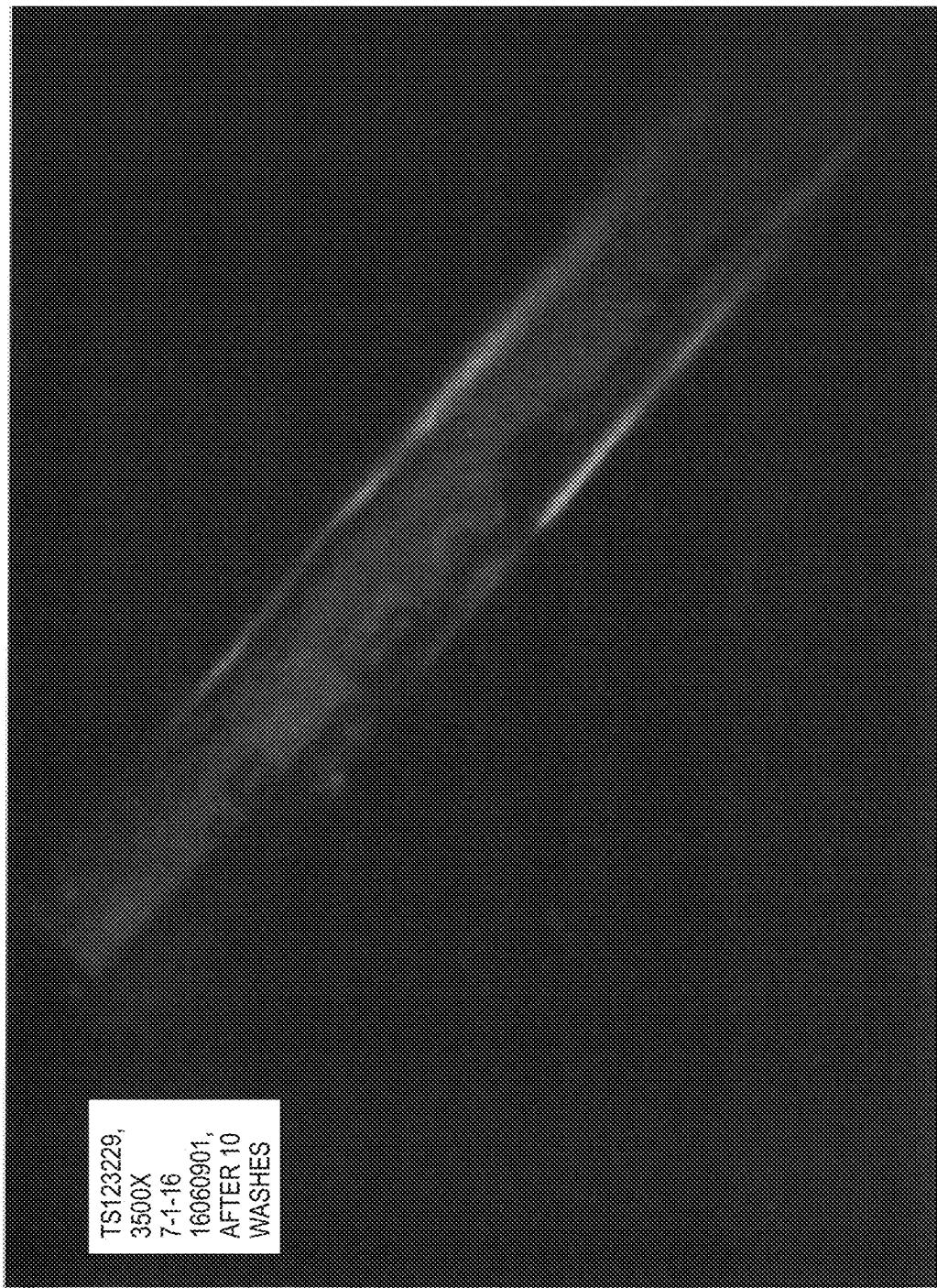
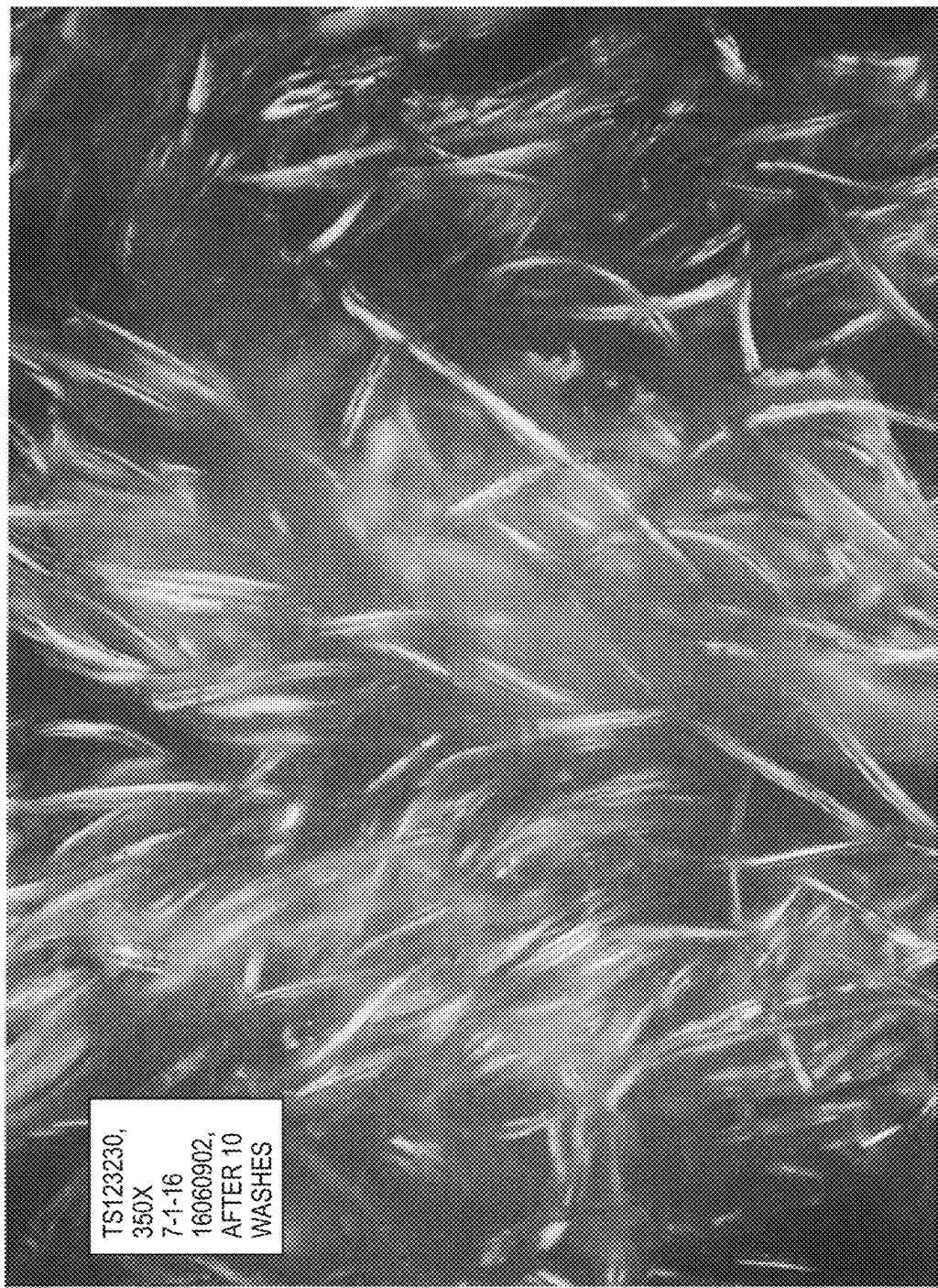


FIG. 367C



TS123230,
350X
7-1-16
16060902,
AFTER 10
WASHES

FIG. 368A

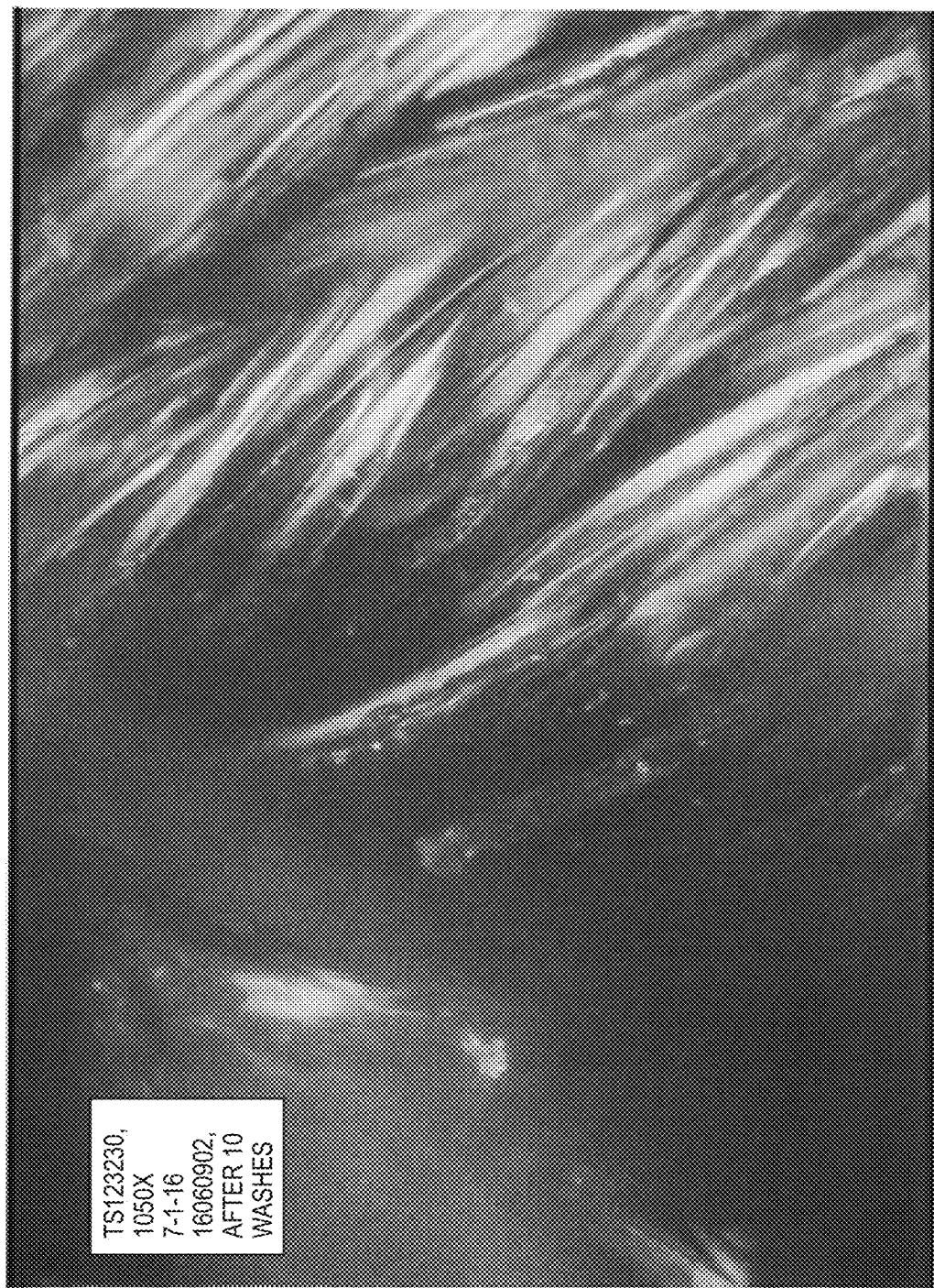


FIG. 368B



FIG. 368C

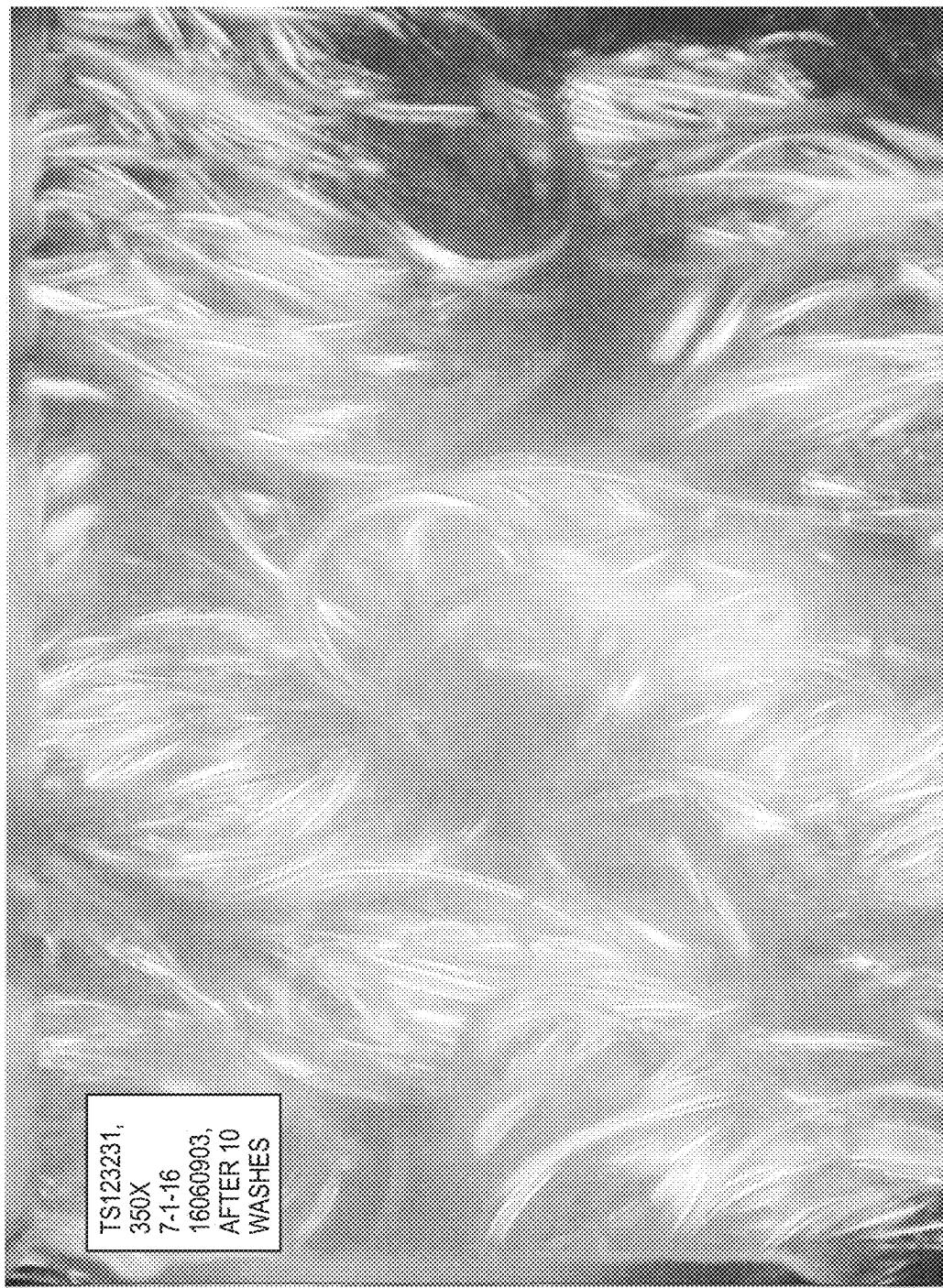


FIG. 369A



FIG. 369B

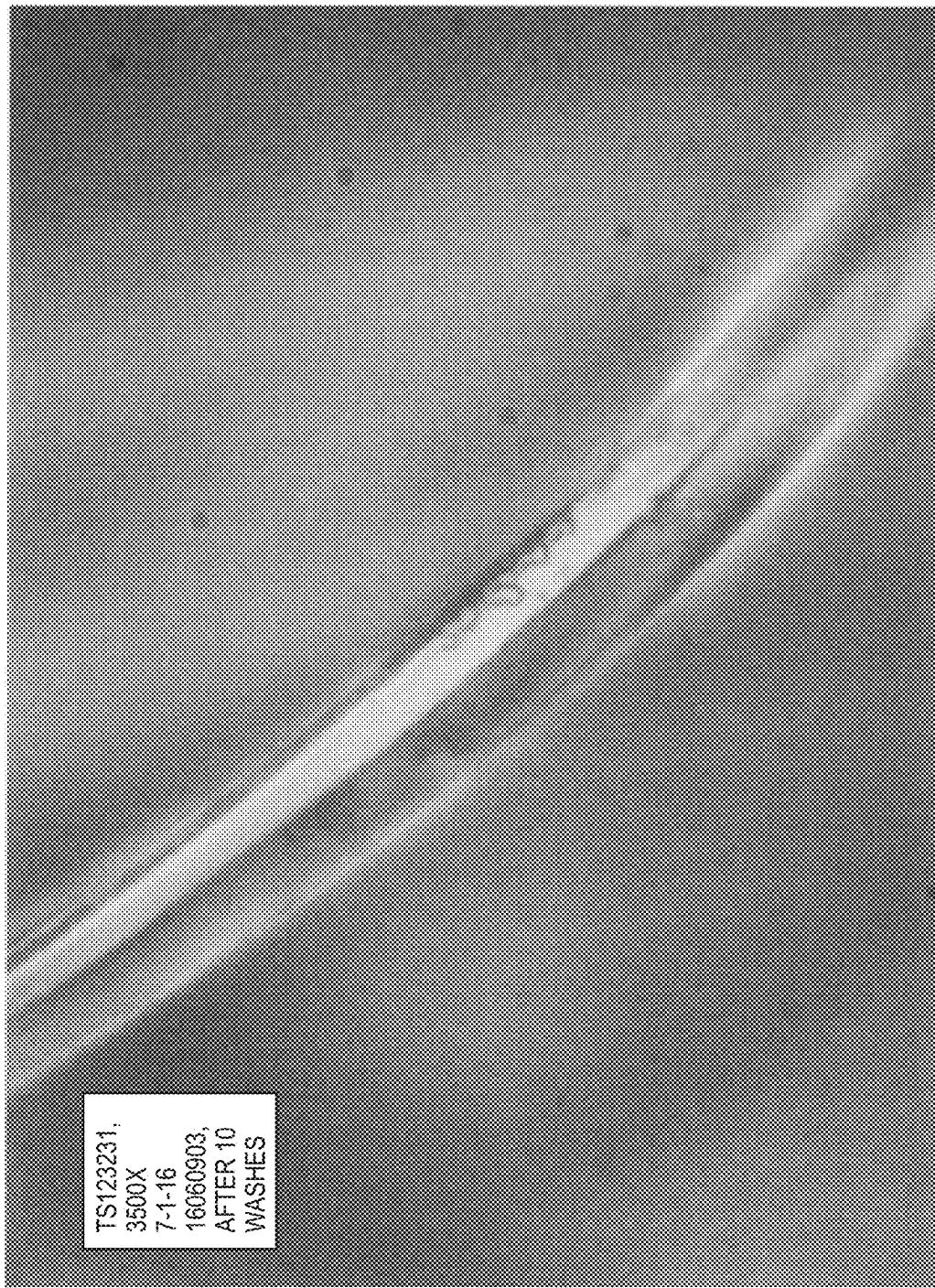


FIG. 369C

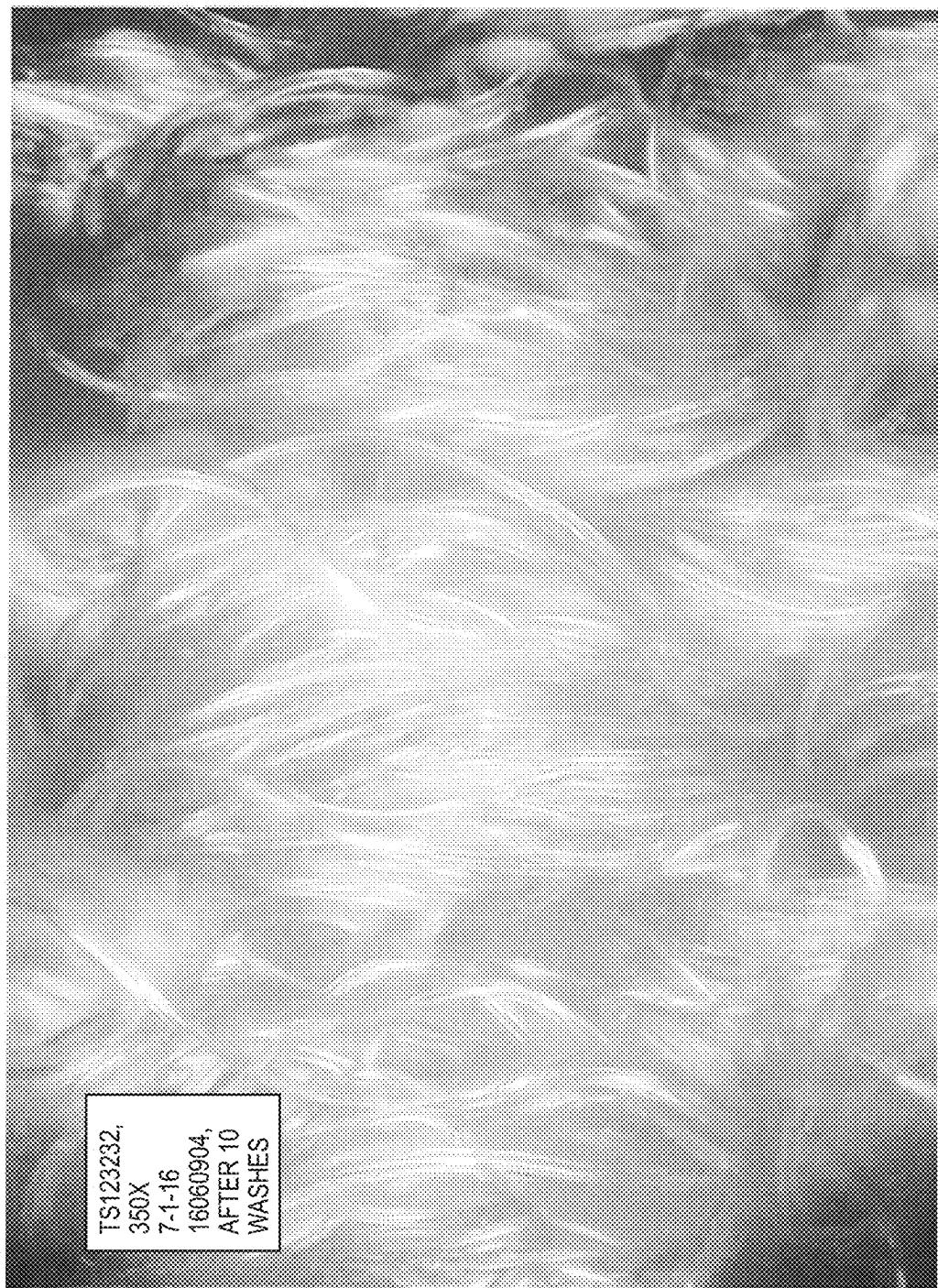


FIG. 370A



FIG. 370B

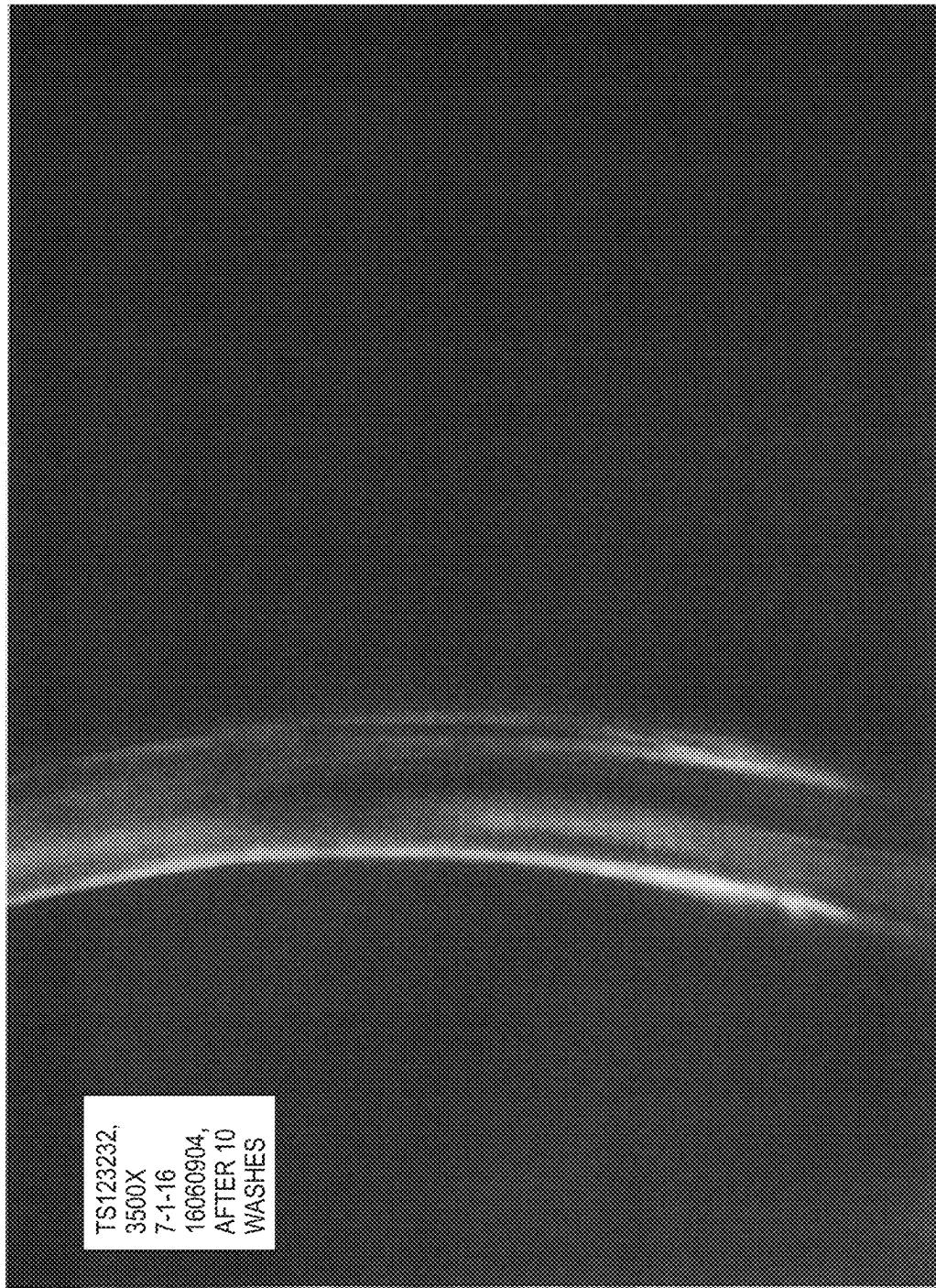


FIG. 370C

Description (% Foreign matter coverage area)	Score
< 5%	0
>5% - <25%	1
>25% - <50%	2
>50% - <75%	3
>75% - <100%	4
	5

Figure #	Magnification	Score	Sample #	Coated	Inoculation	Wash Cycle
359A	350X	1	16060901	no	yes	0
359B	1050X	1	16060901	no	yes	0
359C	3500X	1	16060902	no	no	0
360A	350X	1	16060902	no	no	0
360B	1050X	1	16060903	yes	yes	0
360C	350X	1	16060903	yes	yes	0
361A	350X	1	16060904	yes	no	0
361B	1050X	1	16060904	yes	no	0
361C	3500X	1	16060904	yes	no	0
362A	350X	1	16060904	yes	no	0
362B	1050X	1	16060904	yes	no	0
362C	350X	1	16060904	yes	no	0
363A	350X	1	16060901	no	yes	1
363B	1050X	1	16060901	no	yes	1
363C	3500X	1	16060902	no	yes	1
364A	350X	1	16060902	no	yes	1
364B	1050X	1	16060903	yes	yes	1
364C	3500X	1	16060903	yes	yes	1
365A	350X	1	16060903	yes	yes	1
365B	1050X	1	16060903	yes	yes	1
365C	3500X	1	16060904	yes	no	1
366A	350X	1	16060904	yes	no	1
366B	1050X	1	16060904	yes	no	1
366C	3500X	1	16060904	yes	no	1
367A	350X	1	16060901	no	yes	10
367B	1050X	1	16060901	no	yes	10
367C	3500X	1	16060902	no	yes	10
368A	350X	1	16060902	no	yes	10
368B	1050X	1	16060903	yes	yes	10
368C	3500X	1	16060903	yes	yes	10
369A	350X	1	16060903	yes	yes	10
369B	1050X	1	16060904	yes	no	10
369C	3500X	1	16060904	yes	no	10
370A	350X	1	16060904	yes	no	10
370B	1050X	1	16060904	yes	no	10
370C	3500X	1				

FIG. 371

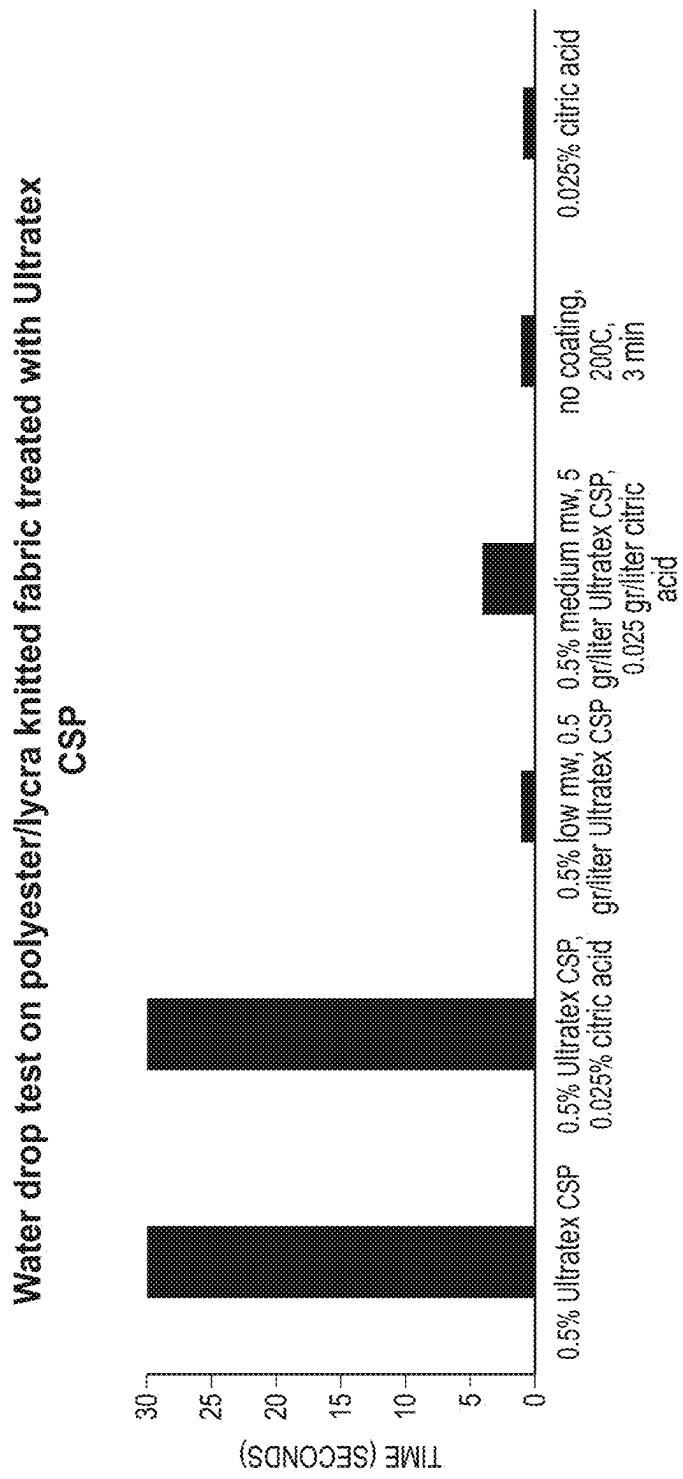


FIG. 372

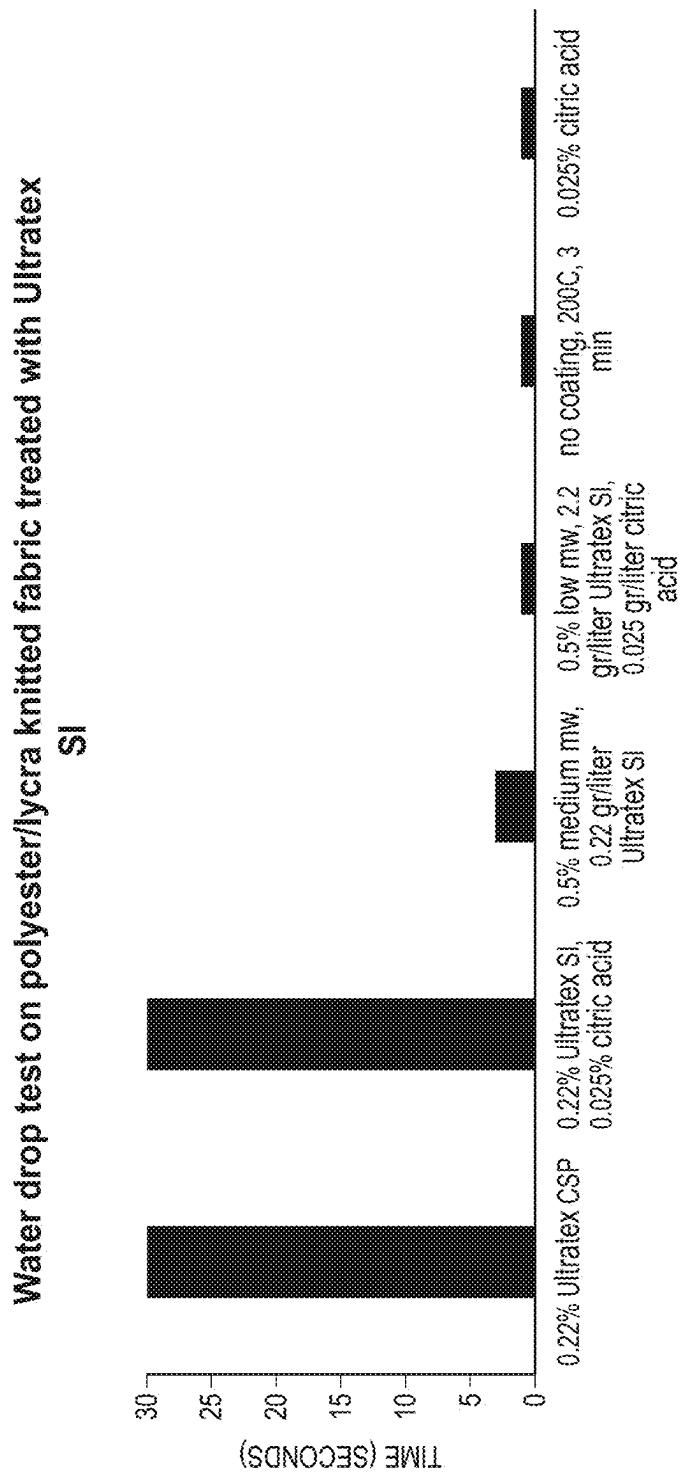


FIG. 373

Water drop test on polyester/lycra knitted fabric treated with RODI and tap water

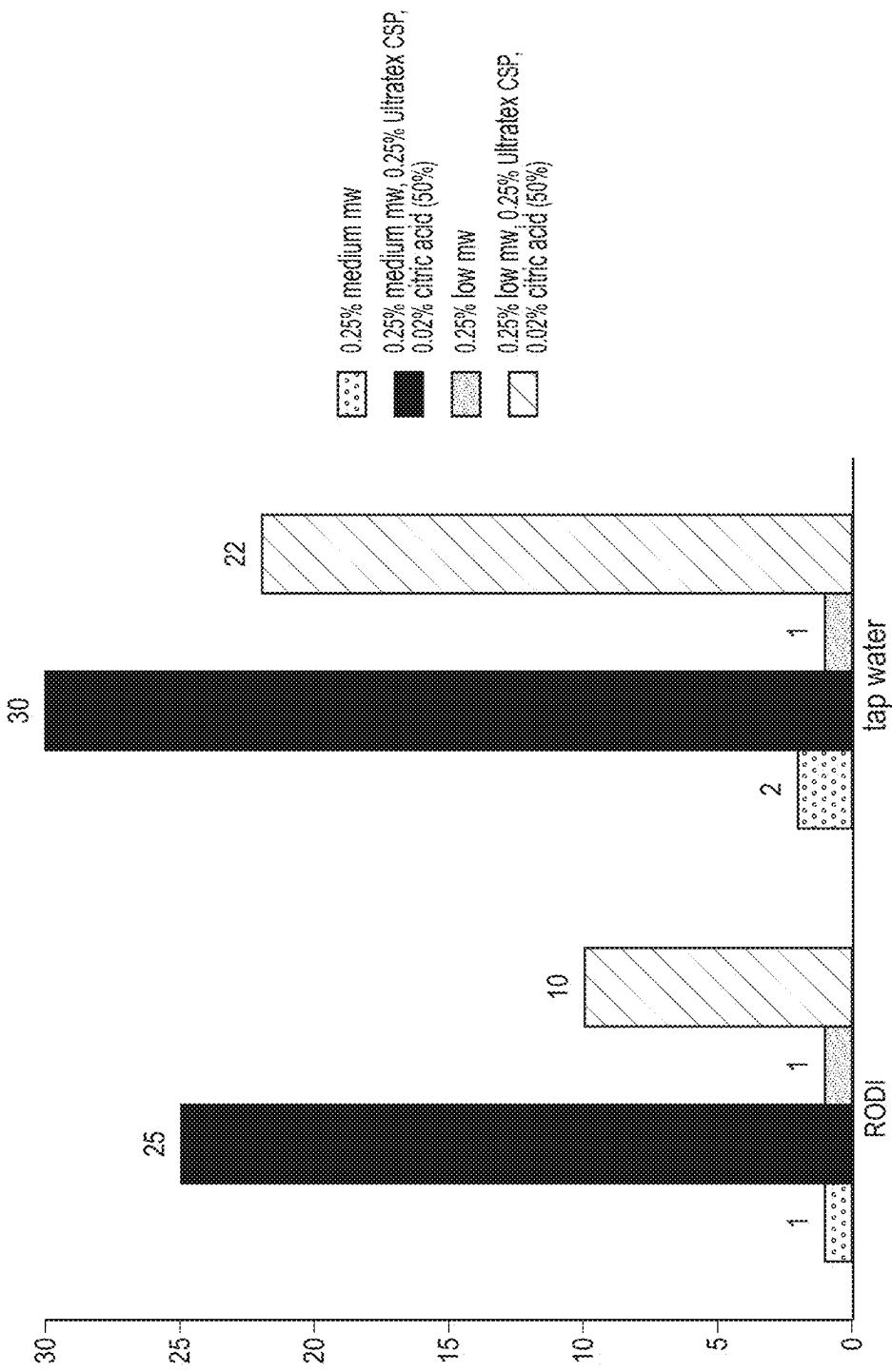


FIG. 374

**SILK PERFORMANCE APPAREL AND
PRODUCTS AND METHODS OF PREPARING
THE SAME**

**CROSS-REFERENCE TO RELATED
APPLICATIONS**

This Application is a continuation of U.S. application Ser. No. 15/744,566 filed Jan. 12, 2018, which is a 371 of PCT/US2016/042316 filed Jul. 7, 2016, which is a continuation-in-part of International Patent Application No. PCT/US2015/063545, filed Dec. 2, 2015, and further claims the benefit of U.S. Provisional Application No. 62/344,273, filed Jun. 1, 2016, and U.S. Provisional Application No. 62/297,929, filed Feb. 21, 2016, and U.S. Provisional Application No. 62/245,221, filed Oct. 22, 2015, and U.S. Provisional Application No. 62/192,477, filed Jul. 14, 2015. The contents of each of these applications are incorporated herein by reference in their entireties.

FIELD OF THE INVENTION

In some embodiments, the invention relates to silk-coated performance apparel and products for use in home and automotive applications, such as fabrics or leather coated with pure silk fibroin-based proteins or protein fragments thereof.

BACKGROUND OF THE INVENTION

Silk is a natural polymer produced by a variety of insects and spiders, and comprises a filament core protein, silk fibroin, and a glue-like coating consisting of a non-filamentous protein, sericin. Silk fibers are light weight, breathable, and hypoallergenic. Silk is comfortable when worn next to the skin and insulates very well; keeping the wearer warm in cold temperatures and is cooler than many other fabrics in warm temperatures.

SUMMARY OF THE INVENTION

Silk performance apparel and methods of preparing the same are disclosed herein. According to aspects illustrated herein, the present disclosure relates to a product, including, but not limited to, apparel, padding, shoes, gloves, luggage, furs, jewelry and bags, configured to be worn or carried on the body, that is at least partially surface treated with a solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating on the product. In some embodiments, the solutions of silk fibroin-based proteins or fragments thereof may be aqueous solutions, organic solutions, or emulsions. In an embodiment, the product is manufactured from a textile material. In an embodiment, the product is manufactured from a non-textile material. In an embodiment, desired additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating having desired additives.

In an embodiment, a method is provided for coating a material with silk fibroin that may include silk-based proteins or fragments thereof to provide a silk fibroin coated material, wherein the silk fibroin coated upon the silk fibroin coated material may be heat resistant to a selected temperature. In some embodiments, the method may include preparing a silk fibroin solution that may include a concentration of one or more of low molecular weight silk fibroin, medium molecular weight silk fibroin, and high molecular

weight silk fibroin at less than about 1% by volume (v/v), or less than about 0.1% by volume (v/v), or less than about 0.01% by volume (v/v), or less than about 0.001% by volume (v/v). In some embodiments, the method may include, coating a surface of the material with the silk fibroin solution. In some embodiments, the method may include drying the surface of the material that has been coated with the silk fibroin solution to provide the silk fibroin coated material, wherein drying the surface of the material comprises heating the surface of the material without substantially decreasing silk fibroin coating performance.

In an embodiment, a method is provided for coating a textile with a silk fibroin solution that may include silk-based proteins or fragments thereof to provide a silk fibroin coated article, wherein the silk fibroin coated upon the silk fibroin coated article may be heat resistant to a selected temperature. In some embodiments, the method may include preparing the silk fibroin solution with one or more of low molecular weight silk fibroin, medium molecular weight silk fibroin, and high molecular weight silk fibroin. In some embodiments, the method may include acidically adjusting the pH of the silk fibroin solution with an acidic agent. In some embodiments, the method may include coating a surface of the textile with the silk fibroin solution. In some embodiments, the method may include drying the surface of the textile that has been coated with the silk fibroin solution to provide the silk fibroin coated article, wherein drying the surface of the textile comprises heating the surface of the textile without substantially decreasing silk fibroin coating performance.

In some embodiments, a method is provided for manufacturing a silk fibroin coated textile that may include selected fabric properties. In some embodiments, the method may include admixing silk-based proteins or fragments thereof with one or more chemical agents to provide a coating solution, wherein the one or more chemical agents may be selected to modify one or more of a first selected property and second selected property of the silk fibroin coated textile. In some embodiments, the method may include providing the coating solution to a textile to be coated with one or more of a bath coating process, a kiss rolling process, a spray process, and a two-sided rolling process. In some embodiments, the method may include removing excess coating solution from the silk fibroin coated textile. In some embodiments, the method may include heating the silk fibroin coated textile to modify a third selected property of the silk fibroin coated textile. In some embodiments, the first selected property may include one or more of an antimicrobial property, a water repellent property, an oil repellent property, a flame retardant property, a coloring property, a fabric softening property, a stain repellent property, a pH adjusting property, an anticrocking property, an antipilling property, and an antifelting property. In some embodiments, the second selected property may include one or more of wetting time, absorption rate, spreading speed, accumulative one-way transport, and overall moisture management capability. In some embodiments, the third selected property may include one or more of fabric hand, fabric stretch, and drapability.

In an embodiment, the silk fibroin coated materials of the invention may be coated with one or more of low molecular weight silk, medium molecular weight silk, and high molecular weight silk to provide resulting coated materials having enhanced hydrophobic or hydrophilic properties.

In an embodiment, materials coated by silk fibroin coatings described herein may include one or more of

textiles, woven materials, non-woven materials, knit materials, crochet materials, and leather materials.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having an average number of amino acid residues of about 1 to 400 residues, or 1 to 300 residues, or 1 to 200 residues, or 1 to 100 residues, or 1 to 50 residues, or 5 to 25 residues, or 10 to 20 residues.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the article is a fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits an improved property, wherein the improved property is an accumulative one-way moisture transport index selected from the group consisting of greater than 40%, greater than 60%, greater than 80%, greater than 100%, greater than 120%, greater than 140%, greater than 160%, and greater than 180%. In an embodiment, the foregoing improved property is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof

having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits an improved property, wherein the improved property is an accumulative one way transport capability increase relative to uncoated fabric selected from the group consisting of 1.2 fold, 1.5 fold, 2.0 fold, 3.0 fold, 4.0 fold, 5.0 fold, and 10 fold. In an embodiment, the foregoing improved property is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits an improved property, wherein the improved property is an overall moisture management capability selected from the group consisting of greater than 0.05, greater than 0.10, greater than 0.15, greater than 0.20, greater than 0.25, greater than 0.30, greater than 0.35, greater than 0.40, greater than 0.50, greater than 0.60, greater than 0.70, and greater than 0.80. In an embodiment, the foregoing improved property is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric exhibits substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles, and wherein the microbial growth is microbial growth of a microbe selected from the group consisting of *Staphylococcus aureus*, *Klebsiella pneumoniae*, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles, wherein the microbial growth is microbial growth of a microbe selected from the group consisting of *Staphylococcus aureus*, *Klebsiella pneumoniae*, and combinations thereof, wherein the microbial growth is reduced by a percentage selected from the group consisting of 50%, 100%, 500%, 1000%, 2000%, and 3000% compared to an uncoated fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5

kDa to about 144 kDa, wherein the article is a fabric, and wherein the coating is applied to the fabric at the fiber level prior to forming the fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the coating is applied to the fabric at the fabric level.

10 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the coating is applied to the fabric at the fabric level, and wherein the fabric is bath coated.

15 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the fabric is spray coated.

20 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the fabric is spray coated.

25 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the fabric is coated with a stencil.

30 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, wherein the coating is applied to at least one side of the fabric using a method selected from the group consisting of

35 a bath coating process, a spray coating process, a stencil process, a silk-foam based process, and a roller-based process.

40 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the coating has a thickness of about one nanolayer.

45 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the coating has a thickness selected from the group consisting of about 5 nm, about 10 nm, about 15 nm, about 20 nm, about 25 nm, about 50 nm, about 100 nm, about 200 nm, about 500 nm, about 1 μ m, about 5 μ m, about 10 μ m, and about 20 μ m.

55 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the coating is adsorbed on the fabric.

60 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and

wherein the coating is attached to the fabric through chemical, enzymatic, thermal, or irradiative cross-linking.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the hand of the coated fabric is improved relative to an uncoated fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the hand of the coated fabric is improved relative to an uncoated fabric, wherein the hand of the coated fabric that is improved is selected from the group consisting of softness, crispness, dryness, silkiness, and combinations thereof.

According to aspects illustrated herein, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is available for application to a product, including, but not limited to, apparel, padding, shoes, gloves, luggage, furs, jewelry and bags, or for directly spraying on the body of a consumer, to impart desired properties to the product. In an embodiment, the product is manufactured from a textile material. In an embodiment, the product is manufactured from a non-textile material. In an embodiment, desired additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating having desired additives.

In an embodiment, a textile comprising a silk coating of the present disclosure is sold to a consumer. In an embodiment, a textile of the present disclosure is used in constructing action sportswear apparel. In an embodiment, a textile of the present disclosure is used in constructing fitness apparel. In an embodiment, a textile of the present disclosure is used in constructing performance apparel. In an embodiment, a textile of the present disclosure is used in constructing golf apparel. In an embodiment, a textile of the present disclosure is used in constructing lingerie. In an embodiment, a silk coating of the present disclosure is positioned on the underlining of action sportswear/apparel. In an embodiment, a silk coating of the present disclosure is positioned on the shell, the lining, or the interlining of action sportswear/apparel. In an embodiment, action sportswear/apparel is partially made from a silk coated textile of the present disclosure and partially made from an uncoated textile. In an embodiment, action sportswear/apparel partially made from a silk coated textile and partially made from an uncoated textile combines an uncoated inert synthetic material with a silk coated inert synthetic material. Examples of inert synthetic material include, but are not limited to, polyester, polyamide, polyaramid, polytetrafluoroethylene, polyethylene, polypropylene, polyurethane, silicone, mixtures of polyurethane and polyethylenglycol, ultrahigh molecular weight polyethylene, high-performance polyethylene, nylon, LYCRA (polyester-polyurethane copolymer, also known as SPANDEX and elastomer), and mixtures thereof. In an embodiment, action sportswear/apparel partially made from a silk coated textile and partially made from an uncoated textile combines an elastomeric material at least partially covered with a silk coating of the present disclosure. In an embodiment, the percentage of silk to elastomeric material can be varied to

achieve desired shrink or wrinkle resistant properties and desired moisture content against the skin surface. In an embodiment, a silk coating of the present disclosure is positioned on an internal layer of a shoe (textile or non-textile based). In an embodiment, a silk coating of the present disclosure positioned on an internal layer of a shoe helps maintain optimal feet microenvironment, such as temperature and humidity while reducing any excessive perspiration.

10 In an embodiment, a silk coating of the present disclosure is visible. In an embodiment, a silk coating of the present disclosure is transparent. In an embodiment, a silk coating of the present disclosure positioned on action sportswear/apparel helps control skin temperature of a person wearing the apparel. In an embodiment, a silk coating of the present disclosure positioned on action sportswear/apparel helps control fluid transfer away from the skin of a person wearing the apparel. In an embodiment, a silk coating of the present disclosure positioned on action sportswear/apparel has a soft feel against the skin decreasing abrasions from fabric on the skin. In an embodiment, a silk coating of the present disclosure positioned on a textile has properties that confer at least one of wrinkle resistance, shrinkage resistance, or machine washability to the textile. In an embodiment, a silk coated textile of the present disclosure is 100% machine washable and dry cleanable. In an embodiment, a silk coated textile of the present disclosure is 100% waterproof. In an embodiment, a silk coated textile of the present disclosure is wrinkle resistant. In an embodiment, a silk coated textile of the present disclosure is shrink resistant. In an embodiment, a silk coated fabric improves the health of the skin. In an embodiment, healthy skin can be determined by visibly seeing an even skin tone. In an embodiment, healthy skin can be determined by visibly seeing a smooth, glowing complexion. In an embodiment, a silk coated fabric decreases irritation of the skin. In an embodiment, a decrease in irritation of the skin can result in a decrease in skin bumps or sores. In an embodiment, a decrease in irritation of the skin can result in a decrease in scaly or red skin. In an embodiment, a decrease in irritation of the skin can result in a decrease in itchiness or burning. In an embodiment, a silk coated fabric decreases inflammation of the skin. In an embodiment, a silk coated textile of the present disclosure has the qualities of being waterproof, breathable, and elastic and possess a number of other qualities which are highly desirable in action sportswear. In an embodiment, a silk coated textile of the present disclosure manufactured from a silk fabric of the present disclosure further includes LYCRA brand spandex fibers (polyester-polyurethane copolymer).

15 In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a breathable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a water-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a shrink-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a machine-washable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a wrinkle resistant fabric. In an embodiment, textile at least partially coated

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hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% bacterial growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% bacterial growth over 24 hours.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 400% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% fungal growth over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% fungal growth over 24 hours.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 400% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% growth of *Staphylococcus aureus* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% growth of *Staphylococcus aureus* over 24 hours.

In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 2000% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 1000% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 500% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein frag-

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ments of the present disclosure shows less than 400% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 300% growth of *Klebsiella pneumoniae* over 24 hours. In an embodiment, the textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure shows less than 200% growth of *Klebsiella pneumoniae* over 24 hours.

In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is used to coat a textile. In an embodiment, the concentration of silk in the solution ranges from about 0.001% to about 20.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.01% to about 15.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.5% to about 10.0%. In an embodiment, the concentration of silk in the solution ranges from about 1.0% to about 5.0%. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is applied directly to a fabric. Alternatively, silk microsphere and any additives may be used for coating a fabric. In an embodiment, additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure before coating (e.g., alcohols) to further enhance material properties. In an embodiment, a silk coating of the present disclosure can have a pattern to optimize properties of the silk on the fabric. In an embodiment, a coating is applied to a fabric under tension and/or lax to vary penetration in to the fabric.

In an embodiment, a silk coating of the present disclosure can be applied at the yarn level, followed by creation of a fabric once the yarn is coated. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure can be spun into fibers to make a silk fabric and/or silk fabric blend with other materials known in the apparel industry.

In an embodiment, a method for silk coating a fabric includes immersion of the fabric in any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure. In an embodiment, a method for silk coating a fabric includes spraying. In an embodiment, a method for silk coating a fabric includes chemical vapor deposition. In an embodiment, a method for silk coating a fabric includes electrochemical coating. In an embodiment, a method for silk coating a fabric includes knife coating to spread any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure onto the fabric. The coated fabric may then be air dried, dried under heat/air flow, or cross-linked to the fabric surface. In an embodiment, a drying process includes curing with additives and/or ambient condition.

According to aspects illustrated herein, methods for preparing aqueous solutions of pure silk fibroin-based protein fragments are disclosed. In an embodiment, at least one pure silk fibroin-based protein fragment (SPF) mixture solution having a specific average weight average molecular weight (MW) range and polydispersity is created. In an embodiment, at least SPF mixture solution having a MW range between about 6 kDa and 16 kDa and a polydispersity range between about 1.5 and about 3.0 is created. In an embodiment, at least one SPF mixture solution having a MW between about 17 kDa and 38 kDa and a polydispersity range between about 1.5 and about 3.0 is created. In an embodiment, at least one SPF mixture solution having a

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MW range between about 39 kDa and 80 kDa and a polydispersity range between about 1.5 and about 3.0 is created.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.01 wt % to about 30.0 wt % pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, anti-oxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosaminoglycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, poly-anhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially

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homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.01 wt % to about 30.0 wt % pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, anti-oxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosaminoglycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, poly-anhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic.

According to aspects illustrated herein, there is disclosed a composition that includes pure silk fibroin-based protein fragments that are substantially devoid of sericin, wherein the composition has an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, wherein the composition has a polydispersity of between about 1.5 and about 3.0, wherein the composition is substantially homogenous, wherein the composition includes between 0 ppm and about 500 ppm of inorganic residuals, and wherein the composition includes between 0 ppm and about 500 ppm of organic residuals. In an embodiment, the pure silk fibroin-based protein fragments have between about 10 ppm and about 300 ppm of lithium bromide residuals and between about 10 ppm and about 100 ppm of sodium carbonate residuals. In an embodiment, the lithium bromide residuals are measurable using a high-performance liquid chromatography lithium bromide assay, and the sodium carbonate

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residuals are measurable using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the composition further includes less than 10% water. In an embodiment, the composition is in the form of a solution. In an embodiment, the composition includes from about 0.01 wt % to about 30.0 wt % pure silk fibroin-based protein fragments. The pure silk fibroin-based protein fragments are stable in the solution for at least 30 days. In an embodiment, the term "stable" refers to the absence of spontaneous or gradual gelation, with no visible change in the color or turbidity of the solution. In an embodiment, the term "stable" refers to no aggregation of fragments and therefore no increase in molecular weight over time. In an embodiment, the composition is in the form of an aqueous solution. In an embodiment, the composition is in the form of an organic solution. The composition may be provided in a sealed container. In some embodiments, the composition further includes one or more molecules selected from the group consisting of therapeutic agents, growth factors, anti-oxidants, proteins, vitamins, carbohydrates, polymers, nucleic acids, salts, acids, bases, biomolecules, glycosaminoglycans, polysaccharides, extracellular matrix molecules, metals, metal ion, metal oxide, synthetic molecules, poly-anhydrides, cells, fatty acids, fragrance, minerals, plants, plant extracts, preservatives and essential oils. In an embodiment, the added molecule or molecules are stable (i.e., retain activity over time) within the composition and can be released at a desired rate. In an embodiment, the one or more molecules is vitamin C or a derivative thereof. In an embodiment, the composition further includes an alpha hydroxy acid selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the composition further includes hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0%. In an embodiment, the composition further includes at least one of zinc oxide or titanium dioxide. In an embodiment, the pure silk fibroin-based protein fragments in the composition are hypoallergenic. In an embodiment, the pure silk fibroin-based protein fragments are biocompatible, non-sensitizing, and non-immunogenic.

According to aspects illustrated herein, there is disclosed a gel that includes pure silk fibroin-based protein fragments substantially devoid of sericin and comprising: an average weight average molecular weight ranging from about 17 kDa to about 38 kDa; and a polydispersity of between about 1.5 and about 3.0; and water from about 20 wt. % to about 99.9 wt. %, wherein the gel includes between 0 ppm and 500 ppm of inorganic residuals, and wherein the gel includes between 0 ppm and 500 ppm of organic residuals. In an embodiment, the gel includes between about 1.0% and about 50.0% crystalline protein domains. In an embodiment, the gel includes from about 0.1 wt. % to about 6.0 wt. % of pure silk fibroin-based protein fragments. In an embodiment, the gel has a pH from about 1.0 to about 7.0. In an embodiment, the gel further includes from about 0.5 wt. % to about 20.0 wt. % of vitamin C or a derivative thereof. In an embodiment, the vitamin C or a derivative thereof remains stable within the gel for a period of from about 5 days to about 5 years. In an embodiment, the vitamin C or a derivative thereof is stable within the gel so as to result in release of the vitamin C in a biologically active form. In an embodiment, the gel further includes an additive selected from the group consisting of vitamin E, rosemary oil, rose oil, lemon juice, lemon grass oil and caffeine. In an embodiment, the gel is packaged in an airtight container. In an embodiment, the

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pure silk fibroin-based protein fragments are hypoallergenic. In an embodiment, the gel has less than 10 colony forming units per milliliter.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, the method including the steps of: degumming a silk source by adding the silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 60° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in an oven having a temperature of about 140° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of silk protein fragments, the aqueous solution comprising: fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, the method including the steps of: adding a silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the

solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, wherein the aqueous solution of silk protein fragments comprises sodium carbonate residuals of between about 10 ppm and about 100 ppm, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments.

According to aspects illustrated herein, there is disclosed a method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, the method including the steps of: adding a silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of about 30 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about

60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, sodium carbonate residuals of between about 10 ppm and about 100 ppm, fragments having an average weight average molecular weight ranging from about 40 kDa to about 65 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. In an embodiment, the method includes the step of drying the silk fibroin extract prior to the dissolving step. In an embodiment, the amount of lithium bromide residuals in the aqueous solution can be measured using a high-performance liquid chromatography lithium bromide assay. In an embodiment, the amount of sodium carbonate residuals in the aqueous solution can be measured using a high-performance liquid chromatography sodium carbonate assay. In an embodiment, the method includes the step of adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method includes the step of adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the vitamin is selected from one of vitamin C or a derivative thereof. In an embodiment, the method further includes the step of adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the alpha hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. In an embodiment, the method further includes the step of adding hyaluronic acid at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. In an embodiment, the method further includes the step of adding at least one of zinc oxide or titanium dioxide to the aqueous solution of pure silk fibroin-based protein fragments.

According to aspects illustrated herein, a method is disclosed for producing silk gels having entrapped molecules or therapeutic agents such as those listed in the following paragraphs. In an embodiment, at least one molecule or therapeutic agent of interest is physically entrapped into a SPF mixture solution of the present disclosure during processing into aqueous gels. An aqueous silk gel of the present disclosure can be used to release at least one molecule or therapeutic agent of interest.

According to aspects illustrated herein, pure silk fibroin-based protein fragments from aqueous solutions of the present disclosure can be formed into yarns and fabrics including for example, woven or weaved fabrics, and these fabrics can be used in textiles, as described above.

According to aspects illustrated herein, silk fabric manufactured from SPF mixture solutions of the present disclosure are disclosed. In an embodiment, at least one molecule or therapeutic agent of interest is physically entrapped into a SPF mixture solution of the present disclosure. A silk film of the present disclosure can be used to release at least one molecule or therapeutic agent of interest.

In some embodiments, the invention may include an article having a fiber or yarn having a coating, wherein the coating may include silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa. In some embodiments, the article

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may be a fabric. In some embodiments, the silk based proteins or fragments thereof may include silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin.

In some embodiments, the silk based proteins or fragments thereof may be selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof.

In some embodiments, the silk based proteins or fragments thereof may be natural silk based proteins or fragments thereof that may be selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof.

In some embodiments, the natural silk based proteins or fragments may be silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof may be *Bombyx mori* silk based proteins or fragments thereof.

In some embodiments, the silk based proteins or fragments may include silk and a copolymer.

In some embodiments, the silk based proteins or protein fragments thereof may have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof may have a polydispersity of between about 1.5 and about 3.0, and wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

In some embodiments, the fiber or yarn may be selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof.

In some embodiments, the fiber or yarn may be natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof.

In some embodiments, the fiber or yarn may be synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof.

In some embodiments, the fabric may exhibit an improved property, wherein the improved property may be an accumulative one-way moisture transport index selected from the group consisting of greater than 40%, greater than 60%, greater than 80%, greater than 100%, greater than 120%, greater than 140%, greater than 160%, and greater than 180%.

In some embodiments, the fabric may exhibit an improved property, wherein the improved property may be an accumulative one way transport capability increase relative to uncoated fabric selected from the group consisting of 1.2 fold, 1.5 fold, 2.0 fold, 3.0 fold, 4.0 fold, 5.0 fold, and 10 fold.

In some embodiments, the fabric may exhibit an improved property, wherein the improved property may be an overall moisture management capability selected from the group consisting of greater than 0.05, greater than 0.10, greater than 0.15, greater than 0.20, greater than 0.25, greater than 0.30, greater than 0.35, greater than 0.40, greater than 0.50, greater than 0.60, greater than 0.70, and greater than 0.80. In some embodiments, the improved

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property may be determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In some embodiments, the fabric may exhibit substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles. In some embodiments, the microbial growth may be microbial growth of a microbe selected from the group consisting of *Staphylococcus aureus*, *Klebsiella pneumoniae*, and combinations thereof. In some embodiments, the microbial growth may be reduced by a percentage selected from the group consisting of 50%, 100%, 500%, 1000%, 2000%, and 3000% compared to an uncoated fabric.

In some embodiments, the coating may be applied to the fabric at the fiber level prior to forming the fabric.

In some embodiments, the coating may be applied to the fabric at the fabric level. In some embodiments, the fabric may be bath coated. In some embodiments, the fabric may be spray coated. In some embodiments, the fabric may be coated with a stencil. In some embodiments, the coating may be applied to at least one side of the fabric using a method selected from the group consisting of a bath coating process, a spray coating process, a stencil process, a silk-foam based process, and a roller-based process.

In some embodiments, the coating may have a thickness of about one nanolayer.

In some embodiments, the coating may have a thickness selected from the group consisting of about 5 nm, about 10 nm, about 15 nm, about 20 nm, about 25 nm, about 50 nm, about 100 nm, about 200 nm, about 500 nm, about 1 μm, about 5 μm, about 10 μm, and about 20 μm.

In some embodiments, the coating may be adsorbed on the fabric.

In some embodiments, the coating may be attached to the fabric through chemical, enzymatic, thermal, or irradiative cross-linking.

In some embodiments, the hand of the coated fabric may be improved relative to an uncoated fabric.

In some embodiments, the hand of the coated fabric that may be improved may be selected from the group consisting of softness, crispness, dryness, silkiness, and combinations thereof.

In some embodiments, a flame retardation property of the coated fabric may be improved relative to an uncoated fabric.

In some embodiments, a flame retardation property of an uncoated fabric may not be adversely affected by the coating.

In some embodiments, the abrasion resistance may be improved relative to an uncoated fabric.

In an embodiment, the invention may include an article comprising a textile or leather having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa.

In some embodiments, the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and wherein the proteins or protein fragments, prior to coating the fabric, do

not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

In some embodiments, at least one property of the article may be improved, wherein the property that may be improved may be selected from the group consisting of color retention, resistance to microbial growth, resistance to bacterial growth, resistance to fungal growth, resistance to the buildup of static electrical charge, resistance to the growth of mildew, transparency of the coating, resistance to freeze-thaw cycle damage, resistance from abrasion, blocking of ultraviolet (UV) radiation, regulation of the body temperature of a wearer, resistance to tearing, elasticity of the article, rebound dampening, tendency to cause itching in the wearer, thermal insulation of the wearer, wrinkle resistance, stain resistance, stickiness to skin, and flame resistance.

In some embodiments, the article may be a textile used for apparel.

In some embodiments, the article may be fabricated as an item selected from the group consisting of an item of athletic apparel, an item of outdoor gear, a jacket, an overcoat, a shoe, a sneaker, a glove, an umbrella, a chair, a blanket, a towel, a surgical drape, a surgical gown, a laboratory coat, a wound dressing, a sterilization wrap, a surgical face mask, a surgical sleeve, a laboratory sleeve, a retention bandage, a support device, a compression bandage, a shoe cover, and a surgical blanket.

In some embodiments, the article may be a textile, leather, or foam used to fabricate an automotive product.

In some embodiments, the article may be fabricated as an item selected from the group consisting of an upholstery, a foam cushion, a fabric cushion, a floor mat, a vehicle carpet, an automotive trim, a children's car seat, a seat belt, a safety harness, a headrest, an armrest, a dashboard, a sunvisor, a seat, an interior panel, an airbag, an airbag cover, a wiring harness, or an insulation.

In an embodiment, the invention may include a method of coating a fabric that may include the step of optionally applying a pretreatment selected from the group consisting of a wetting agent, a detergent, a sequestering or dispersing agent, an enzyme, a bleaching agent, an antifoaming agent, an anti-creasing agent, a dye dispersing agent, a dye leveling agent, a dye fixing agent, a dye special resin agent, a dye anti-reducing agent, a pigment dye system anti-migrating agent, a pigment dye system binder, a delave agent, a wrinkle free treatment, a softener, a handle modifier, a waterborne polyurethane dispersion, a finishing resin, an oil or water repellent, a flame retardant, a crosslinker, a thickener for technical finishing, or any combination thereof. In an embodiment, the method may include the step of applying a coating that may include a solution of silk based proteins or fragments thereof that may have an average molecular weight range of about 5 kDa to about 144 kDa, using a process selected from the group consisting of a continuous spray process, a continuous screen or stencil process, a continuous bath process, a batch spray process, a batch screen or stencil process, and a batch bath process. In an embodiment, the method may include the step of drying and optionally curing the coating.

In an embodiment, the silk based proteins or protein fragments thereof may have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof may have a polydispersity of between about 1.5 and

about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

BRIEF DESCRIPTION OF THE DRAWINGS

The presently disclosed embodiments will be further explained with reference to the attached drawings. The drawings shown are not necessarily to scale, with emphasis instead generally being placed upon illustrating the principles of the presently disclosed embodiments.

FIG. 1 is a flow chart showing various embodiments for producing pure silk fibroin-based protein fragments (SPFs) of the present disclosure.

FIG. 2 is a flow chart showing various parameters that can be modified during the process of producing SPFs of the present disclosure during the extraction and the dissolution steps.

FIG. 3 is a photograph showing dry extracted silk fibroin.

FIG. 4 is a photograph showing an embodiment of a SPF in the form of a solution of the present disclosure.

FIGS. 5A-5D are photographs showing dissolved silk in room temperature lithium bromide (LiBr) solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 6A-6D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 7A-7D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 8 hours (sericin extraction temperature and time were varied).

FIGS. 8A-8D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 12 hours (sericin extraction temperature and time were varied).

FIGS. 9A-9D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 24 hours (sericin extraction temperature and time were varied).

FIGS. 10A-10D are photographs showing dissolved silk in room temperature LiBr solutions dissolved in a 60° C. oven for 168/192 hours (sericin extraction temperature and time were varied).

FIGS. 11A-11C are photographs showing dissolved silk in room temperature LiBr solutions dissolved in 60° C. oven for 1, 4, and 6 hours, where sericin extraction was completed at 100° C. for 60 min.

FIGS. 12A-12D are photographs showing dissolved silk in 60° C. LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 13A-13D are photographs showing dissolved silk in 60° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 14A-14D are photographs showing dissolved silk in 60° C. LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 15A-15D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 16A-16D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 17A-17D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 18A-18D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 19A-19D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 20A-20D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 21A-21D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 60° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 22A-22D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 60° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 23A-23D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 60° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 24A-24D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 80° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 25A-25D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 80° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 26A-26D are photographs showing dissolved silk in 80° C. LiBr solutions dissolved in a 80° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 27A-27D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 100° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 28A-28D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 100° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIGS. 29A-29D are photographs showing dissolved silk in 100° C. LiBr solutions dissolved in a 100° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIGS. 30A-30D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 120° C. oven for 1 hour (sericin extraction temperature and time were varied).

FIGS. 31A-31D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 120° C. oven for 4 hours (sericin extraction temperature and time were varied).

FIG. 32A-32D are photographs showing dissolved silk in 140° C. (boiling point for LiBr) LiBr solutions dissolved in a 120° C. oven for 6 hours (sericin extraction temperature and time were varied).

FIG. 33 shows HPLC chromatograms from samples comprising vitamin C. FIG. 33 shows peaks from (1) a chemically stabilized sample of vitamin C at ambient conditions and (2) a sample of vitamin C taken after 1 hour at ambient conditions without chemical stabilization to prevent oxidation, where degradation products are visible.

FIG. 34 is a table summarizing the LiBr and Sodium Carbonate (Na_2CO_3) concentration in silk protein solutions of the present disclosure.

FIG. 35 is a table summarizing the LiBr and Na_2CO_3 concentration in silk protein solutions of the present disclosure.

FIG. 36 is a table summarizing the stability of vitamin C in chemically stabilized solutions.

FIG. 37 is a table summarizing the Molecular Weights of silk protein solutions of the present disclosure.

FIGS. 38A and 38B are graphs representing the effect of extraction volume on mass loss.

FIG. 39 is a table summarizing the Molecular Weights of silk dissolved from different concentrations of LiBr and from different extraction and dissolution sizes.

FIG. 40 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. LiBr and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 41 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, boiling LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 42 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 60° C. LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 43 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. LiBr and 80° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 44 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 45 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. LiBr and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 46 is a graph summarizing the effect of Extraction Time on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 140° C. LiBr and 140° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 47 is a graph summarizing the effect of Extraction Temperature on Molecular Weight of silk processed under the conditions of 60 minute Extraction Time, 100° C. LiBr and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 48 is a graph summarizing the effect of LiBr Temperature on Molecular Weight of silk processed under the conditions of 60 minute Extraction Time, 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 49 is a graph summarizing the effect of LiBr Temperature on Molecular Weight of silk processed under the conditions of 30 minute Extraction Time, 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

FIG. 50 is a graph summarizing the effect of Oven/ Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 minute Extraction Time, and 100° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 51 is a graph summarizing the effect of Oven/ Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Tempera-

ture, 60 minute Extraction Time, and 100° C. Lithium Bromide. (Oven/Dissolution Time was varied).

FIG. 52 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 minute Extraction Time, and 140° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 53 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 minute Extraction Time, and 140° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 54 is a graph summarizing the effect of Oven/Dissolution Temperature on Molecular Weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 minute Extraction Time, and 80° C. Lithium Bromide (Oven/Dissolution Time was varied).

FIG. 55 is a graph summarizing the Molecular Weights of silk processed under varying conditions including Extraction Time, Extraction Temperature, Lithium Bromide (LiBr) Temperature, Oven Temperature for Dissolution, Oven Time for Dissolution.

FIG. 56 is a graph summarizing the Molecular Weights of silk processed under conditions in which Oven/Dissolution Temperature is equal to LiBr Temperature.

FIG. 57A is a graph illustrating wetting time with spray coating.

FIG. 57B is a graph illustrating wetting time with stencil coating.

FIG. 57C is a graph illustrating wetting time with bath coating.

FIG. 57D is a graph illustrating wetting time with screen coating.

FIG. 58A is a graph illustrating absorption time with spray coating.

FIG. 58B is a graph illustrating absorption time with stencil coating.

FIG. 58C is a graph illustrating absorption time with bath coating.

FIG. 58D is a graph illustrating absorption time with screen coating.

FIG. 59A is a graph illustrating spreading speed with spray coating.

FIG. 59B is a graph illustrating spreading speed with stencil coating.

FIG. 59C is a graph illustrating spreading speed with bath coating.

FIG. 59D is a graph illustrating spreading speed with screen coating.

FIG. 60A is a graph illustrating accumulative one way transport index with spray coating.

FIG. 60B is a graph illustrating accumulative one way transport index with stencil coating.

FIG. 60C is a graph illustrating accumulative one way transport index with bath coating.

FIG. 60D is a graph illustrating accumulative one way transport index with screen coating.

FIG. 61A is a graph illustrating overall moisture management capability with spray coating.

FIG. 61B is a graph illustrating overall moisture management capability with stencil coating.

FIG. 61C is a graph illustrating overall moisture management capability with bath coating.

FIG. 61D is a graph illustrating overall moisture management capability with screen coating.

FIG. 62A is a graph illustrating wetting time top.

FIG. 62B is a graph illustrating wetting time bottom.

FIG. 63A is a graph illustrating top absorption rate.

FIG. 63B is a graph illustrating bottom absorption rate.

FIG. 64A is a graph illustrating top max wetted radius.

FIG. 64B is a graph illustrating bottom max wetted radius.

FIG. 65A is a graph illustrating top spreading speed.

FIG. 65B is a graph illustrating bottom spreading speed.

FIG. 66A is a graph illustrating accumulative one-way transport index.

FIG. 66B is a graph illustrating overall moisture management capability.

FIG. 67A is a graph illustrating wetting time of non-wicking finished.

FIG. 67B is a graph illustrating wetting time of semi-finished before final setting.

FIG. 68A is a graph illustrating absorption time of non-wicking finished.

FIG. 68B is a graph illustrating absorption time of semi-finished before final setting.

FIG. 69A is a graph illustrating spreading speed of non-wicking finished.

FIG. 69B is a graph illustrating spreading speed of semi-finished before final setting.

FIG. 70A is a graph illustrating accumulative one way transport index of non-wicking finished.

FIG. 70B is a graph illustrating accumulative one way transport index of semi-finished before final setting.

FIG. 71A is a graph illustrating overall moisture management capability of non-wicking finished.

FIG. 71B is a graph illustrating overall moisture management capability of semi-finished before final setting.

FIG. 72A is a graph illustrating wetting time with spray coating.

FIG. 72B is a graph illustrating wetting time with stencil coating.

FIG. 72C is a graph illustrating wetting time with bath coating.

FIG. 73A is a graph illustrating absorption time with spray coating.

FIG. 73B is a graph illustrating absorption time with stencil coating.

FIG. 73C is a graph illustrating absorption time with bath coating.

FIG. 74A is a graph illustrating spreading speed with spray coating.

FIG. 74B is a graph illustrating spreading speed with stencil coating.

FIG. 74C is a graph illustrating spreading speed with bath coating.

FIG. 75A is a graph illustrating accumulative one way transport index with spray coating.

FIG. 75B is a graph illustrating accumulative one way transport index with stencil coating.

FIG. 75C is a graph illustrating accumulative one way transport index with bath coating.

FIG. 76A is a graph illustrating overall moisture management capability with spray coating.

FIG. 76B is a graph illustrating overall moisture management capability with stencil coating.

FIG. 76C is a graph illustrating overall moisture management capability with bath coating.

FIG. 77A is a graph illustrating wetting time with 1% SFS.

FIG. 77B is a graph illustrating wetting time with 0.1% SFS.

FIG. 78A is a graph illustrating absorption time with 1% SFS.

FIG. 78B is a graph illustrating absorption time with 0.1% SFS.

FIG. 79A is a graph illustrating spreading speed with 1% SFS.

FIG. 79B is a graph illustrating spreading speed with 0.1% SFS.

FIG. 80A is a graph illustrating accumulative one way transport index with 1% SFS.

FIG. 80B is a graph illustrating accumulative one way transport index with 0.1% SFS.

FIG. 81A is a graph illustrating overall moisture management capability with 1% SFS.

FIG. 81B is a graph illustrating overall moisture management capability with 0.1% SFS.

FIG. 82A is a graph illustrating summary of wetting time top.

FIG. 82B is a graph illustrating summary of wetting time bottom.

FIG. 83A is a graph illustrating summary of top absorption rate.

FIG. 83B is a graph illustrating summary of bottom absorption rate.

FIG. 84A is a graph illustrating summary of top max wetted radius.

FIG. 84B is a graph illustrating summary of bottom max wetted radius.

FIG. 85A is a graph illustrating summary of top spreading speed.

FIG. 85B is a graph illustrating summary of bottom spreading speed.

FIG. 86A is a graph illustrating summary of accumulative one-way transport index.

FIG. 86B is a graph illustrating summary of overall moisture management capability.

FIG. 87 illustrates bacterial growth results.

FIG. 88 illustrates bacterial growth results.

FIG. 89 illustrates bacterial growth results.

FIG. 90 illustrates bacterial growth results.

FIG. 91 illustrates bacterial growth results.

FIG. 92 illustrates bacterial growth results.

FIG. 93 illustrates accumulative one-way transport index versus fabric washing cycles.

FIG. 94 illustrates overall moisture management capability (OMMC) versus fabric washing cycles.

FIG. 95 illustrates wetting time at the top of the fabric versus fabric washing cycles.

FIG. 96 illustrates wetting time at the bottom of the fabric versus fabric washing cycles.

FIG. 97 illustrates absorption rate at the top of the fabric versus fabric washing cycles.

FIG. 98 illustrates absorption rate at the bottom of the fabric versus fabric washing cycles.

FIG. 99 illustrates spreading speed at the top of the fabric versus fabric washing cycles.

FIG. 100 illustrates spreading speed at the bottom of the fabric versus fabric washing cycles.

FIG. 101 illustrates wetted radius at the top of the fabric versus fabric washing cycles.

FIG. 102 illustrates wetted radius at the bottom of the fabric versus fabric washing cycles.

FIG. 103 illustrates percent reduction in growth of *Staphylococcus aureus* ATCC 6538 versus fabric washing cycles.

FIG. 104 illustrates percent reduction in growth of *Klebsiella pneumoniae* ATCC 4354 versus fabric washing cycles.

FIG. 105 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (first view).

FIG. 106 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (second view).

FIG. 107 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (third view).

FIG. 108 illustrates a scanning electron microscopy image of fabric sample FAB-01-BATH-B (fourth view).

FIG. 109 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (first view).

FIG. 110 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (second view).

FIG. 111 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (third view).

FIG. 112 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (fourth view).

FIG. 113 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (fifth view).

FIG. 114 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (sixth view).

FIG. 115 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-B (seventh view).

FIG. 116 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (first view).

FIG. 117 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (second view).

FIG. 118 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (third view).

FIG. 119 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (fourth view).

FIG. 120 illustrates a scanning electron microscopy image of fabric sample FAB-01-SPRAY-C (fifth view).

FIG. 121 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (first view).

FIG. 122 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (second view).

FIG. 123 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (third view).

FIG. 124 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (fourth view).

FIG. 125 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (fifth view).

FIG. 126 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (sixth view).

FIG. 127 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (seventh view).

FIG. 128 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (eighth view).

FIG. 129 illustrates a scanning electron microscopy image of fabric sample FAB-01-STEN-C (ninth view).

FIG. 130 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (first view).

FIG. 131 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (second view).

FIG. 132 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (third view).

FIG. 133 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (fourth view).

FIG. 134 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (fifth view).

FIG. 135 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (sixth view).

FIG. 136 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-B (seventh view).

FIG. 137 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (first view).

FIG. 138 illustrates a scanning electron microscopy image of fabric sample FAB-10-BATH-C (second view).

FIG. 203 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (third view).

FIG. 204 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (fourth view).

FIG. 205 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (fifth view).

FIG. 206 illustrates a scanning electron microscopy image of film sample FIL-01-STEN-C-01-MYL (sixth view).

FIG. 207 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (first view).

FIG. 208 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (second view).

FIG. 209 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (third view).

FIG. 210 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (fourth view).

FIG. 211 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (fifth view).

FIG. 212 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (sixth view).

FIG. 213 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-01MYL (seventh view).

FIG. 214 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (first view).

FIG. 215 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (second view).

FIG. 216 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (third view).

FIG. 217 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (fourth view).

FIG. 218 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-B-007MEL (fifth view).

FIG. 219 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-C-01MYL cross-section (first view).

FIG. 220 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (first view).

FIG. 221 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (second view).

FIG. 222 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (third view).

FIG. 223 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (fourth view).

FIG. 224 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (fifth view).

FIG. 225 illustrates a scanning electron microscopy image of film sample FIL-10-SPRAY-B-01MYL (sixth view).

FIG. 226 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (first view).

FIG. 227 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (second view).

FIG. 228 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (third view).

FIG. 229 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (fourth view).

FIG. 230 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (fifth view).

FIG. 231 illustrates a scanning electron microscopy image of film sample FIL-BATH-C-01-MYL (sixth view).

FIG. 232 illustrates a scanning electron microscopy image of film sample Melinex Control (first view).

FIG. 233 illustrates a scanning electron microscopy image of film sample Melinex Control (second view).

FIG. 234 illustrates a scanning electron microscopy image of film sample Melinex Control (third view).

FIG. 235 illustrates a scanning electron microscopy image of film sample Melinex Control (fourth view).

FIG. 236 illustrates a scanning electron microscopy image of film sample Mylar Control (first view).

FIG. 237 illustrates a scanning electron microscopy image of film sample Mylar Control (second view).

5 FIG. 238 illustrates a scanning electron microscopy image of film sample Mylar Control (third view).

FIG. 239 illustrates a scanning electron microscopy image of film sample Mylar Control (fourth view).

10 FIG. 240 illustrates a scanning electron microscopy image of film sample Mylar Control (fifth view).

FIG. 241 shows results from optical profiling measurements on the Mylar Control sample taken at the top, location 1 (shiny side).

15 FIG. 242 shows results from optical profiling measurements on the Mylar Control sample taken at the bottom, location 2 (more matte side).

FIG. 243 shows results from optical profiling measurements on the Melinex Control sample taken at the top, location 1.

20 FIG. 244 shows results from optical profiling measurements on the Melinex Control sample taken at the bottom, location 2.

FIG. 245 shows results from optical profiling measurements on sample FIL-10-SPRAY-B-01MYL taken at the top, location 1.

25 FIG. 246 shows results from optical profiling measurements on sample FIL-10-SPRAY-B-01MYL taken at the bottom, location 2.

FIG. 247 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-01MYL taken at the top, location 1.

30 FIG. 248 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-01MYL taken at the bottom, location 2.

FIG. 249 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-007MEL taken the top, location 1.

35 FIG. 250 shows results from optical profiling measurements on sample FIL-01-SPRAY-B-007MEL taken at the bottom, location 2.

FIG. 251 shows results from optical profiling measurements on sample FIL-01-SPRAY-C-01MYL taken at the top, location 1.

40 FIG. 252 shows results from optical profiling measurements on sample FIL-01-SPRAY-C-01MYL taken at bottom, location 2.

FIG. 253 shows results from optical profiling measurements on sample FIL-01-STEN-B-01MYL taken at the top, location 1.

45 FIG. 254 shows results from optical profiling measurements on sample FIL-01-STEN-B-01MYL taken at the bottom, location 2.

FIG. 255 shows results from optical profiling measurements on sample FIL-01-STEN-C-01MYL taken at the top, location 1.

50 FIG. 256 shows results from optical profiling measurements on sample FIL-01-STEN-C-01MYL taken at the bottom, location 2.

FIG. 257 shows results from optical profiling measurements on sample FIL-10-BATH-B-01MYL taken at the top, location 1.

55 FIG. 258 shows results from optical profiling measurements on sample FIL-10-BATH-B-01MYL taken at the bottom, Location 2.

60 FIG. 259 shows results from optical profiling measurements on sample FIL-10-BATH-B-007MEL taken at the top, location 1.

FIG. 260 shows results from optical profiling measurements on sample FIL-10-BATH-B-007MEL taken at the bottom, location 2.

FIG. 261 shows results from optical profiling measurements on sample FIL-10-BATH-C-01MYL taken at top, location 1.

FIG. 262 shows results from optical profiling measurements on sample FIL-10-BATH-C-01MYL taken at the bottom, location 2.

FIG. 263 shows results from optical profiling measurements on sample FIL-01-BATH-B-01MYL taken at the top, location 1.

FIG. 264 shows results from optical profiling measurements on sample FIL-01-BATH-B-01MYL taken at the bottom, location 2.

FIG. 265 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL cross-section.

FIG. 266 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL cross-section.

FIG. 267 illustrates a scanning electron microscopy image of film sample FIL-01-SPRAY-B-O1MYL cross-section.

FIG. 268 illustrates a scanning electron microscopy image of film sample FIL-10-BATH-C-01MYL cross-section.

FIG. 269 illustrates accumulative one-way transport index results for natural fibers.

FIG. 270 illustrates overall moisture management capability for natural fibers.

FIG. 271 illustrates flammability test results for a cotton interlock fabric with (16021103) and without (16021101) coating with 1% silk fibroin solution.

FIG. 272 illustrates flammability test results for a cotton interlock fabric with (16021103) and without (16021101) coating with 1% silk fibroin solution.

FIG. 273 illustrates flammability test results for a polyester double knit fabric with (16021104) and without (16021102) coating with 1% silk fibroin solution.

FIG. 274 illustrates flammability test results for a polyester double knit fabric with (16021104) and without (16021102) coating with 1% silk fibroin solution.

FIG. 275 illustrates abrasion test results for a cotton interlock fabric with (16021501) and without (16021101) coating with 1% silk fibroin solution.

FIG. 276 illustrates abrasion test results for a polyester double knit fabric with (16021502) and without (16021102) coating with 1% silk fibroin solution.

FIG. 277 illustrates a scanning electron microscope image of sample 16041301.

FIG. 278 illustrates a scanning electron microscope image of sample 16041301.

FIG. 279 illustrates a scanning electron microscope image of sample 16041301.

FIG. 280 illustrates a scanning electron microscope image of sample 16041301.

FIG. 281 illustrates a scanning electron microscope image of sample 16041301.

FIG. 282 illustrates a scanning electron microscope image of sample 16041302.

FIG. 283 illustrates a scanning electron microscope image of sample 16041302.

FIG. 284 illustrates a scanning electron microscope image of sample 16041302.

FIG. 285 illustrates a scanning electron microscope image of sample 16041302.

FIG. 286 illustrates a scanning electron microscope image of sample 16041302.

FIG. 287 illustrates a scanning electron microscope image of sample 16041303.

FIG. 288 illustrates a scanning electron microscope image of sample 16041303.

FIG. 289 illustrates a scanning electron microscope image of sample 16041303.

FIG. 290 illustrates a scanning electron microscope image of sample 16041303.

FIG. 291 illustrates a scanning electron microscope image of sample 16041303.

FIG. 292 illustrates a scanning electron microscope image of sample 16041304.

FIG. 293 illustrates a scanning electron microscope image of sample 16041304.

FIG. 294 illustrates a scanning electron microscope image of sample 16041304.

FIG. 295 illustrates a scanning electron microscope image of sample 16041304.

FIG. 296 illustrates a scanning electron microscope image of sample 16041304.

FIG. 297 illustrates a scanning electron microscope image of sample 16041305.

FIG. 298 illustrates a scanning electron microscope image of sample 16041305.

FIG. 299 illustrates a scanning electron microscope image of sample 16041305.

FIG. 300 illustrates a scanning electron microscope image of sample 16041305.

FIG. 301 illustrates a scanning electron microscope image of sample 16041305.

FIG. 302 illustrates a scanning electron microscope image of sample 16041306.

FIG. 303 illustrates a scanning electron microscope image of sample 16041306.

FIG. 304 illustrates a scanning electron microscope image of sample 16041306.

FIG. 305 illustrates a scanning electron microscope image of sample 16041306.

FIG. 306 illustrates a scanning electron microscope image of sample 16041306.

FIG. 307 illustrates a scanning electron microscope image of sample 16040803.

FIG. 308 illustrates a scanning electron microscope image of sample 16040803.

FIG. 309 illustrates a scanning electron microscope image of sample 16040803.

FIG. 310 illustrates a scanning electron microscope image of sample 16040803.

FIG. 311 illustrates a scanning electron microscope image of sample 16040803.

FIG. 312 illustrates a scanning electron microscope image of sample 16040808.

FIG. 313 illustrates a scanning electron microscope image of sample 16040808.

FIG. 314 illustrates a scanning electron microscope image of sample 16040808.

FIG. 315 illustrates a scanning electron microscope image of sample 16040808.

FIG. 316 illustrates a scanning electron microscope image of sample 16040808.

FIG. 317 illustrates an exemplary padder roller.

FIG. 318 illustrates an exemplary kiss roller.

FIG. 319 illustrates the process of unrolling an exemplary fabric roller.

FIG. 320 illustrates a square of sample fabric to be coated.

FIG. 321 illustrates an exemplary stainless steel bath.

FIG. 322 illustrates a padder unit having two rollers.

FIG. 323 illustrates a curing frame without fabric provided thereon.

35

FIG. 324 illustrates a curing frame with fabric provided thereon.

FIG. 325 illustrates an exemplary curing oven.

FIG. 326 illustrates a cooling rack with a curing frame and fabric provided thereon.

FIG. 327 illustrates a table that provides testing results for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and overall moisture management capability (OMMC) for sample nos. 16040101, 16040102, 16040103, 16040104, 16040105, and 16040106.

FIG. 328 illustrates testing results in grades for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and OMMC for 16040101, 16040102, 16040103, 16040104, 16040105, and 16040106.

FIG. 329 illustrates testing results for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and OMMC for 16040801, 16040802, 16040803, 16040804, 16040805, 16040806, 16040807, and 16040808.

FIG. 330 illustrates testing results in grades for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and OMMC for 16040801, 16040802, 16040803, 16040804, 16040805, 16040806, 16040807, and 16040808.

FIG. 331 illustrates testing results for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and OMMC for 16041201, 16041202, 16041302, 16041303, 16041203, 16041204, 16041305, 16041306, 16041301, and 16041304.

FIG. 332 illustrates testing results in grades for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and OMMC for 16041201, 16041202, 16041302, 16041303, 16041203, 16041204, 16041305, 16041306, 16041301, and 16041304.

FIG. 333 illustrates testing results for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and OMMC for 16041301, 16041302, 16041303, 16041304, 16041305, 16041306, 16042001, 16040101, and 16040106.

FIG. 334 illustrates testing results in grades for wetting time, absorption rate, wetted radius, spreading speed, accumulative one-way transport, and OMMC for 16041301, 16041302, 16041303, 16041304, 16041305, 16041306, 16042001, 16040101, and 16040106.

FIG. 335 illustrates a map of Liquid Moisture Management Test results for various coated fabrics described herein.

FIG. 336 illustrates drapability coefficient testing results for various SFS coated fabrics.

FIG. 337 illustrates drapability coefficient testing results for an SFS coated fabric after mechanical and steam finishing.

FIG. 338 illustrates the results of a solution depletion calculation during coating.

FIG. 339 illustrates samples used in moisture management testing.

FIG. 340 illustrates the results of moisture management testing.

FIG. 341 illustrates samples used in moisture management testing.

FIG. 342 illustrates the results of moisture management testing.

FIG. 343 illustrates samples used in moisture management testing.

FIG. 344 illustrates the results of moisture management testing.

FIG. 345 illustrates samples used in antimicrobial testing.

36

FIG. 346 illustrates the results of antimicrobial testing.

FIG. 347 illustrates the results of a water drop test on polyester/lycra knitted fabric treated with Ultratex CSP.

FIG. 348 illustrates the results of a water drop test on polyester/lycra knitted fabric treated with Ultratex SI.

FIG. 349 represents a table that describes test variables for an antibacterial study.

FIG. 350 represents a table that describes the study intervals for an antibacterial study.

10 FIG. 351 represents a table that describes the additional fabric bacteria load after washing cycles for an antibacterial study. For example, after 1 washing cycle the additional fabric will receive 4×10^7 of bacteria load.

FIGS. 352A and 352B represent tables that describes parameters and results for an antibacterial study.

FIG. 353 illustrates an image of bacterial colonies for sample 16060901 after washing.

FIG. 354 illustrates an image of bacterial colonies for sample 16060902 after washing.

20 FIG. 355 illustrates an image of bacterial colonies for sample 16060903 after washing.

FIG. 356 illustrates an image of bacterial colonies for sample 16060904 after washing.

FIG. 357 illustrates an image of bacterial colonies for a control.

FIG. 358 illustrates an image of bacterial colonies for a control.

30 FIGS. 359A to 359C illustrate a microscopic image of coated fabric sample 16060901 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, before any wash cycles.

FIGS. 360A to 360C illustrate a microscopic image of coated fabric sample 16060902 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, before any wash cycles.

40 FIGS. 361A to 361C illustrate a microscopic image of coated fabric sample 16060903 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, before any wash cycles.

FIGS. 362A to 362C illustrate a microscopic image of coated fabric sample 16060904 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, before any wash cycles.

45 FIGS. 363A to 363C illustrate a microscopic image of coated fabric sample 16060901 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after one wash cycle.

FIGS. 364A to 364C illustrate a microscopic image of coated fabric sample 16060902 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after one wash cycle.

50 FIGS. 365A to 365C illustrate a microscopic image of coated fabric sample 16060903 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after one wash cycle.

FIGS. 366A to 366C illustrate a microscopic image of coated fabric sample 16060904 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after one wash cycle.

60 FIGS. 367A to 376C illustrate a microscopic image of coated fabric sample 16060901 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after ten wash cycles.

FIGS. 368A to 368C to illustrate a microscopic image of coated fabric sample 16060902 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after ten wash cycles.

FIGS. 369A to 369C illustrate a microscopic image of coated fabric sample 16060903 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after ten wash cycles.

FIGS. 370A to 370C illustrate a microscopic image of coated fabric sample 16060904 at (A) 350 \times magnification, (B) 1050 \times magnification, and (C) 3500 \times magnification, after ten wash cycles.

FIG. 371 provides a qualitative analysis of the bacterial was study by observing the % foreign matter coverage area observed in FIGS. 359A-359C to FIGS. 370A-FIG. 370C.

FIG. 372 illustrates the results of a water drop test on polyester/lycra knitted fabric treated with Ultratex CSP.

FIG. 373 illustrates the results of a water drop test on polyester/lycra knitted fabric treated with Ultratex SI.

FIG. 374 illustrates the results of a water drop test on polyester/lycra knitted fabric treated with RODI water or tap water.

While the above-identified drawings set forth presently disclosed embodiments, other embodiments are also contemplated, as noted in the discussion. This disclosure presents illustrative embodiments by way of representation and not limitation. Numerous other modifications and embodiments can be devised by those skilled in the art which fall within the scope and spirit of the principles of the presently disclosed embodiments.

DETAILED DESCRIPTION OF THE INVENTION

Silk Fibroin-Based Protein Fragments and Solutions Thereof

Provided herein are methods for producing pure and highly scalable silk protein fragment (SPF) mixture solutions that may be used to coat at least a portion of textiles or may be formed into usable fibers for weaving into yarn. In some embodiments, SPF mixture solutions may also refer to silk fibroin solutions (SFS), and vice versa. The solutions are generated from raw pure intact silk protein material and processed in order to remove any sericin and achieve the desired weight average molecular weight (MW) and polydispersity of the fragment mixture. Select method parameters may be altered to achieve distinct final silk protein fragment characteristics depending upon the intended use. The resulting final fragment solution is pure silk protein fragments and water with PPM to non-detectable levels of process contaminants. The concentration, size and polydispersity of silk protein fragments in the solution may further be altered depending upon the desired use and performance requirements. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the pure silk fibroin-based protein fragments in the solution are substantially devoid of sericin, have an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, and have a polydispersity ranging from about 1.5 and about 3.0. In an embodiment, the solutions may be used to generate articles, such as silk gels of varying gel and liquid consistencies by varying water content/concentration, or sold as a raw ingredient into the

consumer market. As used herein, the term "silk solution" may refer to solutions of silk proteins, including solutions of silk fibroin-based protein fragments.

As used herein, "silk based proteins or fragments thereof" includes silk fibroin-based proteins or fragments thereof, natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof. Natural silk based proteins or fragments thereof include spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof. Silkworm based proteins or fragments thereof may include *Bombyx mori* silk based proteins or fragments thereof. The SPF mixture solutions described herein may include silk based proteins or fragments thereof. Moreover, SFS, as described herein, may be replaced with SPF mixture solutions.

As used herein, "low molecular weight" silk fibroin solutions may include those SFS solutions that include silk fibroin-based protein fragments having a molecular weight in a range of about 5 kDa to 20 kDa. In some embodiments, a target low molecular weight for certain silk fibroin-based protein fragments may be about 11 kDa.

As used herein, "medium molecular weight" silk fibroin solutions may include those SFS solutions that include silk-fibroin based protein fragments having a molecular weight in a range of about 20 kDa to about 55 kDa. In some embodiments, a target medium molecular weight for certain silk fibroin-based protein fragments may be about 40 kDa.

As used herein, "high molecular weight" silk fibroin solutions may include those SFS solutions that include silk-fibroin based protein fragments having a molecular weight that is in a range of about 55 kDa to about 150 kDa. In some embodiments, a target high molecular weight for certain silk fibroin-based protein fragments may be about 100 kDa to about 145 kDa.

As used herein, the terms "substantially sericin free" or "substantially devoid of sericin" refer to silk fibers in which a majority of the sericin protein has been removed. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 10.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 9.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 8.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 7.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 6.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.01% (w/w) and about 5.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.05% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.1% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 0.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 1.0% (w/w) and about 4.0% (w/w) sericin. In

an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 1.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 2.0% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having between about 2.5% (w/w) and about 4.0% (w/w) sericin. In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content between about 0.01% (w/w) and about 0.1% (w/w). In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content below about 0.1% (w/w). In an embodiment, silk fibroin that is substantially devoid of sericin refers to silk fibroin having a sericin content below about 0.05% (w/w). In an embodiment, when a silk source is added to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes, a degumming loss of about 26 wt. % to about 31 wt. % is obtained.

As used herein, the term “substantially homogeneous” may refer to pure silk fibroin-based protein fragments that are distributed in a normal distribution about an identified molecular weight. As used herein, the term “substantially homogeneous” may refer to an even distribution of additive, for example vitamin C, throughout a composition of the present disclosure.

As used herein, the term “substantially free of inorganic residuals” means that the composition exhibits residuals of 0.1% (w/w) or less. In an embodiment, substantially free of inorganic residuals refers to a composition that exhibits residuals of 0.05% (w/w) or less. In an embodiment, substantially free of inorganic residuals refers to a composition that exhibits residuals of 0.01% (w/w) or less. In an embodiment, the amount of inorganic residuals is between 0 ppm (“non-detectable” or “ND”) and 1000 ppm. In an embodiment, the amount of inorganic residuals is ND to about 500 ppm. In an embodiment, the amount of inorganic residuals is ND to about 400 ppm. In an embodiment, the amount of inorganic residuals is ND to about 300 ppm. In an embodiment, the amount of inorganic residuals is ND to about 200 ppm. In an embodiment, the amount of inorganic residuals is ND to about 100 ppm. In an embodiment, the amount of inorganic residuals is between 10 ppm and 1000 ppm.

As used herein, the term “substantially free of organic residuals” means that the composition exhibits residuals of 0.1% (w/w) or less. In an embodiment, substantially free of organic residuals refers to a composition that exhibits residuals of 0.05% (w/w) or less. In an embodiment, substantially free of organic residuals refers to a composition that exhibits residuals of 0.01% (w/w) or less. In an embodiment, the amount of organic residuals is between 0 ppm (“non-detectable” or “ND”) and 1000 ppm. In an embodiment, the amount of organic residuals is ND to about 500 ppm. In an embodiment, the amount of organic residuals is ND to about 400 ppm. In an embodiment, the amount of organic residuals is ND to about 300 ppm. In an embodiment, the amount of organic residuals is ND to about 200 ppm. In an embodiment, the amount of organic residuals is ND to about 100 ppm. In an embodiment, the amount of organic residuals is between 10 ppm and 1000 ppm.

Compositions of the present disclosure are “biocompatible” or otherwise exhibit “biocompatibility” meaning that the compositions are compatible with living tissue or a living system by not being toxic, injurious, or physiologically reactive and not causing immunological rejection or an inflammatory response. Such biocompatibility can be evi-

denced by participants topically applying compositions of the present disclosure on their skin for an extended period of time. In an embodiment, the extended period of time is about 3 days. In an embodiment, the extended period of time is about 7 days. In an embodiment, the extended period of time is about 14 days. In an embodiment, the extended period of time is about 21 days. In an embodiment, the extended period of time is about 30 days. In an embodiment, the extended period of time is selected from the group consisting of about 1 month, about 2 months, about 3 months, about 4 months, about 5 months, about 6 months, about 7 months, about 8 months, about 9 months, about 10 months, about 11 months, about 12 months, and indefinitely. For example, in some embodiments, the coatings described herein are biocompatible coatings.

In some embodiments, compositions described herein, which may be biocompatible compositions (e.g., biocompatible coatings that include silk), may be evaluated and comply with International Standard ISO 10993-1, titled the “Biological evaluation of medical devices—Part 1: Evaluation and testing within a risk management process.” In some embodiments, compositions described herein, which may be biocompatible compositions, may be evaluated under ISO 10993-1 for one or more of cytotoxicity, sensitization, hemocompatibility, pyrogenicity, implantation, genotoxicity, carcinogenicity, reproductive and developmental toxicity, and degradation.

In some embodiments, compositions and articles described herein, and methods of preparing the same, include silk coated fabrics and textiles wherein the silk coating is partially dissolved in the fabric or textile. The fabric or textile may be a polymeric material such as those described elsewhere herein. The term “partially dissolved” includes mixing to form a dispersion of, e.g., a portion of a polymeric fabric or textile with a portion of the silk based coating. In some embodiments, the dispersion may be a solid suspension (i.e., a dispersion comprising domains on the order of 10 nm) or a solid solution (i.e., a molecular dispersion) of silk in the polymeric fabric or textile. In some embodiments, the dispersion may be localized at the surface interface between the silk coating and the polymeric fabric or textile, and may have a depth of 1 nm, 2 nm, 5 nm, 10 nm, 25 nm, 50 nm, 75 nm, 100 nm, or greater than 100 nm, depending on the method of preparation. In some embodiments, the dispersion may be a layer sandwiched between the polymeric fabric or textile and the silk coating. In some embodiments, the dispersion may be prepared by coating silk, including silk fibroin with the characteristics described herein, onto the polymeric fabric or textile, and then performing an additional process to form the dispersion, including heating at a temperature of 100° C., 125° C., 150° C., 175° C., 200° C., 225° C., or 250° C. for a time period selected from the group consisting of 1 minute, 2 minutes, 5 minutes, 10 minutes, 15 minutes, 20 minutes, 30 minutes, 1 hour, 2 hours, 4 hours, 8 hours, 16 hours, or 24 hours. In some embodiments, heating may be performed at or above the glass transition temperature (T_g) of silk and/or the polymeric fabric or textile, which may be assessed by methods known in the art. In some embodiments, the dispersion may be formed by coating silk, including silk fibroin with the characteristics described herein, onto the polymeric fabric or textile, and then performing an additional process to impregnate the silk coating into the polymeric fabric or textile, including treatment with an organic solvent. Methods for characterizing the properties of polymers dissolved in one another are well known in the art and

include differential scanning calorimetry and surface analysis methods capable of depth profiling, including spectroscopic methods.

Compositions of the present disclosure are “hypoallergenic” meaning that they are relatively unlikely to cause an allergic reaction. Such hypoallergenicity can be evidenced by participants topically applying compositions of the present disclosure on their skin for an extended period of time. In an embodiment, the extended period of time is about 3 days. In an embodiment, the extended period of time is about 7 days. In an embodiment, the extended period of time is about 14 days. In an embodiment, the extended period of time is about 21 days. In an embodiment, the extended period of time is about 30 days. In an embodiment, the extended period of time is selected from the group consisting of about 1 month, about 2 months, about 3 months, about 4 months, about 5 months, about 6 months, about 7 months, about 8 months, about 9 months, about 10 months, about 11 months, about 12 months, and indefinitely.

In some embodiments, where aqueous solutions are used to prepare SPF compositions or SPF containing coatings, the aqueous solutions may be prepared with DI water or tap water. As used herein, “tap water” refers to potable water provided by public utilities and water of comparable quality, regardless of the source, without further refinement such as by reverse osmosis, distillation, and/or deionization. Therefore, the use of “DI water,” “RODI water,” or “water,” as set forth herein, may be understood to be interchangeable with “tap water” according to the processes described herein without deleterious effects to such processes.

Textiles and Leathers Coated with Silk Fibroin-Based Protein Fragments

As used herein, the term “washable” and “exhibiting washability” means that a silk coated fabric of the present disclosure is capable of being washed without shrinking, fading, or the like.

As used herein, the term “textile” refers to a flexible woven or non-woven material consisting of a network of natural or artificial fibers often referred to as fabric, thread, or yarn. In an embodiment, textiles can be used to fabricate clothing, shoes and bags. In an embodiment, textiles can be used to fabricate carpeting, upholstered furnishings, window shades, towels, and coverings for tables, beds, and other flat surfaces. In an embodiment, textiles can be used to fabricate flags, backpacks, tents, nets, handkerchiefs, balloons, kites, sails, and parachutes.

As used herein, the term “leather” refers to natural leather and synthetic leather. Natural leather includes chrome-tanned leather (e.g., tanned using chromium sulfate and other chromium salts), vegetable-tanned leather (e.g., tanned using tannins), aldehyde-tanned leather (also known as wet-white leather, e.g., tanned using glutaraldehyde or oxa-zolidine compounds), brain-tanned leather, formaldehyde-tanned leather, Chamois leather (e.g., tanned using cod oils), rose-tanned leather (e.g., tanned using rose otto oils), synthetic-tanned leather (e.g., tanned using aromatic polymers), alum-tanned leather, patent leather, Vachetta leather, nubuck leather, and rawhide leather. Natural leather also includes split leather, full-grain leather, top-grain leather, and corrected-grain leather, the properties and preparation of which are known to those of skill in the art. Synthetic leather includes poromeric imitation leathers (e.g., polyurethane on polyester), vinyl and polyamide felt fibers, polyurethane, polyvinyl chloride, polyethylene (PE), polypropylene (PP), vinyl acetate copolymer (EVA), polyamide, polyester, textile-polymer composite microfibers, corfan, koskin, leatherette, BIOTHANE®, BIRKIBUC®, BIRKO-FLOR®, CLA-

RINO®, ECOLORICA®, KYDEX®, LORICA®, NAUGAHYDE®, REXINE®, VEGETAN®, FABRIKOID®, or combinations thereof.

As used herein, the term “hand” refers to the feel of a fabric, which may be further described as the feeling of softness, crispness, dryness, silkiness, and combinations thereof. Fabric hand is also referred to as “drape.” A fabric with a hard hand is coarse, rough, and generally less comfortable for the wearer. A fabric with a soft hand is fluid and smooth, such as fine silk or wool, and generally more comfortable for the wearer. Fabric hand can be determined by comparison to collections of fabric samples, or by use of methods such as the Kawabata Evaluation System (KES) or the Fabric Assurance by Simple Testing (FAST) methods. Behera and Hari, *Ind. J. Fibre & Textile Res.*, 1994, 19, 168-71.

As used herein, the term “yarn” refers to a single or multi-fiber construct.

As used herein, a “coating” refers to a material, or combination of materials, that form a substantially continuous layer or film on an exterior surface of a substrate, such as a textile. In some embodiments, a portion of the coating may penetrate at least partially into the substrate. In some embodiments, the coating may penetrate at least partially into the interstices of a substrate. In some embodiments, the coating may be infused into a surface of the substrate such that the application of the coating, or coating process, may include infusing (at the melting temperature of the substrate) at least one coating component at least partially into a surface of the substrate. A coating may be applied to a substrate by one or more of the processes described herein.

In embodiments described where the coating may be infused into a surface of the substrate, the coating may be codissolved in a surface of the substrate such that a component of the coating may be intermixed in the surface of the substrate to a depth of at least about 1 nm, or at least about 2 nm, or at least about 3 nm, or at least about 4 nm, or at least about 5 nm, or at least about 6 nm, or at least about 7 nm, or at least about 8 nm, or at least about 9 nm, or at least about 10 nm, or at least about 20 nm, or at least about 30 nm, or at least about 40 nm, or at least about 50 nm, or at least about 60 nm, or at least about 70 nm, or at least about 80 nm, or at least about 90 nm, or at least about 100 nm. In some embodiments, the coating may be infused into a surface of the substrate where the substrate includes one or more polymers including, but not limited to, polyester, polyamide, polyaramid, polytetrafluoroethylene, polyethylene, polypropylene, polyurethane, silicone, mixtures of polyurethane and polyethyleneglycol, ultrahigh molecular weight polyethylene, high-performance polyethylene, nylon, and LYCRA.

As used herein, the term “bath coating” encompasses coating a fabric in a batch, immersing a fabric in a bath, and submerging a fabric in a bath. Concepts of bath coating are set forth in U.S. Pat. No. 4,521,458, the entirety of which is incorporated by reference.

As used herein, and unless more specifically described, the term “drying” may refer to drying a coated material as described herein at a temperature greater than room temperature (i.e., 20° C.).

In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile used for human apparel, including performance and/or athletic apparel. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based

proteins or fragments thereof, and wherein the textile or leather product exhibits improved moisture management properties and/or resistance to microbial growth. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product used for home upholstery. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile or leather product is used for automobile upholstery. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile or leather product is used for aircraft upholstery. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile or leather product is used for upholstery in transportation vehicles for public, commercial, military, or other use, including buses and trains. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile or leather product is used for upholstery of a product that requires a high degree of resistance to wear as compared to normal upholstery.

In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as trim on automobile upholstery. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a steering wheel. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a headrest. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as an armrest. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as an automobile floor mat. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as automobile or vehicle carpet. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as automotive trim. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a children's car seat. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a seat belt or safety harness. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a dashboard. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a seat. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated

as a seat panel. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as an interior panel. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as an airbag cover. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as an airbag. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a sunvisor. In an embodiment, the invention provides a textile or leather product coated with silk fibroin-based proteins or fragments thereof, wherein the textile is a textile or leather product fabricated as a wiring harness. In an embodiment, the invention provides a product coated with silk fibroin-based proteins or fragments thereof, wherein the product is a cushion. In an embodiment, the invention provides a product coated with silk fibroin-based proteins or fragments thereof, wherein the product is automotive, aircraft, or other vehicular insulation. The coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

In an embodiment, the invention provides an article comprising a textile or leather coated with silk fibroin-based proteins or fragments thereof. In an embodiment, the textile or leather is a textile or leather used in the manufacture of tents, sleeping bags, ponchos, and soft-walled coolers. In an embodiment, the textile or leather is a textile or leather used in the manufacture of athletic equipment. In an embodiment, the textile or leather is a textile or leather used in the manufacture of outdoor gear. In an embodiment, the textile or leather is a textile or leather used in the manufacture of hiking gear, such as harnesses and backpacks. In an embodiment, the textile or leather is a textile or leather used in the manufacture of climbing gear. In an embodiment, the textile or leather is canvass. In an embodiment, the textile or leather is a textile or leather used in the manufacture of a hat. In an embodiment, the textile or leather is a textile or leather used in the manufacture of an umbrella. In an embodiment, the textile or leather is a textile or leather used in the manufacture of a tent. In an embodiment, the textile or leather is a textile or leather used in the manufacture of a baby sleeper, a baby blanket, or a baby pajama. In an embodiment, the textile or leather is a textile or leather used in the manufacture of a glove, such as a driving glove or an athletic glove. In an embodiment, the textile or leather is a textile or leather used in the manufacture of athletic pants, such as sweat pants, jogging pants, yoga pants, or pants for use in competitive sports. In an embodiment, the textile or leather is a textile or leather used in the manufacture of athletic shirts, such as sweat shirts, jogging shirts, yoga shirts, or shirts for

use in competitive sports. In an embodiment, the textile or leather is a textile or leather used in the manufacture of beach equipment, such as beach umbrellas, beach chairs, beach blankets, and beach towels. In an embodiment, the textile or leather is a textile or leather used in the manufacture of jackets or overcoats. In an embodiment, the textile or leather is a textile or leather used in the manufacture of medical garments, such as surgical drapes, surgical gowns, surgical sleeves, laboratory sleeves, laboratory coats, wound dressings, sterilization wraps, surgical face masks, retention bandages, support devices, compression bandages, shoe covers, surgical blankets, and the like. The coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

In an embodiment, the invention provides a shoe coated with silk fibroin-based proteins or fragments thereof. In an embodiment, the invention provides a shoe coated with silk fibroin-based proteins or fragments thereof, wherein the shoe exhibits an improved property relative to an uncoated shoe. In an embodiment, the invention provides a shoe coated with silk fibroin-based proteins or fragments thereof, wherein the shoe exhibits an improved property relative to an uncoated shoe, and wherein the improved property is stain resistance. In an embodiment, the invention provides a shoe coated with silk fibroin-based proteins or fragments thereof, wherein the shoe exhibits an improved property relative to an uncoated shoe, and wherein the shoe is made of natural leather or synthetic leather. The coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the article is a textile or leather.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the

coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits an improved property, wherein the improved property is an accumulative one-way moisture transport index selected from the group consisting of greater than 40%, greater than 60%, greater than 80%, greater than 100%, greater than 120%, greater than 140%, greater than 160%, and greater than 180%. In an embodiment, the foregoing improved property is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits an improved property, wherein the improved property is an accumulative one way transport capability increase relative to uncoated fabric selected from the group consisting of 1.2 fold, 1.5 fold, 2.0 fold, 3.0 fold, 4.0 fold, 5.0 fold, and 10 fold. In an embodiment, the foregoing improved property is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits an improved property, wherein the improved property is an overall moisture management capability selected from the group consisting of greater than 0.05, greater than 0.10, greater than 0.15, greater than 0.20, greater than 0.25, greater than 0.30, greater than 0.35, greater than 0.40, greater than 0.50, greater than 0.60, greater than 0.70, and greater than 0.80. In an embodiment,

the foregoing improved property is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric exhibits substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles, and wherein the microbial growth is microbial growth of a microbe selected from the group consisting of *Staphylococcus aureus*, *Klebsiella pneumoniae*, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric exhibits substantially no increase in microbial growth after a number of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles, wherein the microbial growth is microbial growth of a microbe selected from the group consisting of *Staphylococcus aureus*, *Klebsiella pneumoniae*, and combinations thereof, wherein the microbial growth is reduced by a percentage selected from the group consisting of 50%, 100%, 500%, 1000%, 2000%, and 3000% compared to an uncoated fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the coating is applied to the fabric at the fiber level prior to forming the fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the coating is applied to the fabric at the fabric level or garment level (e.g., after manufacture of a garment from fabrics, leathers, and/or other materials).

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level or garment level, and wherein the fabric is bath coated.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric,

wherein the coating is applied to the fabric at the fabric level or garment level, and wherein the fabric is spray coated.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level or garment level, and wherein the fabric is coated with a stencil.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level or garment level, and wherein the coating is applied to at least one side of the fabric using a method selected from the group consisting of a bath coating process, a spray coating process, a stencil (i.e., screen) process, a silk-foam based process, a roller-based process, a magnetic roller process, a knife process, a transfer process, a foam process, a lacquering process, and a printing process. In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the coating is applied to both sides of the fabric using a method selected from the group consisting of a bath coating process, a spray coating process, a stencil (i.e., screen) process, a silk-foam based process, a roller-based process, a magnetic roller process, a knife process, a transfer process, a foam process, a lacquering process, and a printing process.

In any of the foregoing embodiment, the coating may be applied at the fabric garment level by any of the methods disclosed herein to recondition fabrics or garments. For example, such reconditioning using a coating comprising silk based proteins or fragments thereof may be performed as part of washing or cleaning a fabric or garment.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the coating has a thickness of about one nanolayer.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the coating has a thickness selected from the group consisting of about 5 nm, about 10 nm, about 15 nm, about 20 nm, about 25 nm, about 50 nm, about 100 nm, about 200 nm, about 500 nm, about 1 μm, about 5 μm, about 10 μm, and about 20 μm.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the coating is adsorbed on the fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and

wherein the coating is attached to the fabric through chemical, enzymatic, thermal, or irradiative cross-linking.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the hand of the coated fabric is improved relative to an uncoated fabric.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the hand of the coated fabric is improved relative to an uncoated fabric, wherein the hand of the coated fabric that is improved is selected from the group consisting of softness, crispness, dryness, silkiness, and combinations thereof.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is applied to the fabric at the fabric level, and wherein the pilling of the fabric is improved relative to an uncoated fabric.

In an embodiment, the silk coating is applied using a bath process, a screen (or stencil) process, a spray process, a silk-foam based process, and a roller based process.

In an embodiment, a fiber or a yarn comprises a synthetic fiber or yarn, including polyester, Mylar, cotton, nylon, polyester-polyurethane copolymer, rayon, acetate, aramid (aromatic polyamide), acrylic, ingeo (polylactide), lurex (polyamide-polyester), olefin (polyethylene-polypropylene), and combinations thereof.

In an embodiment, a fiber or a yarn comprises a natural fiber or yarn (e.g., from animal or plant sources), including alpaca fiber, alpaca fleece, alpaca wool, lama fiber, lama fleece, lama wool, cotton, cashmere and sheep fiber, sheep fleece, sheep wool, byssus, chiengora, quiviu, yak, rabbit, lambswool, mohair wool, camel hair, angora wool, silk-worm silk, abaca fiber, coir fiber, flax fiber, jute fiber, kapok fiber, kenaf fiber, raffia fiber, bamboo fiber, hemp, modal fiber, pina, ramie, sisal, and soy protein fiber.

In an embodiment, a fiber or a yarn comprises a mineral fiber, also known as mineral wool, mineral cotton, or man-made mineral fiber, including fiberglass, glass, glasswool, stone wool, rock wool, slagwool, glass filaments, asbestos fibers, and ceramic fibers.

In an embodiment, a water-soluble silk coating may be used as an adhesive or binder for binding particles to fabrics or for binding fabrics. In an embodiment, an article comprises a fabric bound to another fabric using a silk coating. In an embodiment, an article comprises a fabric with particles bound to the fabric using a silk adhesive.

In an embodiment, the coating is applied to an article including a fabric at the yarn level. In an embodiment, the coating is applied at the fabric level. In an embodiment, the coating has a thickness selected from the group consisting of about 5 nm, about 10 nm, about 15 nm, about 20 nm, about 25 nm, about 50 nm, about 100 nm, about 200 nm, about 500 nm, about 1 μm, about 5 μm, about 10 μm, and about 20 μm. In an embodiment, the coating has a thickness range selected from the group consisting of about 5 nm to about 100 nm,

about 100 nm to about 200 nm, about 200 nm to about 500 nm, about 1 μm to about 2 μm , about 2 μm to about 5 μm , about 5 μm to about 10 μm , and about 10 μm to about 20 μm .

In an embodiment, a fiber or a yarn is treated with a polymer, such as polyglycolide (PGA), polyethylene glycols, copolymers of glycolide, glycolide/L-lactide copolymers (PGA/PLLA), glycolide/trimethylene carbonate copolymers (PGA/TMC), polylactides (PLA), stereopolymers of PLA, poly-L-lactide (PLLA), poly-DL-lactide (PDLLA), L-lactide/DL-lactide copolymers, co-polymers of PLA, lactide/tetramethylglycolide copolymers, lactide/trimethylene carbonate copolymers, lactide/ δ -valerolactone copolymers, lactide/ ϵ -caprolactone copolymers, polydepsipeptides, PLA/polyethylene oxide copolymers, unsymmetrically 3,6-substituted poly-1,4-dioxane-2,5-diones, poly- β -hydroxybutyrate (PHBA), PHBA/ β -hydroxyvalerate copolymers (PHBA/HVA), poly- β -hydroxypropionate (PHPA), poly-p-dioxanone (PDS), poly- δ -valerolactone, poly- ϵ -caprolactone, methylmethacrylate-N-vinyl pyrrolidine copolymers, polyesteramides, polyesters of oxalic acid, polydihydroprans, polyalkyl-2-cyanoacrylates, polyurethanes (PU), polyvinylalcohols (PVA), polypeptides, poly- β -malic acid (PMLA), poly- β -alkanoic acids, polyvinylalcohol (PVA), polyethyleneoxide (PEO), chitine polymers, polyethylene, polypropylene, polyasetal, polyamides, polyesters, polysulfone, polyether ether ketone, polyethylene terephthalate, polycarbonate, polaryl ether ketone, and polyether ketone ketone.

In an embodiment, the silk coating surface can be modified silk crystals that range in size from nm to μm .

The criterion for “visibility” is satisfied by any one of the following: a change in the surface character of the textile; the silk coating fills the interstices where the yarns intersect; or the silk coating blurs or obscures the weave.

In an embodiment, a silk based protein or fragment solution may be utilized to coat at least a portion of a fabric which can be used to create a textile. In an embodiment, a silk based protein or fragment solution may be weaved into yarn that can be used as a fabric in a textile. In an embodiment, a silk based protein or fragment solution may be used to coat a fiber. In an embodiment, the invention provides an article comprising a silk based protein or fragment solution coating at least a portion of a fabric or a textile. In an embodiment, the invention provides an article comprising a silk based protein or fragment solution coating a yarn. In an embodiment, the invention provides an article comprising a silk based protein or fragment solution coating a fiber.

There is disclosed a textile that is at least partially surface treated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure so as to result in a silk coating on the textile. In an embodiment, the silk coating of the present disclosure is available in a spray can and can be sprayed on any textile by a consumer. In an embodiment, a textile comprising a silk coating of the present disclosure is sold to a consumer. In an embodiment, a textile of the present disclosure is used in constructing action sportswear/apparel. In an embodiment, a silk coating of the present disclosure is positioned on the underlining of apparel. In an embodiment, a silk coating of the present disclosure is positioned on the shell, the lining, or the interlining of apparel. In an embodiment, apparel is partially made from a silk coated textile of the present disclosure and partially made from an uncoated textile. In an embodiment, apparel partially made from a silk coated textile and partially made from an uncoated textile combines an uncoated inert synthetic material with a silk coated inert synthetic material. Examples of inert synthetic material include, but are not

limited to, polyester, polyamide, polyaramid, polytetrafluoroethylene, polyethylene, polypropylene, polyurethane, silicone, mixtures of polyurethane and polyethyleneglycol, ultra-high molecular weight polyethylene, high-performance polyethylene, and mixtures thereof. In an embodiment, apparel partially made from a silk coated textile and partially made from an uncoated textile combines an elastomeric material at least partially covered with a silk coating of the present disclosure. In an embodiment, the percentage of silk to elastomeric material can be varied to achieve desired shrink or wrinkle resistant properties.

In an embodiment, a silk coating of the present disclosure is visible. In an embodiment, a silk coating of the present disclosure positioned on apparel helps control skin temperature. In an embodiment, a silk coating of the present disclosure positioned on apparel helps control fluid transfer away from the skin. In an embodiment, a silk coating of the present disclosure positioned on apparel has a soft feel against the skin decreasing abrasions from fabric on skin. In an embodiment, a silk coating of the present disclosure positioned on a textile has properties that confer at least one of wrinkle resistance, shrinkage resistance, or machine washability to the textile. In an embodiment, a silk coated textile of the present disclosure is 100% machine washable and dry cleanable. In an embodiment, a silk coated textile of the present disclosure is 100% waterproof. In an embodiment, a silk coated textile of the present disclosure is wrinkle resistant. In an embodiment, a silk coated textile of the present disclosure is shrink resistant. In an embodiment, a silk coated textile of the present disclosure has the qualities of being waterproof, breathable, and elastic and possess a number of other qualities which are highly desirable in action sportswear. In an embodiment, a silk coated textile of the present disclosure manufactured from a silk fabric of the present disclosure further includes LYCRA® brand spandex fibers.

In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a breathable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a water-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a shrink-resistant fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a machine-washable fabric. In an embodiment, a textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is a wrinkle resistant fabric. In an embodiment, textile at least partially coated with an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure provides moisture and vitamins to the skin.

In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is used to coat a textile or leather. In an embodiment, the concentration of silk in the solution ranges from about 0.1% to about 20.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.1% to about 15.0%. In an embodiment, the concentration of silk in the solution ranges from about 0.5% to about 10.0%. In an embodiment, the concentration of silk in the solution ranges from about 1.0% to about 5.0%. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure is applied directly to a fabric. Alternatively, silk

microsphere and any additives may be used for coating a fabric. In an embodiment, additives can be added to an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure before coating (e.g., alcohols) to further enhance material properties. In an embodiment, a silk coating of the present disclosure can have a pattern to optimize properties of the silk on the fabric. In an embodiment, a coating is applied to a fabric under tension and/or lax to vary penetration in to the fabric.

In an embodiment, a silk coating of the present disclosure can be applied at the yarn level, followed by creation of a fabric once the yarn is coated. In an embodiment, an aqueous solution of pure silk fibroin-based protein fragments of the present disclosure can be spun into fibers to make a silk fabric and/or silk fabric blend with other materials known in the apparel industry.

Uses of Textiles and Leathers Coated with Silk Fibroin-Based Protein Fragments in Apparel and Garment Applications

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article exhibits an improved color retention property. Without being bound by any specific theory, it is postulated that the coating prevents the article from color degradation by separating the fiber or yarn from air or from detergents during washing.

Methods of testing the color retention property of an article are well within the knowledge of one skilled in the art. A specific method of testing of the color retention property of a fabric is described in U.S. Pat. No. 5,142,292, which is incorporated herein by reference in its entirety.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combina-

tions thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article exhibits an improved color retention property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits an improved color retention property. In an embodiment, the foregoing color retention property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits an improved color retention property. In

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an embodiment, the foregoing improved color retention property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx*

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mori silk based proteins or fragments thereof, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article is resistant to microbial (including bacterial and fungal) growth.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is resistant to microbial (including bacterial and fungal) growth. In an embodiment, the foregoing resistant to microbial (including bacterial and fungal) growth property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits resistant to microbial (including bacterial and fungal) growth property. In an embodiment, the foregoing resistant to microbial (including bacterial and fungal) growth property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group con-

sisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article is resistant to the buildup of static electrical charge.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is resistant to the buildup of static electrical charge. In an embodiment, the foregoing resistant to the buildup of static electrical charge property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits resistant to the buildup of static electrical charge property. In an embodiment, the foregoing resistant to the buildup of static electrical charge property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or

fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article is mildew resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is mildew resistant. In an embodiment, the foregoing mildew resistant property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits mildew resistant property. In an embodiment, the foregoing mildew resistant property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the

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coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the coating is transparent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating is transparent. In an embodiment, the foregoing transparent property of the coating is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather comprises a silk coating of the present disclosure, wherein the silk coating is transparent. In an embodiment, the foregoing transparent property of the coating is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof

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having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copo-

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lymer, and combinations thereof, wherein the article is resistant to freeze-thaw cycle damage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is resistant to freeze-thaw cycle damage. In an embodiment, the foregoing resistant to freeze-thaw cycle damage property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits resistant to freeze-thaw cycle damage. In an embodiment, the foregoing resistant to freeze-thaw cycle damage property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5

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kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the coating provides protection from abrasion.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the coating provides protection from abrasion. In an embodiment, the foregoing abrasion resistant property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits abrasion resistant. In an embodiment, the foregoing abrasion resistant property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

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In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or

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fragments comprise silk and a copolymer, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article exhibits the property of blocking ultraviolet (UV) radiation.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits the property of blocking ultraviolet (UV) radiation. In an embodiment, the foregoing UV blocking property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits UV blocking property. In an embodiment, the foregoing UV blocking property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof

having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments thereof are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group

consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the garment regulates the body temperature of a wearer.

In an embodiment, the invention provides a garment comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the garment regulates the body temperature of a wearer. In an embodiment, the foregoing temperature regulation property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits a temperature regulation property. In an embodiment, the foregoing temperature regulation property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or

fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, and wherein the article is tear resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the article is tear resistant. In an embodiment, the foregoing tear resistant property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits a tear resistant property. In an embodiment, the foregoing tear resistant property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the elasticity of the article is improved.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the

coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the elasticity of the article is reduced.

5 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or 10 fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the elasticity of the article is improved.

In an embodiment, the invention provides an article 15 comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or 20 protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the elasticity of the article is reduced.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article exhibits a rebound 25 dampening property. Without being bound by any specific theory, it is postulated that the coating prevents the article from returning to the original shape or orientation, and 30 results in the rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, 35 wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or 40 fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or 45 fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or 50 fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based

proteins or fragments thereof, and combinations thereof, wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article exhibits a rebound dampening property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits a rebound dampening property. In an embodiment, the foregoing rebound dampening property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits a rebound dampening property. In an embodiment, the foregoing rebound dampening property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5

kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article exhibits an anti-itch property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits an anti-itch property. In an embodiment, the foregoing anti-itch property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits an anti-itch property. In an embodiment, the foregoing anti-itch property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article exhibits an improved insulation/warmth property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits an improved insulation/warmth property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article exhibits an improved insulation/warmth property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof

having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits an improved insulation/warmth property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article exhibits an improved insulation/warmth property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article exhibits an improved insulation/warmth property.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article exhibits an improved insulation/warmth property. In an embodiment, the foregoing improved insulation/warmth property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits improved an insulation/warmth property. In an embodiment, the foregoing improved insulation/warmth property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5

kDa to about 144 kDa, wherein the article is a fabric, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece,

lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article is wrinkle resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is wrinkle resistant. In an embodiment, the foregoing wrinkle resistant property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits wrinkle resistant property. In an embodiment, the foregoing wrinkle resistant property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments

thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article is stain resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is stain resistant. In an embodiment, the foregoing stain resistant property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits stain resistant property. In an embodiment, the foregoing stain resistant property of the textile is

determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is sticky. Without being bound to any specific theory, it is postulated that the coating provides stickiness and maintains stickiness.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is sticky.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is sticky.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is sticky. In an embodiment, the foregoing sticky property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure exhibits sticky property. In an embodiment, the foregoing sticky property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides an article comprising a textile or leather coated with silk fibroin-based proteins or fragments thereof, wherein the article exhibits improved flame resistance relative to an uncoated textile. In an embodiment, the invention provides an article comprising a textile or leather coated with silk fibroin-based proteins or fragments thereof, wherein the article exhibits equal flame resistance relative to an uncoated textile or leather. In an embodiment, the invention provides an article comprising a textile or leather coated with silk fibroin-based proteins or fragments thereof, wherein the article exhibits equal flame resistance relative to an uncoated textile or leather, wherein an alternative textile or leather coating exhibits reduced flame resistance. In an embodiment, the invention provides an article comprising a textile or leather coated with silk fibroin-based proteins or fragments thereof, wherein the article exhibits improved resistance to fire relative to an uncoated textile or leather, wherein the improved resistance to fire is determined by a flammability test. In an embodiment, the flammability test measures afterflame time, afterglow time, char length, and the observation of fabric melting or dripping.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the

coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a polyester having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof comprise silk fibroin-based proteins or protein fragments having about 0.01% (w/w) to about 10% (w/w) sericin, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof are selected from the group consisting of natural silk based proteins or fragments thereof, recombinant silk based proteins or fragments thereof, and combinations thereof, wherein the silk based proteins or fragments thereof are natural silk based proteins or fragments thereof that are selected from the group consisting of spider silk based proteins or fragments thereof, silkworm silk based proteins or fragments thereof, and combinations thereof, wherein the natural silk based proteins or fragments are silkworm silk based proteins or fragments thereof, and the silkworm silk based proteins or fragments thereof is *Bombyx mori* silk based proteins or fragments thereof, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the silk based proteins or fragments comprise silk and a copolymer, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the

coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is natural fiber or yarn selected from the group consisting of cotton, alpaca fleece, alpaca wool, lama fleece, lama wool, cotton, cashmere, sheep fleece, sheep wool, and combinations thereof, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the fiber or yarn is selected from the group consisting of natural fiber or yarn, synthetic fiber or yarn, or combinations thereof, wherein the fiber or yarn is synthetic fiber or yarn selected from the group consisting of polyester, nylon, polyester-polyurethane copolymer, and combinations thereof, wherein the article is flame resistant.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, wherein the fabric is flame resistant. In an embodiment, the foregoing flame resistant property of the fabric is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, a textile or leather of the present disclosure is flame resistant. In an embodiment, the foregoing flame resistant property of the textile is determined after a period of machine washing cycles selected from the group consisting of 5 cycles, 10 cycles, 25 cycles, and 50 cycles.

In an embodiment, the invention provides a leather coated with coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the leather exhibits an property selected from the group consisting of an improved color retention property, improved mildew resistance, improved resistance to freeze-thaw cycle damage, improved resistance to abrasion, improved blocking of ultraviolet (UV) radiation, improved regulation of the body temperature of a wearer, improved tear resistance, improved elasticity, improved rebound dampening, improved anti-itch properties, improved insulation, improved wrinkle resistance, improved stain resistance, and improved stickiness. In an embodiment, the invention provides a leather coated with coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the coating is transparent.

In any of the foregoing embodiments, at least one property of the article is improved, wherein the property that is improved is selected from the group consisting of color retention, resistance to microbial growth, resistance to bacterial growth, resistance to fungal growth, resistance to the buildup of static electrical charge, resistance to the growth of mildew, transparency of the coating, resistance to freeze-thaw cycle damage, resistance from abrasion, blocking of ultraviolet (UV) radiation, regulation of the body temperature of a wearer, resistance to tearing, elasticity of the article, rebound dampening, tendency to cause itching in the wearer, thermal insulation of the wearer, wrinkle resistance, stain resistance, stickiness to skin, and flame resistance, and wherein the property is improved by an amount relative to

an uncoated article selected from the group consisting of at least 5%, at least 10%, at least 15%, at least 20%, at least 25%, at least 30%, at least 35%, at least 40%, at least 45%, at least 50%, at least 55%, at least 60%, at least 65%, at least 70%, at least 75%, at least 80%, at least 85%, at least 90%, at least 95%, at least 100%, at least 125%, at least 150%, at least 200%, at least 300%, at least 400%, and at least 500%.

In any of the foregoing embodiments, the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

Additional Agents for Use with Textiles Coated with Silk Fibroin-Based Protein Fragments

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is pretreated with a wetting agent. In an embodiment, the wetting agent improves one or more coating properties. Suitable wetting agents are known to those of skill in the art. Exemplary, non-limiting examples of wetting agents from a representative supplier, Lamberti SPA, are given in the following table.

Imbitex NDT	Non silicone low foaming with high wetting in both hot or cold conditions, with good detergency and good stability to alkalis.
Imbitex TBL	Wetting and de-aerating agent.
Imbitex MRC	Wetting and penetrating agent for mercerizing of cotton.
Tensolam Na liq.	Low foam, special wetting and dispersing agent for non-woven wet treatments.
Imbitex NRW3	Wetting agent for water-and oil repellent finishing.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is pretreated with a detergent. In an embodiment, the detergent improves one or more coating properties. Suitable detergents are known to those of skill in the art. Exemplary, non-limiting examples of detergents from a representative supplier, Lamberti SPA, are given in the following table.

Biorol CPNN	Wetting and detergent agent with alkaline stability in NaOH up to 10° C. Recommended for continuous scouring, bleaching, and Jigger applications.
Biorol JK new	Wetting and detergent agent with extremely low foam properties, recommended for high bath turbulence machine (e.g., jet, overflow, etc.).
Biorol OW 60	General-purpose wetting and detergent agent suitable for desizing, scouring, and bleaching processes.
Biorol OWK	Detergent/wetting agent, low foaming, high concentration, recommended for over-flow. Useful for removal of silicone oil on Lycra blends.

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Cesapon Silk liq.	Specific scouring, de-gumming agent for silk.
Cesapon Extra	High detergent power product containing solvent.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is pretreated with a sequestering or dispersing agent. Suitable sequestering or dispersing agents are known to those of skill in the art. Exemplary, non-limiting examples of sequestering or dispersing agents from a representative supplier, Lamberti SPA, are given in the following table.

Lamegal DSP	Dispersing and anti-redepositing agent useful for preparation dyeing and after soaping of dyed and printed materials with reactive and vat dyes. This product is also useful as an anti-olygomer agent in reduction clearing of polyester, dyed or printed with disperse dyes.
Chelam TLW/T	Multi-purpose sequestering and dispersing agent for a wide variety of textile processes. No shade variation on dyestuff containing metals.
Lamegal TLS	Multi-purpose sequestering and dispersing agent for a wide variety of textile processes.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is pretreated with an enzyme. Suitable enzymes are known to those of skill in the art. Exemplary, non-limiting examples of enzymes from a representative supplier, Lamberti SPA, are given in the following table.

Lazim HT	Thermo-stable amylase for rapid high temperature desizing.
Lazim PE	Specific enzyme for bioscouring; provides optimal wettability, it improves dyeing and color fastness without causing depolymerization and fabric strength loss.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is pretreated with a bleaching agent. Suitable bleaching agents are known to those of skill in the art. Exemplary, non-limiting examples of bleaching agents from a representative supplier, Lamberti SPA, are given in the following table.

Stabilox OTN conc.	Highly concentrated stabilizer for alkaline bleaching with hydrogen peroxide. Suitable for a wide variety of processes.
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In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is pretreated with an antifoaming agent. Suitable antifoaming agents are known to those of skill in

the art. Exemplary, non-limiting examples of antifoaming agents from a representative supplier, Lamberti SPA, are given in the following table.

Antifoam SE 47	General purpose defoaming agent.
Defomex JET	Silicone defoamer effective up to 130° C. Recommended for HT and JET dyeing systems.
Defomex 2033	Non-silicone defoamer.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is pretreated with an anti-creasing agent. Suitable anti-creasing agents are known to those of skill in the art. Exemplary, non-limiting examples of anti-creasing agents from a representative supplier, Lamberti SPA, are given in the following table.

Lubisol AM	Lubricating and anti-creasing agent for rope wet operation on all kind of fibers and machines.
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In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a dye dispersing agent. Suitable dye dispersing agents are known to those of skill in the art. Exemplary, non-limiting examples of dye dispersing agents from a representative supplier, Lamberti SPA, are given in the following table.

Lamegal BO	Liquid dispersing agent (non-ionic), suitable for direct, reactive, disperse dyeing and PES stripping.
Lamegal DSP	Dispersing and anti back-staining agent in preparation, dyeing and soaping of dyed and printed materials. Ant oligomer agent.
Lamegal 619	Effective low foam dispersing leveling agent for dyeing of PES.
Lamegal TL5	Multi-purpose sequestering and dispersing agent for a variety of textile processes.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a dye leveling agent. Suitable dye leveling agents are known to those of skill in the art. Exemplary, non-limiting examples of dye leveling agents from a representative supplier, Lamberti SPA, are given in the following table.

Lamegal A 12	Leveling agent for dyeing on wool, polyamide and its blends with acid or metal complex dyes.
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In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a dye fixing agent. Suitable

dye fixing agents are known to those of skill in the art. Exemplary, non-limiting examples of dye fixing agents from a representative supplier, Lamberti SPA, are given in the following table.

5	Lamfix L	Fixing agent for direct and reactive dyestuffs, containing formaldehyde.
10	Lamfix LU conc.	Formaldehyde free cationic fixing agent for direct and reactive dyes. It does not affect the shade and light fastness.
15	Lamfix PA/TR	Fixing agent to improve the wet fastness of acid dyes on polyamide fabrics, dyed or printed and polyamide yarns. Retarding agent in dyeing of Polyamide/cellulosic blends with direct dyes.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a dye special resin agent. Suitable dye special resin agents are known to those of skill in the art. Exemplary, non-limiting examples of dye special resin agents from a representative supplier, Lamberti SPA, are given in the following table.

30	Denifast TC	Special resin for cationization of cellulose fibers to obtain special effects ("DENIFAST system" and "DENISOL system").
35	Cobra DD/50	Special resin for cationization of cellulose fibers to obtain special effect ("DENIFAST system" and "DENISOL system").

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a dye anti-reducing agent. Suitable dye anti-reducing agents are known to those of skill in the art. Exemplary, non-limiting examples of dye anti-reducing agents from a representative supplier, Lamberti SPA, are given in the following table.

45	Lamberti Redox L2S gra	Anti-reducing agent in grain form. 100% active content.
50	Lamberti Redox L2S liq.	Anti-reducing agent in liquid form for automatic dosage.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a pigment dye system anti-migrating agent. Suitable pigment dye system anti-migrating agents are known to those of skill in the art. Exemplary, non-limiting examples of pigment dye system anti-migrating agents from a representative supplier, Lamberti SPA, are given in the following table.

60	Neopat Compound	Compound, developed as migration inhibitor for 96/m conc.
65		Compound, developed as migration inhibitor for continuous dyeing process with pigments (pad-dry process).

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a pigment dye system binder. Suitable pigment dye system binders are known to those of skill in the art. Exemplary, non-limiting examples of pigment dye system binders from a representative supplier, Lamberti SPA, are given in the following table.

Neopat Binder PM/S conc.	Concentrated version of a specific binder used to prepare pad-liquor for dyeing with pigments (pad-dry process).
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In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a pigment dye system binder and anti-migrating agent combination. Suitable pigment dye system binder and anti-migrating agent combinations are known to those of skill in the art. Exemplary, non-limiting examples of pigment dye system binder and anti-migrating agent combinations from a representative supplier, Lamberti SPA, are given in the following table.

Neopat Compound PK1	Highly concentrated all-in-one product specifically developed as migration inhibitor with specific binder for continuous dyeing process with pigments (pad-dry process).
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In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is treated with a delave agent. Suitable delave agents are known to those of skill in the art. Exemplary, non-limiting examples of delave agents from a representative supplier, Lamberti SPA, are given in the following table.

Neopat compound FTN	Highly concentrated compound of surfactants and polymers specifically developed for pigment dyeing and pigment-reactive dyeing process; especially for medium/dark shades for wash off effect.
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In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is traditionally finished with a wrinkle free treatment. Suitable wrinkle free treatments are known to those of skill in the art. Exemplary, non-limiting examples of wrinkle free treatments from a representative supplier, Lamberti SPA, are given in the following table.

Cellofix ULF conc.	Anti-crease modified glyoxalic resin for finishing of cottons, cellulosics and blends with synthetics fibers.
Poliflex PO 40	Polyethilene resin for waxy, full and slippery handle by foulard applications.
Rolflex WF	Aliphatic waterborne Nano-PU dispersion used as extender for wrinkle free treatments.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is traditionally finished with a softener. Suitable softeners are known to those of skill in the art. Exemplary, non-limiting examples of softeners from a representative supplier, Lamberti SPA, are given in the following table.

Texamina C/FPN	Cationic softening agent with a very soft handle particularly recommended for application by exhaustion for all kind of fabrics. Suitable also for cone application.
Texamina C SAL flakes	100% cationic softening agent in flakes form for all type of fabrics. Dispersible at room temperature.
Texamina CL LIQ.	Anphoteric softening agent for all types of fabrics. Not yellowing.
Texamina HVO	Anphoteric softening agent for woven and knitted fabrics of cotton, other cellulosics and blends. Provides a soft, smooth and dry handle. Applied by padding.
Texamina SIL	Nonionic silicon dispersion in water. Excellent softening, lubricating and anti-static properties for all fibre types by padding.
Texamina SILK	Special cationic softener with silk protein inside. Provides a "swollen touch" particularly suitable for cellulosic, wool, silk.
Lamfinish LW	All-in compound based on special polymeric hydrophilic softeners; by coating, foulard, and exhaustion.
Elastolam E50	General purpose mono-component silicone elastomeric softener for textile finishing.
Elastolam EC 100	Modified polysiloxane micro-emulsion which gives a permanent finishing, with extremely soft and silky handle.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is traditionally finished with a handle modifier. Suitable handle modifiers are known to those of skill in the art. Exemplary, non-limiting examples of handle modifiers from a representative supplier, Lamberti SPA, are given in the following table.

Poliflex CSW	Cationic anti-slipping agent.
Poliflex R 75	Parafine finishing agent to give waxy handle.
Poliflex s	Compound specifically developed for special writing effects.
55 Poliflex m	Compound for special dry-waxy handle.
Lamsoft SW 24	Compound for special slippy handle specifically developed for coating application.
Lamfinish SLIPPY	All-in-one compound to get a slippy touch; by coating.
Lamfinish GUMMY	All-in-one compound to get a gummy touch; by coating.
Lamfinish OLDRY	All-in-one compound to get dry-sandy touch especially suitable for vintage effects; by coating.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5

kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is traditionally finished with a waterborne polyurethane (PU) dispersion. Suitable waterborne polyurethane dispersions for traditional finishing are known to those of skill in the art. Exemplary, non-limiting examples of waterborne polyurethane dispersions for traditional finishing from a representative supplier, Lamberti SPA, are given in the following table.

Rolflex LB 2	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings where bright and rigid top finish is required. It is particularly suitable as a finishing agent for organza touch on silk fabrics. Transparent and shiny.
Rolflex HP 51	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for outerwear, luggage, technical articles especially where hard and flexible touch is required. Transparent and shiny.
Rolflex PU 879	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for outerwear, luggage, technical articles where a medium-hard and flexible touch is required.
Rolflex ALM	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for outerwear, luggage, technical articles where a soft and flexible touch is required. Can be also suitable for printing application.
Rolflex AP	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for outerwear, fashion where a soft and gummy touch is required.
Rolflex W4	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear where a full, soft and non sticky touch is required.
Rolflex ZB7	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, sportswear, fashion and technical articles for industrial applications. The product has a very high charge digestion properties, electrolytes stability and excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.
Rolflex BZ 78	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, sportswear, fashion and technical articles for industrial applications. The product has an excellent hydrolysis resistance, a very high charge digestion and electrolytes stability and an excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.
Rolflex K 110	Gives to the coated fabric a full, soft, and slightly sticky handle with excellent fastness on all types of fabrics.
Rolflex OP 80	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for outerwear, luggage and fashion finishes where an opaque non writing effect is desired.
Rolflex NBC	Aliphatic waterborne PU dispersion generally used by padding application as a filling and zero formaldehyde sizing agent. Can be used for outerwear and fashion finishing where a full, elastic and non-sticky touch is required.
Rolflex PAD	Aliphatic waterborne PU dispersion specifically designed for padding application for outerwear, sportswear and fashion applications where a full, elastic and non sticky touch is required. Excellent washing and dry cleaning fastness as well as good bath stability.
Rolflex PN	Aliphatic waterborne PU dispersion generally applied by padding application for outerwear and fashion high quality applications where strong, elastic non sticky finishes are required.
Elafix PV 4	Aliphatic blocked isocyanate nano-dispersion used in order to give anti-felting and anti-pilling properties to pure wool fabrics and his blend.

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5	Rolflex SW3	Aliphatic waterborne PU dispersion particularly suggested to be used by padding application for the finishing of outerwear, sportswear and fashion where a slippery and elastic touch is required. It is also a good anti-pilling agent. Excellent in wool application.
10	Rolflex C 86	Aliphatic cationic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, fashion where medium-soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.
15	Rolflex CN 29	Aliphatic cationic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, fashion where soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the 20 coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is traditionally finished with a finishing resin. Suitable finishing resins are known to those of skill in the art. Exemplary, non-limiting examples of finishing resins from a representative supplier, Lamberti SPA, are given in the following table.

30	Textol 110	Handle modifier with very soft handle for coating finishes
	Textol RGD	Water emulsion of acrylic copolymer for textile coating, with very rigid handle.
	Textol SB 21	Butadienic resin for finishing and binder for textile printing
35	Appretto PV/CC	Vinylacetate water dispersion for rigid stiffening
	Amisolo B	CMS water dispersion for textile finishing as stiffening agent
	Lamovil RP	PVOH stabilized solution as stiffening agent

40 In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and 45 wherein the fabric is technically finished with a waterborne polyurethane dispersion. Suitable waterborne polyurethane dispersions for technical finishing are known to those of skill in the art. Exemplary, non-limiting examples of waterborne polyurethane dispersions for technical finishing from a representative supplier, Lamberti SPA, are given in the following table.

55	Rolflex AFP	Aliphatic polyether polyurethane dispersion in water. The product has high hydrolysis resistance, good breaking load resistance and excellent tear resistance.
	Rolflex ACF	Aliphatic polycarbonate polyurethane dispersion in water. The product shows good PU and PVC bonding properties, excellent abrasion resistance as well as chemical resistance, included alcohol.
60	Rolflex V 13	Aliphatic polyether/acrylic copolymer polyurethane dispersion in water. The product has good thermoadhesive properties and good adhesion properties on PVC.
65	Rolflex K 80	Aliphatic polyether/acrylic copolymer polyurethane dispersion in water. RÖLFLEX K 80 is specifically designed as a high performing adhesive for textile lamination. The product has excellent perchloroethylene and water fastness.

Rolflex ABC	Aliphatic polyether polyurethane dispersion in water. Particularly, the product presents very high water column, excellent electrolyte resistance, high LOT index, high resistance to multiple bending.
Rolflex ADH	Aliphatic polyether polyurethane dispersion in water. The product has a very high water column resistance.
Rolflex W4	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear where a full, soft and non-sticky touch is required.
Rolflex ZB7	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, sportswear, fashion and technical articles for industrial applications. The product has a very high charge digestion properties, electrolytes stability and excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.
Rolflex BZ 78	Aliphatic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, sportswear, fashion and technical articles for industrial applications. The product has an excellent hydrolysis resistance, a very high charge digestion and electrolytes stability and an excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.
Rolflex PU 147	Aliphatic polyether polyurethane dispersion in water. This product shows good film forming properties at room temperature. It has high fastness to light and ultraviolet radiation and good resistance to water, solvent and chemical agents, as well as mechanical resistance.
Rolflex SG	Aliphatic polyether polyurethane dispersion in water. Due to its thermoplastic properties it is suggested to formulate heat activated adhesives at low temperatures.
Elafix PV 4	Aliphatic blocked isocyanate nano-dispersion used in order to give antifelting and antipilling properties to pure wool fabrics and his blend.
Rolflex C 86	Aliphatic cationic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, fashion where medium-soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.
Rolflex CN 29	Aliphatic cationic waterborne PU dispersion particularly suggested for the formulation of textile coatings for clothing, outerwear, fashion where soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is technically finished with an oil or water repellent. Suitable oil or water repellents for technical finishing are known to those of skill in the art. Exemplary, non-limiting examples of oil or water repellents for technical finishing from a representative supplier, Lamberti SPA, are given in the following table.

Lamgard FT 60	General purpose fluorocarbon resin for water and oil repellency; by padding application.
Lamgard 48	High performance fluorocarbon resin for water and oil repellency; by padding application. High rubbing fastness.
Imbitex NRW3	Wetting agent for water-and oil repellent finishing.
Lamgard EXT	Crosslinker for fluorocarbon resins to improve washing fastness.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof

having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is technically finished with a flame retardant. Suitable flame retardants for technical finishing are known to those of skill in the art. Exemplary, non-limiting examples of flame retardants for technical finishing from a representative supplier, Lamberti SPA, are given in the following table.

10	Piroflam 712	Non-permanent flame retardant compound for padding and spray application.
	Piroflam ECO	Alogen free flame retardant compound for back coating application for all kind of fibers.
15	Piroflam UBC	Flame retardant compound for back coating application for all kind of fibers.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is technically finished with a crosslinker. Suitable crosslinkers for technical finishing are known to those of skill in the art. Exemplary, non-limiting examples of crosslinkers for technical finishing from a representative supplier, Lamberti SPA, are given in the following table.

30	Rolflex BK8	Aromatic blocked polyisocyanate in water dispersion. It is suggested as a cross-linking agent in coating pastes based of polyurethane resins to improve washing fastness.
	Fissativo 05	Water dispersible aliphatic polyisocyanate suitable as crosslinking agent for acrylic and polyurethane dispersions to improve adhesion and wet and dry scrub resistance.
35	Resina MEL	Melamine-formaldheyde resin.
	Cellofix VLF	Low formaldheyde melamine resin.

In an embodiment, the invention provides an article comprising a fiber or yarn having a coating, wherein the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the article is a fabric, and wherein the fabric is technically finished with a thickener for technical finishing. Suitable thickeners for technical finishing are known to those of skill in the art. Exemplary, non-limiting examples of thickeners for technical finishing from a representative supplier, Lamberti SPA, are given in the following table.

50	Lambicol CL 60	Fully neutralised synthetic thickener for pigment printing in oil/water emulsion; medium viscosity type
	Viscolam PU conc.	Nonionic polyurethane based thickener with pseudoplastic behavior.
55	Viscolam 115 new	Acrylic thickener; not neutralised.
	Viscolam PS 202	Nonionic polyurethane based thickener with newtonian behavior.
	Viscolam 1022	Nonionic polyurethane based thickener with moderate pseudoplastic behavior.

In any of the foregoing textile or leather embodiments, the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa. In any of the foregoing textile or leather embodiments, the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 6 kDa to about 16 kDa. In any of

the foregoing textile or leather embodiments, the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 17 kDa to about 38 kDa. In any of the foregoing textile or leather embodiments, the coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 39 kDa to about 80 kDa.

In any of the foregoing textile or leather embodiments, the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

Other Materials Coated with Silk Fibroin-Based Protein Fragments

In an embodiment, the invention provides a material coated with silk fibroin-based proteins or fragments thereof. The material may be any material suitable for coating, including plastics (e.g., vinyl), foams (e.g., for use in padding and cushioning), and various natural or synthetic products.

In an embodiment, the invention provides an automobile component coated with silk fibroin-based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa. In an embodiment, the invention provides an automobile component coated with silk fibroin-based proteins or fragments thereof having a weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days. In an embodiment, the invention provides an automobile component coated with silk fibroin-based proteins or fragments thereof, wherein the automobile component exhibits an improved property relative to an uncoated automobile component. In an embodiment, the invention provides an automobile component coated with silk fibroin-based proteins or fragments thereof, wherein the automobile component exhibits an improved property relative to an uncoated automobile component, and wherein the automobile component is selected from the group consisting of an upholstery fabric, a headliner, a seat, a headrest, a transmission control, a floor mat, a carpet fabric, a dashboard, a steering wheel, a trim, a wiring harness, an airbag cover, an airbag, a sunvisor, a seat belt, a headrest, an armrest, and a children's car seat. In an embodiment, the invention provides an electrical component insulated with a coating comprising silk fibroin-based proteins or fragments thereof.

In an embodiment, the invention provides a foam coated with silk fibroin-based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa. In an embodiment, the invention provides a foam coated with silk fibroin-based proteins or fragments thereof having a weight average molecular weight range

selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days. In an embodiment, the invention provides a foam coated with silk fibroin-based proteins or fragments thereof, wherein the foam exhibits an improved property relative to an uncoated foam, and wherein the foam is selected from the group consisting of a polyurethane foam, an ethylene-vinyl acetate copolymer foam, a low density polyethylene foam, a low density polyethylene foam, a high density polyethylene foam, a polypropylene copolymer foam, a linear low density polyethylene foam, a natural rubber foam, a latex foam, and combinations thereof.

In any of the foregoing embodiments, the material coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa. In any of the foregoing embodiments, the material coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 6 kDa to about 16 kDa. In any of the foregoing embodiments, the material coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 17 kDa to about 38 kDa. In any of the foregoing embodiments, the material coating comprises silk based proteins or fragments thereof having a weight average molecular weight range of about 39 kDa to about 80 kDa.

In any of the foregoing embodiments, the silk based proteins or protein fragments thereof have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

Processes for Coating Textiles and Leathers with Silk Fibroin-Based Protein Fragments

In an embodiment, a method for silk coating a textile, leather, or other material (such as a foam) includes immersion of the textile, leather, or other material in any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure. In an embodiment, a method for coating a textile, leather, or other material (such as a foam) includes spraying. In an embodiment, a method for coating a textile, leather, or other material (such as a foam) includes chemical vapor deposition. In an embodiment, a method for silk coating a textile, leather, or other material (such as a foam) includes electrochemical coating. In an embodiment, a method for silk coating a textile, leather, or other material (such as a foam) includes knife coating to spread any of the aqueous solutions of pure silk fibroin-based protein fragments of the present disclosure onto the fabric. The coated article may then be air dried, dried under heat/air flow, or cross-linked to the fabric surface. In an embodiment, a drying process includes curing with additives, irradiation (e.g., using UV light), heat (e.g., microwave or radiofrequency irradiation), and/or drying at ambient

condition. In an embodiment, the invention provides a method of coating a textile, leather, or other material (such as a foam) comprising the step of applying a coating, wherein the coating comprises a solution of silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, wherein the coating is applied to at least one side of the textile, leather, or other material using a method selected from the group consisting of a bath coating process, a spray coating process, a stencil (i.e., screen) process, a silk-foam based process, a roller-based process, a magnetic roller process, a knife process, a transfer process, a foam process, a lacquering process, a supercritical fluid impregnation process, and a printing process.

In an embodiment, the invention provides a method of coating a textile or leather comprising a step selected from the group consisting of providing an unwinding device used to unroll the fabric supply in a roll configuration, providing a feeding system used to control the feed rate of fabric, providing a material compensator used to maintain consistent the fabric tension, providing a coating machine to apply the silk solution (i.e., silk fibroin-based protein fragments) in different state (liquid or foam) to the fabric, providing a measuring system used to control the amount of silk solution applied, providing a dryer used to cure or dry the silk solution on the fabric, providing a cooling station used to bring the fabric temperature close to room value, providing a steering frame used to guide the fabric to the rewinding device and maintain straight edges, providing a rewinding step used to collect the coated fabric in roll, providing UV irradiation for curing of silk and/or other fabric additives (e.g., in a chemical cross-linking step), providing radiofrequency (RF) irradiation (e.g., using microwave irradiation) for drying and chemical cross-linking, and combinations thereof. Chemical and enzymatic cross-linking steps suitable for use with the compositions, articles, and methods of the invention include any method known to those of skill in the art, including but not limited to N-hydroxysuccinimide ester crosslinking, imidoester crosslinking, carbodiimide crosslinking, dicyclohexyl carbodiimide crosslinking, maleimide crosslinking, haloacetyl crosslinking, pyridyl disulfide crosslinking, hydrazide crosslinking, alkoxyamine crosslinking, reductive amination crosslinking, aryl azide crosslinking, diazirine crosslinking, azide-phosphine crosslinking, transferase crosslinking, hydrolase crosslinking, transglutaminase crosslinking, peptidase crosslinking (e.g., sortase SrtA from *Staphylococcus aureus*), oxidoreductase crosslinking, tyrosinase crosslinking, laccase crosslinking, peroxidase crosslinking (e.g., horseradish peroxidase), lysyl oxidase crosslinking, and combinations thereof.

In an embodiment, the invention provides a method of coating a textile or leather comprising the step of applying a coating, wherein the coating comprises a solution of silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, and wherein the coating is applied to at least one side of the textile or leather using a supercritical fluid impregnation process. The supercritical fluid impregnation process may use CO₂ as the supercritical fluid to solubilize and impregnate silk based proteins or fragments thereof into a textile or leather, wherein the supercritical CO₂ may include optional organic modifiers known in the art (e.g., methanol) and may further include additional agents described herein, such as dyes.

In an embodiment, the invention provides a method of coating a textile or leather comprising the step of applying a coating, wherein the coating comprises a solution of silk

based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, using a handheld aerosol spray suitable for consumer use or an aerosol spray system suitable for use by a professional cleaner (e.g., a dry cleaner).

In an embodiment, the invention provides a method of coating a textile or leather comprising the step of applying a coating, wherein the coating comprises a solution of silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, using a home washing machine.

In an embodiment, the invention provides a method of coating a fabric comprising the steps of:

(a) applying a pretreatment selected from the group consisting of a wetting agent, a detergent, a sequestering or dispersing agent, an enzyme, a bleaching agent, an anti-foaming agent, an anti-creasing agent, a dye dispersing agent, a dye leveling agent, a dye fixing agent, a dye special resin agent, a dye anti-reducing agent, a pigment dye system anti-migrating agent, a pigment dye system binder, a delave agent, a wrinkle free treatment, a softener, a handle modifier, a waterborne polyurethane dispersion, a finishing resin, an oil or water repellent, a flame retardant, a crosslinker, a thickener for technical finishing, or any combination thereof;

(b) applying a coating comprising a solution of silk based proteins or fragments thereof having a weight average molecular weight range of about 5 kDa to about 144 kDa, using a spray, screen, or stencil coating process; and

(c) drying and optionally curing the coating.

In any of the foregoing embodiments of methods, the silk based proteins or protein fragments thereof may have an average weight average molecular weight range selected from the group consisting of about 5 to about 10 kDa, about 6 kDa to about 16 kDa, about 17 kDa to about 38 kDa, about 39 kDa to about 80 kDa, about 60 to about 100 kDa, and about 80 kDa to about 144 kDa, wherein the silk based proteins or fragments thereof have a polydispersity of between about 1.5 and about 3.0, and optionally wherein the proteins or protein fragments, prior to coating the fabric, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

Additives for Silk Fibroin-Based Protein Fragments and Solutions Thereof

In an embodiment, a solution of the present disclosure is contacted with an additive, such as a therapeutic agent and/or a molecule. In an embodiment, molecules include, but are not limited to, antioxidants and enzymes. In an embodiment, molecules include, but are not limited to, ceramics, ceramic particles, metals, metal particles, polymer particles, aldehydes, luminescent molecules, phosphorescent molecules, fluorescent molecules, inorganic particles, organic particles, selenium, ubiquinone derivatives, thiol-based antioxidants, saccharide-containing antioxidants, polyphenols, botanical extracts, caffeic acid, apigenin, pycnogenol, resveratrol, folic acid, vitamin B12, vitamin B6, vitamin B3, vitamin E, vitamin C and derivatives thereof, vitamin D, vitamin A, astaxanthin, Lutein, lycopene, essential fatty acids (omegas 3 and 6), iron, zinc, magnesium, flavonoids (soy, Curcumin, Silymarin, Pycnogeol), growth factors, aloe, hyaluronic acid, extracellular matrix proteins, cells, nucleic acids, biomarkers, biological reagents, zinc oxide, benzoyl peroxide, retinoids, titanium, allergens in a known dose (for sensitization treatment), essential oils including, but not limited to, lemongrass or rosemary oil, and fragrances. Therapeutic agents include,

but are not limited to, small molecules, drugs, proteins, peptides and nucleic acids. In an embodiment, a solution of the present disclosure is contacted with an allergen of known quantity prior to forming the article. Allergens include but are not limited to milk, eggs, peanuts, tree nuts, fish, shellfish, soy and wheat. Known doses of allergen loaded within a silk article can be released at a known rate for controlled exposure allergy study, tests and sensitization treatment.

In an embodiment, silk fibroin-based protein fragments and solutions thereof may be combined with other soluble and insoluble additives coated onto textiles and leather as described herein, wherein the silk fibroin-based protein fragments and solutions functions as a binder or a dispersion medium for the additives. Additives described herein and those known of ordinary skill in the art for use with coating textiles and leather may be used. The combinations of silk fibroin-based protein fragments and solutions thereof with other soluble and insoluble additives may exhibit improved properties as described herein. The property that is improved may be selected from the group consisting of color retention, resistance to microbial growth, resistance to bacterial growth, resistance to fungal growth, resistance to the buildup of static electrical charge, resistance to the growth of mildew, transparency of the coating, resistance to freeze-thaw cycle damage, resistance from abrasion, blocking of ultraviolet (UV) radiation, regulation of the body temperature of a wearer, resistance to tearing, elasticity of the article, rebound dampening, tendency to cause itching in the wearer, thermal insulation of the wearer, wrinkle resistance, stain resistance, stickiness to skin, flame resistance, and combinations thereof. For example, silk fibroin-based protein fragments and solutions thereof may be combined with insoluble ceramic particles as a suspension, and subsequently coated onto a textile using any of the methods described herein to provide further thermal insulation for the wearer and/or to provide improved flame resistance, or to provide other improved properties.

In an embodiment, a solution of the present disclosure is used to create an article with microneedles by standard methods known to one in the art for controlled delivery of molecules or therapeutic agents to or through the skin.

Processes for Production of Silk Fibroin-Based Protein Fragments and Solutions Thereof

As used herein, the term "fibroin" includes silkworm fibroin and insect or spider silk protein. In an embodiment, fibroin is obtained from *Bombyx mori*. In an embodiment, the spider silk protein is selected from the group consisting of swathing silk (Achniform gland silk), egg sac silk (Cylindiform gland silk), egg case silk (Tubuliform silk), non-sticky dragline silk (Ampullate gland silk), attaching thread silk (Pyriform gland silk), sticky silk core fibers (Flagelliform gland silk), and sticky silk outer fibers (Aggregate gland silk).

FIG. 1 is a flow chart showing various embodiments for producing pure silk fibroin-based protein fragments (SPFs) of the present disclosure. It should be understood that not all of the steps illustrated are necessarily required to fabricate all silk solutions of the present disclosure. As illustrated in FIG. 1, step A, cocoons (heat-treated or non-heat-treated), silk fibers, silk powder or spider silk can be used as the silk source. If starting from raw silk cocoons from *Bombyx mori*, the cocoons can be cut into small pieces, for example pieces of approximately equal size, step B1. The raw silk is then extracted and rinsed to remove any sericin, step C1a. This results in substantially sericin free raw silk. In an embodiment, water is heated to a temperature between 84° C. and

100° C. (ideally boiling) and then Na₂CO₃ (sodium carbonate) is added to the boiling water until the Na₂CO₃ is completely dissolved. The raw silk is added to the boiling water/Na₂CO₃ (100° C.) and submerged for approximately 5 15-90 minutes, where boiling for a longer time results in smaller silk protein fragments. In an embodiment, the water volume equals about 0.4×raw silk weight and the Na₂CO₃ volume equals about 0.848×raw silk weight. In an embodiment, the water volume equals 0.1×raw silk weight and the 10 Na₂CO₃ volume is maintained at 2.12 g/L. This is demonstrated in FIG. 38A and FIG. 38B silk mass (x-axis) was varied in the same volume of extraction solution (i.e., the same volume of water and concentration of Na₂CO₃) achieving sericin removal (substantially sericin free) as 15 demonstrated by an overall silk mass loss of 26 to 31 percent (y-axis). Subsequently, the water dissolved Na₂CO₃ solution is drained and excess water/Na₂CO₃ is removed from the 20 silk fibroin fibers (e.g., ring out the fibroin extract by hand, spin cycle using a machine, etc.). The resulting silk fibroin extract is rinsed with warm to hot water to remove any remaining adsorbed sericin or contaminant, typically at a 25 temperature range of about 40° C. to about 80° C., changing the volume of water at least once (repeated for as many times as required). The resulting silk fibroin extract is a 30 substantially sericin-depleted silk fibroin. In an embodiment, the resulting silk fibroin extract is rinsed with water at a temperature of about 60° C. In an embodiment, the volume of rinse water for each cycle equals 0.1 L to 0.2 L×raw silk 35 weight. It may be advantageous to agitate, turn or circulate the rinse water to maximize the rinse effect. After rinsing, excess water is removed from the extracted silk fibroin fibers (e.g., ring out fibroin extract by hand or using a machine). Alternatively, methods known to one skilled in the art such 40 as pressure, temperature, or other reagents or combinations thereof may be used for the purpose of sericin extraction. Alternatively, the silk gland (100% sericin free silk protein) can be removed directly from a worm. This would result in liquid silk protein, without any alteration of the protein structure, free of sericin.

The extracted fibroin fibers are then allowed to dry completely. FIG. 3 is a photograph showing dry extracted silk fibroin. Once dry, the extracted silk fibroin is dissolved using a solvent added to the silk fibroin at a temperature 45 between ambient and boiling, step C1b. In an embodiment, the solvent is a solution of Lithium bromide (LiBr) (boiling for LiBr is 140° C.). Alternatively, the extracted fibroin fibers are not dried but wet and placed in the solvent; solvent concentration can then be varied to achieve similar concentrations as to when adding dried silk to the solvent. The final concentration of LiBr solvent can range from 0.1M to 9.3M. FIG. 39 is a table summarizing the Molecular Weights of silk dissolved from different concentrations of Lithium Bromide (LiBr) and from different extraction and dissolution sizes. Complete dissolution of the extracted fibroin fibers can be 50 achieved by varying the treatment time and temperature along with the concentration of dissolving solvent. Other solvents may be used including, but not limited to, phosphate phosphoric acid, calcium nitrate, calcium chloride solution or other concentrated aqueous solutions of inorganic salts. To ensure complete dissolution, the silk fibers should be fully immersed within the already heated solvent solution and then maintained at a temperature ranging from about 60° C. to about 140° C. for 1-168 hrs. In an embodiment, the silk fibers should be fully immersed within the solvent solution and then placed into a dry oven at a 55 temperature of about 100° C. for about 1 hour.

The temperature at which the silk fibroin extract is added to the LiBr solution (or vice versa) has an effect on the time required to completely dissolve the fibroin and on the resulting molecular weight and polydispersity of the final SPF mixture solution. In an embodiment, silk solvent solution concentration is less than or equal to 20% w/v. In addition, agitation during introduction or dissolution may be used to facilitate dissolution at varying temperatures and concentrations. The temperature of the LiBr solution will provide control over the silk protein fragment mixture molecular weight and polydispersity created. In an embodiment, a higher temperature will more quickly dissolve the silk offering enhanced process scalability and mass production of silk solution. In an embodiment, using a LiBr solution heated to a temperature between 80° C.-140° C. reduces the time required in an oven in order to achieve full dissolution. Varying time and temperature at or above 60° C. of the dissolution solvent will alter and control the MW and polydispersity of the SPF mixture solutions formed from the original molecular weight of the native silk fibroin protein.

Alternatively, whole cocoons may be placed directly into a solvent, such as LiBr, bypassing extraction, step B2. This requires subsequent filtration of silk worm particles from the silk and solvent solution and sericin removal using methods known in the art for separating hydrophobic and hydrophilic proteins such as a column separation and/or chromatography, ion exchange, chemical precipitation with salt and/or pH, and or enzymatic digestion and filtration or extraction, all methods are common examples and without limitation for standard protein separation methods, step C2. Non-heat treated cocoons with the silkworm removed, may alternatively be placed into a solvent such as LiBr, bypassing extraction. The methods described above may be used for sericin separation, with the advantage that non-heat treated cocoons will contain significantly less worm debris.

Dialysis may be used to remove the dissolution solvent from the resulting dissolved fibroin protein fragment solution by dialyzing the solution against a volume of water, step E1. Pre-filtration prior to dialysis is helpful to remove any debris (i.e., silk worm remnants) from the silk and LiBr solution, step D. In one example, a 3 µm or 5 µm filter is used with a flow-rate of 200-300 mL/min to filter a 0.1% to 1.0% silk-LiBr solution prior to dialysis and potential concentration if desired. A method disclosed herein, as described above, is to use time and/or temperature to decrease the concentration from 9.3M LiBr to a range from 0.1M to 9.3M to facilitate filtration and downstream dialysis, particularly when considering creating a scalable process method. Alternatively, without the use of additional time or temperate, a 9.3M LiBr-silk protein fragment solution may be diluted with water to facilitate debris filtration and dialysis. The result of dissolution at the desired time and temperate filtration is a translucent particle-free room temperature shelf-stable silk protein fragment-LiBr solution of a known MW and polydispersity. It is advantageous to change the dialysis water regularly until the solvent has been removed (e.g., change water after 1 hour, 4 hours, and then every 12 hours for a total of 6 water changes). The total number of water volume changes may be varied based on the resulting concentration of solvent used for silk protein dissolution and fragmentation. After dialysis, the final silk solution maybe further filtered to remove any remaining debris (i.e., silk worm remnants).

Alternatively, Tangential Flow Filtration (TFF), which is a rapid and efficient method for the separation and purification of biomolecules, may be used to remove the solvent from the resulting dissolved fibroin solution, step E2. TFF

offers a highly pure aqueous silk protein fragment solution and enables scalability of the process in order to produce large volumes of the solution in a controlled and repeatable manner. The silk and LiBr solution may be diluted prior to 5 TFF (20% down to 0.1% silk in either water or LiBr). Pre-filtration as described above prior to TFF processing may maintain filter efficiency and potentially avoids the creation of silk gel boundary layers on the filter's surface as the result of the presence of debris particles. Pre-filtration 10 prior to TFF is also helpful to remove any remaining debris (i.e., silk worm remnants) from the silk and LiBr solution that may cause spontaneous or long-term gelation of the resulting water only solution, step D. TFF, recirculating or single pass, may be used for the creation of water-silk 15 protein fragment solutions ranging from 0.1% silk to 30.0% silk (more preferably, 0.1%-6.0% silk). Different cutoff size TFF membranes may be required based upon the desired concentration, molecular weight and polydispersity of the silk protein fragment mixture in solution. Membranes ranging from 1-100 kDa may be necessary for varying molecular 20 weight silk solutions created for example by varying the length of extraction boil time or the time and temperate in dissolution solvent (e.g., LiBr). In an embodiment, a TFF 5 or 10 kDa membrane is used to purify the silk protein 25 fragment mixture solution and to create the final desired silk-to-water ratio. As well, TFF single pass, TFF, and other methods known in the art, such as a falling film evaporator, 30 may be used to concentrate the solution following removal of the dissolution solvent (e.g., LiBr) (with resulting desired concentration ranging from 0.1% to 30% silk). This can be used as an alternative to standard HFIP concentration methods known in the art to create a water-based solution. A larger pore membrane could also be utilized to filter out small silk protein fragments and to create a solution of 35 higher molecular weight silk with and/or without tighter polydispersity values. FIG. 37 is a table summarizing Molecular Weights for some embodiments of silk protein solutions of the present disclosure. Silk protein solution processing conditions were as follows: 100° C. extraction 40 for 20 min, room temperature rinse, LiBr in 60° C. oven for 4-6 hours. FIGS. 40-49 further demonstrate manipulation of extraction time, LiBr dissolution conditions, and TFF processing and resultant example molecular weights and polydispersities. These examples are not intended to be 45 limiting, but rather to demonstrate the potential of specifying parameters for specific molecular weight silk fragment solutions.

An assay for LiBr and Na₂CO₃ detection was performed using an HPLC system equipped with evaporative light scattering detector (ELSD). The calculation was performed by linear regression of the resulting peak areas for the analyte plotted against concentration. More than one sample of a number of formulations of the present disclosure was used for sample preparation and analysis. Generally, four 50 samples of different formulations were weighed directly in a 10 mL volumetric flask.

The analytical method developed for the quantitation of Na₂CO₃ and LiBr in silk protein formulations was found to be linear in the range 10-165 µg/mL, with RSD for injection 55 precision as 2% and 1% for area and 0.38% and 0.19% for retention time for sodium carbonate and lithium bromide respectively. The analytical method can be applied for the quantitative determination of sodium carbonate and lithium bromide in silk protein formulations.

The final silk protein fragment solution, as shown in FIG. 65 4, is pure silk protein fragments and water with PPM to undetectable levels of particulate debris and/or process

contaminants, including LiBr and Na₂CO₃. FIG. 34 and FIG. 35 are tables summarizing LiBr and Na₂CO₃ concentrations in solutions of the present disclosure. In FIG. 34, the processing conditions included 100° C. extraction for 60 min, 60° C. rinse, 100° C. LiBr in 100° C. oven for 60 min. TFF conditions including pressure differential and number of diafiltration volumes were varied. In FIG. 35, the processing conditions included 100° C. boil for 60 min, 60° C. rinse, LiBr in 60° C. oven for 4-6 hours. In an embodiment, a SPF composition of the present disclosure is not soluble in an aqueous solution due to the crystallinity of the protein. In an embodiment, a SPF composition of the present disclosure is soluble in an aqueous solution. In an embodiment, the SPFs of a composition of the present disclosure include a crystalline portion of about two-thirds and an amorphous region of about one-third. In an embodiment, the SPFs of a composition of the present disclosure include a crystalline portion of about one-half and an amorphous region of about one-half. In an embodiment, the SPFs of a composition of the present disclosure include a 99% crystalline portion and a 1% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 95% crystalline portion and a 5% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 90% crystalline portion and a 10% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 85% crystalline portion and a 15% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 75% crystalline portion and a 25% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 70% crystalline portion and a 30% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 65% crystalline portion and a 35% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 60% crystalline portion and a 40% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 50% crystalline portion and a 50% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 40% crystalline portion and a 60% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 35% crystalline portion and a 65% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 30% crystalline portion and a 70% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 25% crystalline portion and a 75% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 20% crystalline portion and a 80% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 15% crystalline portion and a 85% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 10% crystalline portion and a 90% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 5% crystalline portion and a 90% amorphous region. In an embodiment, the SPFs of a composition of the present disclosure include a 1% crystalline portion and a 99% amorphous region.

A unique feature of the SPF compositions of the present disclosure are shelf stability (they will not slowly or spontaneously gel when stored in an aqueous solution and there is no aggregation of fragments and therefore no increase in

molecular weight over time), from 10 days to 3 years depending on storage conditions, percent silk, and number of shipments and shipment conditions. Additionally pH may be altered to extend shelf-life and/or support shipping conditions by preventing premature folding and aggregation of the silk. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 2 weeks at room temperature (RT). In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 4 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 6 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 8 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 10 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability for up to 12 weeks at RT. In an embodiment, a SPF solution composition of the present disclosure has a shelf stability ranging from about 4 weeks to about 52 weeks at RT. Table 1 below shows shelf stability test results for embodiments of SPF compositions of the present disclosure.

TABLE 1

Shelf Stability of SPF Compositions of the Present Disclosure		
% Silk	Temperature	Time to Gelation
2	RT	4 weeks
2	4 C.	>9 weeks
4	RT	4 weeks
4	4 C.	>9 weeks
6	RT	2 weeks
6	4 C.	>9 weeks

A silk fragment-water solution of the present disclosure can be sterilized following standard methods in the art not limited to filtration, heat, radiation or e-beam. It is anticipated that the silk protein fragment mixture, because of its shorter protein polymer length, will withstand sterilization better than intact silk protein solutions described in the art. Additionally, silk articles created from the SPF mixtures described herein may be sterilized as appropriate to application.

FIG. 2 is a flow chart showing various parameters that can be modified during the process of producing a silk protein fragment solution of the present disclosure during the extraction and the dissolution steps. Select method parameters may be altered to achieve distinct final solution characteristics depending upon the intended use, e.g., molecular weight and polydispersity. It should be understood that not all of the steps illustrated are necessarily required to fabricate all silk solutions of the present disclosure.

In an embodiment, a process for producing a silk protein fragment solution of the present disclosure includes forming pieces of silk cocoons from the *Bombyx mori* silk worm; extracting the pieces at about 100° C. in a solution of water and Na₂CO₃ for about 60 minutes, wherein a volume of the water equals about 0.4×raw silk weight and the amount of Na₂CO₃ is about 0.848×the weight of the pieces to form a silk fibroin extract; triple rinsing the silk fibroin extract at about 60° C. for about 20 minutes per rinse in a volume of rinse water, wherein the rinse water for each cycle equals about 0.2 L×the weight of the pieces; removing excess water from the silk fibroin extract; drying the silk fibroin extract; dissolving the dry silk fibroin extract in a LiBr solution, wherein the LiBr solution is first heated to about 100° C. to

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create a silk and LiBr solution and maintained; placing the silk and LiBr solution in a dry oven at about 100° C. for about 60 minutes to achieve complete dissolution and further fragmentation of the native silk protein structure into mixture with desired molecular weight and polydispersity; filtering the solution to remove any remaining debris from the silkworm; diluting the solution with water to result in a 1% silk solution; and removing solvent from the solution using Tangential Flow Filtration (TFF). In an embodiment, a 10 kDa membrane is utilized to purify the silk solution and create the final desired silk-to-water ratio. TFF can then be used to further concentrate the pure silk solution to a concentration of 2% silk to water.

Each process step from raw cocoons to dialysis is scalable to increase efficiency in manufacturing. Whole cocoons are currently purchased as the raw material, but pre-cleaned cocoons or non-heat treated cocoons, where worm removal leaves minimal debris, have also been used. Cutting and cleaning the cocoons is a manual process, however for scalability this process could be made less labor intensive by, for example, using an automated machine in combination with compressed air to remove the worm and any particulates, or using a cutting mill to cut the cocoons into smaller pieces. The extraction step, currently performed in small batches, could be completed in a larger vessel, for example an industrial washing machine where temperatures at or in between 60° C. to 100° C. can be maintained. The rinsing step could also be completed in the industrial washing machine, eliminating the manual rinse cycles. Dissolution of the silk in LiBr solution could occur in a vessel other than a convection oven, for example a stirred tank reactor. Dialyzing the silk through a series of water changes is a manual and time intensive process, which could be accelerated by changing certain parameters, for example diluting the silk solution prior to dialysis. The dialysis process could be scaled for manufacturing by using semi-automated equipment, for example a tangential flow filtration system.

Varying extraction (i.e., time and temperature), LiBr (i.e., temperature of LiBr solution when added to silk fibroin extract or vice versa) and dissolution (i.e., time and temperature) parameters results in solvent and silk solutions with different viscosities, homogeneities, and colors (see FIGS. 5-32). Increasing the temperature for extraction, lengthening the extraction time, using a higher temperature LiBr solution at emersion and over time when dissolving the silk and increasing the time at temperature (e.g., in an oven as shown here, or an alternative heat source) all resulted in less viscous and more homogeneous solvent and silk solutions. While almost all parameters resulted in a viable silk solution, methods that allow complete dissolution to be achieved in fewer than 4 to 6 hours are preferred for process scalability.

FIGS. 5-10 show photographs of four different silk extraction combinations tested: 90° C. 30 min, 90° C. 60 min, 100° C. 30 min, and 100° C. 60 min. Briefly, 9.3 M LiBr was prepared and allowed to sit at room temperature for at least 30 minutes. 5 mL of LiBr solution was added to 1.25 g of silk and placed in the 60° C. oven. Samples from each set were removed at 4, 6, 8, 12, 24, 168 and 192 hours. The remaining sample was photographed.

FIGS. 11-23 show photographs of four different silk extraction combinations tested: 90° C. 30 min, 90° C. 60 min, 100° C. 30 min, and 100° C. 60 min. Briefly, 9.3 M LiBr solution was heated to one of four temperatures: 60° C., 65

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Samples from each set were removed at 1, 4 and 6 hours. The remaining sample was photographed.

FIGS. 24-32 show photographs of four different silk extraction combinations tested: Four different silk extraction combinations were used: 90° C. 30 min, 90° C. 60 min, 100° C. 30 min, and 100° C. 60 min. Briefly, 9.3 M LiBr solution was heated to one of four temperatures: 60° C., 80° C., 100° C. or boiling. 5 mL of hot LiBr solution was added to 1.25 g of silk and placed in the oven at the same temperature of the LiBr. Samples from each set were removed at 1, 4 and 6 hours. 1 mL of each sample was added to 7.5 mL of 9.3 M LiBr and refrigerated for viscosity testing. The remaining sample was photographed.

Molecular weight of the silk protein fragments may be controlled based upon the specific parameters utilized during the extraction step, including extraction time and temperature; specific parameters utilized during the dissolution step, including the LiBr temperature at the time of submersion of the silk in to the lithium bromide and time that the solution is maintained at specific temperatures; and specific parameters utilized during the filtration step. By controlling process parameters using the disclosed methods, it is possible to create SPF mixture solutions with polydispersity equal to or lower than 2.5 at a variety of different molecular weight ranging from 5 kDa to 200 kDa, more preferably between 10 kDa and 80 kDa. By altering process parameters to achieve silk solutions with different molecular weights, a range of fragment mixture end products, with desired polydispersity of equal to or less than 2.5 may be targeted based upon the desired performance requirements. Additionally, SPF mixture solutions with a polydispersity of greater than 2.5 can be achieved. Further, two solutions with different average molecular weights and polydispersities can be mixed to create combination solutions. Alternatively, a liquid silk gland (100% sericin free silk protein) that has been removed directly from a worm could be used in combination with any of the SPF mixture solutions of the present disclosure. Molecular weight of the pure silk fibroin-based protein fragment composition was determined using High Pressure Liquid Chromatography (HPLC) with a Refractive Index Detector (RID). Polydispersity was calculated using Cirrus GPC Online GPC/SEC Software Version 3.3 (Agilent).

Parameters were varied during the processing of raw silk cocoons into silk solution. Varying these parameters affected the MW of the resulting silk solution. Parameters manipulated included (i) time and temperature of extraction, (ii) temperature of LiBr, (iii) temperature of dissolution oven, and (iv) dissolution time. Molecular weight was determined with mass spec as shown in FIGS. 40-54.

Experiments were carried out to determine the effect of varying the extraction time. FIGS. 40-46 are graphs showing these results, and Tables 2-8 summarize the results. Below is a summary:

A sericin extraction time of 30 minutes resulted in larger MW than a sericin extraction time of 60 minutes
MW decreases with time in the oven
140° C. LiBr and oven resulted in the low end of the confidence interval to be below a MW of 9500 Da
30 min extraction at the 1 hour and 4 hour time points have undigested silk
30 min extraction at the 1 hour time point resulted in a significantly high molecular weight with the low end of the confidence interval being 35,000 Da
The range of MW reached for the high end of the confidence interval was 18000 to 216000 Da (important for offering solutions with specified upper limit)

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TABLE 2

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. Lithium Bromide (LiBr) and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30	1	57247	12780	35093 - 93387	1.63
60	1	31520	1387	11633 - 85407	2.71
30	4	40973	2632	14268 - 117658	2.87
60	4	25082	1248	10520 - 59803	2.38
30	6	25604	1405	10252 - 63943	2.50
60	6	20980	1262	10073 - 43695	2.08

TABLE 3

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, boiling Lithium Bromide (LiBr) and 60° C. Oven Dissolution for 4 hr.

Sample	Boil Time	Average Mw	Std dev	Confidence Interval	PD
30 min, 4 hr	30	49656	4580	17306 - 142478	2.87
60 min, 4 hr	60	30042	1536	11183 - 80705	2.69

TABLE 4

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60° C. Lithium Bromide (LiBr) and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30 min, 1 hr	30	1	58436		22201 - 153809	2.63
60 min, 1 hr	60	1	31700		11931 - 84224	2.66
30 min, 4 hr	30	4	61956.5	13337	21463 - 178847	2.89
60 min, 4 hr	60	4	25578.5	2446	9979 - 65564	2.56

TABLE 5

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. Lithium Bromide (LiBr) and 80° C. Oven Dissolution for 6 hr.

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30 min, 6 hr	30		63510		18693 - 215775	3.40
60 min, 6 hr	60		25164	238	9637 - 65706	2.61

TABLE 6

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 80° C. Lithium Bromide (LiBr) and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30 min, 4 hr	30	4	59202	14028	19073 - 183760	3.10
60 min, 4 hr	60	4	26312.5	637	10266 - 67442	2.56
30 min, 6 hr	30	6	46824		18076 - 121293	2.59
60 min, 6 hr	60	6	26353		10168 - 68302	2.59

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TABLE 7

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 100° C. Lithium Bromide (LiBr) and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30 min, 4 hr	30	4	47853		19758 - 115900	2.42
60 min, 4 hr	60	4	25082	1248	10520 - 59804	2.38
30 min, 6 hr	30	6	55421	8992	19153 - 160366	2.89
60 min, 6 hr	60	6	20980	1262	10073 - 43694	2.08

TABLE 8

The effect of extraction time (30 min vs 60 min) on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 140° C. Lithium Bromide (LiBr) and 140° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD
30 min, 4 hr	30	4	9024.5	1102	4493 - 18127	2.00865
60 min, 4 hr	60	4	15548		6954 - 34762	2.2358
30 min, 6 hr	30	6	13021		5987 - 28319	2.1749
60 min, 6 hr	60	6	10888		5364 - 22100	2.0298

Experiments were carried out to determine the effect of varying the extraction temperature. FIG. 47 is a graph showing these results, and Table 9 summarizes the results. Below is a summary:

Sericin extraction at 90° C. resulted in higher MW than sericin extraction at 100° C. extraction

Both 90° C. and 100° C. show decreasing MW over time in the oven

TABLE 9

The effect of extraction temperature (90° C. vs. 100° C.) on molecular weight of silk processed under the conditions of 60 min. Extraction Temperature, 100° C. Lithium Bromide (LiBr) and 100° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	Boil Time	Oven Time	Average Mw	Std dev	Confidence Interval	PD
90° C., 4 hr	60	4	37308	4204	13368 - 104119	2.79
100° C., 4 hr	60	4	25082	1248	10520 - 59804	2.38
90° C., 6 hr	60	6	34224	1135	12717 - 92100	2.69
100° C., 6 hr	60	6	20980	1262	10073 - 43694	2.08

Experiments were carried out to determine the effect of varying the Lithium Bromide (LiBr) temperature when added to silk. FIGS. 48-49 are graphs showing these results, and Tables 10-11 summarize the results. Below is a summary:

No impact on MW or confidence interval (all CI ~10500-6500 Da)

Studies illustrated that the temperature of LiBr-silk dissolution, as LiBr is added and begins dissolving, rapidly drops below the original LiBr temperature due to the majority of the mass being silk at room temp

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TABLE 10

The effect of Lithium Bromide (LiBr) temperature on molecular weight of silk processed under the conditions of 60 min. Extraction Time., 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	LiBr					
	Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60° C. LiBr, 1 hr	60	1	31700		11931 84223	2.66
100° C. LiBr, 1 hr	100	1	27907	200	10735 72552	2.60
RT LiBr, 4 hr	RT	4	29217	1082	10789 79119	2.71
60° C. LiBr, 4 hr	60	4	25578	2445	9978 65564	2.56
80° C. LiBr, 4 hr	80	4	26312	637	10265 67441	2.56
100° C. LiBr, 4 hr	100	4	27681	1729	11279 67931	2.45
Boil LiBr, 4 hr	Boil	4	30042	1535	11183 80704	2.69
RT LiBr, 6 hr	RT	6	26543	1893	10783 65332	2.46
80° C. LiBr, 6 hr	80	6	26353		10167 68301	2.59
100° C. LiBr, 6 hr	100	6	27150	916	11020 66889	2.46

TABLE 11

The effect of Lithium Bromide (LiBr) temperature on molecular weight of silk processed under the conditions of 30 min. Extraction Time., 100° C. Extraction Temperature and 60° C. Oven Dissolution (Oven/Dissolution Time was varied).

Sample	LiBr					
	Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60° C. LiBr, 4 hr	60	4	61956	13336	21463 178847	2.89
80° C. LiBr, 4 hr	80	4	59202	14027	19073 183760	3.10
100° C. LiBr, 4 hr	100	4	47853		19757 115899	2.42
80° C. LiBr, 6 hr	80	6	46824		18075 121292	2.59
100° C. LiBr, 6 hr	100	6	55421	8991	19152 160366	2.89

Experiments were carried out to determine the effect of varying the oven/dissolution temperature. FIGS. 50-54 are graphs showing these results, and Tables 12-16 summarize the results. Below is a summary:

Oven temperature has less of an effect on 60 min extracted silk than 30 min extracted silk. Without wishing to be bound by theory, it is believed that the 30 min silk is less degraded during extraction and therefore the oven temperature has more of an effect on the larger MW, less degraded portion of the silk.

For 60° C. vs. 140° C. oven the 30 min extracted silk showed a very significant effect of lower MW at higher oven temp, while 60 min extracted silk had an effect but much less

The 140° C. oven resulted in a low end in the confidence interval at ~6000 Da

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TABLE 12

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 min. Extraction Time, and 100° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied)

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
10	30	60	4	47853	19758 115900	2.42
	30	100	4	40973	2632 14268 117658	2.87
	30	60	6	55421	8992 19153 160366	2.89
	30	100	6	25604	1405 10252 63943	2.50

TABLE 13

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 min. Extraction Time, and 100° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
15	60	60	1	27908	200 10735 72552	2.60
	60	100	1	31520	1387 11633 85407	2.71
	60	60	4	27681	1730 11279 72552	2.62
	60	100	4	25082	1248 10520 59803	2.38
	60	60	6	27150	916 11020 66889	2.46
	60	100	6	20980	1262 10073 43695	2.08

TABLE 14

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 min. Extraction Time, and 140° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
35	60	60	4	30042	1536 11183 80705	2.69
	60	140	4	15548	7255 33322	2.14

TABLE 15

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 30 min. Extraction Time, and 140° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
40	30	60	4	49656	4580 17306 142478	2.87
	30	140	4	9025	1102 4493 18127	2.01
	30	60	6	59383	11640 17641 199889	3.37
	30	140	6	13021	5987 28319	2.17

TABLE 16

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 min. Extraction Time, and 80° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60	60	60	4	26313	637 10266 67442	2.56
	60	80	4	30308	4293 12279 74806	2.47

TABLE 16-continued

The effect of oven/dissolution temperature on molecular weight of silk processed under the conditions of 100° C. Extraction Temperature, 60 min. Extraction Time, and 80° C. Lithium Bromide (LiBr) (Oven/Dissolution Time was varied).

Boil Time	Oven Temp (° C.)	Oven Time	Average Mw	Std dev	Confidence Interval	PD
60	60	6	26353		10168 68302	2.59
60	80	6	25164	238	9637 65706	2.61

In an embodiment, when producing a silk gel, an acid is used to help facilitate gelation. In an embodiment, when producing a silk gel that includes a neutral or a basic molecule and/or therapeutic agent, an acid can be added to facilitate gelation. In an embodiment, when producing a silk gel, increasing the pH (making the gel more basic) increases the shelf stability of the gel. In an embodiment, when producing a silk gel, increasing the pH (making the gel more basic) allows for a greater quantity of an acidic molecule to be loaded into the gel.

In an embodiment, natural additives may be added to the silk gel to further stabilize additives. For example, trace elements such as selenium or magnesium or L-methionine can be used. Further, light-block containers can be added to further increase stability.

In an embodiment, the methods disclosed herein result in a solution with characteristics that can be controlled during manufacturing, including, but not limited to: MW—may be varied by changing extraction and/or dissolution time and temp (e.g., LiBr temperature), pressure, and filtration (e.g., size exclusion chromatography); Structure—removal or cleavage of heavy or light chain of the fibroin protein polymer; Purity—hot water rinse temperature for improved sericin removal or filter capability for improved particulate removal that adversely affects shelf stability of the silk fragment protein mixture solution; Color—the color of the solution can be controlled with, for example, LiBr temp and time; Viscosity; Clarity; and Stability of solution. The resultant pH of the solution is typically about 7 and can be altered using an acid or base as appropriate to storage requirements.

In an embodiment, the above-described SPF mixture solutions may be utilized to coat at least a portion of a fabric which can be used to create a textile. In an embodiment, the above-described SPF mixture solutions may be weaved into yarn that can be used as a fabric in a textile.

FIG. 33 shows two HPLC chromatograms from samples comprising vitamin C. The chromatogram shows peaks from (1) a chemically stabilized sample of vitamin C at ambient conditions and (2) a sample of vitamin C taken after 1 hour at ambient conditions without chemical stabilization to prevent oxidation, where degradation products are visible. FIG. 36 is a table summarizing the stability of vitamin C in chemically stabilized solutions.

In some embodiments, a composition of the present disclosure can further include skin penetration enhancers, including, but not limited to, sulfoxides (such as dimethylsulfoxide), pyrrolidones (such as 2-pyrrolidone), alcohols (such as ethanol or decanol), azones (such as laurocapram and 1-dodecylazacycloheptan-2-one), surfactants (including alkyl carboxylates and their corresponding acids such as oleic acid, fluoroalkylcarboxylates and their corresponding acids, alkyl sulfates, alkyl ether sulfates, docosates such as dioctyl sodium sulfosuccinate, alkyl benzene sulfonates, alkyl ether phosphates, and alkyl aryl ether phosphates), glycols (such as propylene glycol), terpenes (such as limo-

nene, p-cymene, geraniol, farnesol, eugenol, menthol, terpineol, carveol, carvone, fenchone, and verbenone), and dimethyl isosorbide.

Following are non-limiting examples of suitable ranges for various parameters in and for preparation of the silk solutions of the present disclosure. The silk solutions of the present disclosure may include one or more, but not necessarily all, of these parameters and may be prepared using various combinations of ranges of such parameters.

- 10 In an embodiment, the percent silk in the solution is less than 30%. In an embodiment, the percent silk in the solution is less than 25%. In an embodiment, the percent silk in the solution is less than 20%. In an embodiment, the percent silk in the solution is less than 19%. In an embodiment, the percent silk in the solution is less than 18%. In an embodiment, the percent silk in the solution is less than 17%. In an embodiment, the percent silk in the solution is less than 16%. In an embodiment, the percent silk in the solution is less than 15%. In an embodiment, the percent silk in the solution is less than 14%. In an embodiment, the percent silk in the solution is less than 13%. In an embodiment, the percent silk in the solution is less than 12%. In an embodiment, the percent silk in the solution is less than 11%. In an embodiment, the percent silk in the solution is less than 10%. In an embodiment, the percent silk in the solution is less than 9%. In an embodiment, the percent silk in the solution is less than 8%. In an embodiment, the percent silk in the solution is less than 7%. In an embodiment, the percent silk in the solution is less than 6%. In an embodiment, the percent silk in the solution is less than 5%. In an embodiment, the percent silk in the solution is less than 4%. In an embodiment, the percent silk in the solution is less than 3%. In an embodiment, the percent silk in the solution is less than 2%. In an embodiment, the percent silk in the solution is less than 1%. In an embodiment, the percent silk in the solution is less than 0.9%. In an embodiment, the percent silk in the solution is less than 0.8%. In an embodiment, the percent silk in the solution is less than 0.7%. In an embodiment, the percent silk in the solution is less than 0.6%. In an embodiment, the percent silk in the solution is less than 0.5%. In an embodiment, the percent silk in the solution is less than 0.4%. In an embodiment, the percent silk in the solution is less than 0.3%. In an embodiment, the percent silk in the solution is less than 0.2%. In an embodiment, the percent silk in the solution is less than 0.1%. In an embodiment, the percent silk in the solution is greater than 0.1%. In an embodiment, the percent silk in the solution is greater than 0.2%. In an embodiment, the percent silk in the solution is greater than 0.3%. In an embodiment, the percent silk in the solution is greater than 0.4%. In an embodiment, the percent silk in the solution is greater than 0.5%. In an embodiment, the percent silk in the solution is greater than 0.6%. In an embodiment, the percent silk in the solution is greater than 0.7%. In an embodiment, the percent silk in the solution is greater than 0.8%. In an embodiment, the percent silk in the solution is greater than 0.9%. In an embodiment, the percent silk in the solution is greater than 1%. In an embodiment, the percent silk in the solution is greater than 2%. In an embodiment, the percent silk in the solution is greater than 3%. In an embodiment, the percent silk in the solution is greater than 4%. In an embodiment, the percent silk in the solution is greater than 5%. In an embodiment, the percent silk in the solution is greater than 6%. In an embodiment, the percent silk in the solution is greater than 7%. In an embodiment, the percent silk in the solution is greater than 8%. In an embodiment, the percent silk in the solution is greater than 9%. In an embodiment, the percent

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an embodiment, the percent silk in the solution is 2.4%. In another embodiment, the percent silk in the solution is 2.0%.

In an embodiment, the percent sericin in the solution is non-detectable to 30%. In an embodiment, the percent sericin in the solution is non-detectable to 5%. In an embodiment, the percent sericin in the solution is 1%. In an embodiment, the percent sericin in the solution is 2%. In an embodiment, the percent sericin in the solution is 3%. In an embodiment, the percent sericin in the solution is 4%. In an embodiment, the percent sericin in the solution is 5%. In an embodiment, the percent sericin in the solution is 10%. In an embodiment, the percent sericin in the solution is 30%.

In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 1 year. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 2 years. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 3 years. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 0 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 2 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 3 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 1 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 2 to 3 years. In an embodiment, the stability of the LiBr-silk fragment solution is 2 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 2 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 3 to 4 years. In an embodiment, the stability of the LiBr-silk fragment solution is 3 to 5 years. In an embodiment, the stability of the LiBr-silk fragment solution is 4 to 5 years.

In an embodiment, the stability of a composition of the present disclosure is 10 days to 6 months. In an embodiment, the stability of a composition of the present disclosure is 6 months to 12 months. In an embodiment, the stability of a composition of the present disclosure is 12 months to 18 months. In an embodiment, the stability of a composition of the present disclosure is 18 months to 24 months. In an embodiment, the stability of a composition of the present disclosure is 24 months to 30 months. In an embodiment, the stability of a composition of the present disclosure is 30 months to 36 months. In an embodiment, the stability of a composition of the present disclosure is 36 months to 48 months. In an embodiment, the stability of a composition of the present disclosure is 48 months to 60 months.

In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 6 kDa to 16 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 17 kDa to 38 kDa. In an embodiment, 50 a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 39 kDa to 80 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an 55 average weight average molecular weight ranging from 1 to 5 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 5 to 10 kDa. In an embodiment, a composition of the 60 present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 10 to 15 kDa. In an embodiment, a 65 present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 16 to 30 kDa.

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to 325 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 325 to 330 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 330 to 335 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 35 to 340 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 340 to 345 kDa. In an embodiment, a composition of the present disclosure includes pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from 345 to 350 kDa.

In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1 to about 5.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1.5 to about 3.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1 to about 1.5. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 1.5 to about 2.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has a polydispersity ranging from about 2.0 to about 2.5. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments, has a polydispersity ranging from about 2.0 to about 3.0. In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments, has a polydispersity ranging from about 2.5 to about 3.0.

polymer property ranging from about 0.5 to about 3.0.

In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments has non-detectable levels of LiBr residuals. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is between 10 ppm and 1000 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is between 10 ppm and 300 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 25 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 50 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 75 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 100 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 200 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 300 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 400 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 500 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 600 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 700 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 800 ppm. In an embodiment, the amount of the LiBr residuals in a

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composition of the present disclosure is less than 900 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is less than 1000 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 500 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 450 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 400 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 350 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 300 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 250 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 200 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 150 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is non-detectable to 100 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 100 ppm to 200 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 200 ppm to 300 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 300 ppm to 400 ppm. In an embodiment, the amount of the LiBr residuals in a composition of the present disclosure is 400 ppm to 500 ppm.

In an embodiment, a composition of the present disclosure having pure silk fibroin-based protein fragments, has non-detectable levels of Na₂CO₃ residuals. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 100 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 200 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 300 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 400 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 500 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 600 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 700 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 800 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 900 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is less than 1000 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 500 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 450 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 400 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 350 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 300 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 250 ppm.

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non-detectable to 250 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 200 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 150 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is non-detectable to 100 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is 100 ppm to 200 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is 200 ppm to 300 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is 300 ppm to 400 ppm. In an embodiment, the amount of the Na₂CO₃ residuals in a composition of the present disclosure is 400 ppm to 500 ppm.

In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 50 to 100%. In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 60 to 100%. In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 70 to 100%. In an embodiment, the water solubility of pure silk fibroin-based protein fragments of the present disclosure is 80 to 100%. In an embodiment, the water solubility is 90 to 100%. In an embodiment, the silk fibroin-based fragments of the present disclosure are non-soluble in aqueous solutions.

In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 50 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 60 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 70 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 80 to 100%. In an embodiment, the solubility of pure silk fibroin-based protein fragments of the present disclosure in organic solutions is 90 to 100%. In an embodiment, the silk fibroin-based fragments of the present disclosure are non-soluble in organic solutions.

In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is greater than 84° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is less than 100° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 84° C. to 100° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 84° C. to 94° C. In an embodiment, the extraction temperature during a method of preparing a composition of the present disclosure is 94° C. to 100° C.

Compositions and Processes Including Silk Fibroin-Based Coatings

In an embodiment, the invention may include textiles, such as fibers, yarns, fabrics, or other materials and combinations thereof, that may be coated with an SPF mixture solution (i.e., silk fibroin solution (SFS)) as described herein to produce a coated article. In an embodiment, the coated articles described herein may be treated with additional chemical agents that may enhance the properties of the coated article. In an embodiment, the SFS may include one or more chemical agents that may enhance the properties of the coated article.

In an embodiment, textiles may be flexible materials (woven or non-woven) that include a network of natural and/or man-made fibers, thread, yarn, or a combination thereof. SFS may be applied at any stage of textile processing from individual fibers, to yarn, to fabric, to thread, or a combination thereof.

In an embodiment, fibers may be natural fibers that may include a natural fiber cellulose base, wherein the natural fiber cellulose base may include one or more of: (1) a baste such as flax, hemp, kenaf, jute, linen, and/or ramie; (2) a leaf such as flax, hemp, sisal, abaca, banana, henequen, ramie, sunn, and/or coir; and (3) seed hair such as cotton and/or kapok. In an embodiment, fibers may be natural fibers that may include a natural fiber protein base, wherein the natural fiber protein base may include one or more of: (1) hair such as alpaca, camel, cashmere, llama, mohair, and/or vicuna; (2) wool such as sheep; (3) filament such as silk. In an embodiment, fibers may be natural fibers that may include a natural fiber mineral base, including asbestos. In an embodiment, fibers may be man-made fibers that may include a man-made fiber organic natural polymer base, which may include one or more of: (1) a cellulose base such as bamboo, rayon, lyocell, acetate, and/or triacetate; (2) a protein base such as azlon; (3) an alginate; and (4) rubber. In an embodiment, fibers may be man-made fibers that may include a man-made fiber organic synthetic base, which may include one or more of acrylic, anidex, aramid, fluorocarbon, modacrylic, novoloid, nylon, nytril, olefin, PBI, polycarbonate, polyester, rubber, saran, spandex, vinal vinvon. In an embodiment, fibers may be man-made fibers that may include a man-made fiber inorganic base, which may include one or more of a glass material, metallic material, and carbon material.

In an embodiment, yarn may include natural fibers that may include a natural fiber cellulose base, wherein the natural fiber cellulose base may be from: (1) a baste such as flax, hemp, kenaf, jute, linen, and/or ramie; (2) a leaf such as flax, hemp, sisal, abaca, banana, henequen, ramie, sunn, and/or coir; or (3) seed hair such as cotton and/or kapok. In an embodiment, yarn may include natural fibers that may include a natural fiber protein base, wherein the natural fiber protein base may be from: (1) hair such as alpaca, camel, cashmere, llama, mohair, and/or vicuna; (2) wool such as sheep; or (3) filament such as silk. In an embodiment, yarn may include natural fibers that may include a natural fiber mineral base, including asbestos. In an embodiment, yarn may include man-made fibers that may include a man-made fiber organic natural polymer base, which may include: (1) a cellulose base such as bamboo, rayon, lyocell, acetate, and/or triacetate; (2) a protein base such as azlon; (3) an alginate; or (4) rubber. In an embodiment, yarn may include man-made fibers that may include a man-made fiber organic synthetic base, which may include acrylic, anidex, aramid, fluorocarbon, modacrylic, novoloid, nylon, nytril, olefin, PBI, polycarbonate, polyester, rubber, saran, spandex, vinal and/or vinvon. In an embodiment, yarn may include man-made fibers that may include a man-made fiber inorganic base, which may include a glass material, metallic material, carbon material, and/or specialty material.

In an embodiment, fabrics may include natural fibers and/or yarn that may include a natural fiber cellulose base, wherein the natural fiber cellulose base may be from: (1) a baste such as flax, hemp, kenaf, jute, linen, and/or ramie; (2) a leaf such as flax, hemp, sisal, abaca, banana, henequen, ramie, sunn, and/or coir; or (3) seed hair such as cotton and/or kapok. In an embodiment, fabric may include natural fibers and/or yarn that may include a natural fiber protein

base, wherein the natural fiber protein base may be from: (1) hair such as alpaca, camel, cashmere, llama, mohair, and/or vicuna; (2) wool such as sheep; or (3) filament such as silk. In an embodiment, fabric may include natural fibers and/or yarn that may include a natural fiber mineral base, including asbestos. In an embodiment, fabric may include man-made fibers and/or yarn that may include a man-made fiber organic natural polymer base, which may include: (1) a cellulose base such as bamboo, rayon, lyocell, acetate, and/or triacetate; (2) a protein base such as azlon; (3) an alginate; or (4) rubber. In an embodiment, fabric may include man-made fibers and/or yarn that may include a man-made fiber organic synthetic base, which may include acrylic, anidex, aramid, fluorocarbon, modacrylic, novoloid, nylon, nytril, olefin, PBI, polycarbonate, polyester, rubber, saran, spandex, vinal and/or vinvon. In an embodiment, fabric may include man-made fibers and/or yarn that may include a man-made fiber inorganic base, which may include a glass material, metallic material, carbon material, and/or specialty material.

In an embodiment, textiles may be manufactured via one or more of the following processes weaving processes, knitting processes, and non-woven processes. In an embodiment, weaving processes may include plain weaving, twill weaving, and/or satin weaving. In an embodiment, knitting processes may include weft knitting (e.g., circular, flat bed, and/or full fashioned) and/or warp knitting (e.g., tricot, Raschel, and/or crochet). In an embodiment, non-woven processes may include stable fiber (e.g., dry laid and/or wet laid) and/or continuous filament (e.g., spun laid and/or melt blown).

In some embodiments, SFS may be applied to fibers and/or yarn having a diameter of less than about 100 nm, or less than about 200 nm, or less than about 300 nm, or less than about 400 nm, or less than about 500 nm, or less than about 600 nm, or less than about 700 nm, or less than about 800 nm, or less than about 900 nm, or less than about 1000 nm, or less than about 2 µm, or less than about 5 µm, or less than about 10 µm, or less than about 20 µm, or less than about 30 µm, or less than about 40 µm, or less than about 50 µm, or less than about 60 µm, or less than about 70 µm, or less than about 80 µm, or less than about 90 µm, or less than about 100 µm, or less than about 200 µm, or less than about 300 µm, or less than about 400 µm, or less than about 500 µm, or less than about 600 µm, or less than about 700 µm, or less than about 800 µm, or less than about 900 µm, or less than about 1000 µm, or less than about 2 mm, or less than about 3 mm, or less than about 4 mm, or less than about 5 mm, 6 mm, or less than about 7 mm, or less than about 8 mm, or less than about 9 mm, or less than about 10 mm, or less than about 20 mm, or less than about 30 mm, or less than about 40 mm, or less than about 50 mm, or less than about 60 mm, or less than about 70 mm, or less than about 80 mm, or less than about 90 mm, or less than about 100 mm, or less than about 200 mm, or less than about 300 mm, or less than about 400 mm, or less than about 500 mm, or less than about 600 mm, or less than about 700 mm, or less than about 800 mm, or less than about 900 mm, or less than about 1000 mm.

In some embodiments, SFS may be applied to fibers and/or yarn having a diameter of greater than about 100 nm, or greater than about 200 nm, or greater than about 300 nm, or greater than about 400 nm, or greater than about 500 nm, or greater than about 600 nm, or greater than about 700 nm, or greater than about 800 nm, or greater than about 900 nm, or greater than about 1000 nm, or greater than about 2 µm, or greater than about 5 µm, or greater than about 10 µm, or greater than about 20 µm, or greater than about 30 µm, or greater than about 40 µm, or greater than about 50 µm, or

or less than about 5%, or less than about 6%, or less than about 7%, or less than about 8%, or less than about 9%, or less than about 10%, or less than about 20%, or less than about 30%, or less than about 40%, or less than about 50%, or less than about 60%, or less than about 70%, or less than about 80%, or less than about 90%, or less than about 100, or less than about 110%, or less than about 120%, or less than about 130%, or less than about 140%, or less than about 150%, or less than about 160%, or less than about 170%, or less than about 180%, or less than about 190%, or less than about 200%. Stretch percentage may be determined for a fabric having an unstretched width and stretching the fabric to a stretched width, then subtracting the unstretched width from the stretched width to yield the net stretched width, then dividing the net stretched width and multiplying the quotient by 100 to find the stretch percentage (%)

$$\text{(.Stretch Percentage} = \frac{\text{(Stretched Width} - \text{Unstretched Width})}{\text{Unstretched Width}} * 100\text{)}.$$

In some embodiments, SFS may be applied to fabric having a stretch percentage of greater than about 1%, or greater than about 2%, or greater than about 3%, or greater than about 4%, or greater than about 5%, or greater than about 6%, or greater than about 7%, or greater than about 8%, or greater than about 9%, or greater than about 10%, or greater than about 20%, or greater than about 30%, or greater than about 40%, or greater than about 50%, or greater than about 60%, or greater than about 70%, or greater than about 80%, or greater than about 90%, or greater than about 100, or greater than about 110%, or greater than about 120%, or greater than about 130%, or greater than about 140%, or greater than about 150%, or greater than about 160%, or greater than about 170%, or greater than about 180%, or greater than about 190%, or greater than about 200%

In some embodiments, SFS may be applied to fabric having a tensile energy (N/cm^2) of less than about 1 cN/cm^2 , or less than about 2 cN/cm^2 , or less than about 3 cN/cm^2 , or less than about 4 cN/cm^2 , or less than about 5 cN/cm^2 , or less than about 5 cN/cm^2 , or less than about 6 cN/cm^2 , or less than about 7 cN/cm^2 , or less than about 8 cN/cm^2 , or less than about 9 cN/cm^2 , or less than about 10 cN/cm^2 , or less than about 20 cN/cm^2 , or less than about 30 cN/cm^2 , or less than about 40 cN/cm^2 , or less than about 50 cN/cm^2 , or less than about 60 cN/cm^2 , or less than about 70 cN/cm^2 , or less than about 80 cN/cm^2 , or less than about 90 cN/cm^2 , or less than about 100 cN/cm^2 , or less than about 2 N/cm^2 , or less than about 3 N/cm^2 , or less than about 4 N/cm^2 , or less than about 5 N/cm^2 , or less than about 6 N/cm^2 , or less than about 7 N/cm^2 , or less than about 8 N/cm^2 , or less than about 9 N/cm^2 , or less than about 10 N/cm^2 , or less than about 20 N/cm^2 , or less than about 30 N/cm^2 , or less than about 40 N/cm^2 , or less than about 50 N/cm^2 , or less than about 60 N/cm^2 , or less than about 70 N/cm^2 , or less than about 80 N/cm^2 , or less than about 90 N/cm^2 , or less than about 100 N/cm^2 , or less than about 150 N/cm^2 , or less than about 200 N/cm^2 .

In some embodiments, SFS may be applied to fabric having a tensile energy (N/cm^2) of greater than about 1 cN/cm^2 , or greater than about 2 cN/cm^2 , or greater than about 3 cN/cm^2 , or greater than about 4 cN/cm^2 , or greater than about 5 cN/cm^2 , or greater than about 6 cN/cm^2 , or greater than about 7 cN/cm^2 , or greater than about 8 cN/cm^2 , or greater than about 9

cN/cm², or greater than about 10 cN/cm², or greater than about 20 cN/cm², or greater than about 30 cN/cm², or greater than about 40 cN/cm², or greater than about 50 cN/cm², or greater than about 60 cN/cm², or greater than about 70 cN/cm², or greater than about 80 cN/cm², or greater than about 90 cN/cm², or greater than about 100 cN/cm², or greater than about 2 N/cm², or greater than about 3 N/cm², or greater than about 4 N/cm², or greater than about 5 N/cm², or greater than about 6 N/cm², or greater than about 7 N/cm², or greater than about 8 N/cm², or greater than about 9 N/cm², or greater than about 10 N/cm², or greater than about 20 N/cm², or greater than about 30 N/cm², or greater than about 40 N/cm², or greater than about 50 N/cm², or greater than about 60 N/cm², or greater than about 70 N/cm², or greater than about 80 N/cm², or greater than about 90 N/cm², or greater than about 100 N/cm², or greater than about 150 N/cm², or greater than about 200 N/cm².

In some embodiments, SFS may be applied to fabric having a shear rigidity (N/cm-degree) of less than about 1 cN/cm-degree, or less than about 2 cN/cm-degree, or less than about 3 cN/cm-degree, or less than about 4 cN/cm-degree, or less than about 5 cN/cm-degree, or less than about 6 cN/cm-degree, or less than about 7 cN/cm-degree, or less than about 8 cN/cm-degree, or less than about 9 cN/cm-degree, or less than about 10 cN/cm-degree, or less than about 20 cN/cm-degree, or less than about 30 cN/cm-degree, or less than about 40 cN/cm-degree, or less than about 50 cN/cm-degree, or less than about 60 cN/cm-degree, or less than about 70 cN/cm-degree, or less than about 80 cN/cm-degree, or less than about 90 cN/cm-degree, or less than about 100 cN/cm-degree, or less than about 2 N/cm-degree, or less than about 3 N/cm-degree, or less than about 4 N/cm-degree, or less than about 5 N/cm-degree, or less than about 6 N/cm-degree, or less than about 7 N/cm-degree, or less than about 8 N/cm-degree, or less than about 9 N/cm-degree, or less than about 10 N/cm-degree, or less than about 20 N/cm-degree, or less than about 30 N/cm-degree, or less than about 40 N/cm-degree, or less than about 50 N/cm-degree, or less than about 60 N/cm-degree, or less than about 70 N/cm-degree, or less than about 80 N/cm-degree, or less than about 90 N/cm-degree, or less than about 100 N/cm-degree, or less than about 150 N/cm-degree, or less than about 200 N/cm-degree.

45 In some embodiments, SFS may be applied to fabric having a shear rigidity (N/cm-degree) of greater than about 1 cN/cm-degree, or greater than about 2 cN/cm-degree, or greater than about 3 cN/cm-degree, or greater than about 4 cN/cm-degree, or greater than about 5 cN/cm-degree, or
50 greater than about 5 cN/cm-degree, or greater than about 6 cN/cm-degree, or greater than about 7 cN/cm-degree, or greater than about 8 cN/cm-degree, or greater than about 9 cN/cm-degree, or greater than about 10 cN/cm-degree, or greater than about 20 cN/cm-degree, or greater than about 30
55 cN/cm-degree, or greater than about 40 cN/cm-degree, or greater than about 50 cN/cm-degree, or greater than about 60 cN/cm-degree, or greater than about 70 cN/cm-degree, or greater than about 80 cN/cm-degree, or greater than about 90 cN/cm-degree, or greater than about 100 cN/cm-degree, or
60 greater than about 2 N/cm-degree, or greater than about 3 N/cm-degree, or greater than about 4 N/cm-degree, or greater than about 5 N/cm-degree, or greater than about 6 N/cm-degree, or greater than about 7 N/cm-degree, or greater than about 8 N/cm-degree, or greater than about 9
65 N/cm-degree, or greater than about 10 N/cm-degree, or greater than about 20 N/cm-degree, or greater than about 30 N/cm-degree, or greater than about 40 N/cm-degree, or

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In some embodiments, chemical finishes may be applied to textiles before or after such textiles are coated with SFS. In an embodiment, chemical finishing may be intended as the application of chemical agents and/or SFS to textiles, including fibers, yarn, and fabric, or to garments that are prepared by such fibers, yarn, and fabric to modify the original textile's or garment's properties and achieve properties in the textile or garment that would be otherwise absent. With chemical finishes, textiles treated with such chemical finishes may act as surface treatments and/or the treatments may modify the elemental analysis of treated textile base polymers.

In an embodiment, a type of chemical finishing may include the application of certain silk-fibroin based solutions to textiles. For example, SFS may be applied to a fabric after it is dyed, but there are also scenarios that may require the application of SFS during processing, during dyeing, or after a garment is assembled from a selected textile or fabric, thread, or yarn. In some embodiments, after its application, SFS may be dried with the use of heat. SFS may then be fixed to the surface of the textile in a processing step called curing.

In some embodiments, SFS may be supplied in a concentrated form suspended in water. In some embodiments, SFS may have a concentration by weight (% w/w or w/v) or by volume (v/v) of less than about 50%, or less than about 45%, or less than about 40%, or less than about 35%, or less than about 30%, or less than about 25%, or less than about 20%, or less than about 15%, or less than about 10%, or less than about 5%, or less than about 4%, or less than about 3%, or less than about 2%, or less than about 1%, or less than about 0.1%, or less than about 0.01%, or less than about 0.001%, or less than about 0.0001%, or less than about 0.00001%. In some embodiments, SFS may have a concentration by weight (% w/w or % w/v) or by volume (v/v) of greater than about 50%, or greater than about 45%, or greater than about 40%, or greater than about 35%, or greater than about 30%, or greater than about 25%, or greater than about 20%, or greater than about 15%, or greater than about 10%, or greater than about 5%, or greater than about 4%, or greater than about 3%, or greater than about 2%, or greater than about 1%, or greater than about 0.1%, or greater than about 0.01%, or greater than about 0.001%, or greater than about 0.0001%, or greater than about 0.00001%.

In some embodiments, the solution concentration and the wet pick up of the material determines the amount of silk fibroin solution (SFS), which may include silk-based proteins or fragments thereof, that may be fixed or otherwise adhered to the textile being coated. The wet pick up may be expressed by the following formula:

$$\text{wet pick up (\%)} = \frac{\text{weight of SFS applied} \times 100}{\text{weight of dry textile material}}.$$

The total amount of SFS added to the textile material may be expressed by the following formula:

$$\text{SFS added (\%)} = \frac{\text{weight of dry SFS coated textile material} \times 100}{\text{weight of dry textile material before coating}}.$$

Regarding methods for applying SFS to textiles more broadly, SFS may be applied to textiles through a pad or roller application on process, a saturation and removal process, and/or a topical application process. Moreover, the

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methods of silk application (i.e., SFS application or coating) may include bath coating, kiss rolling, spray coating, and/or two-sided rolling. In some embodiments, the coating processes (e.g., bath coating, kiss rolling, spray coating, two-sided rolling, roller application, saturation and removal application, and/or topical application), drying processes, and curing processes may be varied as described herein to modify one or more selected textile (e.g., fabric) properties of the resulting coated textile wherein such properties include, but are not limited to wetting time, absorption rate, spreading speed, accumulative one-way transport, and/or overall moisture management capability. In some embodiments, the aforementioned selected properties may be enhanced by varying one or more of the coating processes, drying processes, and curing processes as described herein.

In an embodiment, the pad application may be used on dry or wet textile. For example, it may be applied on fabric after the dyeing process. The fabric may be fed into a water bath solution and may reach saturation. The fabric to be coated may then pass through a set of rollers that, based on multiple variables, extract the bath solution in excess to the desired wet pick up %. The variables that affect the wet pick up % are the roller pressure and materials, the fabric composition and construction, and the SFS viscosity. An exemplary pad roller configuration is shown in FIG. 317.

In an embodiment, the pad application on wet textile may be used to reduce the cost of drying the fabric post dyeing. The fabric exiting the pad rollers may maintain a higher weight % than the incoming fabric to maintain a SFS deposit on the fabric; and the SFS solution may need to account for any dilution taking place due to water present on the incoming fabric.

In an embodiment, the saturation and removal application is a low wet pick up method that may, for example, solve some of the issues associated with removing large amounts of water during drying processes. Since fabric may dry in an oven from the outside surface towards the inside, water may move from the inside to the outside resulting in a higher coating concentration on the outside surface. With less water content, migration may be reduced due to a higher viscosity in the solution. However, decreased wet pick up may result in an uneven solution deposit.

In an embodiment, vacuum extraction may be used as a method for low wet pick up. Saturated fabric may be subject to a vacuum that pulls solution out of the fabric and returns it to an application loop. Air jet ejection may be a method for providing low wet pick up. The saturated fabric may be subjected to high pressure steam that removes solution out of the fabric and returns it to an application loop.

In an embodiment, a porous bowl method may be used for low wet pick up. Solid pad rollers may be substituted with rubber coated fiber rollers. Saturated fabric may be subjected to the pressure of the roller since the porosity of the rollers may allow for more solution to be squeezed from the fabric.

In an embodiment, a transfer padding method may be used for low wet pick up. Saturated fabric may be passed through two continuous dry non-woven fabrics and may be pressed at low pressure. The non-woven fabrics may extract excess solution from the fabric being treated.

In an embodiment, topical application may be used as a low wet pick up method of application that deposits the desired amount of SFS to the fabric without removing any excess material. The methods described above may be used for one-sided coating applications, but there are variations that may allow for two-sided coating.

In an embodiment, kiss rolling may be used as a topical method of application that transfers the SFS from a roller

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(i.e., a kiss roller) to one side of the fabric. The solution viscosity, roller surface finish, speed of the roller, speed of the fabric, contact angle of the fabric on the roller and properties of the fabric are parameters that control the amount of solution deposited on the fabric. An exemplary kiss roller is depicted in FIG. 318.

In an embodiment, a variation to the kiss roller technique may be the Triatex MA system that uses two moisture content sensors to determine the solution pick up at the kiss roller and adjust the kiss roller controllable variable to maintain consistent the solution deposit onto the fabric.

In an embodiment, a loop transfer application may be used as a topical method of application that transfers the SFS from a saturated loop fabric to the fabric to be coated between low pressure pad rollers. There is a two rollers version that may allow for minimum contact with the fabric and a three rollers version that allows for greater contact with the fabric.

In an embodiment, an engrave roller application may be used as a topical method of application that may transfer a metered amount of SFS onto the fabric. This may be achieved by engraving a pattern on the surface of the roller with precise depth and design that contains a controlled amount of SFS. A blade may be used to remove any solution that is deposited on the surface of the roller in order to maintain a consistent transfer of solution to the fabric to be coated.

In an embodiment, rotary screen printing may be used as a topical method of application that may deposit SFS onto the fabric by seeping the solution through a roller screen. The solution may be contained in the screen print roller core at a set level while a blade may be used to remove any excess solution from the interior roller wall, providing a clean surface for the next revolution of the screen printer roller.

In an embodiment, magnetic roller coating may be used as a topical method of application that may deposit SFS from a kiss roller onto the fabric to be coated. The kiss roller is semi-submersed in a bath solution while a magnetic field created in the fabric driving roller determines the amount of pressure applied by the kiss roller, controlling the solution pick up rate.

In an embodiment, spraying may be used as a topical method of application that may transfer SFS onto the fabric by nebulizing the solution. The spray pattern may be controlled by the nozzle pattern, size, and the air flow. Spray application may be used for one side application or also two sided application.

In an embodiment, foam application may be used a topical method of application that may transfer SFS onto the fabric. Foam may be made by substituting part of the water in the solution with air therefore reducing the amount of water to be applied to the fabric. Foam application may be used for one-sided application or two-sided application where the same foam may be deposited through a squeeze roller or different foam solutions may be provided through transfer rolls or through a slot applicator.

In an embodiment, the application of SFS may take place after a garment is assembled. In an embodiment, the process may take place in a washing and dyeing machine or in a spray booth. For example, a washing and dyeing machine may be similar in shape to a household front loader washing machine, it allows the process to take place at exhaustion post dyeing or with an independent processing cycle. In an embodiment, a spray booth machine may include a manual or a fully automated process. For example, a garment may be held by a mannequin while an operator or an anthropomorphic robot may spray the solution onto the fabric.

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In an embodiment, SFS may be a water based solution that, after its application to the textile, may require thermal vaporization to infuse the SFS onto the textile. Thermal vaporization may be applied by heat transfer through radiation with equipment such as infrared or radio frequency dryer.

In an embodiment, thermal vaporization may be applied by convection through heated air circulating in an oven to the required temperature, while the fabric is clamped and is transported by a conveyor. This allows full control on fabric width dimension.

In an embodiment, thermal vaporization may be applied by conduction through contacting the textile with heated cylinder or calendar cylinder. Since the fabric is not clamp there is minimal control on fabric width.

In an embodiment, curing of the SFS on the textile may be completed with the same equipment used for the thermal vaporization in a continuous cycle or in a separate cycle.

In an embodiment, curing time temperature may be dependent the textile polymer content and the binding method of preference for the SFS with the specific polymer. The curing process may not start until the thermal vaporization is completed.

In some embodiments, sensor may be used to monitor SFS deposition on the textile and the drying and curing steps.

In some embodiments, for monitoring the deposition of SFS, a contactless sensor, like the one supplied by Pleva model AF120 based on microwave absorption of water, may be used. Measurement of the material moisture may be based on microwave absorption by water. A semiconductor oscillator transmits microwave energy through the web. The non-absorbed part of the energy may be received on the opposite side by a microwave receiver. The amount of absorption is a measurement of the absolute moisture content. The microwave sensor is capable of detecting and measuring water content from a minimum of 0 up to 2000 gH₂O/m².

In some embodiments, for wide fabric processing multiple sensor may be paired side by side, delivering the data analysis to a centralized control system loop capable to add more solution in the area of the fabric that is low.

In some embodiments, another sensor may be used that is based on microwave technology, such as Aqualot by Mahlo. The sensor may evaluate the shift in the resonant frequency of the two standing waves with respect to each other rather than the attenuation of the microwaves by the quantity of water molecules in the measuring gap.

In some embodiments, another contactless sensor for SFS may be the IR-3000 by MoistTech based on near infrared sensing technology. The sensor measures the amount of near infrared energy reflected at a given wavelength that is inversely proportional to the quantity of absorbing molecules in the fabric.

In some embodiments, the residual moister at the end of the curing process may be measured to further confirm the drying and curing process. In addition to the above sensor, a contact sensor such as the Textometer RMS by Mahlo may be used for measuring moister through conductivity.

In some embodiments, monitoring the end of the drying process phase may be achieved by measuring the fabric temperature with a contactless temperature sensor. When wet product enters the dryer, it first heats up to the cooling limit temperature. In some embodiments, when the water content drops to residual moisture levels, the product temperature may begin to rise again. The closer the product temperature approaches the circulation air temperature in the

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dryer, the slower the temperature continues to rise. In some embodiments, at a certain temperature threshold (called the fixing temperature) the temperature necessary for processing, fixing, or condensing is reached.

In some embodiments, to determine the dwell time for a desired product temperature, the surface temperature of the product may be measured without contact at several locations in the dryer using high-temperature resistant infrared pyrometers. Mahlo PermaSet VMT is an infrared Pyrometer that may be assembled in multiple units to monitors temperature through the dryer. Setex is another manufacturer offering fabric temperature sensors for use in dryers and oven like the models WTM V11, V21, and V41.

In some embodiments, SFS may be applied to a textile during exhaust dyeing. In some embodiments, the process may involve loading fabric into a bath, originally known as a batch, and allowing it to come into equilibrium with the solution. Exhaust dyeing may be the ability of the silk fibroin molecules to move from the solution onto the fibers or thread of a textile (substantivity). The substantivity of the silk fibroin may be influenced by temperature or additives, such as salt.

In some embodiments, an exhaust dyeing process may take anywhere from a few minutes to a few hours. When the fabric has been absorbed, or fixed, as much silk fibroin as it can, the bath may be emptied and the fabric may be rinsed to remove any excess solution.

In some embodiments, an important parameter in exhaust dyeing may be what is known as the specific liquor ratio. This describes the ratio of the mass of the fabric to the volume of the SFS bath and determines the amount of silk fibroin deposited on a textile.

In some embodiments, SFS can be applied to a textile during jet dyeing processes. A jet dyeing machine may be formed by closed tubular system where the fabric is placed. For transporting the fabric through the tube, a jet of dye liquor is supplied through a venturi. The jet may create turbulence. This may help in SFS penetration along with preventing the fabric from touching the walls of the tube. For example, as the fabric is often exposed to comparatively higher concentrations of liquor within the transport tube, a small SFS bath is needed in the bottom of the vessel. This arrangement may be enough for the smooth movement from rear to front of the vessel.

In some embodiments, SFS may be applied during Paddle dyeing. Paddle dyeing machines may be generally used to many forms of textiles but the method best suits to garments. Heat may be generated through steam injection directly into the coating bath. In an embodiment, a paddle dyeing machine operates through a paddle that circulates both the bath and garments in a perforated central island. It is here that the SFS, water, and steam for heat are added. The overhead paddle machine may be described as a vat with a paddle that has blades of full width. The blades may generally dip a few centimeters into the vat. This action may stir the bath and push garments to be died down, thus keeping them submerged in the dye liquor.

In some embodiments, the processing methods set forth herein may be used to apply SFS to textiles with one or more of the following parameters including, but not limited to, fabric speed, solution viscosity, solution added to fabric, fabric range width, drying temperature, drying time, curing time, fabric tension, padder pressure, pad roller shore hardness, stenter temperature, and common drying and curing temperatures. In an embodiment, the processing method parameters may also include a condensation tem-

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perature, which may vary depending upon the chemical recipe used to apply the SFS to the textiles.

In an embodiment, the fabric speed for the processes of the invention may be less than about 0.1 m/min, or less than about 0.2 m/min, or less than about 0.3 m/min, or less than about 0.4 m/min, or less than about 0.5 m/min, or less than about 0.6 m/min, or less than about 0.7 m/min, or less than about 0.8 m/min, or less than about 0.9 m/min, or less than about 1 m/min, or less than about 2 m/min, or less than about 3 m/min, or less than about 4 m/min, or less than about 5 m/min, or less than about 6 m/min, or less than about 7 m/min, or less than about 8 m/min, or less than about 9 m/min, or less than about 10 m/min, or less than about 20 m/min, or less than about 30 m/min, or less than about 40 m/min, or less than about 50 m/min, or less than about 60 m/min.

In an embodiment, the fabric speed for the processes of the invention may be greater than about 0.1 m/min, or greater than about 0.2 m/min, or greater than about 0.3 m/min, or greater than about 0.4 m/min, or greater than about 0.5 m/min, or greater than about 0.6 m/min, or greater than about 0.7 m/min, or greater than about 0.8 m/min, or greater than about 0.9 m/min, or greater than about 1 m/min, or greater than about 2 m/min, or greater than about 3 m/min, or greater than about 4 m/min, or greater than about 5 m/min, or greater than about 6 m/min, or greater than about 7 m/min, or greater than about 8 m/min, or greater than about 9 m/min, or greater than about 10 m/min, or greater than about 20 m/min, or greater than about 30 m/min, or greater than about 40 m/min, or greater than about 50 m/min, or greater than about 60 m/min.

In an embodiment, the solution viscosity for the processes of the invention may be less than about 1000 mPas, or less than about 1500 mPas, or less than about 2000 mPas, or less than about 2500, or less than about 3000 mPas, or less than about 4000 mPas, or less than about 4500 mPas, or less than about 5000 mPas, or less than about 5500 mPas, or less than about 6000 mPas, or less than about 6500 mPas, or less than about 7000 mPas, or less than about 7500 mPas, or less than about 8000 mPas, or less than about 8500 mPas, or less than about 9000 mPas, or less than about 9500 mPas, or less than about 10000 mPas, or less than about 10500 mPas, or less than about 11000 mPas, or less than about 11500 mPas, or less than about 12000 mPas.

In an embodiment, the solution viscosity for the processes of the invention may be greater than about 1000 mPas, or greater than about 1500 mPas, or greater than about 2000 mPas, or greater than about 2500, or greater than about 3000 mPas, or greater than about 4000 mPas, or greater than about 4500 mPas, or greater than about 5000 mPas, or greater than about 5500 mPas, or greater than about 6000 mPas, or greater than about 6500 mPas, or greater than about 7000 mPas, or greater than about 7500 mPas, or greater than about 8000 mPas, or greater than about 8500 mPas, or greater than about 9000 mPas, or greater than about 9500 mPas, or greater than about 10000 mPas, or greater than about 10500 mPas, or greater than about 11000 mPas, or greater than about 11500 mPas, or greater than about 12000 mPas.

In an embodiment, the solution may be added to a textile (e.g., fabric) for the processes of the invention in less than about 0.01 g/m², or less than about 0.02 g/m², or less than about 0.03 g/m², or less than about 0.04 g/m², or less than about 0.05 g/m², or less than about 0.06 g/m², or less than about 0.07 g/m², or less than about 0.08 g/m², or less than about 0.09 g/m², or less than about 0.10 g/m², or less than about 0.2 g/m², or less than about 0.3 g/m², or less than about 0.4 g/m², or less than about 0.5 g/m², or less than

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In an embodiment, the curing time for the processes of the invention may be greater than about 1 second, or greater than about 2 seconds, or greater than about 3 seconds, or greater than about 4 seconds, or greater than about 5 seconds, or greater than about 6 seconds, or greater than about 7 seconds, or greater than about 8 seconds, or greater than about 9 seconds, or greater than about 10 seconds, or greater than about 20 seconds, or greater than about 30 seconds, or greater than about 40 seconds, or greater than about 50 seconds, or greater than about 60 seconds, or greater than about 2 minutes, or greater than about 3 minutes, or greater than about 4 minutes, or greater than about 5 minutes, or greater than about 6 minutes, or greater than about 7 minutes, or greater than about 8 minutes, or greater than about 9 minutes, or greater than about 10 minutes, or greater than about 20 minutes, or greater than about 30 minutes, or greater than about 40 minutes, or greater than about 50 minutes, or greater than about 60 minutes.

In an embodiment, the fabric tension for the processes of the invention may be less than about 1 N, or less than about 2 N, or less than about 3 N, or less than about 4 N, or less than about 5 N, or less than about 6 N, or less than about 7 N, or less than about 8 N, or less than about 9 N, or less than about 10 N, or less than about 20 N, or less than about 30 N, or less than about 40 N, or less than about 50 N, or less than about 60 N, or less than about 70 N, or less than about 80 N, or less than about 90 N, or less than about 100 N, or less than about 150 N, or less than about 200 N, or less than about 250 N, or less than about 300 N.

In an embodiment, the fabric tension for the processes of the invention may be greater than about 1 N, or greater than about 2 N, or greater than about 3 N, or greater than about 4 N, or greater than about 5 N, or greater than about 6 N, or greater than about 7 N, or greater than about 8 N, or greater than about 9 N, or greater than about 10 N, or greater than about 20 N, or greater than about 30 N, or greater than about 40 N, or greater than about 50 N, or greater than about 60 N, or greater than about 70 N, or greater than about 80 N, or greater than about 90 N, or greater than about 100 N, or greater than about 150 N, or greater than about 200 N, or greater than about 250 N, or greater than about 300 N.

In an embodiment, the padder pressure for the processes of the invention may be less than about 1 N/mm, or less than about 2 N/mm, or less than about 3 N/mm, or less than about 4 N/mm, or less than about 4 N/mm, or less than about 5 N/mm, or less than about 6 N/mm, or less than about 7 N/mm, or less than about 8 N/mm, or less than about 9 N/mm, or less than about 10 N/mm, or less than about 20 N/mm, or less than about 30 N/mm, or less than about 40 N/mm, or less than about 50 N/mm, or less than about 60 N/mm, or less than about 70 N/mm, or less than about 80 N/mm, or less than about 90 N/mm.

In an embodiment, the padder pressure for the processes of the invention may be greater than about 1 N/mm, or greater than about 2 N/mm, or greater than about 3 N/mm, or greater than about 4 N/mm, or greater than about 4 N/mm, or greater than about 5 N/mm, or greater than about 6 N/mm, or greater than about 7 N/mm, or greater than about 8 N/mm, or greater than about 9 N/mm, or greater than about 10 N/mm, or greater than about 20 N/mm, or greater than about 30 N/mm, or greater than about 40 N/mm, or greater than about 50 N/mm, or greater than about 60 N/mm, or greater than about 70 N/mm, or greater than about 80 N/mm, or greater than about 90 N/mm.

In an embodiment, the padder roller shore hardness for the processes of the invention may be less than about 70 shore

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A, or less than about 75 shore A, or less than about 80 shore A, or less than about 85 shore A, or less than about 90 shore A, or less than about 95 shore A, or less than about 100 shore A.

5 In an embodiment, the padder roller shore hardness for the processes of the invention may be greater than about 70 shore A, or greater than about 75 shore A, or greater than about 80 shore A, or greater than about 85 shore A, or greater than about 90 shore A, or greater than about 95 shore A, or greater than about 100 shore A.

10 In an embodiment, the stenter temperature for the processes of the invention may be less than about 70° C., or less than about 75° C., or less than about 80° C., or less than about 85° C., or less than about 90° C., or less than about 95° C., or less than about 100° C., or less than about 110° C., or less than about 120° C., or less than about 130° C., or less than about 140° C., or less than about 150° C., or less than about 160° C., or less than about 170° C., or less than about 180° C., or less than about 190° C., or less than about 200° C., or less than about 210° C., or less than about 220° C., or less than about 230° C.

15 In an embodiment, the stenter temperature for the processes of the invention may be greater than about 70° C., or greater than about 75° C., or greater than about 80° C., or greater than about 85° C., or greater than about 90° C., or greater than about 95° C., or greater than about 100° C., or greater than about 110° C., or greater than about 120° C., or greater than about 130° C., or greater than about 140° C., or greater than about 150° C., or greater than about 160° C., or greater than about 170° C., or greater than about 180° C., or greater than about 190° C., or greater than about 200° C., or greater than about 210° C., or greater than about 220° C., or greater than about 230° C.

20 In an embodiment, the common drying temperatures for the processes of the invention may be less than about 110° C., or less than about 115° C., or less than about 120° C., or less than about 125° C., or less than about 130° C., or less than about 135° C., or less than about 140° C., or less than about 145° C., or less than about 150° C.

25 In an embodiment, the common drying temperatures for the processes of the invention may be greater than about 110° C., or greater than about 115° C., or greater than about 120° C., or greater than about 125° C., or greater than about 130° C., or greater than about 135° C., or greater than about 140° C., or greater than about 145° C., or greater than about 150° C.

30 In some embodiments, a silk fibroin coated material (e.g., fabric) may be heat resistant to a selected temperature where the selected temperature is chosen for drying, curing, and/or heat setting a dye that may be applied to the material (e.g., LYCRA). As used herein, a "heat resistant" may refer to a property of the silk fibroin coating deposited on the material where the silk fibroin coating and/or silk fibroin protein does not exhibit a substantial modification (i.e., "substantially modifying") in silk fibroin coating performance as compared to a control material having a comparable silk fibroin coating that was not subjected to the selected temperature for drying, curing, wash cycling, and/or heat setting purposes. In some embodiments, the selected temperature is the glass transition temperature (T_g) for the material upon which the silk fibroin coating is applied. In some embodiments, the selected temperature is greater than about 65°, or greater than about 70° C., or greater than about 80° C., or greater than about 90° C., or greater than about 100° C., or greater than about 110° C., or greater than about 120° C., or greater than about 130° C., or greater than about 140° C., or greater than about 150° C., or greater than about 160° C., or

greater than about 170° C., or greater than about 180° C., or greater than about 190° C., or greater than about 200° C., or greater than about 210° C., or greater than about 220° C. In some embodiments, the selected temperature is less than about 65° C., or less than about 70° C., or less than about 80° C., or less than about 90° C., or less than about 100° C., or less than about 110° C., or less than about 120° C., or less than about 130° C., or less than about 140° C., or less than about 150° C., or less than about 160° C., or less than about 170° C., or less than about 180° C., or less than about 190° C., or less than about 200° C., or less than about 210° C., or less than about 220° C.

In an embodiment, "substantially modifying" silk fibroin coating performance may be a decrease in a selected property of silk fibroin coating, such as wetting time, absorption rate, spreading speed, accumulative one-way transport, or overall moisture management capability as compared to a control silk fibroin coating that was not subjected to the selected temperature for drying, curing, wash cycling, and/or heat setting purposes, where such decrease is less than about a 1% decrease, or less than about a 2% decrease, or less than about a 3% decrease, or less than about a 4% decrease, or less than about a 5% decrease, or less than about a 6% decrease, or less than about a 7% decrease, or less than about an 8% decrease, or less than about a 9% decrease, or less than about a 10% decrease, or less than about a 15% decrease, or less than about a 20% decrease, or less than about a 25% decrease, or less than about a 30% decrease, or less than about a 35% decrease, or less than about a 40% decrease, or less than about a 45% decrease, or less than about a 50% decrease, or less than about a 60% decrease, or less than about a 70% decrease, or less than about a 80% decrease, or less than about a 90% decrease, or less than about 100% decrease in wetting time, absorption rate, spreading speed, accumulative one-way transport, or overall moisture management capability as compared to a control silk fibroin coating that was not subjected to the selected temperature for drying, curing, wash cycling, and/or heat setting purposes. In some embodiments, "wash cycling" may refer to at least one wash cycle, or at least two wash cycles, or at least three wash cycles, or at least four wash cycles, or at least five wash cycles.

In an embodiment, "substantially modifying" silk fibroin coating performance may be an increase in a selected property of silk fibroin coating, such as wetting time, absorption rate, spreading speed, accumulative one-way transport, or overall moisture management capability as compared to a control silk fibroin coating that was not subjected to the selected temperature for drying, curing, wash cycling, and/or heat setting purposes, where such increase is less than about a 1% increase, or less than about a 2% increase, or less than about a 3% increase, or less than about a 4% increase, or less than about a 5% increase, or less than about a 6% increase, or less than about a 7% increase, or less than about an 8% increase, or less than about a 9% increase, or less than about a 10% increase, or less than about a 15% increase, or less than about a 20% increase, or less than about a 25% increase, or less than about a 30% increase, or less than about a 35% increase, or less than about a 40% increase, or less than about a 45% increase, or less than about a 50% increase, or less than about a 60% increase, or less than about a 70% increase, or less than about a 80% increase, or less than about a 90% increase, or less than about 100% increase in wetting time, absorption rate, spreading speed, accumulative one-way transport, or overall moisture management capability as compared to a control silk fibroin coating that was not subjected to the

selected temperature for drying, curing, wash cycling, and/or heat setting purposes. In some embodiments, "wash cycling" may refer to at least one wash cycle, or at least two wash cycles, or at least three wash cycles, or at least four wash cycles, or at least five wash cycles.

In some embodiments, the SFS coated article may be subjected to heat setting in order to set one or more dyes that may be applied to the SFS coated article in order to permanently set the one or more dyes on the SFS coated article. In some embodiments, the SFS coated article may be heat setting resistant, wherein the SFS coating on the SFS coated article may resist a heat setting temperature of greater than about 100° C., or greater than about 110° C., or greater than about 120° C., or greater than about 130° C., or greater than about 140° C., or greater than about 150° C., or greater than about 160° C., or greater than about 170° C., or greater than about 180° C., or greater than about 190° C., or greater than about 200° C., or greater than about 210° C., or greater than about 220° C. In some embodiments, the selected temperature is less than about 100° C., or less than about 110° C., or less than about 120° C., or less than about 130° C., or less than about 140° C., or less than about 150° C., or less than about 160° C., or less than about 170° C., or less than about 180° C., or less than about 190° C., or less than about 200° C., or less than about 210° C., or less than about 220° C.

In an embodiment, a material coated by the silk fibroin coating as described herein may partially dissolved or otherwise partially incorporated within a portion of the material after the silk fibroin coated material is subjected to heating and/or curing as described herein. Without being limited to any one theory of the invention, where the silk fibroin coated material is heated to greater than about the glass transition temperature (Tg) for the material that is coated, the silk fibroin coating may become partially dissolved or otherwise partially incorporated within a portion of the material.

In some embodiments, a material coated by the silk fibroin coating as described herein may be sterile or may be sterilized to provide a sterilized silk fibroin coated material. Alternatively, or in addition thereto, the methods described herein may include a sterile SFS prepared from sterile silk fibroin.

In some embodiments, the fabric constructions that are compatible with the processes of the invention include woven fabrics, knitted fabrics, and non-woven fabrics.

In some embodiments, the coating pattern provided by the processes of the invention include one side coating, two side coating, and/or throughout coating.

In some embodiments, the equipment manufacturers that are capable of producing equipment configured to continuously coat SFS on textiles include, but are not limited to, Aigle, Amba Projex, Bombi, Bruckner, Cavitec, Crosta, Dienes Apparatebau, Eastsign, Europlasma, Fermor, Fontanet, Gaston Systems, Hansa Mixer, Harish, Has Group, Icomatex, Idealtech, Interspare, Isotex, Klieverik, KTP, M P, Mageba, Mahr Feinpruef, Matex, Mathis, Menzel LP, Meyer, Monforts, Morrison Textile, Mtex, Muller Frick, Murata Tex, Reliant Machinery, Rollmac, Salvade, Sandvik Tps, Santex, Chmitt-Machinen, Schott & Meissner, Sellers, Sicam, Siltex, Starlinger, Swatik Group India, Techfull, TMT Manenti, Unitech Textile Machinery, Weko, Willy, Wumag Texroll, Yamuna, Zappa, and Zimmer Austria.

In some embodiments, the equipment manufacturers that are capable of producing equipment configured to dry SFS coated on textiles include, but are not limited to, Alea, Alkan Makina, Anglada, Atac Makina, Bianco, Bruckner, Campen,

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CHTC, CTMTC, Dilmenler, Elteksmak, Erbatech, Fontanet, Harish, Icomatex, Ilsung, Inspiron, Interspare, Master, Mathis, Monfongs, Monforts, Salvade, Schmitt-Maschinen, Sellers, Sicam, Siltex, Swastik Group India, Tacome, Tubetex, Turbang, Unitech Textile Machinery, and Yamuna.

In some embodiments, SFS may be used in combination with chemical agents. In some embodiments, SFS may include a chemical agent. In some embodiments, a chemical agent may be applied to a textile to be coated prior to providing an SFS coating. In some embodiments, a chemical agent may be applied to a textile after such textile has been coated with an SFS coating. One or more chemical agents may be applied, as set forth above, and may include a first chemical agent, second chemical agent, third chemical agent, and the like, where the chemical agents may be the same or a combination of two or more of the chemical agents described herein. In some embodiments, chemical agents may provide selected properties to coated textile (e.g., fabric) including, but not limited to, an antimicrobial property, a water repellent property, an oil repellent property, a coloring property, a flame retardant property, a fabric softening property, a pH adjusting property, an anticrocking property, an antipilling property, and/or an antifelting property. In some embodiments, chemical agents may include, but are not limited to, an antimicrobial agent, acidic agents (e.g., Bronsted acids, citric acid, acetic acid, etc.), a softener, a water repellent agent, an oil repellent agent, a dye, a flame retardant, a fabric softener, a pH adjusting agent (e.g., an acidic agent), an anticrocking agent, an antipilling agent, and/or an antifelting agent. Such chemical agents may include, but are not limited to, softeners (e.g., chemical fabric softeners), acidic agents, antimicrobials, dyes, finishing agents including monomers (e.g., melted polyester), and combinations thereof.

In some embodiments, SFS may be used in an SFS coating, where such coating includes one or more chemical agents (e.g., a silicone). SFS may be provided in such an SFS coating at a concentration by weight (% w/w or % w/v) or by volume (v/v) of less than about 25%, or less than about 20%, or less than about 15%, or less than about 10%, or less than about 9%, or less than about 8%, or less than about 7%, or less than about 6%, or less than about 5%, or less than about 4%, or less than about 3%, or less than about 2%, or less than about 1%, or less than about 0.9%, or less than about 0.8%, or less than about 0.7%, or less than about 0.6%, or less than about 0.5%, or less than about 0.4%, or less than about 0.3%, or less than about 0.2%, or less than about 0.1%, or less than about 0.01%, or less than about 0.001%. In some embodiments, SFS may be provided in such an SFS coating at a concentration by weight (% w/w or % w/v) or by volume (v/v) of greater than about 25%, or greater than about 20%, or greater than about 15%, or greater than about 10%, or greater than about 9%, or greater than about 8%, or greater than about 7%, or greater than about 6%, or greater than about 5%, or greater than about 4%, or greater than about 3%, or greater than about 2%, or greater than about 1%, or greater than about 0.9%, or greater than about 0.8%, or greater than about 0.7%, or greater than about 0.6%, or greater than about 0.5%, or greater than about 0.4%, or greater than about 0.3%, or greater than about 0.2%, or greater than about 0.1%, or greater than about 0.01%, or greater than about 0.001%.

In some embodiments, chemical fabric softeners may include silicones as described herein.

In some embodiments, the chemical agents may include the following, which are supplied by CHT Bezema and are associated with certain selected textile (e.g., fabric) proper-

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ties, which may be used to strengthen SFS binding on coated surfaces and/or SFS may be used for enhancing the following chemical agents' properties:

ALPAPRINT CLEAR

5 Silicone printing and coating
Component B is mentioned in the technical leaflet

Dry handle

Good rubbing fastness

Good washfastness

10 ALPAPRINT ELASTIC ADD

Silicone printing and coating
Component B is mentioned in the technical leaflet

Good rubbing fastness

Good washfastness

15 Suited for yardage printing

ALPAPRINT WHITE

Silicone printing and coating
Component B is mentioned in the technical leaflet

Dry handle

Good rubbing fastness

Good washfastness

20 ALPATEC 30142 A

Textile finishing

Coating

Silicone printing and coating

Component B is mentioned in the technical leaflet

Suitable for narrow ribbon coating

Good rubbing fastness

Good washfastness

25 ALPATEC 30143 A

Silicone printing and coating

Component B is mentioned in the technical leaflet

Good rubbing fastness

Good washfastness

30 Suited for yardage printing

ALPATEC 30191 A

Silicone printing and coating

Component B is mentioned in the technical leaflet

Suitable for narrow ribbon coating

High transparency

Coating

35 ALPATEC 30203 A

Silicone printing and coating

Component B is mentioned in the technical leaflet

Suitable for narrow ribbon coating

High transparency

Coating

40 ALPATEC 3040 LSR KOMP. A

Functional coatings, Silicone printing and coating

Component B is mentioned in the technical leaflet

High abrasion resistance

High transparency

Coating

45 ALPATEC 3060 LSR KOMP. A

Functional coatings, Silicone printing and coating

Component B is mentioned in the technical leaflet

High abrasion resistance

High transparency

Coating

50 ALPATEC 530

Silicone printing and coating

Suitable for narrow ribbon coating

High transparency

Coating

55 One component system

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ALPATEC 540
 Silicone printing and coating
 Suitable for narrow ribbon coating
 High transparency
 Coating
 One component system

ALPATEC 545
 Silicone printing and coating
 Suitable for narrow ribbon coating
 High transparency
 Coating
 One component system

ALPATEC 550
 Silicone printing and coating
 Suitable for narrow ribbon coating
 High transparency
 Coating
 One component system

ALPATEC 730
 Silicone printing and coating
 Suitable for narrow ribbon coating
 Good washfastness
 High abrasion resistance
 High transparency

ALPATEC 740
 Silicone printing and coating
 Suitable for narrow ribbon coating
 Good washfastness
 High abrasion resistance
 High transparency

ALPATEC 745
 Silicone printing and coating
 Suitable for narrow ribbon coating
 Good washfastness
 High abrasion resistance
 High transparency

ALPATEC 750
 Silicone printing and coating
 Suitable for narrow ribbon coating
 Good washfastness
 High abrasion resistance
 High transparency

ALPATEC BANDAGE A
 Silicone printing and coating
 Component B is mentioned in the technical leaflet
 Suitable for narrow ribbon coating
 Coating
 Two component system

APYROL BASE2 E
 Flame retardants
 Liquid
 Soft handle
 For BS 5852/1+2
 Suited for paste coating

APYROL FCR-2
 Water repellency/oil repellency
 Cationic
 High effectiveness
 Water-based
 Liquid

APYROL FFD E
 Flame retardants
 Liquid
 Suited for polyester
 Suited for polyamide
 Flame inhibiting filler

APYROL FR CONC E
 Flame retardants, Functional coatings
 Liquid
 Suited for polyester
 5 Suited for polyamide
 Flame inhibiting filler

APYROL GBO-E
 Flame retardants, Functional coatings
 Suited for polyester
 Black-out coating
 10 For DIN 4102/B1
 Containing halogen

APYROL LV 21
 Flame retardants, Functional coatings
 For DIN 4102/B1
 15 Suited for paste coating
 Suited for backcoating of black-out vertical blinds and roller blinds
 Containing halogen

APYROL PP 31
 20 Flame retardants
 Liquid
 Free from antimony
 Flame inhibiting filler
 For BS 5852/1+2

25 APYROL PP 46
 Flame retardants
 Powder
 Free from antimony
 Flame inhibiting filler
 30 Suited for paste coating

APYROL PREM E
 Flame retardants
 Soft handle
 For BS 5852/1+2
 35 Containing halogen
 Semi-permanent

APYROL PREM2 E
 Flame retardants
 Soft handle
 40 For BS 5852/1+2
 Containing halogen
 Semi-permanent

COLORDUR 005 WHITE
 Flock adhesives, Functional coatings, Silicone printing
 45 and coating
 Based on silicone
 Dyestuff pigment suspension

COLORDUR 105 LEMON
 Flock adhesives, Functional coatings, Silicone printing
 50 and coating
 Based on silicone
 Dyestuff pigment suspension

COLORDUR 115 GOLDEN YELLOW
 Flock adhesives, Functional coatings, Silicone printing
 55 and coating
 Based on silicone
 Dyestuff pigment suspension

COLORDUR 185 ORANGE
 Flock adhesives, Functional coatings, Silicone printing
 60 and coating
 Based on silicone
 Dyestuff pigment suspension

COLORDUR 215 RED
 Flock adhesives, Functional coatings, Silicone printing
 65 and coating
 Based on silicone
 Dyestuff pigment suspension

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COLORDUR 225 DARK RED	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR 285 VIOLET	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR 305 BLUE	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR 355 MARINE	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR 405 GREEN	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR 465 OLIVE GREEN	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR 705 BLACK	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR AM ADDITIVE	Flock adhesives, Silicone printing and coating
	Based on silicone
	Migration prevention
	Dyestuff pigment suspension
COLORDUR FL 1015 YELLOW	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR FL 1815 ORANGE	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR FL 2415 PINK	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
COLORDUR FL 4015 GREEN	Flock adhesives, Functional coatings, Silicone printing and coating
	Based on silicone
	Dyestuff pigment suspension
ECOPERL 1	Water repellency/oil repellency
	Washfast
	Sprayable
	Based on special functionalised polymers/waxes
	Cationic

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	ECOPERL ACTIVE
	Water repellency/oil repellency
	Washfast
	Based on special functionalised polymers/waxes
5	Cationic
	High effectiveness
	LAMETHAN 1 ET 25 BR 160
	Functional coatings, Lamination
	Washfast
10	Transparent
	25 µm strong
	Film based on polyester urethane
	LAMETHAN ADH-1
	Functional coatings, Lamination
	Breathable
	Suited for dry laminating
	Good stability to washing at 40° C.
	Stable foam adhesive
15	LAMETHAN ADH-L
	Functional coatings, Lamination
	Washfast
	Transparent
	Suited for paste coating
20	25 Suited for wet laminating
	LAMETHAN ALF-K
	Functional coatings, Lamination
	Adhesive additive for bondings
	Suited for dry laminating
	Stable foam adhesive
	Suited for stable foam coating
25	LAMETHAN LB 15-T BR 152DK
	Functional coatings, Lamination
	Transparent
	15 µm strong
	Breathable
	Suited for dry laminating
	LAMETHAN LB 25 BR 155
	Functional coatings, Lamination
	Transparent
	25 µm strong
	Suited for dry laminating
30	Good stability to washing at 40° C.
	LAMETHAN LB 25 W BR 152
	Lamination
	25 µm strong
	Breathable
	Suited for dry laminating
	Good stability to washing at 40° C.
35	LAMETHAN TAPE DE 80
	Functional coatings, Lamination
	Polymer base: polyurethane
	Transparent
	Good stability to washing at 40° C.
40	55 Tape for seam sealing
	LAMETHAN TAPE ME 160
	Functional coatings, Lamination
	Polymer base: polyurethane
	Transparent
	Good stability to washing at 40° C.
45	60 Good stability to washing at 40° C.
	Tape for seam sealing
	LAMETHAN VL-H920 0 BR150
	Functional coatings, Lamination
	Two coats with membrane and PES charmeuse
	Breathable
	Suited for dry laminating
50	65 Good stability to washing at 40° C.

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LAMETHAN VL-H920 S BR 150
 Functional coatings, Lamination
 Two coats with membrane and PES charmeuse
 Breathable
 Suited for dry laminating
 Good stability to washing at 40° C.

LAMETHAN VL-H920 W BR150
 Functional coatings, Lamination
 Two coats with membrane and PES charmeuse
 Breathable
 Suited for dry laminating
 Good stability to washing at 40° C.

TUBICOAT A 12 E
 Binders, Functional coatings
 Anionic
 Liquid
 Formaldehyde-free
 Polymer base: polyacrylate

TUBICOAT A 17
 Binders, Functional coatings
 Suitable for tablecloth coating
 Anionic
 Liquid
 Self-crosslinking

TUBICOAT A 19
 Binders, Functional coatings
 Washfast
 Anionic
 Formaldehyde-free
 Good stability to washing

TUBICOAT A 22
 Binders, Functional coatings
 Washfast
 Medium-hard film
 Anionic
 Liquid

TUBICOAT A 23
 Binders
 Medium-hard film
 Anionic
 Liquid
 Application for varying the handle

TUBICOAT A 28
 Binders, Functional coatings
 Anionic
 Liquid
 Formaldehyde-free
 Good stability to washing

TUBICOAT A 36
 Binders, Functional coatings
 Washfast
 Anionic
 Liquid
 Low formaldehyde

TUBICOAT A 37
 Binders, Functional coatings
 Washfast
 Suitable for tablecloth coating
 Anionic
 Liquid

TUBICOAT A 41
 Binders, Functional coatings
 Anionic
 Liquid
 Self-crosslinking
 Good fastnesses

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TUBICOAT A 61
 Binders, Functional coatings
 Suitable for tablecloth coating
 Liquid

5 Non-ionic
 Self-crosslinking

TUBICOAT A 94
 Binders, Functional coatings
 Anionic
 Liquid
 Self-crosslinking
 Good fastnesses

TUBICOAT AIB 20
 Fashion coatings
 Transparent
 Suited for foam coating
 Pearl Gloss Finish

TUBICOAT AOS
 10 Foaming auxiliaries
 Non-ionic
 Foaming
 Suited for the fluorocarbon finishing

TUBICOAT ASK
 15 Functional coatings, Lamination
 Adhesive additive for bondings
 Transparent
 Suited for paste coating
 Suited for dry laminating

TUBICOAT B-H
 20 Binders, Functional coatings
 Polymer base: Styrene butadiene
 Anionic
 Liquid

30 35 Formaldehyde-free

TUBICOAT B 45
 Binders, Functional coatings
 Washfast

40 45 Polymer base: Styrene butadiene
 Anionic
 Liquid

TUBICOAT BO-NB
 Functional coatings

45 50 Medium hard
 Suited for black-out coating
 Good flexibility at low temperatures
 Suited for stable foam coating

TUBICOAT BO-W
 Functional coatings
 Suited for black-out coating
 Impermeable for light
 Suited for stable foam coating

55 Water vapour permeable

TUBICOAT BOS
 Foaming auxiliaries
 Anionic
 Foaming

60 65 Foam stabilizer

TUBICOAT DW-FI
 Functional coatings, Special products
 Anionic
 Suited for coating pastes
 Suited for stable foam
 Foamable

TUBICOAT E 4
 Binders
 Anionic
 Self-crosslinking
 Low formaldehyde
 Polymer base: polyethylene vinyl acetate

TUBICOAT ELC
 Functional coatings
 Suited for paste coating
 Black
 Electrically conductive
 Soft

TUBICOAT EMULGATOR HF
 Functional coatings, Special products
 Anionic
 Dispersing
 Suited for coating pastes
 Suited for stable foam

TUBICOAT ENTSCHÄUMER N
 Defoamers and deaerators
 Liquid
 Non-ionic
 Silicone-free
 Suited for coating pastes

TUBICOAT FIX FC
 Fixing agents
 Cationic
 Water-based
 Liquid
 Formaldehyde-free

TUBICOAT FIX ICB CONC.
 Fixing agents
 Liquid
 Non-ionic
 Formaldehyde-free
 Suited for crosslinking

TUBICOAT FIXIERER AZ
 Fixing agents
 Liquid
 Suited for crosslinking
 Based on polyaziridin
 Unblocked

TUBICOAT FIXIERER FA
 Fixing agents
 Anionic
 Water-based
 Liquid
 Low formaldehyde

TUBICOAT FIXIERER H 24
 Fixing agents
 Anionic
 Water-based
 Liquid
 Formaldehyde-free

TUBICOAT FIXIERER HT
 Fixing agents
 Water-based
 Liquid
 Non-ionic
 Suited for crosslinking

TUBICOAT FOAMER NY
 Foaming auxiliaries
 Non-ionic
 Foaming
 Suited for the fluorocarbon finishing
 Non-yellowing

TUBICOAT GC PU
 Fashion coatings
 Washfast
 Soft handle
 5 Polymer base: polyurethane
 Transparent

TUBICOAT GRIP
 Functional coatings
 Slip resistant
 10 Suited for stable foam coating
 Soft

TUBICOAT HEC
 Thickeners
 Powder
 15 Non-ionic
 Stable to electrolytes
 Stable to shear forces

TUBICOAT HOP-S
 20 Special products
 Anionic
 Suited for coating pastes
 Coating
 Adhesion promoter

TUBICOAT HS 8
 Binders
 Anionic
 Liquid
 30 Formaldehyde-free
 Hard film

TUBICOAT HWS-1
 Functional coatings
 Suited for paste coating
 Water-proof
 35 Suited for giant umbrellas and tents

TUBICOAT KL-TOP F
 Fashion coatings, Functional coatings
 Washfast

40 Polymer base: polyurethane
 Transparent
 Suited for paste coating

TUBICOAT KLS-M
 Fashion coatings, Functional coatings
 45 Washfast
 Soft handle
 Polymer base: polyurethane
 Breathable

TUBICOAT MAF
 50 Fashion coatings
 Washfast
 Matrix effect
 Improves the rubbing fastnesses

55 Soft handle

TUBICOAT MD TC 70
 Fashion coatings
 Vintage wax
 60 Suited for foam coating
 Suited for topcoats

TUBICOAT MEA
 Functional coatings
 Washfast
 65 Polymer base: polyurethane
 Suited for paste coating
 Suited for topcoat coatings

TUBICOAT MG-R
 Fashion coatings
 Washfast
 Soft handle
 Suited for paste coating
 Duo Leather Finish
 TUBICOAT MOP NEU
 Functional coatings, Special products
 Washfast
 Anionic
 Foamable
 Finish
 TUBICOAT MP-D
 Fashion coatings, Functional coatings
 Washfast
 Soft handle
 Medium hard
 Breathable
 TUBICOAT MP-W
 Functional coatings
 Washfast
 Polymer base: polyurethane
 Breathable
 Water-proof
 TUBICOAT NTC-SG
 Functional coatings
 Washfast
 Transparent
 Suited for paste coating
 Medium hard
 TUBICOAT PERL A22-20
 Fashion coatings
 Suited for paste coating
 Suited for foam coating
 Pearl Gloss Finish
 TUBICOAT PERL HS-1
 Functional coatings
 Suited for paste coating
 Suited for black-out coating
 Suited for pearlescent coating
 Suited for topcoat coatings
 TUBICOAT PERL PU SOFT
 Fashion coatings
 Washfast
 Scarabaeus effect
 Soft handle
 Polymer base: polyurethane
 TUBICOAT PERL VC CONC.
 Fashion coatings, Functional coatings
 Soft handle
 Polymer base: polyurethane
 Suited for paste coating
 Suited for black-out coating
 TUBICOAT PHV
 Functional coatings
 Medium hard
 Suited for three-dimensional dot coating
 TUBICOAT PSA 1731
 Functional coatings, Lamination
 Transparent
 Suited for paste coating
 Suited for dry laminating
 Non-breathable
 TUBICOAT PU-UV
 Binders
 Anionic
 Liquid

Formaldehyde-free
 Good fastnesses
 TUBICOAT PU 60
 Binders
 5 Anionic
 Liquid
 Application for varying the handle
 Formaldehyde-free
 TUBICOAT PU 80
 10 Binders, Functional coatings
 Washfast
 Anionic
 Liquid
 Can be washed off
 TUBICOAT PUH-BI
 Binders
 Anionic
 Liquid
 15 Formaldehyde-free
 Hard film
 TUBICOAT PUL
 Functional coatings
 Polymer base: polyurethane
 20 Suited for paste coating
 Suited for three-dimensional dot coating
 Slip resistant
 TUBICOAT PUS
 Binders, Functional coatings
 25 Anionic
 Liquid
 Formaldehyde-free
 Polymer base: polyurethane
 TUBICOAT PUW-M
 30 Binders
 Medium-hard film
 Anionic
 Liquid
 Formaldehyde-free
 35 TUBICOAT PUW-S
 Binders
 Anionic
 Liquid
 Formaldehyde-free
 40 TUBICOAT PUW-S
 Binders
 Anionic
 Liquid
 Formaldehyde-free
 45 Good stability to washing
 TUBICOAT PW 14
 Binders, Functional coatings
 Anionic
 Formaldehyde-free
 50 Heat-sealable
 Not wetting
 TUBICOAT SA-M
 Functional coatings
 Washfast
 55 Suited for paste coating
 Suited for three-dimensional dot coating
 TUBICOAT SCHÄUMER HP
 Foaming auxiliaries, Functional coatings
 Non-ionic
 60 Foaming
 Suited for the fluorocarbon finishing
 TUBICOAT SF-BASE
 Fashion coatings
 Washfast
 65 Soft handle
 Suited for foam coating
 Silk gloss effect

TUBICOAT SHM
Foaming auxiliaries
Anionic
Foam stabilizer
TUBICOAT SI 55
Special products
Pseudo-cationic
Suited for coating pastes
Foamable
Coating
TUBICOAT STABILISATOR RP
Foaming auxiliaries
Anionic
Foam stabilizer
TUBICOAT STC 100
Fashion coatings, Functional coatings
Transparent
Breathable
Suited for stable foam coating
TUBICOAT STC 150
Fashion coatings, Functional coatings
Washfast
Soft handle
Transparent
Breathable
TUBICOAT STL
Functional coatings
Washfast
Slip resistant
Suited for stable foam coating
Soft
TUBICOAT TCT
Fashion coatings, Functional coatings
Washfast
Polymer base: polyurethane
Transparent
Suited for paste coating
TUBICOAT VA 10
Binders
Anionic
Liquid
Formaldehyde-free
Hard film
TUBICOAT VCP
Functional coatings
Suited for paste coating
Medium hard
Suited for black-out coating
TUBICOAT VERDICKER 17
Thickeners
Anionic
High efficiency
Synthetic
TUBICOAT VERDICKER ASD
Thickeners
Anionic
Quick swelling
Stable to shear forces
Pseudoplastic
TUBICOAT VERDICKER LP
Thickeners
Anionic
Stable to shear forces
Pseudoplastic
Dispersible

TUBICOAT VERDICKER PRA
Thickeners
Anionic
Liquid
5 Stable to electrolytes
Rheological additive
TUBICOAT WBH 36
Special products
Finish
10 Application for preventing roller deposits
TUBICOAT WBV
Special products
Non-ionic
Finish
15 Application for preventing roller deposits
TUBICOAT WEISS EU
Functional coatings, Special products
Suited for coating pastes
20 Suited for stable foam
Suited for topcoat coatings
Titanium dioxide paste
TUBICOAT WLI-LT KONZ
Functional coatings
25 Washfast
Suited for paste coating
Slip resistant
Soft
30 TUBICOAT WLI
Fashion coatings, Functional coatings
Washfast
Scarabaeus effect
Soft handle
35 Suited for paste coating
TUBICOAT WOT
Fashion coatings
Washfast
Soft handle
40 Suited for paste coating
Wash-out effect
TUBICOAT WX-TCA 70
Fashion coatings, Functional coatings
45 Vintage wax
Suited for paste coating
Suited for topcoat coatings
TUBICOAT WX BASE
Fashion coatings
50 Vintage wax
Soft handle
Suited for paste coating
Application in the prime coat
55 TUBICOAT ZP NEU
Water repellency/oil repellency
Zircon-paraffine base
Suited for aqueous systems
Cationic
60 Foamable
TUBIGUARD 10-F
Water repellency/oil repellency
Washfast
65 Sprayable
Cationic
Liquid

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TUBIGUARD 21
 Water repellency/oil repellency
 Washfast
 Cationic
 High effectiveness
 Water-based

TUBIGUARD 25-F
 Water repellency/oil repellency
 Washfast
 Sprayable
 Cationic
 High effectiveness

TUBIGUARD 270
 Functional coatings, Water repellency/oil repellency
 Washfast
 Cationic
 High effectiveness
 Liquid

TUBIGUARD 30-F
 Water repellency/oil repellency
 Washfast
 Sprayable
 Cationic
 High effectiveness

TUBIGUARD 44 N
 Water repellency/oil repellency
 Washfast
 Sprayable
 Suited for aqueous systems
 Liquid

TUBIGUARD 44N-F
 Water repellency/oil repellency
 Suited for aqueous systems
 Non-ionic
 Suited for polyester
 Foamable

TUBIGUARD 66
 Water repellency/oil repellency
 Washfast
 Sprayable
 High effectiveness
 Liquid

TUBIGUARD 90-F
 Water repellency/oil repellency
 Washfast
 Cationic
 High effectiveness
 Liquid

TUBIGUARD AN-F
 Water repellency/oil repellency
 Washfast
 Sprayable
 Cationic
 High effectiveness

TUBIGUARD FA2-F
 Water repellency/oil repellency
 Sprayable
 Cationic
 Suited for polyester
 Foamable

TUBIGUARD PC3-F
 Functional coatings, Water repellency/oil repellency
 Washfast
 Cationic
 Liquid
 Paste

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TUBIGUARD SR 2010-F W
 Water repellency/oil repellency
 Cationic
 High effectiveness
 5 Foamable
 Based on C6 fluorocarbon
 In some embodiments, the chemical agents may include the following, which are supplied by CHT Bezema and are associated with certain selected textile (e.g., fabric) properties, which may be used to strengthen SFS binding to inkjet printing dye:
 CHT-ALGINAT MVU
 Ink jet printing preparation, Thickeners
 Cationic
 Powder
 Anionic
 High colour brilliance

PRISULON CR-F 50
 15 Ink jet printing preparation, Thickeners
 Liquid
 Good outlines
 High surface levelness
 Good penetration

TUBIJET DU 01
 Ink jet printing preparation
 Antimigrant
 Anionic
 25 Liquid
 Formaldehyde-free

TUBIJET NWA
 Ink jet printing preparation
 Liquid
 30 Non-ionic
 Without impact on the handle
 Formaldehyde-free

TUBIJET PUS
 35 Ink jet printing preparation
 Film forming
 Anionic
 Liquid
 Formaldehyde-free

TUBIJET VDK
 Ink jet printing preparation
 Liquid
 Formaldehyde-free
 45 Halogen-free
 Flame protection effect

TUBIJET WET
 Ink jet printing preparation
 Anionic
 50 Liquid
 Without impact on the handle
 Formaldehyde-free
 In some embodiments, the chemical agents of the invention may include the following inkjet printing dyes, which are supplied by CHT Bezema and are associated with certain selected textile (e.g., fabric) properties, which may be used in combination with SFS:
 BEZAFLUOR BLUE BB
 55 Pigments
 High Performance
 BEZAFLUOR (fluorescent pigments)

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- BEZAFLUOR GREEN BT
 Pigments
 High Performance
 BEZAFLUOR (fluorescent pigments)
- BEZAFLUOR ORANGE R
 Pigments
 High Performance
 BEZAFLUOR (fluorescent pigments)
- BEZAFLUOR PINK BB
 Pigments
 High Performance
 BEZAFLUOR (fluorescent pigments)
- BEZAFLUOR RED R
 Pigments
 High Performance
 BEZAFLUOR (fluorescent pigments)
- BEZAFLUOR VIOLET BR
 Pigments
 High Performance
 BEZAFLUOR (fluorescent pigments)
- BEZAFLUOR YELLOW BA
 Pigments
 High Performance
 BEZAFLUOR (fluorescent pigments)
- BEZAPRINT BLACK BDC
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BLACK DT
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BLACK DW
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BLACK GOT
 Pigments
 High Performance
 BEZAKTIV GOT (GOTS)
- BEZAPRINT BLUE BN
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BLUE BT
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BLUE GOT
 Pigments
 High Performance
 BEZAKTIV GOT (GOTS)
- BEZAPRINT BLUE RR
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BLUE RT
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BLUE™
 Pigments
 Advanced
 BEZAPRINT (classic pigments)

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- BEZAPRINT BLUE TB
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- 5 BEZAPRINT BORDEAUX K2R
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BROWN RP
 10 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT BROWN™
 15 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT CITRON 10G
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT CITRON GOT
 Pigments
 High Performance
- 20 BEZAKTIV GOT (GOTS)
- BEZAPRINT GREEN 2B
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- 30 BEZAPRINT GREEN BS
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- 35 BEZAPRINT GREEN BT
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT GREY BB
 40 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT NAVY GOT
 Pigments
 45 High Performance
 BEZAKTIV GOT (GOTS)
- BEZAPRINT NAVY RRM
 Pigments
 Advanced
- 50 BEZAPRINT (classic pigments)
- BEZAPRINT NAVY TR
 Pigments
 Advanced
- 55 BEZAPRINT (classic pigments)
- BEZAPRINT OLIVE GREEN BT
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- 60 BEZAPRINT ORANGE 2G
 Pigments
 Advanced
 BEZAPRINT (classic pigments)
- BEZAPRINT ORANGE GOT
 65 Pigments
 High Performance
 BEZAKTIV GOT (GOTS)

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- BEZAPRINT ORANGE GT
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT ORANGE RG
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT PINK BW
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT RED 2BN
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT RED GOT
 - Pigments
 - High Performance
 - BEZAKTIV GOT (GOTS)
- BEZAPRINT RED KF
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT RED KGC
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT SCARLET GRL
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT SCARLET RR
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT TURQUOISE GT
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT VIOLET FB
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT VIOLET KB
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT VIOLET R
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT VIOLET TN
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT YELLOW 2GN
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- BEZAPRINT YELLOW 3GT
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)

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- BEZAPRINT YELLOW 4RM
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- 5 BEZAPRINT YELLOW GOT
 - Pigments
 - High Performance
 - BEZAKTIV GOT (GOTS)
- BEZAPRINT YELLOW RR
 - Pigments
 - Advanced
 - BEZAPRINT (classic pigments)
- 10 In some embodiments, the chemical agents of the invention may include the following, which are supplied by Lamberti SPA and are associated with certain selected textile (e.g., fabric) properties, which may be used to strengthen SFS binding on coated surfaces or SFS may be used for enhancing such chemical agent properties:
- 15 Pre Treatment:
- 20 Waterborne Polyurethanes Dispersions
 - Rolflex AFP.
 - Aliphatic polyether polyurethane dispersion in water. The product has high hydrolysis resistance, good breaking load resistance and excellent tear resistance.
- 25 Rolflex ACF.
- Aliphatic polycarbonate polyurethane dispersion in water. The product shows good PU and PVC bonding properties, excellent abrasion resistance as well as chemical resistance, included alcohol.
- 30 Rolflex V 13.
- Aliphatic polyether/acrylic copolymer polyurethane dispersion in water. The product has good thermoadhesive properties and good adhesion properties on PVC.
- 35 Rolflex K 80.
- Aliphatic polyether/acrylic copolymer polyurethane dispersion in water. ROLFLEX K 80 is specifically designed as a high performing adhesive for textile lamination. The product has excellent perchloroethylene and water fastness.
- 40 Rolflex ABC.
- Aliphatic polyether polyurethane dispersion in water. Particularly, the product presents very high water column, excellent electrolytes resistance, high LOI index, high resistance to multiple bending.
- 45 Rolflex ADH.
- Aliphatic polyether polyurethane dispersion in water. The product has a very high water column resistance.
- 50 Rolflex W4.
- Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear where a full, soft and non sticky touch is required.
- 55 Rolflex ZB7.
- Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, sportswear, fashion and technical articles for industrial applications. The product has a very high charge digestion properties, electrolytes stability and excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.
- 60 Rolflex BZ 78.
- Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, sportswear, fashion and technical

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articles for industrial applications. The product has an excellent hydrolysis resistance, a very high charge digestion and electrolytes stability and an excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.

Rolflex PU 147.

Aliphatic polyether polyurethane dispersion in water. This product shows good film forming properties at room temperature. It has high fastness to light and ultraviolet radiation and good resistance to water, solvent and chemical agents, as well as mechanical resistance.

Rolflex SG.

Aliphatic polyether polyurethane dispersion in water. Due to its thermoplastic properties it is suggested to formulate heat activated adhesives at low temperatures.

Elafix PV 4.

Aliphatic blocked isocyanate Nano-dispersion used in order to give antifelting and antipilling properties to pure wool fabrics and his blend.

Rolflex C 86.

Aliphatic cationic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, fashion where medium-soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.

Rolflex CN 29.

Aliphatic cationic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, fashion where soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.

Oil and Water Repellents

Lamgard FT 60.

General purpose fluorocarbon resin for water and oil repellency; by padding application.

Lamgard 48.

High performance fluorocarbon resin for water and oil repellency; by padding application. High rubbing fastness.

Imbitex NRW3

Wetting agent for water- and oil repellent finishing.

Lamgard EXT.

Crosslinker for fluorocarbon resins to improve washing fastness.

Flame Retardants

Piroflam 712.

Non-permanent flame retardant compound for padding and spray application.

Piroflam ECO.

Alogen free flame retardant compound for back coating application for all kind of fibers.

Piroflam UBC.

Flame retardant compound for back coating application for all kind of fibers.

Crosslinkers

Rolflex BK8.

Aromatic blocked polyisocyanate in water dispersion.

It is suggested as a cross-linking agent in coating pastes based of polyurethane resins to improve washing fastness.

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Fissativo 05.

Water dispersible aliphatic polyisocyanate suitable as crosslinking agent for acrylic and polyurethane dispersions to improve adhesion and wet and dry scrub resistance.

Resina MEL.

Melammine-formaldheyde resin.

Cellofix VLF.

Low formaldheyde malammine resin.

10 Thickeners

Lambicol CL 60.

Fully neutralised synthetic thickener for pigment printing in oil/water emulsion; medium viscosity type

Viscolam PU conc.

Nonionic polyurethane based thickener with pseudoplastic behavior

Viscolam 115 new.

Acrylic thickener not neutralised

Viscolam PS 202.

Nonionic polyurethane based thickener with newtonian behavior

Viscolam 1022.

Nonionic polyurethane based thickener with moderate pseudoplastic behavior.

Dyeing

Dispersing Agents

Lamegal BO.

Liquid dispersing agent non ionic, suitable for direct, reactive, disperse dyeing and PES stripping

Lamegal DSP.

Dispersing/anti back-staining agent in preparation, dyeing and soaping of dyed and printed materials.

Antioligomer agent.

Lamegal 619.

Effective low foam dispersing leveling agent for dyeing of PES

Lamegal TLS.

Multi-purpose sequestring and dispersing agent for all kind of textile process

Levelling Agents

Lamegal A 12.

Leveling agent for dyeing on wool, polyamide and its blends with acid or metalcomplex dyes

Fixing Agents

Lamfix L.

Fixing agent for direct and reactive dyestuffs, containing formaldehyde

Lamfix LU conc.

Formaldehyde free cationic fixing agent for direct and reactive dyes. It does not affect the shade and light fastness.

Lamfix PA/TR.

Fixing agent to improve the wet fastness of acid dyes on polyamide fabrics, dyed or printed and polyamide yarns. Retarding agent in dyeing of Polyamide/cellulosic blends with direct dyes.

Special Resins

Denifast TC.

Special resin for cationization of cellulose fibers to obtain special effects ("DENIFAST system" and "DENISOL system").

Cobral DD/50.

Special resin for cationization of cellulose fibers to obtain special effect ("DENIFAST system" and "DENISOL system").

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Antireducing Agents	
Lamberti Redox L2S gra.	
Anti-reducing agent in grain form. 100% active content	
Lamberti Redox L2S liq.	
Anti-reducing agent in liquid form for automatic dosage.	5
Anticreasing Agent	
Lubisol AM.	
Lubricating and anti creasing agent for rope wet operation on all kind of fibers and machines.	10
Pigment Dye	
Antimigrating Agent	
Neopat Compound 96/m conc.	
Compound, developed as migration inhibitor for continuous dyeing process with pigments (pad-dry process).	15
Binding Agent	
Neopat Binder PM/S conc.	
Concentrated version of a specific binder used to prepare pad-liquor for dyeing with pigments (pad-dry process).	20
All in One Agent	
Neopat Compound PK1.	
High concentrated compound specifically developed as migration inhibitor with specific binder for continuous dyeing process with pigments (pad-dry process) all in one	25
Delavè Agent	
Neopat compound FTN.	
High concentrated compound of surfactants and polymers specifically developed for pigment dyeing and pigment-reactive dyeing process; especially for medium/dark shades for wash off effect	30
Traditional Finishing Agents	
Wrinkle Free Treatment	
Cellofix ULF conc.	
Anti-crease modified glyoxalic resin for finishing of cottons, cellulosics and blend with synthetics fibers.	40
Poliflex PO 40.	
Polyethilenic resin for waxy, full and slippy handle by foulard applications.	
Rolflex WF.	
Aliphatic waterborned Nano-PU dispersion used as extender for wrinkle free treatments.	45
Softeners	
Texamina C/FPN.	
Cationic softening agent with a very soft handle particularly recommended for application by exhaustion for all kind of fabrics. Suitable also for cone application.	50
Texamina C SAL flakes.	
100% cationic softening agent in flakes form for all type of fabrics. Dispersible at room temperature.	55
Texamina CL LIQ.	
Anphoteric softening agent for all types of fabrics. Not yellowing.	
Texamina HVO.	
Anphoteric softening agent for woven and knitted fabrics of cotton, other cellulosics and blends. Gives a soft, smooth and dry handle. Applied by padding.	60
Texamina SIL.	
Nonionic silicon dispersion in water. Excellent softening, lubricating and anti-static properties for all fibre types by padding.	65

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Texamina SIL.K.	
Special cationic softener with silk protein inside. Gives a "swollen touch" particularly suitable for cellulosic, wool, silk.	
Lamfinish LW.	
All-in compound based on special polymeric hydrophilic softeners; by coating, foulard, and exhaustion.	
Elastolam E50.	
General purpose mono-component silicone elastomeric softener for textile finishing.	10
Elastolam EC 100.	
Modified polysiloxane micro-emulsion which gives a permanent finishing, with extremely soft and silky handle.	
Handle Modifier	
Poliflex CSW.	
Cationic anti-slipping agent.	
Poliflex R 75.	
Parafine finishing agent to give waxy handle.	
Poliflex s.	
Compound specifically developed for special writing effects.	
Poliflex m.	
Compound for special dry-waxy handle.	
Lamsoft SW 24.	
Compound for special slippy handle specifically developed for coating application.	
Lamfinish SLIPPY.	
All-in compound to get a slippy touch; by coating.	
Lamfinish GUMMY.	
All-in compound to get a gummy touch; by coating.	
Lamfinish OLDRY.	
All-in compound to get dry-sandy touch especially suitable for vintage effects; by coating	
Waterborne Polyurethanes Dispersions	
Rolflex LB 2.	
Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings where bright and rigid top finish is required. It is particularly suitable as a finishing agent for organza touch on silk fabrics. Transparent and shiny.	
Rolflex HP 51.	
Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for outwear, luggage, technical articles especially where hard and flexible touch is required. Transparent and shiny.	
Rolflex PU 879.	
Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for outwear, luggage, technical articles where a medium-hard and flexible touch is required.	
Rolflex ALM.	
Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for outwear, luggage, technical articles where a soft and flexible touch is required. Can be also suitable for printing application.	
Rolflex AP.	
Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for outwear, fashion where a soft and gummy touch is required.	
Rolflex W4.	
Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear where a full, soft and non sticky touch is required.	

Rolflex ZB7.

Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, sportswear, fashion and technical articles for industrial applications. The product has a very high charge digestion properties, electrolytes stability and excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.

Rolflex BZ 78.

Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, sportswear, fashion and technical articles for industrial applications. The product has an excellent hydrolysis resistance, a very high charge digestion and electrolytes stability and an excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.

Rolflex K 110.

Gives to the coated fabric a full, soft, and slightly sticky handle with excellent fastness on all types of fabrics.

Rolflex OP 80.

Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for outwear, luggage and fashion finishes where an opaque non writing effect is desired.

Rolflex NBC.

Aliphatic waterborned PU dispersion generally used by padding application as a filling and zero formaldehyde sizing agent. Can be used for outwear and fashion finishings where a full, elastic and non sticky touch is required.

Rolflex PAD.

Aliphatic waterborned PU dispersion specifically designed for padding application for outwear, sportswear and fashion applications where a full, elastic and non sticky touch is required. Excellent washing and dry cleaning fastness as well as good bath stability.

Rolflex PN.

Aliphatic waterborned PU dispersion generally applied by padding application for outerwear and fashion high quality applications where strong, elastic non sticky finishes are required.

Elafix PV 4.

Aliphatic blocked isocyanate Nano-dispersion used in order to give antifelting and antipilling properties to pure wool fabrics and his blend.

Rolflex SW3.

Aliphatic waterborned PU dispersion particularly suggested to be used by padding application for the finishing of outwear, sportswear and fashion where a slippery and elastic touch is required. It is also a good antipilling agent. Excellent in wool application.

Rolflex C 86.

Aliphatic cationic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, fashion where medium-soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.

Rolflex CN 29.

Aliphatic cationic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, fashion where soft and pleasant full touch is required. Fabrics treated with the

product can be dyed with a selection of dyes, to get double-color effects of different intensity.

Other Resins

Textol 110.

Handle modifier with very soft handle for coating finishes

Textol RGD.

Water emulsion of acrylic copolymer for textile coating, with very rigid handle.

Textol SB 21.

Butadienic resin for finishing and binder for textile printing

Appretto PV/CC.

Vinylacetate water dispersion for rigid stiffening

Amisolo B.

CMS water dispersion for textile finishing as stiffening agent

Lamovil RP.

PVOH stabilized solution as stiffening agent

Technical Finishing Agents

Waterborne Polyurethanes Dispersions

Rolflex AFP.

Aliphatic polyether polyurethane dispersion in water.

The product has high hydrolysis resistance, good breaking load resistance and excellent tear resistance.

Rolflex ACF.

Aliphatic polycarbonate polyurethane dispersion in water. The product shows good PU and PVC bonding properties, excellent abrasion resistance as well as chemical resistance, included alcohol.

Rolflex V 13.

Aliphatic polyether/acrylic copolymer polyurethane dispersion in water. The product has good thermoadhesive properties and good adhesion properties on PVC.

Rolflex K 80.

Aliphatic polyether/acrylic copolymer polyurethane dispersion in water. ROLFLEX K 80 is specifically designed as a high performing adhesive for textile lamination. The product has excellent perchloroethylene and water fastness.

Rolflex ABC.

Aliphatic polyether polyurethane dispersion in water.

Particularly, the product presents very high water column, excellent electrolytes resistance, high LOI index, high resistance to multiple bending.

Rolflex ADH.

Aliphatic polyether polyurethane dispersion in water. The product has a very high water column resistance.

Rolflex W4.

Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear where a full, soft and non sticky touch is required.

Rolflex ZB7.

Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, sportswear, fashion and technical articles for industrial applications. The product has a very high charge digestion properties, electrolytes stability and excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.

Rolflex BZ 78.

Aliphatic waterborned PU dispersion particularly suggested for the formulation of textile coatings for

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clothing, outwear, sportswear, fashion and technical articles for industrial applications. The product has an excellent hydrolysis resistance, a very high charge digestion and electrolites stability and an excellent mechanical and tear resistance. Can be also suitable for foam coating and printing application.

Rolflex PU 147.

Aliphatic polyether polyurethane dispersion in water. This product shows good film forming properties at room temperature. It has high fastness to light and ultraviolet radiation and good resistance to water, solvent and chemical agents, as well as mechanical resistance.

Rolflex SG.

Aliphatic polyether polyurethane dispersion in water. Due to its thermoplastic properties it is suggested to formulate heat activated adhesives at low temperatures.

Elafix PV 4.

Aliphatic blocked isocyanate Nano-dispersion used in order to give antifelting and antipilling properties to pure wool fabrics and his blend.

Rolflex C 86.

Aliphatic cationic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, fashion where medium-soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.

Rolflex CN 29.

Aliphatic cationic waterborned PU dispersion particularly suggested for the formulation of textile coatings for clothing, outwear, fashion where soft and pleasant full touch is required. Fabrics treated with the product can be dyed with a selection of dyes, to get double-color effects of different intensity.

Oil and Water Repellents

Lamgard FT 60.

General purpose fluorocarbon resin for water and oil repellency; by padding application.

Lamgard 48.

High performance fluorocarbon resin for water and oil repellency; by padding application. High rubbing fastness.

Imbitex NRW3.

Wetting agent for water- and oil repellent finishing.

Lamgard EXT.

Crosslinker for fluorocarbon resins to improve washing fastness.

Flame Retardants

Piroflam 712.

Non-permanent flame retardant compound for padding and spray application.

Piroflam ECO.

Alogen free flame retardant compound for back coating application for all kind of fibers.

Piroflam UBC.

Flame retardant compound for back coating application for all kind of fibers.

Crosslinkers

Rolflex BK8.

Aromatic blocked polyisocyanate in water dispersion.

It is suggested as a cross-linking agent in coating pastes based of polyurethane resins to improve washing fastness.

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Fissativo 05.

Water dispersible aliphatic polyisocyanate suitable as crosslinking agent for acrylic and polyurethane dispersions to improve adhesion and wet and dry scrub resistance.

Resina MEL.

Melammime-formaldheyde resin.

Cellofix VLF.

Low formaldheyde malammime resin.

Thickeners

Lambicol CL 60.

Fully neutralised synthetic thickener for pigment printing in oil/water emulsion; medium viscosity type Viscolam PU conc.

Nonionic polyurethane based thickener with pseudo-plastic behavior

Viscolam 115 new.

Acrylic thickener not neutralised

Viscolam PS 202.

Nonionic polyurethane based thickener with newtonian behavior

Viscolam 1022.

Nonionic polyurethane based thickener with moderate pseudoplastic behavior.

In some embodiments, the chemical agent may include one or more of a silicone, an acidic agent, a dyeing agent, a pigment dye, a traditional finishing agent, and a technical finishing agent. The dyeing agent may include one or more of a dispersing agent, a levelling agent, a fixing agent, a special resin, an antireducing agent, and an anticreasing agent. The pigment dye may include one or more of an antimigrating agent, a binding agent, an all in one agent, and a delave agent. The traditional finishing agent may include one or more of a wrinkle free treatment, a softener, a handle modifier, a waterborne polyurethanes dispersion, and other resins. The technical finishing agent may include one or more of a waterborne polyurethanes dispersion, an oil repellent, a water repellant, a crosslinker, and a thickener.

In some embodiments, certain chemical agents of the invention may be provided by one or more of the following chemical suppliers: Adrasa, AcHitex Minerva, Akkim, Archroma, Asutex, Avocet dyes, BCC India, Bozzetto group, CHT, Clarity, Dilube, Dystar, Eksoy, Erca group, Genkim, Giovannelli e Figli, GrafChemie, Huntsman, KDN Bio, Lamberti, LJ Specialties, Marlateks, Montegauno, Protectex, Pulera Chemicals, Ran Chemicals, Fratelli Ricci, Ronkimya, Sarex, Setas, Silitex, Soko Chimica, Tanatex Chemicals, Zaitex, Zetaesseti, and Z Schimmer.

In some embodiments, the chemical agent may include an acidic agent. Accordingly, in some embodiments, SFS may include an acidic agent. In some embodiments, an acidic agent may be a Bronsted acid. In an embodiment, the acidic agent includes one or more of citric acid and acetic acid. In an embodiment, the acidic agent aids the deposition and coating of SPF mixtures (i.e., SFS coating) on the textile to be coated as compared to the absence of such acidic agent. In an embodiment, the acidic agent improves crystallization of the SPF mixtures at the textile to be coated.

In an embodiment, the acidic agent is added at a concentration by weight (% w/w or % w/v) or by volume (v/v) of greater than about 0.001%, or greater than about 0.002%, or greater than about 0.003%, or greater than about 0.004%, or greater than about 0.005%, or greater than about 0.006%, or greater than about 0.007%, or greater than about 0.008%, or greater than about 0.009%, or greater than about 0.01%, or greater than about 0.02%, or greater than about 0.03%, or greater than about 0.04%, or greater than about 0.05%, or greater than about 0.06%, or greater than about 0.07%, or

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greater than about 0.08%, or greater than about 0.09%, or greater than about 0.1%, or greater than about 0.2%, or greater than about 0.3%, or greater than about 0.4%, or greater than about 0.5%, or greater than about 0.6%, or greater than about 0.7%, or greater than about 0.8%, or greater than about 0.9%, or greater than about 1.0% or greater than about 2.0%, or greater than about 3.0%, or greater than about 4.0%, or greater than about 5.0%.

In an embodiment, the acidic agent is added at a concentration by weight (% w/w or % w/v) or by volume (v/v) of less than about 0.001%, or less than about 0.002%, or less than about 0.003%, or less than about 0.004%, or less than about 0.005%, or less than about 0.006%, or less than about 0.007%, or less than about 0.008%, or less than about 0.009%, or less than about 0.01%, or less than about 0.02%, or less than about 0.03%, or less than about 0.04%, or less than about 0.05%, or less than about 0.06%, or less than about 0.07%, or less than about 0.08%, or less than about 0.09%, or less than about 0.1%, or less than about 0.2%, or less than about 0.3%, or less than about 0.4%, or less than about 0.5%, or less than about 0.6%, or less than about 0.7%, or less than about 0.8%, or less than about 0.9%, or less than about 1.0% or less than about 2.0%, or less than about 3.0%, or less than about 4.0%, or less than about 5.0%.

In some embodiments, SFS may have a pH of less than about 9, or less than about 8.5, or less than about 8, or less than about 7.5, or less than about 7, or less than about 6.5, or less than about 6, or less than about 5.5, or less than about 5, or less than about 4.5, or less than about 4, or greater than about 3.5, or greater than about 4, or greater than about 4.5, or greater than about 5, or greater than about 5.5, or greater than about 6, or greater than about 6.5, or greater than about 7, or greater than about 7.5, or greater than about 8, or greater than about 8.5.

In some embodiments, SFS may include an acidic agent, and may have a pH of less than about 9, or less than about 8.5, or less than about 8, or less than about 7.5, or less than about 7, or less than about 6.5, or less than about 6, or less than about 5.5, or less than about 5, or less than about 4.5, or less than about 4, or greater than about 3.5, or greater than about 4, or greater than about 4.5, or greater than about 5, or greater than about 5.5, or greater than about 6, or greater than about 6.5, or greater than about 7, or greater than about 7.5, or greater than about 8, or greater than about 8.5.

In an embodiment, the chemical agent may include silicone. In some embodiments, a SFS may include silicone. In some embodiments, silicone may include a silicone emulsion. The term "silicone," may generally refer to a broad family of synthetic polymers, mixtures of polymers, and/or emulsions thereof, that have a repeating silicon-oxygen backbone including, but not limited to, polysiloxanes. For example, a silicone may include ULTRATEX® CSP, which is a commercially available (Huntsman International LLC) silicone emulsion that may be used as a softening agent and which may also increase fabric resilience, elasticity of knitted fabrics, and fiber lubrication and also improve sewability. A silicone may also include ULTRATEX® CI, which is a commercially available silicone composition (Huntsman International LLC) that may be used as a fabric softening agent. In some embodiments, a silicone may include any silicone species disclosed herein.

Describing the compositions and coatings more broadly, silicone may be used, for example to improve fabric hand, but may also increase the water repellency (or reduce water transport properties) of a fabric coated with silicone. Silicone may be used in combination with SFS to counteract the water repellent (water transport) properties of silicone.

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In some embodiments, SFS may include silicone in a concentration by weight (% w/w or % w/v) or by volume (v/v) of less than about 25%, or less than about 20%, or less than about 15%, or less than about 10%, or less than about 9%, or less than about 8%, or less than about 7%, or less than about 6%, or less than about 5%, or less than about 4%, or less than about 3%, or less than about 2%, or less than about 1%, or less than about 0.9%, or less than about 0.8%, or less than about 0.7%, or less than about 0.6%, or less than about 0.5%, or less than about 0.4%, or less than about 0.3%, or less than about 0.2%, or less than about 0.1%, or less than about 0.01%, or less than about 0.001%.

In some embodiments, SFS may include silicone in a concentration by weight (% w/w or % w/v) or by volume (v/v) of greater than about 25%, or greater than about 20%, or greater than about 15%, or greater than about 10%, or greater than about 9%, or greater than about 8%, or greater than about 7%, or greater than about 6%, or greater than about 5%, or greater than about 4%, or greater than about 3%, or greater than about 2%, or greater than about 1%, or greater than about 0.9%, or greater than about 0.8%, or greater than about 0.7%, or greater than about 0.6%, or greater than about 0.5%, or greater than about 0.4%, or greater than about 0.3%, or greater than about 0.2%, or greater than about 0.1%, or greater than about 0.01%, or greater than about 0.001%.

In some embodiments, SFS may be supplied in a concentrated form suspended in water. In some embodiments, SFS may have a concentration by weight (% w/w or w/v) or by volume (v/v) of less than about 50%, or less than about 45%, or less than about 40%, or less than about 35%, or less than about 30%, or less than about 25%, or less than about 20%, or less than about 15%, or less than about 10%, or less than about 5%, or less than about 4%, or less than about 3%, or less than about 2%, or less than about 1%, or less than about 0.1%, or less than about 0.01%, or less than about 0.001%, or less than about 0.0001%, or less than about 0.00001%. In some embodiments, SFS may have a concentration by weight (% w/w or % w/v) or by volume (v/v) of greater than about 50%, or greater than about 45%, or greater than about 40%, or greater than about 35%, or greater than about 30%, or greater than about 25%, or greater than about 20%, or greater than about 15%, or greater than about 10%, or greater than about 5%, or greater than about 4%, or greater than about 3%, or greater than about 2%, or greater than about 1%, or greater than about 0.1%, or greater than about 0.01%, or greater than about 0.001%, or greater than about 0.0001%, or greater than about 0.00001%.

In some embodiments, an SFS coating may include SFS, as described herein. In some embodiments, SFS may include a silicone and/or an acidic agent. In some embodiments, SFS may include a silicone and an acidic agent. In some embodiments, the SFS may include a silicone, an acidic agent, and/or an additional chemical agent, wherein the additional chemical agent may be one or more of the chemical agents described herein. In some embodiments, SFS may include a silicone emulsion and an acidic agent, such as acetic acid or citric acid.

In some embodiments, the coating processes of the invention may include a finishing step for the resulting coated textiles. In some embodiments, the finishing or final finishing of the textiles (e.g., fabrics) that are coated with SFS under the processes of the invention may include sueding, steaming, brushing, polishing, compacting, raising, tigering, shearing, heatsetting, waxing, air jet, calendaring, pressing, shrinking, treatment with polymerizer, coating, lamination, and/or laser etching. In some embodiments, finishing of the

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SFS coated textiles may include treatment of the textiles with an AIRO® 24 dryer that may be used for continuous and open-width tumbling treatments of woven, non-woven, and knitted fabrics.

In some embodiments, a coated textile (e.g., a fabric) may be prepared by unrolling a fabric roll (FIG. 319) to prepare a piece of fabric. The perimeter of such fabric may be processed. For example, fabric (FIG. 320) may have dimensions of 35 cmx35 cm (13.5 inch×13.5 inch) with a tolerance of +/- 1 cm (+/- 0.4 inch). In some embodiments, every fabric sample may be massed on analytical balance by folding the fabric sample multiple times until it may be contained by a weighing boat on a balance. Each measurement may be recorded. In some embodiments, a coating process may be initiated by preparing a curing oven by setting a selected temperature therein. A padder laboratory unit may be turned on and the speed of said padder unit may be set to a selected velocity and the roller pressure may be adjusted to a selected pressure by operating a cam lever system and locking it in place once the desired pressure is achieved. A silk solution (i.e., SFS) may be poured into a bath (e.g., a stainless steel bath) (FIG. 321). After a fabric sample is submerged in the bath, it may be allowed to reach saturation, and the fabric sample may then be removed from the bath and laid between two rollers of the padder unit (FIG. 322). The fabric sample as it is transported through the rollers it may be squeezed of excessive fluid as determined by the rollers' pressure. The fabric sample may then exit to the opposite side of the rollers. The resulting fabric sample may then be placed on top of the curing frame and may then be gently pushed one edge at a time to engage the fabric edges with frame pins (see FIGS. 323 and 324). The frame may be placed in the drying and curing oven, with the door of said oven secured and kept closed for the drying and curing time (FIG. 325). A timer may be started to alert when the drying and curing time has elapsed. When the timer signals completion of the curing process, the oven door is opened and a temperature sensor (e.g., an IR temperature sensor) may be used to measure the fabric sample surface temperature. The frame bearing the fabric sample may then be removed from the oven and placed on a cooling rack (FIG. 326). The sample fabric may then be removed from the frame and weighed.

In some embodiments, the SFS coated textiles (e.g., fabrics) described herein may meet or exceed requirements established by the following Test Methods:

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Test Description	Test Method	Requirements
5 Pilling Resistance Abrasion Resistance	ASTM D 3512 ASTM D 4966	Minimum 3.0 No rupture to 10,000 cycles (plain fabrics up to 7.5 oz/yd ² ; or no rupture to 15,000 cycles (plain fabrics over 7.5 oz/yd ²)
10 Tearing Strength	ASTM D 1424	Shorts, Pants, Jeans, Jackets, All Plus Size Styles: 2.5 Lbs Minimum; or Blouse, Skirt Dress, Lining, excluding plus size styles: 1.5 Lbs Minimum; or Intimate: <3 oz/yd ² : Minimum 1.5 lbs; 3-6 oz/yd ² : Minimum 2.0 lbs >6 oz/yd ² : Minimum 2.5 lbs
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20 Colorfastness to Laundering/Colorfastness to Washing Colorfastness to Dry Cleaning	AATCC 61, 2A AATCC 132	Color Change: Minimum 4.0 Staining: Minimum 3.0 Color Change: Minimum 4.0
25 Colorfastness to Crocking/Colorfastness to Rubbing	AATCC 8	Staining: Minimum 3.0 All except below—Dry: Minimum 4.0; Wet: Minimum 3.0; or Dark Shades (black, red, navy)—Dry: Minimum 4.0; Wet: Minimum 2.5; or Indigos—Dry: Minimum 3.0; Wet: Minimum 2.0; or Pigments—Dry: Minimum 3.5; Wet: Minimum 2.5.
30		
35 Colorfastness to Water Colorfastness to Perspiration Colorfastness to Light	AATCC 107 AATCC 15 AATCC 16/20 AFU	Color Change: Minimum 4.0; Staining: Minimum 3.0 Color Change: Minimum 4.0; Staining: Minimum 3 Color Change: Minimum 4.0
40	AATCC 16/5 AFU	
pH Value	AATCC 81	4.0~8.5 or 4.0~7.5 (children <36 months)
45 Antimicrobial	AATCC 147	Original: 0% Bacterial Growth 20 Washes: 0% Bacterial Growth
	AATCC 100 ASTM E 2149	Minimum 99.9% Reduction Original: Minimum 99.9% Reduction 20 Washes: Minimum 80% Reduction
50 Wicking Water Repellency—Spray Test	AATCC 79 AATCC 22	1.0 second or less Original: 100 Rating After 3x Washes: Minimum 70 Rating
55 Water Resistance—Rain Test	AATCC 35	Maximum 1 gram on original and after 3x washes
60 Dimensional Stability to Laundering (Yoga Garment)	AATCC 150	Maximum, Length = -3%, Width = -3% Maximum, Length = -3%, Width = -5% for two-way Stretch Fabrics Maximum, Length = -5%, Width = -5% for four-way Stretch Fabrics No Growth
65		Maximum, Length = -3%, Width = -3% Maximum, Length = -3%, Width = -5% for four-way Stretch fabrics No Distortion Between Components No Growth

-continued

Test Description	Test Method	Requirements
Dimensional Stability to Dry Cleaning (Yoga Garment)	AATCC 158	Maximum, Length = -3%, Width = -3% Maximum, Length = -3%, Width = -5%, for two-way Stretch Fabrics Maximum, Length = -5%, Width = -5%, for four-way Stretch Fabrics No Distortion Between Components No Growth Minimum 3.0
Pilling Resistance (Yoga Garment)	ASM D 3512	
Colorfastness to Laundering/Colorfastness to Washing (Yoga Garment)	AATCC 61, 2A	Color Change: Minimum 4.0 Staining: Minimum 3.0
Colorfastness Crocking/Colorfastness to Rubbing (Yoga Garment)	AATCC 8	General: Dry: Minimum 4.0; Wet: Minimum 3.0; For Dark Colors (Black, Red, Navy): Wet: Minimum 2.5 Pigment: Dry: Minimum 3.5; Wet: Minimum 2.5 Indigos: Dry: Minimum 3.0; Wet: Minimum 2.0
Colorfastness to Water (Yoga Garment)	AATCC 107	Color Change: Minimum 4.0 Staining: Minimum 3.0
Colorfastness to Perspiration (Yoga Garment)	AATCC 15	Color Change: 4.0 or better Staining: 3.0 or better
Colorfastness to Light (Yoga Garment)	AATCC 16, 20	Minimum 4.0, All, Except Silk/Minimum 4.0, Silk
pH Value (Yoga Garment)	AFU/5 AFU AATCC 81	Children (>36 months) & Adults: 4.0-8.5 Children <36 months): 4.0-7.5

In some embodiments, the SFS coated textiles (e.g., fabrics) described herein may meet requirements established by the foregoing Test Methods. In some embodiments, the SFS coated textiles (e.g., fabrics) described herein may exceed the requirements established by the foregoing Test Methods.

In some embodiments, the SFS coated textiles (e.g., fabrics) may have antimicrobial activity (e.g., antifungal and/or antibacterial activity) due to the SFS coating. In an embodiment, antibacterial activity may be determined by the ability of bacteria on the SFS coated textile's surface to be washed away from the SFS coated textile surface following one or more wash cycles, or two or more wash cycles, or three or more wash cycles, or four or more wash cycles, or five or more wash cycles, where the bacteria do not adhere to the surface of the SFS coated textile. In an embodiment, antibacterial activity may be determined by the ability of the SFS coating to reduce the quantity of the bacteria deposited on a surface of the SFS coated textile, wherein the SFS coating may reduce the quantity of the bacteria by greater than about 1%, or greater than about 2%, or greater than about 3%, or greater than about 4%, or greater than about 5%, or greater than about 10%, or greater than about 20%, or greater than about 30%, or greater than about 40%, or greater than about 50%, or greater than about 60%, or greater than about 70%, or greater than about 80%, or greater than about 90%, or greater than about 95%, or greater than about 96%, or greater than about 97%, or greater than about 98%, or greater than about 99%, or by about 100%. In an embodiment, antibacterial activity of the SFS coating on the coated textile may be determined by

fluorescent activity (see, e.g., U.S. Pat. Nos. 5,089,395 and 5,968,762, the entirety of which are incorporated herein by reference). In an embodiment, antibacterial activity for an SFS coating may be determined by the ability of the SFS coating on a coated textile to break up colonies of bacteria that may be deposited on a surface of the coated textile. In an embodiment, antibacterial activity for an SFS coating may be determined by the ability of the SFS coating on a coated textile to: (a) prevent the formation of a bacterial biofilm on the coated textile; and/or (b) reduce the size of a bacterial biofilm on the coated textile.

In some embodiments, SFS may be coated upon a textile or other material having antimicrobial (e.g., antibacterial and/or antifungal) properties without interfering with such properties or otherwise inhibiting such properties.

In an embodiment, a textile may be coated with SFS to provide an SFS coated article. In some embodiments, the textile may include one or more of polyester, polyamide, polyaramid, polytetrafluoroethylene, polyethylene, polypropylene, polyurethane, silicone, mixtures of polyurethane and polyethyleneglycol, ultrahigh molecular weight polyethylene, high-performance polyethylene, nylon, and LYCRA (polyester-polyurethane copolymer, also known as SPANDEX and elastomer). In some embodiments, the textile may include LYCRA.

In some embodiments, the SFS coated article may have a crocking value of greater than 4 as determined by AATCC 8. In some embodiments, the SFS coated article may have a crocking value of greater than 4 as determined by AATCC 8, wherein the SFS coated article includes one or more of a silicone and an acidic agent. In some embodiments, the SFS coated article may have a crocking value of greater than 4 as determined by AATCC 8, wherein the SFS coated article includes a silicone.

In some embodiments, the SFS coated article may have an overall moisture management capability (OMMC) of greater than 0.3. In some embodiments, the SFS coated article may have an overall moisture management capability (OMMC) of greater than 0.3, wherein the SFS coated article includes one or more of a silicone and an acidic agent. In some embodiments, the SFS coated article may have an overall moisture management capability (OMMC) of greater than 0.3, wherein the SFS coated article includes a silicone.

In some embodiments, the SFS coated article may contain no sites for bacterial adhesion. In some embodiments, the SFS coated article may contain no sites for bacterial adhesion after heat treatment. In some embodiments, the SFS coated article may contain no sites for bacterial adhesion following a wash cycle with non-chlorinated bleach. In some embodiments, the SFS coated article may contain no bacteria after washing.

EXAMPLES

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the described embodiments, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all or the only experiments performed. Efforts have been made to ensure accuracy with respect to numbers used (e.g., amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is weight aver-

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age molecular weight, temperature is in degrees Centigrade, and pressure is at or near atmospheric.

Example 1. Tangential Flow Filtration (TFF) to Remove Solvent from Dissolved Silk Solutions

A variety of % silk concentrations have been produced through the use of Tangential Flow Filtration (TFF). In all cases a 1% silk solution was used as the input feed. A range of 750-18,000 mL of 1% silk solution was used as the starting volume. Solution is diafiltered in the TFF to remove lithium bromide. Once below a specified level of residual LiBr, solution undergoes ultrafiltration to increase the concentration through removal of water. See examples below.

7.30% Silk Solution: A 7.30% silk solution was produced beginning with 30 minute extraction batches of 100 g silk cocoons per batch. Extracted silk fibers were then dissolved using 100° C. 9.3 M LiBr in a 100° C. oven for 1 hour. 100 g of silk fibers were dissolved per batch to create 20% silk in LiBr. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 15,500 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 1300 mL. 1262 mL of 7.30% silk was then collected. Water was added to the feed to help remove the remaining solution and 547 mL of 3.91% silk was then collected.

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6.44% Silk Solution: A 6.44% silk solution was produced beginning with 60 minute extraction batches of a mix of 25, 33, 50, 75 and 100 g silk cocoons per batch. Extracted silk fibers were then dissolved using 100° C. 9.3M LiBr in a 100° C. oven for 1 hour. 35, 42, 50 and 71 g per batch of silk fibers were dissolved to create 20% silk in LiBr and combined. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 17,000 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 3000 mL. 1490 mL of 6.44% silk was then collected. Water was added to the feed to help remove the remaining solution and 1454 mL of 4.88% silk was then collected

2.70% Silk Solution: A 2.70% silk solution was produced beginning with 60 minute extraction batches of 25 g silk cocoons per batch. Extracted silk fibers were then dissolved using 100° C. 9.3 M LiBr in a 100° C. oven for 1 hour. 35.48 g of silk fibers were dissolved per batch to create 20% silk in LiBr. Dissolved silk in LiBr was then diluted to 1% silk and filtered through a 5 um filter to remove large debris. 1000 mL of 1%, filtered silk solution was used as the starting volume/diafiltration volume for TFF. Once LiBr was removed, the solution was ultrafiltered to a volume around 300 mL. 312 mL of 2.7% silk was then collected.

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Example 2. Preparation of Silk Gels

TABLE 17

Gel Samples - Silk gel formulations including additives, concentration of silk and additive, gelation conditions and gelation times.

Sample Name	mL 2% silk solution	Mass Vit C (g)	Ratio silk:VitC	Additive	Amount of additive	Temp/ Treatment	Days to Gelation
1	10	0.04	5:01	None	None	RT	8
2	10	0.08	2.5:1	None	None	RT	8
3	10	0.2	1:01	None	None	RT	8
4	10	0.4	1:02	None	None	RT	14
5	10	0.8	1:04	None	None	RT	None
6	10	0.04	5:01	None	None	Fridge	~39
7	10	0.08	2.5:1	None	None	Fridge	~39
8	10	0.2	1:01	None	None	Fridge	~39
9	10	0.4	1:02	None	None	Fridge	None
10	10	0.8	1:04	None	None	Fridge	None
11	10	0.2	1:01	None	None	RT/Shake vigorously	8
O-1	10	0.04	5:01	None	None	37 C. Oven	3
O-2	10	0.04	5:01	None	None	50° C., Oven	2
O-3	10	0.2	1:01	None	None	37 C. Oven	4
O-4	10	0.2	1:01	None	None	50° C., Oven	3
M	40	0.16	5:01	None	None	RT	5
D	40	0.16	5:01	None	None	RT	5
E1	10	0.04	5:01	Vit E	1 drop	RT	7
E2	10	0.04	5:01	Vit E	3 drops	RT	7
E3	10	0	None	Vit E	1 drop	RT	None
E4	10	0	None	Vit E	3 drops	RT	None
L1	10	0.04	5:01	Lemon	300 µL	RT	6
L2	10	0.04	5:01	Lemon Juice	300 µL	RT	6
L3	10	0.04	5:01	Lemon Juice	1000 µL	RT	5
L4	10	0	None	Lemon	300 µL	RT	6
L5	10	0	None	Lemon Juice	300 µL	RT	7
Jar 1	20	0.08	5:01	Lemon Juice	2000 µL	RT	5-7
Jar 2	5	0.02	5:01	Lemongrass Oil	1 drop	RT	2-3
R-1	10	0.04	5:01	Rosemary Oil	1 drop	RT	7
T-1	10	0.04	5:01	None	None	RT/Tube	7
RO-1	10	0.04	5:01	Rose Oil	1 drop	RT	6
RO-2	10	None	None	Rose Oil	1 drop	RT	None

Ratio of Silk to Vitamin C

Samples 1-10 were used to examine the effect of silk to vitamin C ratio on serum gelation. Samples 1-3 with less vitamin C gelled quicker than samples 4 and 5. All other conditions were kept constant. Samples 6-8 with less vitamin C gelled quicker than samples 9 and 10. All other conditions were kept constant. It is concluded that decreasing the ratio of silk to vitamin C (increasing the amount of vitamin C), will lengthen the time to gel creation. At ratios with small amounts of vitamin C, days to gel creation did not vary greatly.

Physical Stimulation

Samples 3 and 11 were used to examine the effect of physical stimulation on serum gelation. Each sample was prepared under the same conditions. Sample 11 was vigorously shaken for about 3 minutes after addition of vitamin C. Treatment of 3 and 11 was otherwise the same. The shaking resulted in bubbles but did not significantly change gel creation time.

Temperature Treatment

Samples 1, 3, 6, 8, O-1, O-2, O-3, and O-4 were used to examine the effect of temperature treatment on serum gelation time. Samples 1, 6, O-1, and O-2 were identical other than temperature treatment. Samples 3, 8, O-3, and O-4 were identical other than temperature treatment. The two groups differed in silk to vitamin C ratio. Time to serum gelation was directly related to temperature treatment with a higher temperature resulting in quicker serum gelation.

Solution Volume

Samples 1, M and D were used to examine the effect of solution volume on serum gelation time. Samples M and D varied from sample 1 only by an increased solution volume. Samples M and D gelled in 5 days while sample 1 gelled in 8 days. Samples M and D were definitely noticed to be gelled on the day of gelling while sample 1 gelled over a weekend.

Additives

Samples E1, E2, E3, E4, L1, L2, L3, L4, L5, Jar 2, R1, RO-1 and RO-2 were used to examine the effect of additives on serum gelation time. Samples E1-4 contained Vitamin E. Only samples E1 and E2 contained vitamin C and only these two samples gelled. Vitamin E can be added to a solution to become a gel but it appears that another additive may be needed to create a gel. Samples L1-5 contained a form of lemon juice. Samples L1 and L4 had juice directly from a lemon while samples L2, L3 and L5 contained lemon juice from a plastic lemon container. Samples L4 and L5 did not have vitamin C while all others did. All samples gelled showing that lemon juice can create gel on its own. Amount of lemon juice and type of lemon juice had little effect on gelation time. Sample Jar 2 contained lemon grass oil which formed an albumen like substance when initially added. This sample also had vitamin C but gelation time was significantly quicker than with other vitamin C samples. Sample R1 contained rosemary oil, which seemed to be soluble, as well as vitamin C. The sample gelled in a similar time frame to other samples with only vitamin C. Samples RO-1 and RO-2 contained rose oil while only RO-1 had vitamin C. Only RO-1 gelled showing that rose oil will not create a gel quickly on its own. In both cases the rose oil was immiscible and visible as yellow bubbles.

Aqueous silk fibroin-based fragment solution and essential oils are immiscible liquids. In an embodiment, to increase the fragrance of the silk fibroin-based fragment solution, without entrapping oils within the solution, the solution is mixed with the essential oil with the use of a stir bar. The stir bar is rotated at a speed such that some

turbulence is observed in the mixture, thus causing contact between the fragrant essential oil and the molecules in solution, adding a scent to the solution. Before casting of product from the solution, mixing may be stopped and the oil allowed to separate to the top of the solution. Dispensing from the bottom fraction of the solution into the final product allows for fragrance without visible essential oil within the final product.

Alternatively, the silk fibroin-based solution and essential oil can be combined with or without additional ingredients and/or an emulsifier to create a composition containing both ingredients.

In an embodiment, mixing of the solution as described above can reduce gelation time if the solution is used to create a gel formulation.

Vessel

Samples T1 and Jar 1 were used to examine the effect of casting vessel on serum gelation time. Jar 1 was cast in a glass jar while T1 was cast in an aluminum tube. Both samples gelled and did not affect serum gel time.

Summary

All treatments of silk solution for gel solution were in a conical tube at room temperature unless otherwise stated. The ratio of silk to vitamin C did affect the ability of a solution to gel as ratios above 1:2 did not gel and a 1:2 ratio took twice as long as other lower ratios (5:1, 2.5:1, 1:1). Temperature affected gel creation time with higher temperatures resulting in quicker gel times. 50° C. treatment gelled in as quick as 2 days, 37° C. treatment gelled in as quick as 3 days, room temperature treatment gelled in 5-8 days and storage in a refrigerator took at least 39 days to gel. The effects of additives on gel creation were dependent on the additive. Vitamin E, Rosemary Oil and Rose Oil all had no effect on gel creation. Each of these additives did not prevent gelation or affect the time to gelation. Each also required the presence of vitamin C to gel. Lemon juice from a fresh lemon, pre-squeezed lemon juice from a plastic lemon container and lemon grass oil did affect gel creation. Without wishing to be bound by theory, it is believed that the lower pH as a result of these additives is the reason the additives had an impact on decreasing gelation time. Both lemon juice types were able to cause gelation without the presence of vitamin C. This occurred in the same number of days as with vitamin C. The lemongrass oil was able to decrease the number of days to gelation to 2-3 days. All additives appeared soluble other than lemongrass oil and rose oil. Rose oil remained in yellow bubbles while the lemongrass oil was partially soluble and formed an albumen like chunk. In an embodiment, oils that are not fully soluble, can still be suspended within the gel as an additive. Physical stimulation by shaking, vessel the solution was cast into and solution volume did not affect gelation time.

TABLE 18

Concentration of vitamin C in various gel formulations.

	Sample Info	Sample Weight (mg)	Concentration of Vitamin C (mg/g)	
			In Sample	Average
Rosemary (Room Temperature storage)		685.7	3.2511 3.2804	3.2657
Lemongrass (Room		638	3.3336 3.3132	3.3334
		646	2.8672 2.8868	2.877

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TABLE 18-continued

Concentration of vitamin C in various gel formulations.			
	Sample Weight	Concentration of Vitamin C (mg/g)	
Sample Info	(mg)	In Sample	Average
Temperature storage)	645.5	2.9051 2.9052	2.9051
Rosemary (Room	645.2	3.9063 3.923	3.9147
Temperature; Foil Covered storage)	649	3.9443 3.9305	3.9374
Lemongrass (Room	630.1	3.8253 3.8295	3.8274
Temperature; Foil Covered storage)	660.4	3.8283 3.8222	3.8253
Rosemary (Fridge, Foil Covered storage)	672.4	5.1616 5.1352	5.1484
Lemongrass (Fridge, Foil Covered storage)	616.5	5.1984 5.2036	5.201
	640.5	5.1871 5.1776	5.1824
	627.7	5.2098 5.2154	5.2126

Example 3. Preparation of Silk Gels

Additional gels may be prepared according to Table 19, 35 Table 20, Table 21, and Table 22.

TABLE 19

Lemongrass Gel		
% Silk Solution	2%	
Quantity Vitamin C	100 mg/15 mL solution	
Quantity Lemongrass Oil	20 µL/15 mL solution	

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TABLE 20

Rosemary Gel		
5 % Silk Solution	2%	
Quantity Vitamin C	100 mg/15 mL solution	
Quantity Rosemary Oil	20 µL/50 mL solution	

TABLE 21

Lemongrass Gel (50 mL)		
10 % Silk Solution (60 minute boil, 25 kDa)	2%	
Quantity Vitamin C (ascorbyl glucoside)	12.82 mg/mL solution (641 mg total)	
Quantity Lemongrass Oil pH	1.33 µL/mL solution 4	

TABLE 22

Rosemary Gel (50 mL)		
20 % Silk Solution (60 minute boil, 25 kDa)	2%	
Quantity Vitamin C (ascorbyl glucoside)	12.82 mg/mL solution (641 mg total)	
Quantity Rosemary Oil pH	0.8 µL/mL solution 4	

30 Gels of the present disclosure can be made with about 0.5% to about 8% silk solutions. Gels of the present disclosure can be made with ascorbyl glucoside at concentrations of about 0.67% to about 15% w/v. Gels of the present disclosure be clear/white in color. Gels of the present disclosure can have a consistency that is easily spread and absorbed by the skin. Gels of the present disclosure can produce no visual residue or oily feel after application. Gels of the present disclosure do not brown over time.

35 Silk gels with essential oils were prepared by diluting a silk solution of the present disclosure to 2%. Vitamin C was added to the solution and allowed to dissolve. The essential oil was added, stirred and dissolved. The solution was aliquot into jars.

Example 4. Coating Fabrics with Aqueous Silk Solutions

TABLE 23

Silk Solution Characteristics					
Molecular Weight:	57 kDa				
Polydispersity:	1.6				
% Silk	5.0%	3.0%	1.0%	0.5%	
Process Parameters					
Extraction					
Boil Time:	30 minutes				
Boil Temperature:	100 ° C.				
Rinse Temperature:	60 ° C.				
Dissolution					
LiBr Temperature:	100 ° C.				
Oven Temperature:	100 ° C.				
Oven Time:	60 minutes				

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TABLE 23-continued

Silk Solution Characteristics					
Molecular Weight:	25 kDa				
Polydispersity:	2.4				
% Silk	5.0%	3.0%	1.0%	0.5%	
Process Parameters					
Extraction					
Boil Time:	60 minutes				
Boil Temperature:	100 ° C.				
Rinse Temperature:	60 ° C.				
Dissolution					
LiBr Temperature:	100 ° C.				
Oven Temperature:	100 ° C.				
Oven Time:	60 minutes				

Silk Solution and Silk Gel Application to Fabric and Yarn Samples

Three 50 mm diameter fabric samples from each of three different fabric materials, cotton, polyester, and nylon/LY-CRA®, were placed in plastic containers. about 0.3 mL of about 5.8% silk fibroin solution was deposited using a 1 mL syringe and 18 gauge needle on two samples of each material, and allowed to sit for about 1 minute. About 0.3 mL of denatured alcohol (containing methanol and ethanol) was then deposited using a 1 mL syringe and 30 gauge needle on one of the silk-coated samples of each material.

In an additional experiment, silk gel with Rosemary Essential Oil (water, silk, ascorbyl glucoside, rosemary essential oil) was collected on a tip and applied to half the length of 2 pieces of 400 µm tencel yarn. One sample was then wetted with about 0.3 mL alcohol.

Silk Solution Dip Test

Polyester fabric samples were dipped in silk fibroin solutions of varying concentration. Samples were placed in incubator with air flow on foil and allowed to dry at about 22.5° C. for about 15.5 hours. Change in mass before and after silk coating was measured.

TABLE 25

Polyester Fabric Samples with Silk Coatings of the Present Disclosure				
Silk Fibroin Concentration (%)	Starting Mass (g)	Mass after coating (g)	Change (%)	Average Change (%)
1	0.25	0.26	+4	-3%
	0.30	0.27	-10	
	0.24	0.24	0	
	0.22	0.21	-5	

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TABLE 25-continued

Polyester Fabric Samples with Silk Coatings of the Present Disclosure				
Silk Fibroin Concentration (%)	Starting Mass (g)	Mass after coating (g)	Change (%)	Average Change (%)
3	0.30	0.36	+20	15%
	0.28	0.31	+11	
	0.29	0.33	+14	
	0.29	0.34	+15	
5	0.25	0.29	+16	16%
	0.28	0.33	+18	
	0.31	0.35	+13	
	0.27	0.31	+15	

Silk Solution Spray Test

A spray test was performed to verify the handle impact of silk fibroin solution sprayed on polyester fabric. About 0.5% silk fibroin solution was applied to a 4 inch by 4 inch square of polyester fabric using a spray gun from a distance of about 10 inches. Three passes were completed from left to right and from right to left (six passes total). Samples were placed in a 50° C. oven on aluminum foil over a water bath for about 1.5 hours. Methods were repeated with a second polyester fabric sample with an about 5.8% silk fibroin solution spray application. No change in material hand was observed in samples sprayed with either 0.5% or 5.8% solutions. Perceived increase in materials smoothness was observed for samples sprayed with either the 0.5% and 5.8% solutions.

Example 5. Optimized Fabric Coating Processes

The coating processes described in Table 26 were used to produce multiple fabric samples for performance testing, as described in more detail below.

TABLE 26

Coating Processes.

- 1 Spray
 - 1.1 Material for coating
 - 1.1.1 cork board 24" x 36" Hobby Lobby part 132894
 - 1.1.2 Covered the cork board with polyester interlock fabric
 - 1.1.3 Saw horse for support
 - 1.1.4 Several clamps for holding cork panel to saw horse
 - 1.1.5 Double filter to remove oil residue from compressor and dehumidification salt
 - 1.1.6 Iwata eclipse MP-CS airbrush
 - 1.1.7 Husky 30.3 liter tank compression system
 - 1.1.8 Push pin to hold fabric on cork panel Hobby Lobby part #523456

TABLE 26-continued

Coating Processes.	
1.2 Material for preparation	
1.2.1 Scissor	
1.2.2 Ruler	
1.2.3 Balance AWS model Pnx-203	
1.3 Material for drying	
1.3.1 Wolf stove set up at 150° F. maintaining 71-78° C. with fan system.	
1.3.2 Flat baking sheet	
1.3.3 Aluminum foil	
1.3.4 SC 307T thermometer with probe	
1.4 Execution	
1.1.1 lay fabric to be coated on top of cork panel covered with polyester fabric	
1.1.2 secure fabric with pin to the cork panel	
1.1.3 set compressor with oil and humidity filters	
1.1.4 set air pressure supply to 55 psi	
1.1.5 load solution to airbrush gun	
1.1.6 position airbrush gun approximately 10 inches from board	
1.1.7 pull the airbrush gun trigger and over spray 2 inches side to side the fabric to be coated	
1.1.8 remove pin from cork panel and place coated fabric on aluminum foil	
1.1.9 place coated fabric in oven for 30-60 min at 150° C.	
2. Stencil/Spray	
2.1 Material for coating	
2.1.1 cork board 24" x 36" Hobby Lobby part 132894	
2.1.2 Covered the cork board with polyester interlock fabric	
2.1.3 Saw horse for support	
2.1.4 Several clamps for holding cork panel to saw horse	
2.1.5 Double filter to remove oil residue front compressor and dehumidification salt	
2.1.6 Iwata eclipse MP-CS airbrush	
2.1.7 Husky 30.3 liter tank compression system	
2.1.8 Push pin to hold fabric on cork panel Hobby Lobby part #523456	
2.1.9 Stencil pattern SKU#75244 Lincaine 12" x 24" x 0.020" Hobby Lobby	
2.2 Material for preparation	
2.2.1 Scissor	
2.2.2 Ruler	
2.2.3 Balance AWS model Pnx-203	
2.3 Material for drying	
2.3.1 Wolf stove set up at 150° F. maintaining 71-78° C. with fan system.	
2.3.2 Flat baking sheet	
2.3.3 Aluminum foil	
2.3.4 SC 307T thermometer with probe	
2.4 Execution	
2.4.1 lay fabric to be coated on top of cork panel covered with polyester fabric	
2.4.2 lay stencil pattern on top of fabric	
2.4.3 secure stencil with pin to the cork panel	
2.4.4 set compressor with oil and humidity filters	
2.4.5 set air pressure supply to 55 psi	
2.4.6 load solution to airbrush gun	
2.4.7 position airbrush gun approximately 10 inches from board	
2.4.8 pull the airbrush gun trigger and over spray 2 inches side to side the fabric to be coated	
2.4.9 remove pin from cork panel and place coated fabric on aluminum foil	
2.4.10 place coated fabric in oven for 30-60 min at 150° C.	
3 Screen print	
3.1 Material for coating	
3.1.1 cork board 24" x 36" Hobby Lobby part 132894	
3.1.2 Covered the cork board with polyester interlock fabric	
3.1.3 Saw horse for support	
3.1.4 Several clamps for holding cork panel to saw horse	
3.1.5 screen print frame 12" x 18" part#4710 made by Speed Ball	
3.1.6 silicon spatula	
3.2 Material for preparation	
3.2.1 Scissor	
3.2.2 Ruler	
3.2.3 Balance AWS model Prix-203	
3.3 Material for drying	
3.3.1 Wolf stove set up at 150° F. maintaining 71-78° C. with fan system.	
3.3.2 Flat baking sheet	
3.3.3 Aluminum foil	
3.3.4 SC 307T thermometer with probe	

TABLE 26-continued

Coating Processes.	
3.4 Execution	
3.4.1 lay fabric to be coated on top of cork panel covered with polyester fabric	
3.4.2 lay screen print frame on top of fabric	
3.4.3 load solution to one edge of the screen print frame	
3.4.4 with a silicon spatula move solution across the screen print frame until the entire fabric to be coated surface is covered	
3.4.5 remove screen print frame and place coated fabric on aluminum foil	
3.4.6 place coated fabric in oven for 30-60 min at 150° C.	
4 Bath	
4.1 Material for coating	
4.1.1 cork board 24" x 36" Hobby Lobby part 132894	
4.1.2 Covered the cork board with polyester interlock fabric	
4.1.3 Saw horse for support	
4.1.4 Several clamps for holding cork panel to saw horse	
4.1.5 Paint tray liner Item #: 170418 Model #: LOWES0-PK170418 at Lowes Hardware	
4.1.6 Noodle making machine Imperia model #15-4590	
4.2 Material for preparation	
4.2.1 Scissor	
4.2.2 Ruler	
4.2.3 Balance AWS model Pnx-203	
4.3 Material for drying	
4.3.1 Wolf stove set up at 150° F. maintaining 71-78° C. with fan system.	
4.3.2 Flat baking sheet	
4.3.3 Aluminum foil	
4.3.4 SC 3071 thermometer with probe	
4.4 Execution	
4.4.1 load silk solution inside the paint tray liner well	
4.4.2 immerse the fabric sample to be coated inside the silk solution until it is all saturated	
4.4.3 pass the saturated fabric between pressure roller (noodle making machine) to remove any excess solution	
4.4.4 place coated fabric on aluminum foil	
4.4.5 place coated fabric in oven for 30-60 min at 150° C.	

The products produced using the coating processes described above were tested for accumulative one way transport capability (or index) and other properties using Association of Textile, Apparel & Materials Professionals (AATCC) test method 195-2012 for the measurement, evaluation, and classification of liquid moisture management properties of textile fabrics. The details of the test methods are available from AATCC, and a synopsis of the methods and calculations is provided here. The absorption rate (ART) (top surface) and (ARB) (bottom surface) is defined as the average speed of liquid moisture absorption for the top and bottom surfaces of the specimen during the initial change of water content during a test. The accumulative one-way transport capability (R) is defined as the difference between the area of the liquid moisture content curves of the top and bottom surfaces of a specimen with respect to time. The bottom surface (B) is defined for testing purposes as the side of the specimen placed down against the lower electrical sensor which is the side of the fabric that would be the outer exposed surface of a garment when it is worn or product when it is used. The top surface (T) for testing purposes is defined as the side of a specimen that, when the specimen is placed on the lower electrical sensor, is facing the upper sensor. This is the side of the fabric that would come in contact with the skin when a garment is worn or when a product is used. The maximum wetted radius (MWRT) and (MWRB) (mm) is defined as the greatest ring radius measured on the top and bottom surfaces. Moisture management is defined, for liquid moisture management

³⁵ testing, as the engineered or inherent transport of aqueous liquids such as perspiration or water (relates to comfort) and includes both liquid and vapor forms of water. The overall (liquid) moisture management capability (OMMC), an index of the overall capability of a fabric to transport liquid moisture as calculated by combining three measured attributes of performance: the liquid moisture absorption rate on the bottom surface (ARB), the one way liquid transport capability (R), and the maximum liquid moisture spreading speed on the bottom surface (SS_B). The spreading speed (SS_i) is defined as the accumulated rate of surface wetting from the center of the specimen where the test solution is dropped to the maximum wetted radius. The total water content (U) (%) is defined as the sum of the percent water content of the top and bottom surfaces. The wetting time (WTT) (top surface) and (WTB) (bottom surface) is defined as the time in seconds when the top and bottom surfaces of the specimen begin to be wetted after the test is started.

⁴⁰ A moisture management tester (MMT) is used to perform the test. The accumulative one way liquid transport capability (R) is calculated as: [Area (U_B)—Area (U_T)]/total testing time. The OMMC is calculated as: $OMMC = C_1 * AR_{B_ndv} + C_2 R_{ndv} + C_3 * SS_{B_ndv}$, where C_1 , C_2 , and C_3 are the weighting values * for AR_{B_ndv} , R_{ndv} and SS_{B_ndv} ; (ARB)=absorption rate; (R)=one-way transport capability, and (SS_B)=spreading speed. Detailed calculations of these parameters, and other parameters of interest, are provided in AATCC test method 195-2012.

A description of the samples used is given in Table 27.

TABLE 27

Sample ID	Description
15051201	no coating (polyester)
15051301	1% silk solution stray coating on 15051201
15051302	0.1% silk solution spray coating on 15051201
15051303	0.05% silk solution spray coating on 15051201
15051304	1% silk solution spray stencil coating on 15051201
15051305	0.1% silk solution spray stencil coating on 15051201
15051306	0.05% silk solution spray stencil coating on 15051201
15051401	1% silk solution bath coating on 15051201
15051402	0.1% silk solution bath coating on 15051201
15051403	0.05% silk solution bath coating on 15051201
15051404	PureProC screen print on 15051201
15042001	non wicking finished
15042002	semifinished before final setting
15042003	with wicking finished
15042101	non wicking finished (15042001) 1% silk solution spray coating
15042102	non wicking finished (15042001) 0.1% silk solution spray coating
15061206	non wicking finished (15042001) 1% silk solution stencil coating
15061207	non wicking finished (15042001) 1% silk solution bath coating
15061205	non wicking finished (15042001) 0.1% silk solution stencil coating
15061209	non wicking finished (15042001) 0.1% silk solution bath coating
15061201	semifinished before final setting (15042002) 1% silk solution spray coating
15061203	semifinished before final setting (15042002) 1% silk solution stencil coating
15061208	semifinished before final setting (15042002) 1% silk solution bath coating
15061202	semifinished before final setting (15042002) 0.1% silk solution spray coating
15061204	semifinished before final setting (15042002) 0.1% silk solution stencil coating
15061210	semifinished before final setting (15042002) 0.1% silk solution bath coating

The results of the tests are depicted in FIG. 57A through FIG. 86B and illustrate the superior performance of silk coated fabric, including superior performance with respect to accumulative one way transport capability (index) and overall moisture management capability.

Example 6. Antimicrobial Properties of Silk Coatings on Fabrics

The antimicrobial properties of silk coatings were testing on four materials: a cotton/LYCRA jersey (15051201), a cotton/LYCRA jersey with 1% silk fibroin solution (sfs) bath coating (15070701), a polyester/LYCRA finish after final setting (15042003), and a polyester/LYCRA semi-finished

³⁵ 1% sfs bath coating (15070702) (wherein LYCRA is the trade name of a polyester-polyurethane copolymer). AATCC test method 100-2012 for the assessment of antibacterial finishes on textile materials was used. The details of the test method are available from AATCC. Briefly, the tests were performed using tryptic soy broth as a growth medium, a sample size of 4 layers, autoclave sterilization, 100 mL Lethen broth with Tween for neutralization, a target inoculation level of $1-2 \times 10^5$ CFU/mL, 5% nutrient broth as an inoculent carrier and dilution medium, a contact time of 18 to 24 hours, and a temperature of $37 +/ - 2^\circ$ C.

The results of the tests are summarized in Table 28 and are depicted in FIG. 87 to FIG. 92, and illustrate the superior antimicrobial performance of the silk-coated fabrics.

TABLE 28

Antimicrobial test results.					
		Results: cfu/sample			
sample #	bacteria	Zero Contact Time	24 hr Contact Time	Percent Reduction	
15051201	<i>Staphylococcus aureus</i> ATCC 6538	1.23E+05	4.90E+06	-3883.74%	
	<i>Klebsiella pneumoniae</i> ATCC 4352	1.65E+05	4.90E+06	-2869.70%	
15070701	<i>Staphylococcus aureus</i> ATCC 6538	1.23E+05	4.90E+06	-3883.74%	
	<i>Klebsiella pneumoniae</i> ATCC 4352	1.65E+05	4.90E+06	-2869.70%	

TABLE 28-continued

		Antimicrobial test results.		
sample #	bacteria	Results: cfu/sample		
		Zero Contact Time	24 hr Contact Time	Percent Reduction
15042003	<i>Staphylococcus aureus</i> ATCC 6538	1.23E+05	4.90E+06	-3883.74%
	<i>Klebsiella pneumoniae</i> ATCC 4352	1.65E+05	4.90E+06	-2869.70%
15070702	<i>Staphylococcus aureus</i> ATCC 6538	1.23E+05	1.03E+04	91.63%
	<i>Klebsiella pneumoniae</i> ATCC 4352	1.65E+05	2.33E+05	-40.91%

Example 7. Methods of Preparing Fabrics with Silk Coatings

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa includes the steps of: degumming a silk source by adding the silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 60° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in an oven having a temperature of about 140° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of silk protein fragments, the aqueous solution comprising: fragments having an average weight average molecular weight ranging from about 6 kDa to about 16 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based

protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide.

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa includes the steps of: adding a silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of between about 30 minutes to about 60 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, wherein the aqueous solution of silk protein fragments comprises sodium carbonate residuals of between about 10 ppm and about 100 ppm, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises fragments having an average weight average molecular weight ranging from about 17 kDa to about 38 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The method may further comprise adding an alpha hydroxy acid to the aqueous

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solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide.

A method for preparing an aqueous solution of pure silk fibroin-based protein fragments having an average weight average molecular weight ranging from about 39 kDa to about 80 kDa, includes the steps of: adding a silk source to a boiling (100° C.) aqueous solution of sodium carbonate for a treatment time of about 30 minutes so as to result in degumming; removing sericin from the solution to produce a silk fibroin extract comprising non-detectable levels of sericin; draining the solution from the silk fibroin extract; dissolving the silk fibroin extract in a solution of lithium bromide having a starting temperature upon placement of the silk fibroin extract in the lithium bromide solution that ranges from about 80° C. to about 140° C.; maintaining the solution of silk fibroin-lithium bromide in a dry oven having a temperature in the range between about 60° C. to about 100° C. for a period of at least 1 hour; removing the lithium bromide from the silk fibroin extract; and producing an aqueous solution of pure silk fibroin-based protein fragments, wherein the aqueous solution of pure silk fibroin-based protein fragments comprises lithium bromide residuals of between about 10 ppm and about 300 ppm, sodium carbonate residuals of between about 10 ppm and about 100 ppm, fragments having an average weight average molecular weight ranging from about 40 kDa to about 65 kDa, and wherein the aqueous solution of pure silk fibroin-based protein fragments comprises a polydispersity of between about 1.5 and about 3.0. The method may further comprise drying the silk fibroin extract prior to the dissolving step. The aqueous solution of pure silk fibroin-based protein fragments may comprise lithium bromide residuals of less

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than 300 ppm as measured using a high-performance liquid chromatography lithium bromide assay. The aqueous solution of pure silk fibroin-based protein fragments may comprise sodium carbonate residuals of less than 100 ppm as measured using a high-performance liquid chromatography sodium carbonate assay. The method may further comprise adding a therapeutic agent to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a molecule selected from one of an antioxidant or an enzyme to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding a vitamin to the aqueous solution of pure silk fibroin-based protein fragments. The vitamin may be vitamin C or a derivative thereof. The method may further comprise adding an alpha hydroxy acid to the aqueous solution of pure silk fibroin-based protein fragments. The alpha hydroxy acid may be selected from the group consisting of glycolic acid, lactic acid, tartaric acid and citric acid. The method may further comprise adding hyaluronic acid or its salt form at a concentration of about 0.5% to about 10.0% to the aqueous solution of pure silk fibroin-based protein fragments. The method may further comprise adding at least one of zinc oxide or titanium dioxide.

Example 8. Characterization of Silk Coatings on Polyester

A summary of the results from studies of silk coatings on polyester are given in Table 29 and Table 30. The results shown in FIG. 93 and FIG. 94 illustrate that the accumulative one way transport index and OMMC performance is maintained even at 50 wash cycles. Additional test results are shown in FIG. 95 to FIG. 102. The antimicrobial performance of the silk coated polyester fabrics are maintained to 25 to 50 washing cycles, as shown in FIG. 103 to FIG. 104. The results illustrate the surprising improvement in moisture management properties, as well as the surprising result that the improved properties survive many wash cycles.

TABLE 29

Test results for semifinished polyester with 1% silk solution coating.
Testing Results: Semifinished polyester with 1% silk solution coating

Number of Washes	Raw Data:	Wetting Time Top (sec)	Wetting Time Bottom (sec)	Top Absorption Rate (%) / sec)	Bottom Absorption Rate (%) / sec)	Top		Bottom		Accumulative One-Way Transport index (%)	Overall Moisture Management Capability OMMC
						Max Wetted Radius (mm)	Max Wetted Radius (mm)	Spreading Speed (mm/sec)	Spreading Speed (mm/sec)		
						Max Wetted Radius (mm)	Spreading Speed (mm/sec)	Spreading Speed (mm/sec)	Spreading Speed (mm/sec)		
0 Cycles	Mean	5.63	3.95	7.24	28.73	5	5	0.90	1.22	133.26	0.27
	S. Deviation	1.20	0.38	1.46	8.62	0	0	0.20	0.12	34.81	0.06
	CV	0.21	0.10	0.20	0.30	0	0	0.22	0.09	0.26	0.21
10 Cycles	Mean	23.87	7.96	4.82	8.55	5	5	0.46	0.68	144.84	0.22
	S. Deviation	31.51	3.30	0.84	2.94	0	0	0.28	0.23	27.71	0.03
	CV	1.32	0.41	0.17	0.34	0	0	0.61	0.33	0.19	0.14
25 Cycles	Mean	6.09	4.59	7.36	17.22	5	5	0.83	1.05	124.05	0.22
	S. Deviation	1.61	0.44	2.98	3.28	0	0	0.17	0.09	11.70	0.02
	CV	0.26	0.10	0.40	0.19	0	0	0.20	0.09	0.09	0.09
50 Cycles	Mean	25.20	11.64	6.84	7.80	5	5	0.39	0.53	58.81	0.13
	S. Deviation	28.06	6.36	3.38	5.70	0	0	0.30	0.27	26.56	0.03
	CV	1.11	0.55	0.49	0.73	0	0	0.77	0.51	0.45	0.25

TABLE 30

Test results for wicking finished polyester without silk coating. Testing Results: Wicking Finished Polyester											
Number of Washes	Raw Data:	Wetting Time Top (sec)	Wetting Time Bottom (sec)	Top Absorption Rate (%/sec)	Bottom Absorption Rate (%/sec)	Top Max Wetted Radius (mm)	Bottom Max Wetted Radius (mm)	Top Spreading Speed (mm/sec)	Bottom Spreading Speed (mm/sec)	Accumulative One-Way Transport index (%)	Over all Moisture Management Capability OMMC
0 Cycles	Mean	3.46	3.48	37.30	56.90	5	5	1.37	1.36	62.37	0.29
	S. Deviation	0.07	0.04	12.89	10.24	0	0	0.02	0.02	9.74	0.03
	CV	0.02	0.01	0.35	0.18	0	0	0.02	0.01	0.16	0.12
25 Cycles	Mean	6.69	6.71	7.23	6.89	5	5	0.75	0.76	30.40	0.09
	S. Deviation	1.48	1.92	1.27	2.74	0	0	0.13	0.19	16.22	0.02
	CV	0.22	0.29	0.18	0.40	0	0	0.17	0.25	0.53	0.20
50 Cycles	Mean	11.27	8.46	6.70	9.35	5	5	0.54	0.65	31.21	0.09
	S. Deviation	6.57	3.53	1.45	5.21	0	0	0.23	0.25	18.26	0.03
	CV	0.58	0.42	0.22	0.56	0	0	0.44	0.38	0.59	0.30

Example 9. Characterization of Silk Coatings on Polyester Fabrics

Scanning electron microscopy (SEM) analysis was performed using a Hitachi S-4800 field-emission SEM (FE-SEM) operated at 2 kV accelerating voltage. Pieces from each sample were sectioned using a razor blade and placed on carbon adhesive tape mounted on aluminum SEM stubs. A coating of iridium approximately 2 nm thick was applied via sputter deposition in order to minimize the buildup of surface charge.

The samples used in the SEM study are described in Table 31. SEM micrographs for fabric samples are shown in FIG. 105 to FIG. 167.

TABLE 31

Fabric samples tested by scanning electron microscopy and optical profilometry.			
Sample ID	Fabric	Silk solution for coating/treatment (average molecular weight, Da)	Silk coating/treatment method using silk fibroin solution (sfs)
FAB-10-SPRAY-B	15042002	41,576	spray with 1% sfs
FAB-01-SPRAY-B	15042002	41,576	spray with 0.1% sfs
FAB-10-STEN-B	15042002	41,576	stencil spray with 1% sfs
FAB-10-BATH-B	15042002	41,576	bath with 1% sfs
FAB-01-BATH-B	15042002	41,576	bath with 0.1% sfs
FAB-01-SPRAY-C	15042002	10,939	spray with 0.1% sfs
FAB-01-STEN-C	15042002	10,939	stencil spray with 0.1% sfs
FAB-10-BATH-C	15042002	10,939	bath with 1% sfs

The fabric SEM results show that the silk solution has very clearly been deposited along and between individual polyester fibers. The use of 0.1% silk solution results in less coating than 1.0% silk solution. The use of a bath for 0.1%

20 silk solution, with an average molecular weight of 41 kDa, results in uniform coating along fibers with large, smooth features. The use of a spray with a 0.1% silk solution, with an average molecular weight of 41 kDa, in coating along fibers as well as connected, webbed coating between fibers. The use of a spray for 0.1% silk solution, with an average molecular weight of 11 kDa, results in uniform coating along fibers with small, spotted/ribbed features. The use of a stencil for 0.1% silk solution, with an average molecular weight of 11 kDa, results in coating along fibers that has clear edges and delineation between coated and non coated sides. The use of a bath for 1.0% silk solution, with an average molecular weight of 41 kDa, results in thick coating along fibers as well as thick connected, webbed coating between fibers. The use of a bath for 1.0% silk solution, with an average molecular weight of 11 kDa, results in coating along all sides of individual fibers. Coating appears uniform on surface with many single point extrusions. The use of a spray for 1.0% silk solution, with an average molecular weight of 41 kDa, results in coating along fibers as well as connected, webbed coating between fibers, which was thicker than that observed using 0.1% silk solution. The use of a stencil for 1.0% silk solution, with an average molecular weight of 41 kDa, results in coating along fibers and between fibers, and the coating appears well organized.

45 The SEM results demonstrate that the silk coating has been applied as an even, thin, uniform coating to the fibers of the fabric. This illustrates the surprising result that the silk coating was applied to the fibers without the use of any additives or cross-linking, using a water based delivery system.

Example 10. Characterization of Silk Coatings on Polyester Films

The film samples are described in Table 32. The SEM images from these films are shown in FIG. 168 to FIG. 237.

TABLE 32

Film samples tested scanning electron microscopy and optical profilometry.				
Sample identifier	Polyester substrate material	Silk solution for coating/treatment (average molecular weight, Da)	Silk coating/treatment method using silk fibroin solution (sfs)	
FIL-10-SPRAY-B-01MYL	0.01 Mylar	41,576	spray with 1% sfs	
FIL-01-SPRAY-B-01MYL	0.01 Mylar	41,576	spray with 0.1% sfs	

TABLE 32-continued

Film samples tested scanning electron microscopy and optical profilometry.			
Sample identifier	Polyester substrate material	Silk solution for coating/treatment (average molecular weight, Da)	Silk coating/treatment method using silk fibroin solution (sfs)
FIL-01-SPRAY-B-007MEL	0.007 Melinex	41,576	spray with 0.1% sfs
FIL-01-SPRAY-C-01MYL	0.01 Mylar	10,939	spray with 0.1% sfs
FIL-01-STEN-B-01MYL	0.01 Mylar	41,576	stencil spray with 0.1% sfs
FIL-01-STEN-C-01MYL	0.01 Mylar	10,939	stencil spray with 0.1% sfs
FIL-10-BATH-B-01MYL	0.01 Mylar	41,576	bath with 1% sfs
FIL-10-BATH-B-007MEL	0.007 Melinex	41,576	bath with 1% sfs
FIL-10-BATH-C-01MYL	0.01 Mylar	10,939	bath with 1% sfs
FIL-01-BATH-B-01MYL	0.01 Mylar	41,576	bath with 0.1% sis

The results show that the silk coatings are applied uniformly. Little to no variation is observed in the characteristics or topology of the coated polyester films. Surprisingly, the coating is even, uniform, and thin. Furthermore, surprising, the silk coated the fibers without any additives or cross-linking using a water-based system.

Optical profiling was carried out using a Zyglo New View 6200 optical profilometer. Two locations on each sample were randomly selected and measured with 10x magnification. The results are shown in FIG. 241 to FIG. 264. The results indicate that the silk-coated samples have a homogeneous deposition of silk fibroin. Surface roughness features observed in the control are visible after silk coating on Mylar films, which is consistent with the presence of a

BATH-B-01MYL, the coating ranged from approximately 140 nm to 400 nm in 4 locations. SEM images from cross-sections show similar trends, with one location on sample FIL-10-SPRAY-B-10MYL having a cross-section that measures approximately 500 nm and one on FIL-10-BATH-B-01MYL measuring approximately 180 nm.

Example 11. Preparation of Silk Fibroin Solutions with Higher Molecular Weights

The preparation of silk fibroin solutions with higher molecular weights is given in Table 33.

TABLE 33

Preparation and properties of silk fibroin solutions.						
Sample Name	Extraction Time (mins)	Extraction			Oven/Sol'n Temp	Average weight average molecular weight (kDa)
		Extraction Temp (° C.)	LiBr Temp (° C.)	Average polydispersity		
Group A TFF	60	100	100	100° C. oven	34.7	2.94
Group A DIS	60	100	100	100° C. oven	44.7	3.17
Group B TFF	60	100	100	100° C. sol'n	41.6	3.07
Group B DIS	60	100	100	100° C. sol'n	44.0	3.12
Group C TFF	60	100	140	140° C. sol'n	10.9	3.19
Group C DIS	60	100	140	140° C. sol'n		
Group D DIS	30	90	60	60° C. sol'n	129.7	2.56
Group D FIL	30	90	60	60° C. sol'n	144.2	2.73
Group E DIS	15	100	RT	60° C. sol'n	108.8	2.78
Group E FIL	15	100	RT	60° C. sol'n	94.8	2.62

relatively thin silk film that is forming a conformal coating on Mylar. The results substantiate the uniformity of the coating, and demonstrate that silk can be stenciled into discrete locations.

Contact profilometry was performed and the cross-sectioned samples were examined by SEM. Results are shown in FIG. 265 to FIG. 268. For sample FIL-10-SPRAY-B-10MYL, the thickness ranged from approximately 260 nm to 850 nm in 4 locations analyzed. For sample FIL-10-

Example 12. Silk Coatings on Natural Fabrics

The coating of natural fabric with silk fibroin-based protein fragment solutions and the resulting properties are illustrated in Table 34, Table 35, FIG. 269, and FIG. 270. The results demonstrate that silk fibroin solutions can coat cotton-Lycra natural fabrics including LUON and POWER LUXTREME.

TABLE 34

Legend	Fabric
15072201	Power Luxtreme RT1211362
15072202	Luon RT20602020
15072301	Power Luxtreme RT1211362 (15072201) 1% silk solution spray coating
15072302	Luon RT20602020 (15072202) 1% silk solution spray coating
15072303	Power Luxtreme RT 211362 (15072201) 0.1% silk solution spray coating
15072304	Luon RT20602020 (15072202) 0.1% silk solution spray coating
15072305	Power Luxtreme RT1211362 (15072201) 1% silk solution stencil coating
15072306	Luon RT20602020 (15072202) 1% silk solution stencil coating
15072307	Power Luxtreme RT1211362 (15072201) 0.1% silk solution stencil coating
15072308	Luon RT20602020 (15072202) 0.1% silk solution stencil coating
15072309	Power Luxtreme RT1211362 (5072201) 1% silk solution bath coating
15072310	Luon RT20602020 (15072202) 1% silk solution bath coating
15072311	Power Luxtreme RT1211362 (15072201) 0.1% silk solution bath coating
15072312	Luon RT20602020 (15072202) 0.1% silk solution bath coating

TABLE 35

Raw Data:	Wetting Time Top (sec)	Wetting Time Bottom (sec)	Top Absorption Rate (%/sec)	Bottom Absorption Rate (%/sec)	Top Max Wetted Radius (mm)	Bottom Max Wetted Radius (mm)	Top Spreading Speed (mm/sec)	Bottom Spreading Speed (mm/sec)	Accumulative One-Way Transport index (%)	Over all Moisture Management Capability OMMC	
	Mean	64.3786	3.4072	8.8123	8.60494	5	0.15038	1.41686	151.65248	0.25898	
15072201	Mean	25.1766	28.1922	5.4636	6.195	5	0.216	0.4244	80.9572	0.1529	
15072301	Mean	16.7172	12.2604	21.9859	33.6196	5	0.4304	0.4906	143.6659	0.2808	
15072302	Mean	25.8898	41.5026	6.16512	8.70282	5	0.23336	0.1791	14.06124	0.10704	
15072303	Mean	42.152	4.7268	7.9114	19.3725	4	5	0.3261	1.364	370.2757	0.5297
15072304	Mean	78.4746	34.3138	5.01486	6.63212	5	0.0661	0.38728	94.97976	0.16848	
15072305	Mean	36.1954	17.2038	6.27158	6.25526	5	0.18872	0.89046	139.73478	0.23052	
15072306	Mean	78.4746	34.3138	5.01486	6.63212	5	0.0661	0.38728	94.97976	0.16848	
15072307	Mean	36.195	17.2038	6.2716	6.2553	5	0.1887	0.8905	139.7348	0.2305	
15072308	Mean	57.335	25.7588	5.6432	6.4437	5	0.1274	0.6389	117.3573	0.1995	
15072309	Mean	54.1384	9.2662	4.01594	9.11064	5	0.09398	0.85306	267.0755	0.36724	
15072310	Mean	28.4544	13.6658	6.8844	7.8956	5	0.3059	0.5111	104.5035	0.1794	
15072311	Mean	5.1292	4.4738	8.8047	13.0277	5	0.9486	1.1702	246.6729	0.3597	
15072312	Mean	6.8516	9.4722	11.0684	11.7268	5	0.7394	0.5794	73.4005	0.1461	

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Example 13. Manufacturing Processes for Silk Coated Textiles and Leathers

Silk coated textiles and leathers may be manufactured on larger scales according to the methods provided herein using standard textile and leather manufacturing equipment with the addition of silk fibroin-based protein fragment coating steps (e.g., via bath, stencil, or spray methods). For example, a tentering and stentering frame, representing a typical process for applying the silk solution in a continuous process, may include the following units:

- An unwinding device used to unroll the fabric supply in a roll configuration;
- A feeding system used to control the feed rate of fabric;
- A material compensator used to maintain consistent the fabric tension;
- A coating machine used to apply the silk solution (i.e., silk fibroin-based protein fragments) in different state (liquid or foam) to the fabric;
- A measuring system used to control the amount of silk solution applied;

A dryer used to cure or dry the silk solution on the fabric; A cooling station used to bring the fabric temperature close to room value;

A steering frame used to guide the fabric to the rewinding device and maintain straight edges; and

A rewinding used to collect the coated fabric in roll.

Frames may also include rollers and sprayers for application of silk fibroin-based protein fragment coating, UV irradiators for curing of silk and/or other fabric additives (e.g., in a chemical cross-linking step), and RF irradiators (e.g., using microwave irradiation) for drying and chemical cross-linking.

Tentering and stentering equipment and other equipment capable of coating silk solutions onto continuous flat fabric or textile material, including leather, according to the above process, is available from the following suppliers: Aigle, Amba Projex, Bombi, Bruckner, Cavitec, Crosta, Dienes Apparatebau, Eastsign, Europlasma, Fermor, Fontanet, Gaston Systems, Hansa Mixer, Harish, Has Group, Icomatex, Idealtech, Interspare, Isotex, Klieverik, KTP, MP, Mageba, Mahr Feinpruef, Matex, Mathis, Menzel LP,

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Meyer, Monforts, Morrison Textile, Mtex, Muller Frick, Muratex Textile, Reliant Machinery, Rollmac, Salvade, Sandvik Tps, Santex, Chmitt-Machinen, Schott & Meissner, Sellers, Sicam, Siltex, Starlinger, Swatik Group India, Techfull, TMT Manenti, Unitech Textile Machinery, Weko, Willy, Wumag Texroll, Yamuna, Zappa, and Zimmer Austria.

Equipment capable of drying silk solution coatings on fabric or other textile materials, including leather, is available from the following suppliers: Alea, Alkan Makina, Anglada, Atac Makina, Bianco, Bruckner, Campen, CHTC, CTMTC, Dilmenler, Elteksmak, Erbatech, Fontanet, Harish, Icomatex, Ilsung, Inspiron, Interspare, Master, Mathis, Monfongs, Monforts, Salvade, Schmitt-Maschinen, Sellers, Sicam, Siltex, Swastik Group India, Tacome, Tubetex, Turbang, Unitech Textile Machinery, and Yamuna.

Example 14. Flammability Testing for Silk Coated Textiles

Flame resistant testing of textiles and other products of the invention, coated with silk fibroin-based protein fragments prepared using any of the methods disclosed herein may be performed using methods known to those of skill in the art, and may provide results that demonstrate flame resistant property for textiles and other products coated with silk fibroin-based protein fragments relative to uncoated textiles. Flame resistant testing of fabrics coated with silk fibroin-based protein fragments may be determined, for example, using 16 C.F.R. 1615 or 16 C.F.R. 1616 or other suitable versions of flame resistant testing standards known to those of skill in the art. Briefly, a piece of textile coated with silk fibroin-based protein fragments prepared using any of the methods disclosed herein, after 25 washing cycles, is cut into 3.5 inches wide×10 inches long rectangle specimen. One specimen is suspended in a test chamber through a specimen holder. The test chamber should be a steel chamber and at least with dimensions 32.9 cm. (1215/16 in.) wide, 32.9 cm. (12^{15/16} in.) deep, and 76.2 cm. (30 in.) long. The specimen is suspended in the test chamber vertically along the length of the specimen, and is lit up by a burner. Then the char length is measured. The testing is repeated for 5 times and average char length is calculated based on the individual result. The same testing is performed with a textile without a silk coating as a control. The specimen after 5, 10, 15, 20, 30, 35, 40, 45, and 50 washing cycles are also tested. The average char length needs to be less than 7 inches (177.8 mm) to be determined as flame resistant. The char length is the value used to evaluate passing grade for sleepwear flammability.

Two representative fabrics were used in the flammability tests. A cotton interlock fabric coated with 1% silk fibroin solution (16021103) was compared to the same fabric without (16021101) coating. A polyester double knit fabric coated with 1% silk fibroin solution (16021104) was compared to the same fabric without coating (16021102) with 1% silk fibroin solution. The SFS used to coat the fabrics in these experiments had a weight average molecular weight range of about 32-44 kDa.

Results for a cotton interlock fabric are shown in FIG. 271 and FIG. 272. The coating with silk fibroin-based protein fragments does not adversely affect the flammability of the fabric. Similarly, the results for a polyester double-knit fabric, shown in FIG. 273 and FIG. 274, also indicate that coating with silk fibroin-based protein fragments does not adversely affect the flammability of the fabric. No significant differences between samples made from same material (cotton or polyester) were observed. The differences between fabric made with the same material for afterglow and after

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flame time were not significant. Cotton, as expected, was flammable and none of the samples were left after the test.

Example 15. Abrasion Testing for Silk Coated Textiles

Abrasion testing of textiles and other products coated with silk fibroin-based protein fragments prepared using any of the methods disclosed herein may be performed using methods known to those of skill in the art, and may provide results that demonstrate improved resistance to abrasion for textiles and other products coated with silk fibroin-based protein fragments relative to uncoated textiles. Improved resistance to abrasion is useful in applications such as upholstery, including upholstery designed for home, automotive, aircraft, or other uses. Abrasion testing of fabrics coated with silk fibroin-based protein fragments may be determined, for example, using ASTM Method D4966-12 (Standard Test Method for Abrasion Resistance of Textile Fabrics (Martindale Abrasion Tester Method), ASTM, 2013) or other suitable versions of ASTM Method D4966. Briefly, abrasion resistance is measured by subjecting a textile specimen to a rubbing motion that takes the form of a geometric figure, beginning with a straight line, which becomes a gradually widening ellipse until it forms another straight line in the opposite direction, after which the motion reverses repeatedly. The rubbing occurs under known conditions of pressure and abrasive action. A Martindale Abrasion Tester (commercially available from James H. Heal Co., Ltd.) is used for testing. Resistance to abrasion is evaluated.

Four samples were testing using ASTM Method D4966-12. Sample 16021101 was a 100% cotton interlock fabric. Sample 16021102 was a 100% polyester double knit. Sample 16021501 was the 100% cotton interlock fabric after bath coating (as described herein) with 1% silk fibroin solution (SFS). Sample 16021502 was the 100% polyester double knit fabric after bath coating (as described herein) with 1% SFS. The SFS used to coat the fabrics in these experiments had a weight average molecular weight range of about 11 kDa.

Testing Results:	160211011	Testing Results:	160211012
Specimen 1	943 rubs	Specimen 1	2,000 rubs
Specimen 2	1,253 rubs	Specimen 2	1,862 rubs
Specimen 3	737 rubs	Specimen 3	2,637 rubs
Average	978 rubs	Average	2,166 rubs
standard deviation	260	standard deviation	413

Testing Results:	16021501	Testing Results:	16021502
Specimen 1	805 rubs	Specimen 1	4,910 rubs
Specimen 2	897 rubs	Specimen 2	3,090 rubs
Specimen 3	797 rubs	Specimen 3	6,000 rubs
Average	833 rubs	Average	4,667 rubs
standard deviation	56	standard deviation	1,470

The foregoing results are illustrated in FIG. 275 and FIG. 276, which show the improved abrasion resistance of polyester after coating with a silk fibroin-based solution.

Example 16: Surface Analysis of Coated Fabrics to Demonstrate the Applied Coatings

SEM images of the back side of certain coated fabrics disclosed in Table 36 were obtained at various magnifications as shown in FIGS. 277 to 316.

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TABLE 36

Sample No.	Associated SEM Images	Coating Properties
16041301	FIGS. 277 to 281	no coating, 150 C., 5 min
16041302	FIGS. 282 to 286	1%, low mw silk, 150 C., 5 min
16041303	FIGS. 287 to 291	1%, low mw silk, 200 C., 3 min
16041304	FIGS. 292 to 296	no coating, 200 C., 3 min
16041305	FIGS. 297 to 301	1%, medium mw silk, 200 C., 3 min
16041306	FIGS. 302 to 306	1%, medium mw silk, 150 C., 5 min
16040803	FIGS. 307 to 311	0.075%, medium mw silk, 150 C., 5 min
16040808	FIGS. 312 to 316	0.01%, low mw silk, 150 C., 5 min

Upon examination of the figures, there are some formations visible on top of controls 16041301 and 16041304, they can be identified as cyclic trimer, which may be a polyester byproduct, salt, or excess dye. The low molecular weight coated fibers present broken bridges between fibers. It may be noted that at low concentration the low molecular weight conglomerates in globs; more than at equivalent concentrations with the medium molecular weight. The

This experiment tested the impact of temperature on silk coated fabric.

Material 15042001—Non-wicking finish—fabric having a composition of 82% polyester and 18% elastane.

Material TFF-01-0012/TFF-01-0010—6% silk solution, medium molecular weight.

Material TFF-01-0013—6% silk solution, low molecular weight.

TABLE 38

Sample	Sample Preparation
16040101 (Sample 1)	TFF-01-0012 @ 1% silk solution, 50 setting on padders, 65° C. drying temperature, 10 min curing time, temperature on fabric surface at end of curing was 51.6° C.
16040102 (Sample 2)	TFF-01-0012 @ 1% silk solution, 50 setting on padders, 150° C. drying temperature; 5 min curing tie, temperature on fabric surface at end of curing was 125.3° C.
16040103 (Sample 3)	TFF-01-0012 @ 1% silk solution, 50 setting on padders, 200° C. drying temperature, 3 min drying time, temperature on fabric surface at the end of curing was 165.8° C.
16040104 (Sample 4)	TFF-01-0013 @ 1% silk solution, 50 setting on padders, 200° C. drying temperature, 3 min drying time, temperature on fabric surface at the end of curing was 144° C.
106040105 (Sample 5)	TFF-01-0013 @ 1% silk solution, 50 setting on padders, 150° C. drying temperature, 5 min drying time, temperature on fabric at the end of curing was 130.7° C.
106040106 (Sample 6)	TFF-01-0013 @ 1% silk solution, 50 setting on padders, 65° C. drying temperature, 10 min drying time, temperature on fabric surface at the end of curing was 64° C.

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medium molecular weight fibers have excellent polyester fibers at any concentration and temperature and a network of bridging fibers may be more visible at higher concentrations.

The samples mass recording is reported in the following table for each variable tested.

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TABLE 39

Sample #	Variables	Mass Before Coating	Mass Post Coating	Coating Mass %
16040101	1%, medium 65 C., 10 min	28.357	28.6268	0.95%
16040102	1%, medium, 150 C., min.	28.2137	28.4231	0.74%
16040103	1%, medium, 200 C., 3 min	28.2459	28.4365	0.67%
16040104	1% low, 200 C., 3 min	28.0225	28.1442	0.43%
16040105	1% low, 150 C., 5 min	27.9803	28.1203	0.50%
16040106	1% low, 65 C., 10 min	28.5204	28.7611	0.84%

50 The collective results are provided in FIG. 327 for each tested material. However, sample 16040102 did not produce acceptable results and 15042001 is provided as a reference, which is not coated.

55 The results of these analyses are provided in table form in FIG. 338. Specifically, FIG. 338 describes the grading for each tested sample (medium and low molecular weight samples) in terms of wetting (top and bottom), absorption rate (top and bottom), wetted radius (top max and bottom

TABLE 37

Experimental parameters	Variables		
silk solution concentration	1%		
silk solution molecular weight	medium	low	
Wet pickup	at 50 setting on padder		
Temperature @ heat setting (C.)	65	150	200
Curing time (min)	10	5	3

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max), spreading speed (top and bottom), accumulative one-way transport, and overall moisture management capability (OMMC).

From the presented results the SFS coated fabric has an impact on the MMT grading of fabric, significantly improving the accumulative one way transport index from the non-coated standard of grade 2 to the SFS coated grades of 4-5 depending on molecular weight and curing time and temperature. While with the OMMC index the non-coated standard has a grade of 1 compared to the SFS coated grades of 3 independent of tested variables.

Example 18: Impact of SFS Concentration at Low and Medium Molecular Weight Samples

This experiment tested the impact of SFS concentration at 2 molecular weights using the same drying and curing temperature time. The fabrics were characterized by mass and Liquid Moisture Management Properties of Textile Fabrics (MMT) following AATCC Test Method 195-2012.

The experimental parameters are provided in Table 40.

TABLE 40

Experimental parameters	Variables							
silk solution concentration	0.750%	0.500%	0.250%	0.100%	0.075%	0.050%	0.025%	0.010%
silk solution molecular weight	medium	low	medium	low	medium	low	medium	low
Wet pick up	at 50 setting on padder							
Temperature @ heat setting °C.	150							
Curing time (min)	5							
Padder speed (m/min)	3							

The samples mass recording is reported in the following table for each variable tested (Table 41).

TABLE 41

Sample #	Variables	Mass Before Coating	Mass Post Coating	Mass Post 24 hrs Coating	Coating Mass %
16040801	0.75%, medium mw silk, 150 C., 5 min	27.7229	27.8157	27.8731	0.54%
16040802	0.25%, medium mw silk, 150 C., 5 min	27.5821	27.5660	27.6011	0.07%
16040803	0.075%, medium mw silk, 150 C., 5 min	27.5871	27.5154	27.5582	-0.10%
16040804	0.025%, medium mw silk, 150 C., 5 min	27.7265	27.6364	27.6771	-0.18%
16040805	0.50%, low mw silk, 150 C., 5 min	27.9121	27.9367	27.9646	0.19%
16040806	0.10%, low mw silk, 150 C., 5 min	27.6692	27.5963	27.6298	-0.14%
16040807	0.05%, low mw silk, 150 C., 5 min	27.8840	27.8040	27.8389	-0.16%
16040808	0.01%, low mw silk, 150 C., 5 min	28.1490	28.0500	28.0755	-0.26%

Sample test results for each variable tested are reported in the table set forth in FIG. 329, where sample 15042001 is a non-coated control. Sample test grading for each variable tested are reported in the table provided in FIG. 340.

From the presented results the SFS coated fabric has an impact on the MNIT grading of fabric, significantly improving the accumulative one way transport index from the non-coated standard of grade 2 to the SFS coated grades of

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5 depending on molecular weight (low vs. medium) and SFS concentration. While with the OMIVIC index the non-coated standard has a grade of 1 compared to the SFS coated grades of 3 independent of tested variables.

Example 19: Tested Impact of Curing Time on Coatings at Two Molecular Weights

This experiment tested the impact of curing time at 150° C. and 200° C. with SFS at 1% concentration at two molecular weights. The fabrics were characterized by mass and Liquid Moisture Management Properties of Textile Fabrics (MMT) following AATCC Test Method 195-2012. The experimental parameters are provided in Table 42.

TABLE 42

Experimental Parameters	Variables	
silk solution concentration	1.000%	
silk solution molecular weight	medium	low
Wet pick up	at 50 setting on padder	

TABLE 42-continued

40	Experimental Parameters	Variables		
Temperature @ heat setting °C.	150	200		
Curing time (min)	3	5		10
Padder speed (m/min)	3	3		

The samples mass recording is reported in the following table for each variable tested (Table 43).

TABLE 43

50	Sample #	Variables	Mass Before Coating	Mass Post Coating	Mass Post 24 hrs Coating	Coating Mass %
16041201	1% low mw silk, 150 C., 10 min	28.2130	28.2708	28.3311	0.42%	
16041202	1% low mw silk, 200 C., 10 min	28.0331	28.0221	28.0575	0.09%	
16041302	1%, low mw silk, 150 C., 5 min	27.7916	27.8905	27.9608	0.61%	
16041303	1%, low mw silk, 200 C., 3 min	27.7066	27.7484	27.7973	0.33%	
16041903	1% medium mw silk, 200 C., 10 min	77.8510	27.8545	27.9256	0.27%	
16041204	1% medium mw silk, 150 C., 10 min	27.0315	27.1104	27.1567	0.46%	
16041305	1%, medium mw silk, 200 C., 3 min	28.1509	28.2656	28.3306	0.64%	

TABLE 43-continued

Sample #	Variables	Mass				
		Before Coating	Mass Coating	Post Coating	24 hrs Coating	Coating %
16041306	1% medium mw silk, 150 C., 5 min	27.3574	27.5165	27.5715	0.78%	
16041301	no coating, 150 C., 5 min	26.7848	26.6993	26.7412	-0.16%	
16041304	no coating, 200 C., 3 min	27.8559	27.7539	27.7896	-0.24%	

Sample test results for each variable tested are reported in the table set forth in FIG. 341, where samples 16041301 and 16041304 are non-coated fabrics for reference. Sample test grading for each variable tested are reported in the table provided in FIG. 342.

From the presented results the curing temperature time may reduce the MMT grading when 1% SFS coated fabric is exposed between 5-10 minutes at 150° C. or 200° C. At the other curing time tested 3 and 5 minutes at 150° C. or 200° C. there is no apparent impact on accumulative one way transport or OMMC grades.

Example 20

This experiment tested the impact of temperatures of 65° C., 150° C., and 200° C. at the minimum drying and curing time with 1% SFS at two molecular weights. The fabrics were characterized by mass and Liquid Moisture Management Properties of Textile Fabrics (MMT) following AATCC Test Method 195-2012.

The experimental parameters are provided in Table 44.

TABLE 44

Experimental Parameters		Variables	
silk solution concentration	1%	no solution	
silk solution molecular weight	medium	low	
Wet pick up	at 50 setting on padder		
Temperature @ heat setting (C.)	150	200	
Curing time (min)	5	3	
Padder speed	3	3	

The samples mass recording is reported in the following table for each variable tested (Table 45).

TABLE 45

Sample #	Variables	Mass				
		Before Coating	Mass Coating	Post Coating	24 hrs Coating	Coating %
16041301	no coating, 150 C., 5 min	26.7848	26.6993	26.7412	-0.16%	
16041302	1%, low mw silk, 150 C., 5 min	27.7916	27.8905	27.9608	0.61%	
16041303	1%, low mw silk, 20 C., 3 min	27.7066	27.7484	27.7973	0.33%	
16041304	no coating, 200 C., 3 min	27.8559	27.7539	27.7896	-0.24%	
16041305	1%, medium mw silk, 200 C., 3 min	28.1509	28.2656	28.3306	0.64%	
16041306	1%, medium mw silk, 150 C., 5 min	27.3574	27.5165	27.5715	0.78%	

TABLE 45-continued

Sample #	Variables	Mass				
		Before Coating	Mass Coating	Post Coating	24 hrs Coating	Coating %
15042001	no coating					
16040101	1%, medium mw silk, 65 C., 10 min	28.357	28.6268			
16040106	1%, low mw silk, 65 C., 10 min	28.5204	28.7611			

Sample test results for each variable tested are reported in the table set forth in FIG. 333, where samples 16041301, 16041304, and 15042001 are non-coated fabrics for reference. Sample test grading for each variable tested is reported in the table provided in FIG. 334.

From the presented results the curing temperature of 65° C., 150° C., and 200° C. has limited to no impact on the MMT grading when 1% SFS coated fabric is exposed for respectively 3, 5, and 10 minutes. Medium molecular weight coated fabrics have faster wetting time than low molecular weight coated fabrics or non-coated control fabrics. Low molecular weight coated fabrics exhibit a faster spreading time than medium molecular weight coated fabrics or non-coated control fabrics. Medium molecular weight coated fabrics or low molecular weight coated fabrics perform equal to or better than non-coated control fabrics in terms of Accumulative One Way Transport and OMMC.

Example 21: Listing of Specific Fabrics

Table 46 includes a listing of coated and non-coated fabrics tested in the present Examples and their associated coating process variables.

TABLE 46

Sample ID	Variables
16040101	1% SFS, medium, 65 C., 10 min
16040102	1% SFS, medium, 150 C., 5 min
16040103	1% SFS, medium, 200 C., 3 min
16040104	1% SFS, low, 200 C., 3 min
16040105	1% SFS, low, 150 C., 5 min
16040106	1% SFS, low, 65 C., 10 min
16040801	0.75% SFS, medium mw silk, 150 C., 5 min
16040802	0.25% SFS, medium mw silk, 150 C., 5 min
16040803	0.075% SFS, medium mw silk, 150 C., 5 min
16040804	0.025% SFS, medium mw silk, 150 C., 5 min
16040805	0.50% SFS, low mw silk, 150 C., 5 mm
16040806	0.10% SFS, low mw silk, 150 C., 5 min
16040807	0.05% SFS, low mw silk, 150 C., 5 min
16040808	0.01% SFS, low mw silk, 150 C., 5 min
16041201	1% SFS, low mw silk, 150 C., 10 min
16041202	1% SFS, low mw silk, 200 C., 10 min
16041203	1% SFS, medium mw silk, 200 C., 10 min
16041204	1% SFS, medium mw silk, 150 C., 10 min
16041301	no coating, 150 C., 5 min
16041302	1% SFS, low mw silk, 150 C., 5 min
16041303	1% SFS, low mw silk, 200 C., 3 min
16041304	no coating, 200 C., 3 min
16041305	1% SFS, medium mw silk, 200 C., 3 min
16041306	1% SFS, medium mw silk, 150 C., 5 min
16042501	0.075% SFS, medium mw silk skin side up
16042502	0.075% SFS, medium mw silk skin side down
16042503	0.1% SFS, low mw silk skin side up
16042504	0.01% SFS, low mw silk skin side down
16050301	1% SFS, low mw silk, 200 C. 3 min
16050302	0.1% SFS, low mw silk, 200 C., 3 min
16050303	1% SFS, medium mw silk, 200 C. 3 min
16050304	1% SFS, medium mw silk, 200 C. 3 min
16050305	1% SFS, medium mw silk, 200 C. 3 min
16050306	0.1% SFS, medium mw silk, 200 C., 3 min

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TABLE 46-continued

Sample ID	Variables
16050307/	non wicking finished, 200 C., 3 min
15042001	
16050308/	non wicking finished, 200 C., 3 min
15042001	
16050309/	non wicking finished, 200 C., 3 min
15042001	
16050310/	non wicking finished, 150 C., 5 min
15042001	
16050311/	non wicking finished, 150 C., 5 min
15042001	
16050312/	non wicking finished, 150C. 5 min
15042001	
16050401	0.1% SFS, medium mw silk, 65 C. 10 min
16050402	0.1% SFS, medium mw silk, 150 C. 5 min
16050403	0.1% SFS, medium mw silk, 200 C. 3 min
16050404	0.25% SFS, medium mw silk, 65 C. 10 min

	Sample ID	Variables
5	16050405	0.25% SFS, medium mw silk, 150 C. 5 min
	16050406	0.25% SFS, medium mw silk, 200 C. 3 min
	16050407	0.1% SFS, low mw silk, 65 C. 10 min
	16050408	0.1% SFS, low mw silk, 150 C. 5 min
	16050409	0.1% SFS, low mw silk, 200 C. 3 min
	16050410	0.25% SFS, low mw silk, 65 C. 10 min
10	16050411	0.25% SFS, low mw silk, 150 C. 5 tnin
	16050412	0.25% SFS, low mw silk, 200 C. 3 min

TABLE 46-continued

Example 22: A Map of the Fabric Samples Tested

15 A number of the coated and non-coated fabrics described
herein were tested for anti-microbial activity. Those fabrics,
and their identities and process variables, are set forth in
Table 47.

TABLE 47

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Example 23: Results of Liquid Moisture Management Tests

FIG. 335 provides a map of Liquid Moisture Management Test results for various coated fabrics described herein.

Example 24: Silk Fibroin Solution with Silicone Softener

The objective of this study will be to evaluate the impact to the hand of the fabric of two types of silicon softeners in conjunction with silk fibroin solution. In addition, Liquid Moisture Management testing (MMT) according to AATCC 195-2012 will be completed on the samples, and a drapability test according to the drape elevator method modified to accommodate samples dimension.

This study will be performed to evaluate the changes in hand characteristics of a fabric when commercially available silicon softeners are mixed with different percentage and molecular weight of silk fibroin solution followed by a drying and curing process. The fabrics will be characterized for Moisture Management properties and drapability.

Materials and equipment for the study include Silk Therapeutics medium molecular weight solution at 6%, Silk Therapeutics low molecular weight solution at 6%, Huntsman Ultratex CSP, Huntsman Ultratex SI, Acetic acid, Citric acid, RODI water, Fabric sample 15042001 non-wicking finish, a permanent marker, Werner Mathis MA0881 padder/coater, curing frame, Across International Oven FO-19140, Balance Veritas M314-AI, Universal plastic PH test strip, Drape elevator test fixture, and an LG Nexus 5× phone camera.

Silk coated fabric will be prepared following SOP-TEMP-001. Silk solution concentration will be prepared at the desired concentration as reported in the table below and is mixed to the desired concentration of silicon softener as reported in Table 48. The coating solution is applied to the fabric with bath immersion and pad roller pressure setting at 50. After coating the fabric is dry/cure in the oven at 200 C for 3 minutes.

TABLE 48

Experiment Variables				
Silk solution medium mw silk	Ultratex SI	Ultratex CSP	Acetic acid	Citric acid
1%	22 gr/liter			
1%		50 gr/liter		
1%	22 gr/liter		0.5 gr/liter	
1%		50 gr/liter	1 gr/liter	
1%				1 gr/liter
1%				0.5 gr/liter
No Silk	22 gr/liter			
No Silk		50 gr/liter		
No Silk	22 gr/liter		0.5 gr/liter	
No Silk		50 gr/liter	1 gr/liter	

Post curing the fabric is left to condition at room temperature for 24 hr.

Samples are cut to 8 cm by 8 cm square and delivered to MSC lab for MMT testing.

After conditioning the fabric is tested for drapability using the drape elevator test modified to accommodate the MMT sample size dimension. After placing the sample on the testing jig an image is recorded with a camera; the elevator is lowered until no more contact is made with the fabric by the elevator table and a second image is recorded. Image

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analysis of the fabric area is performed through photoshop. A drape coefficient is calculated with the following formula:

$$Drape\ Coefficient = \frac{Ad - S1}{S2 - S1} * 100,$$

where Ad is the vertical projection of the draping sample, S1 the area of the round sample holder, and S2 is the area of the sample.

Example 25: Antibacterial Study

An experiment is devised for evaluating the antibacterial proliferation on SFS coated fabrics through multiple washing cycles. Specifically, the study will examine whether bacteria will adhere to silk-coated fabric following wash.

The study will mimic the bacterial deposition on textile material during regular exercise and home laundering.

The antibacterial testing will be at 0, 1, 10, and 25 minute cycles using a front loading washer with water at less than 30° C. The fabrics will be air or tumble dried at less than 50° C.

A 13.5×13.5 inch fabric swatch will spotted with eight (8) inoculation sites and tested following washing at the disclosed intervals to determine the presence and quantity of bacteria.

Example 26: Drapability of Exemplary Silk Coated Fabrics

The following coated fabrics were prepared according to the processes described herein and tested for drapability according to the method described in Mizutani, et al., "A New Apparatus for the Study of Fabric Drape." *Textile Research Journal* (2005) 75: 81-87.

The materials in the method include a sample and camera holding fixture, sample holding fixture of 5 cm in diameter, an elevator plane, and a camera. The fabric specimens were 8×8 cm². The procedure included: (1) cutting the sample to 8×8 cm square (8 cm diameter may be used); (2) placing the specimen at the center of a fixture; (3) elevating the fixture to examine the draping of the specimen; and (4) capture an image of the specimen.

The images were opened in Adobe Photoshop CS5.1 and the lazo function was used to delimit the perimeter of the specimen. The measurement function was then used to count all the pixels within the selected area and such data was saved. This process was repeated for each specimen. A drape coefficient was calculated based on the following formula:

$$Drape\ Coefficient = \frac{Ad - S1}{S2 - S1} * 100,$$

where Ad is the vertical projection of the draping sample, S1 is the area of the round sample holder, and S2 is the area of the sample. The data for such analysis is set forth in Table 49 and associated FIG. 336.

TABLE 49

Sample No.	Sample Properties	Avg. Drapability Coefficient	STDev
16052001	1% medium mw silk solution, + 2.2% ULTRATEX ® SI ("SI")	80.0	1.9

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TABLE 49-continued

Sample No.	Sample Properties	Avg. Drapability Coefficient	STDev
16052002	1% medium mw silk, + 2.2% SI + acetic acid 0.5%	88.2	2.1
16052003	1% medium mw silk solution, + 5% ULTRATEX ® CSP ("CSP")	81.8	3.1
16052004	1% medium mw silk solution, + 5% CSP + acetic acid 1%	88.2	2.9
16052005	1% medium mw silk solution, + 0.1% citric acid	92.7	0.7
16052006	1% medium mw silk solution, + 0.05% citric acid	89.9	0.4
16051103	no coating, 200 C., 3 min	83.2	1.4
16051109	0.25%, medium mw silk solution, 200 C. 3 min	85.7	1.7
16051115	0.25%, low mw silk solution, 200 C. 3 min	89.9	2.4
16052501	2.2% SI	69.1	4.4
16052502	2.2% SI acetic acid 0.5%	61.7	1.9
16052503	5% CSP	61.6	4.8
16052504	5% CSP + acetic acid 1%	59.5	3.5

According to the foregoing study, silk solution, drying parameters, and silicone compositions were used to adjust the drapability for a variety of coated fabrics.

Example 27: Effect of Mechanical and Steam Finishing on a Silk Coated Fabric

A sample was prepared according to the method set forth in Example 26, wherein the sample was a polyester/LYCRA non-finished fabric coated with a 1% SFS (medium molecular weight) that was dried at 200° C. for 3 minutes. In addition, the same fabric was subjected to a 41 minutes dryer cycle at normal setting on medium temperature (mechanical finishing) and to steaming on a steam table for 5 seconds (steam finishing). The resulting samples, after finishing, were examined for drapability as shown in Table 50 and in FIG. 337.

TABLE 50

Sample No.	Sample Properties	Avg. Drapability Coefficient	STDev
16041305	1% medium mw silk, 200 C. 3 min	82.1	1.2176
16041305	post mechanical finish	80.0	2.3692
16041305	post steam finish	91.4	2.7572

While the mechanical finishing with the dryer reduced the drapability coefficient (i.e., less stiff fabric), the steam finishing increased the drapability coefficient (i.e., stiffer fabric).

Results of experiments measuring solution depletion calculation during coating are shown in FIG. 338, and illustrate the amount of silk fibroin deposited on fabrics.

Additional results of moisture management testing of coated fabrics are given in FIG. 339 to FIG. 344.

Additional results from antimicrobial testing of coated fabrics are given in FIG. 345 and FIG. 346.

Example 28: Effectiveness of Diluting Silk with Tap Water

The silk compositions described herein are stable and effective when prepared with tap water.

A 1:1 ratio between the silicone and silk gave a softer hand to a resulting fabric with a 20:1 ratio between silk/silicone and citric acid.

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The parameters for the study between tap water and reverse-osmosis/deionized (RODI) water are set forth in Table 51.

TABLE 51

Silk Solution	Water	Softener	pH Correction
0.25% med mw silk	RODI		
0.25% med mw silk	RODI	0.25% Ultratex CSP	0.02% citric acid (50%)
0.25% low mw silk	RODI	0.25% Ultratex CSP	0.02% citric acid (50%)
0.25% med mw silk	Unfiltered tap		
0.25% med mw silk	Unfiltered tap	0.25% Ultratex CSP	0.02% citric acid (50%)
0.25% low mw silk	Unfiltered tap	0.25% Ultratex CSP	0.02% citric acid (50%)

The parameters for a second study are set forth in Tables 56 and 57. The results of this study are illustrated in FIG. 373. The second study relates to a water drop test on polyester/lycra knitted fabric treated with RODI water and tap water.

TABLE 56

Experimental Parameters	Variables
silk solution concentration	0.25%
silk solution molecular weight	medium
water	low
RODI	tap water
Wet pick up	—
at 50 setting on padder	—
Temperature @ heat setting (C.)	200
Curing time (min)	3
silicon softener Ultratex CSP	0.25%
citric acid	0.0200%

TABLE 57

Sample Number	Description	Time to absorb (sec)
16070601	0.25% medium mw silk (RODI)	—
16070602	0.25% medium mw silk, 0.25% Ultratex CSP, 0.02% citric acid (50%)	25
16070603	0.25% low mw silk	1
16070604	0.25% low raw silk, 0.25% Ultratex CSP, 0.02% citric acid (50%)	10
16070605	0.25% medium mw silk (tap water)	2
16070606	0.25% medium mw silk, 0.25% Ultratex CSP, 0.02% citric acid (50%)	30
16070607	0.25% low mw silk	—
16070608	0.25% low mw silk, 0.25% Ultratex CSP, 0.02% citric acid (50%)	22

The results of the foregoing study indicated that there was no difference in the resulting properties of those silk solutions prepared in RODI water as compared to unfiltered tap water. Moreover, the silk solutions did not precipitate with the use of tap water.

Example 29: A Study of Silk Solution as a Wicking Agent

Silk solutions as disclosed herein can be adopted as a wicking agent in common finishing recipes to balance the water repellency of silicone softeners.

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The present test is a modification to AATCC-79-2014 that was prepared to accommodate the dimensions of the tested samples (8×8 cm samples), where the AATCC test is designed for a sample of 150 cm in diameter. Here, the samples are cut in 8 cm by 8 cm and placed in a drapability jig suspended on a 7 cm diameter round metal hoop so the back of the fabric has no surface contact. An RODI water drop is dispensed with an eye dropper from approximately 3 cm above the fabric. A video imaging recording captures the time from the water drop contacting the fabric until its full absorption or up to 30 seconds.

Without silk, the water drop stays on the fabric surface up to the test end of 30 seconds; while in the presence of silk the water drop is absorbed in as long as 4 seconds or as fast as 1 second depending on the tested variables.

The parameters for this study are set forth in Table 52 with the results set forth in FIGS. 347 and 348.

TABLE 52

Sample Number	Description	Time to absorb (sec)
16062901	0.22% Ultratex SI	30
16062902	0.5% Ultratex CSP	30
16062905	0.22% Ultratex SI, 0.025% citric acid	30
16062906	0.5% Ultratex CSP, 0.025% citric acid	30
16062105	0.5% medium mw silk, 0.22 gr/liter Ultatex SI	3
16062106	0.5% low mw silk, 0.5 gr/liter Ultatex. CSP	
16062107	0.5% low mw silk, 2.2 gr/liter Ultratex SI, 0.025 gr/liter citric acid	1
16062108	0.5% medium mw silk, 5 gr/liter Ultratex CSP, 0.025 gr/liter citric acid	4

Example 30: A Study of Dyeing Polyester and Nylon Fabrics Followed by the Application of Silicone and Silk Solution through Exhaust

The objective of this study is to evaluate the application of silk fibroin solution on fabrics made with polyester/spandex and nylon/spandex. The application will take place after dyeing the fabrics at exhaust. In addition, silicon softeners will be added to the silk solution to improve the hand of the fabrics. Liquid Moisture Management testing (MMT) according to AATCC 195-2012, a drapability test according to the drape elevator method modified to accommodate samples dimension, and a water drop test will be used to characterize the fabrics.

This study was performed for research and development purposes to evaluate the feasibility to apply silk fibroin solution at exhaust post dyeing. In addition, commercially available silicon softeners were mixed with different percentage and molecular weight of silk fibroin solution to improve hand and drapability of the fabric.

Materials:

Silk Therapeutics medium molecular weight solution at 6%;
Silk Therapeutics low molecular weight solution at 6%;
Huntsman Ultratex CSP;
Huntsman Ultratex SI;
Acetic acid;
Fabric sample polyester/spandex; and
Fabric sample nylon/spandex.

Equipment:

5 pounds paddle dyer by Rome Machine Foundry Co. SN #640115;
5 pounds pressure dyer by Optidye RS Basic Plus;

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Hydroextractor;
Balance Veritas M314-AI;
Universal plastic PH test strip;
Drape elevator test fixture; and
5x phone camera.

Methods:

Nylon

The fabric sample is placed in the 5-pound paddle dryer along with enough dunnage to total 3-pound load. The tub is filled with water. The following wetting and scouring agent are added:

1.0% wetter D.75 OWG;
1.0% scour SKB OWG;
4.0% black 2RSLD OWG;
acetic acid 56% to reach PH 5.5;
2.0% softener RWS Hydrophilic OWG; and
3% fix agent ED 73% OWG.

The dyer is run at 100 F for 5 minutes. Dye is added and run for 10 minutes. The sample is heated at a rate of 4 F/minute up to 200 F. Acetic acid is added to a pH of 5.5. The sample is allowed to run for 45 more minutes.

A sample color shade is prepared and, if acceptable, the sample is allowed to cool to 160 F.

The solution is dropped and refilled than refilled and run for 5 times, with the entire process repeated 4 times.

Softener is then added (i.e., silicon and silk solution at the concentration reported in Table 53) heat to 160 F and run for 10 minutes. Drop solution and remove fabric from the machine.

TABLE 53

Silk solution	Ultratex SI	Ultratex CSP
0.1% low mw silk	1 gr/liter	2.5 gr/liter
0.1% low mw silk	1 gr/liter	2.5 gr/liter
0.5% low mw silk	1 gr/liter	2.5 gr/liter
0.1% medium mw silk	1 gr/liter	2.5 gr/liter
0.1% medium mw silk	1 gr/liter	2.5 gr/liter
0.5% medium mw silk	1 gr/liter	2.5 gr/liter
0.5% medium mw silk	1 gr/liter	2.5 gr/liter
0.5% medium mw silk	1 gr/liter	2.5 gr/liter
0.5% medium mw silk	1 gr/liter	2.5 gr/liter
Control (only dye)	Control only dye	Control (only dye)

Polyester

The fabric sample is placed in the 5-pound pressure dryer along with enough dunnage to total 3-pound load. The tub is filled with water. The following wetting and scouring agent are added for pre-scouring process: 1.0% wetter and 2.0% scour.

The solution was heated to 180 F for 20 minutes. The solution was dropped and rinsed. To the solution was added 1% wetter, acetic acid to PH 5.0, with a leveler used as desired, and heated to 110 F. Dissolved dyes were added and heated to 180 F, with the temperature held for 10 minutes. The solution was then heated to 265 F at 3 F/minute and held at 265 F for 90 minutes.

The solution was then cooled to 180 F and the color shade was sampled. Upon acceptance, the solution was dropped and rinsed three times. The solution was further cooled to 140 F and hydro was added for 15 minutes. The solution was again dropped and rinsed 2-3 times until clean. The solution was then cooled to 110 F and softener was added (silicone and silk solution at the concentration reported in Table 53) for 10 minutes. The solution was dropped and the fabric was removed from the machine.

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The fabric is dried by first removing excess fluid with Hydroextractor followed by a dryer cycle at normal setting with low temperature. Samples are cut to 8 cm by 8 cm square and delivered to MSC lab for MMT testing. Samples cut in 8 cm by 8 cm that are not tested for MMT are placed in the drapability jig suspended on a 7 cm diameter round metal hoop. A RODI water drop is dispensed with an eye dropper from approximately 3 cm above the fabric. A video image recording captured the time from the water drop contacting the fabric until its full absorption or up to 60 seconds.

After conditioning, the fabric is tested for drapability using the drape elevator test modified to accommodate the MMT sample size dimension. After placing the sample on the testing jig an image is recorded with a camera; the elevator is lowered until no more contact is made with the fabric by the elevator table and a second image is recorded. Image analysis of the fabric area is performed through photoshop. A drape coefficient is calculated with the following formula:

$$\text{Drape Coefficient} = \frac{Ad - S1}{S2 - S1} * 100,$$

where Ad is the vertical projection of the draping sample, S1 the area of the round sample holder, and S2 is the area of the sample. The fabrics with a water drop test<3 seconds and a drapability of <90 were submitted for MMT testing.

Example 31: Bacterial Wash Adherence Study through Washing Machine Cycle

The objective of this study was to evaluate the bacterial proliferation through multiple washing cycles in the laboratory while duplicating the bacterial deposition on textile materials that take place during regular exercise.

Materials. The following list of materials were used for fabric sample preparation and study execution:

Polyester/Lycra fabric 15042201;

Deionized water;

6% Mid-MW silk provided by Silk Therapeutics, Inc.;

6% Low-MW Silk provided by Silk Therapeutics, Inc.;

Launtry Permanent Marker;

Front loader washing machine LG model WM3370HWA;

AATCC detergent without optical brightener liquid H/E;

Satphylococcus aureus subsp. *aureus* Rosenbach ATCC® 6538;

Inoculum carrier to be 5% Nu-broth;

Letheen broth with tween as neutralizer for enumeration;

BD Difco Leethen broth #268110; and

Concentrated Clorox regular bleach.

Equipment. The following is a list of equipment used from the fabric sample preparation and study execution:

Werner Mathis MA-881 paddler/coater;

Curing frame;

Across International Oven FO-19140;

Balance Veritas M314-AI;

Universal plastic PH test strip; and

Tempo Filler and Reader from BioMerieux for enumeration.

Methods.

Fabric Sample Preparation. Silk coated fabric is prepared following SOP-TEMP-001. Silk solution concentration at 0.05% is applied to the fabric with bath immersion with the paddler's roller pressure setting at 50 and 200 C curing time

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for 3 minutes. Fabric sample with 13.5 inches by 13.5 inches are divided with a permanent marker to delimit 8 equivalent areas.

Bacteria Inoculation. At the center for each of the 8 areas 5 2×10^7 cfu of bacteria solution was inoculated. The total load per washing cycle was expected to be $1-2 \times 10^8$ CFU. The inoculated fabric was allowed to air dry for 60 minutes.

Washing Cycle. The inoculated fabric was placed in the washing machine with 1.8 kg of cotton towel as dunnage 10 with 50 mL of detergent. A washing machine cycle at gentle setting with warm water at less than 30 C was completed. The inoculated fabric was removed from the washing machine and allowed to air dry for 120 minutes. After each 15 washing cycle the dunnage was bleached with 120 mL concentrated Clorox regular bleach to eliminate any bacteria transfers from the tested specimen to the dunnage.

Bacteria Enumeration. At the preset interval reported in FIG. 349, from the dried inoculated fabric 2 square samples 20 were cut out and the bacteria count was enumerated following, as a guideline, the enumeration method of AATCC 100.

Tested Variables. FIG. 349 reports the variables tested with this study.

Study Execution. For the fabric to be inoculated, multiple bacteria inoculation washing cycles and testing for bacteria 25 enumeration at different intervals were executed on each tested fabric as reported in FIG. 350. For the fabric with no inoculation, the same washing cycle and testing for bacteria enumeration at the same intervals reported in FIG. 350. Since at enumeration swatches of fabric were removed from 30 the fabric, to maintain the total bacterial load per washing cycle, an additional piece of control fabric was added to the dunnage. The additional fabric was inoculated with the balance of bacteria load. For example, after 1 washing cycle the additional fabric received 4×10^7 of bacteria load. FIG. 350 reports the additional load required.

Methods of Analysis. Analysis was performed to determine antibacterial properties of the fabric following, as guidelines, the enumeration method of AATCC 100: Antibacterial Finishes. The fabric sample is placed in a polypropylene container with 100 mL of Lethem broth and shaken for 60 seconds. The bacteria count is then enumerated with Tempo filler reader. At each tested interval two side by side tested samples are cut out from the fabric as 40 reported in FIG. 349 and tested with duplicates. After each 45 enumeration the fabric was tested for any odor intensity and for any changes between T=0 and the enumerated tested sample. Odor is evaluated on the following scale: 0=no odor; 1=very weak (odor threshold); 2=weak; 3=distinct; 4=strong; 5=very strong; and 6=intolerable. After each 50 enumeration, high resolution image recording was taken for each sample so enumerated.

FIG. 350 describes the bacterial counts and various wash conditions for samples tested in accordance with the foregoing.

55 FIGS. 354 to 356 illustrate bacterial colony formation in the Lethem broth for coated samples 16060901 and 16060903 and non-coated samples 16060902 and 16060904.

FIGS. 357 and 358 illustrate control colony formation in Lethem broths.

60 The fabric surfaces were also examined during the study for both the coated and non-coated fabrics. FIGS. 359A-359C to 362A-362C illustrate microscopic images of the coated (Samples 16060901 and 16060903) and non-coated samples (Samples 16060902 and 16060904) prior to washing. FIGS. 363A-363C to 366A-366C illustrate microscopic images of the coated (Samples 16060901 and 16060903) and non-coated samples (Samples 16060902 and 16060904)

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after one washing. FIGS. 367A-367C to 370A-370C illustrate microscopic images of the coated (Samples 16060901 and 16060903) and non-coated samples (Samples 16060902 and 16060904) after 10 washings. A qualitative analysis of the foregoing microscopic images was performed to observe the % foreign matter coverage area on the observable fibers in FIGS. 359A-359C to FIGS. 370A-370C (See FIG. 371). As shown in FIG. 371, the coated inoculated fibers displayed little or no foreign matter on their observable surfaces as compared to the non-coated inoculated fibers.

FIG. 352A demonstrates how the bacteria enumeration at time 0 without any bacteria load is maintained by all fabric study variables that are inoculated with bacteria and non inoculated with bacteria subject to the same 1 washing cycle and 10 washing cycles.

In addition, FIG. 352B demonstrates that through all the bacteria loading and washing cycles no odor is noticeable on the fabric surfaces except for a weak detergent scent in all the tested variables.

The presence of silk does not contribute to increased bacteria adherence on the fabric surface, while any bacteria that may be deposited on the surface it can be removed through a standard home laundering cycle.

As described by the foregoing data, bacteria did not appear to adhere to the coated materials after washing.

Example 32. A Water Drop Study with Silk and Silicone Coated Fabrics

A study was performed to determine the effect of water wicking on fabrics coated with silk and silicone that have been treated with citric acid.

As shown herein, citric acid does not function as a wicking agent. However, with a 1:1 ratio of silk/silicone at 0.25%, the water took a longer time to absorb than that observed with previously described water drop studies.

The parameters for a first study are set forth in Table 54 and 55. The results of this study are illustrated in FIGS. 373 and 374.

TABLE 54

Experimental Parameters	Variables
silk solution concentration	
silk solution molecular weight	
Wet pick up	at 50 setting on padder
Temperature @ heat setting (C.)	200
Curing time (min)	3
silicon softener Ultratex SI	0.22%
silicon softener Ultratex CSP	0.50%
citric acid	0.0250%

TABLE 55

Sample Number	Description	Time to Absorb (sec)
16062901	0.22% Ultratex SI	30
16062902	0.5% Ultratex CSP	30
16062905	0.22% Ultratex SI, 0.025% citric acid	30
16062906	0.5% Ultratex CSP, 0.025% citric acid	30
16062105	0.5% medium mw silk, 0.22 gr/liter Ultratex SI	
16062106	0.5% low mw silk, 0.5 gr/liter Ultatex CSP	
16062107	0.5% low mw silk, 2.2 gr/liter Ultratex SI, 0.025 gr/liter citric acid	1

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TABLE 55-continued

Sample Number	Description	Time to Absorb (sec)
16062108	0.5% medium mw silk, 5 gr/liter Ultratex CSP, 0.025 gr/liter citric acid	4
16051103	no coating, 200 C., 3 min	1
16070701	0.025% citric acid	1

All patents, patent applications, and published references cited herein are hereby incorporated by reference in their entirety. While the methods of the present disclosure have been described in connection with the specific embodiments thereof, it will be understood that it is capable of further modification. Further, this application is intended to cover any variations, uses, or adaptations of the methods of the present disclosure, including such departures from the present disclosure as come within known or customary practice in the art to which the methods of the present disclosure pertain.

We claim:

1. An article comprising leather having a coating, wherein the coating comprises silk fibroin fragments having an average weight average molecular weight selected from between about 5 kDa and about 144 kDa, between about 5 and about 10 kDa, between about 6 kDa and about 16 kDa, between about 17 kDa and about 38 kDa, between about 39 kDa and about 80 kDa, between about 60 and about 100 kDa, or between about 80 kDa and about 144 kDa, wherein the silk fibroin fragments have a polydispersity of between 1 and about 5.0, and wherein the silk fibroin fragments, prior to coating the leather, do not spontaneously or gradually gelate and do not visibly change in color or turbidity when in a solution for at least 10 days.

2. The article of claim 1, wherein the silk fibroin fragments have an average weight average molecular weight selected from between about 5 kDa and about 10 kDa, between about 6 kDa and about 16 kDa, between about 17 kDa and about 38 kDa, between about 10 kDa and about 80 kDa, between about 39 kDa and about 80 kDa, between about 60 kDa and about 100 kDa, or between about 80 kDa and about 144 kDa.

3. The article of claim 1, further comprising about 0.01% (w/w) to about 10% (w/w) sericin relative to the silk fibroin fragments.

4. The article of claim 1, wherein the silk fibroin is selected from natural silk fibroin and recombinant silk fibroin.

5. The article of claim 1, wherein the silk fibroin is selected from spider silk fibroin and silkworm silk fibroin.

6. The article of claim 5, wherein the silkworm silk fibroin is *Bombyx mori* silk fibroin.

7. The article of claim 1, wherein the coating comprises a copolymer.

8. The article of claim 1, wherein the leather is natural leather.

9. The article of claim 8, wherein the natural leather is selected from chrome-tanned leather, vegetable-tanned leather, aldehyde-tanned leather, brain-tanned leather, formaldehyde-tanned leather, Chamois leather, rose-tanned leather, synthetic-tanned leather, alum-tanned leather, patent leather, Vachetta leather, nubuck leather, rawhide leather, split leather, full-grain leather, top-grain leather, and corrected-grain leather.

10. The article of claim 1, wherein the leather is synthetic leather.

11. The article of claim 10, wherein the synthetic leather is selected from poromeric imitation leather, vinyl and polyamide felt fibers, polyurethane, polyvinyl chloride, 5 polyethylene (PE), polypropylene (PP), vinyl acetate copolymer (EVA), polyamide, polyester, textile-polymer composite microfibers, corfan, koskin, leatherette, BIOTHANE®, BIRKIBUC®, BIRKO-FLOR®, CLARINOR, ECOLORICAR, KYDEX®, LORICAR, 10 NAUGAHYDER, REXINER, VEGETAN®, FABRIKOID®, or combinations thereof.

12. The article of claim 1, wherein the coating is applied to the leather prior to forming the article.

13. The article of claim 1, wherein the coating is applied 15 to at least one side of the leather using a method selected from a bath coating process, a spray coating process, a stencil process, a silk-foam based process, and a roller-based process.

14. The article of claim 1, wherein the coating has a 20 thickness selected from the group consisting of about 5 nm, about 10 nm, about 15 nm, about 20 nm, about 25 nm, about 50 nm, about 100 nm, about 200 nm, about 500 nm, about 1 m, about 5 µm, about 10 µm, and about 20 µm.

15. The article of claim 1, wherein the coating is adsorbed 25 on the leather.

16. The article of claim 1, wherein the coating is attached to the leather through chemical cross-linking, enzymatic cross-linking, thermal cross-linking, or irradiative cross-linking. 30

17. The article of claim 1, wherein the hand of the coated leather is improved relative to an uncoated leather.