SUPPLEMENTARY INFORMATION: Polymers for Near-field Electrospinning with Spatial Control

Antonio Osamu Katagiri Tanaka, Héctor Alán Aguirre Soto

Email addresses: oskatagiri@gmail.com (Antonio Osamu Katagiri Tanaka), alan.aguirre@tec.mx (Héctor Alán Aguirre Soto)

December 1, 2020

Table 1: Electrospun Polymer Solutions - Solution and Process Parameters

Polymer(s)	Solvent(s)	NFES Variant	Process Parameters and Fiber Characterization	Ref.
Poly(ethylene oxide) (PEO; MW = 4,000,000 g/mol)	Deionized water	Low-Voltage NFES (LV NFES)	**Solution Concentration:** 1, 2, and 3 $wt\%$ PEO **Nozzle:** 27 gauge type 304; stainless steel needle **Solution deposition rate:** lower than $1\mu L/h$ **Nozzle-to-substrate distance:** $1mm$ **Substrate composition:** Pyrolyzed SU-8 carbon and Si **Applied voltage:** polymer jet initiated at 400-600 V and dispensed at 200-400 V **x-y stage velocity:** 10-40mm/s **Fiber Diameter:** 50-425nm **Distance between adjacent fibers:** *Not determined*	[1]

Continued on next page

Table 1 continued

Poly[2-methoxy-5-(2-ethylhexyloxy)-1,4-phenylenevinylene] (MEH-PPV; MW = 380,000 g/mol) with Poly(ethylene oxide) (PEO; MW = 300,000 g/mol)	acetonitrile toluene mixture (65/35); acetic acid toluene (17/83); pure toluene	Typical process	NFES	**Solution Concentration:** $10mg$ of MEH-PPV in $2mL$ of toluene; $500\mu L$ of MEH-PPV solution with $250mg$ of PEO in $3.5mL$ of acetonitrile / toluene (65 / 35); $500\mu L$ of MEH-PPV solution with $250mg$ of PEO in $3mL$ of acetic acid / toluene (17 / 83). The resulting MEH-PPV/PEO concentration is 0.08 $wt\%$ **Nozzle:** mm-diameter tip Tungsten spinneret in a 26 gauge needle **Solution deposition rate:** $50\mu L/h$ **Nozzle-to-substrate distance:** $500\mu m$ **Substrate composition:** SiO2/Si (oxide thickness = 800 nm) **Applied voltage:** around $1.3kV$ **x-y stage velocity:** $50cm/s$ **Fiber Diameter:** $100nm$ **Distance between adjacent fibers:** around $100\mu m$	[2]

Continued on next page

Table 1 continued

Poly(ethylene oxide) (PEO; MV = 300,000 g/mol)	Water	Scanning Tip Electrospinning and NFES	**Solution Concentration:** $7wt\%$ PEO **Nozzle:** Needle outer diameter of $200\mu m$ and inner diameter of $100\mu m$ **Solution deposition rate:** $0.1\mu L/h$ **Nozzle-to-substrate distance:** $500\mu m$ **Substrate composition:** *Not determined* **Applied voltage:** polymer jet initiated at 1.5 kV and dispensed at $600V$ **x-y stage velocity:** $120mm/s$ **Fiber Diameter:** $709\pm131nm$; 49-$74nm$ when applied voltage is $800V$ **Distance between adjacent fibers:** *Not determined* **Notes:** $108m$ yield in $15min$ with a fiber diameter of $709\pm131nm$	[3]
Poly(vinylidine fluorid) (PVDF; MW = 440,000 g/mol)	N,N Dimethylformamide (DMF)	Helix Electrohydrodynamic Printing (HE-printing)	**Solution Concentration:** $1.8g$ PVDF in $4.1g$ of DMF and $4.1g$ of acetone. The resulting concentration is 18% PVDF. **Nozzle:** Needle outer diameter of $510\mu m$ and inner diameter of $260\mu m$ **Solution deposition rate:** $400nL/min$ **Nozazle-to-substrate distance:** 10-$50mm$ **Substrate composition:** Poly(dimethylsiloxane) (PDMS) on Ecoflex **Applied voltage:** 1.5–$3kV$ **x-y stage velocity:** 0-$400mm/min$ **Fiber Diameter:** about 1.5-$3\mu m$ **Distance between adjacent fibers:** *Not determined*	[4]

Continued on next page

Table 1 continued

Polyhedral Oligomeric Silsesquioxane-Poly(Carbonate-Urea)Urethane (POSS-PCU) and Polyhedral Oligomeric Silsesquioxane Poly(Caprolactone-Poly(Carbonate-Urea)Urethane) (POSS-PCL-PCU) (Dry Polycarbonate MW = 2000 g/mol)	Dimethyl acetamide (DMAC) and 1-Butanol	Electrohydrodynamic 3D Print-patterning or Electrohydrodynamic Jetting	**Solution Concentration:** POSS-PCU and POSS-PCL-PCU used in 20%w/w concentration in DMAC **Nozzle:** needle of 750 μm in diameter **Solution deposition rate:** less than 1$\mu L/min$ **Nozzle-to-substrate distance:** about between 500μm to 2mm **Substrate composition:** *Not determined* **Applied voltage:** 8.0-10.0kV **x-y stage velocity:** 10mm/s **Fiber Diameter:** 15-50μm **Distance between adjacent fibers:** 250μm	[5]
Poly(ethylene oxide) (PEO; MW = 300,000 g/mol)	Distilled water	Electrohydrodynamic Writing or Mechano-electrospinning (MES)	**Solution Concentration:** 6wt% PEO **Nozzle:** *Not determined* **Solution deposition rate:** 1200nL/min **Nozzle-to-substrate distance:** 7.5mm **Substrate composition:** *Not determined* **Applied voltage:** polymer jet initiated at 2 kV and dispensed at 0.8-1kV **x-y stage velocity:** around 400mm/s **Fiber Diameter:** 200-350nm **Distance between adjacent fibers:** 5μm	[6]

Continued on next page

Table 1 continued

Poly(ethylene oxide) (PEO; MW = 300,000 g/mol)	Deionized water and ethanol with a volume ratio of 3:1	Airflow-assisted Electrohydrodynamic Direct-writing (EDW)	**Solution Concentration:** $8wt\%$ PEO **Nozzle:** Outer airflow passage diameter: $1mm$ Airflow gas pump pressure: $25kPa$ Inner liquid passage diameter: $0.21mm$ **Solution deposition rate:** $30\mu L/h$ **Nozzle-to-substrate distance:** $2mm$ **Substrate composition:** Silicon **Applied voltage:** about $2kV$ **x-y stage velocity:** 1-20mm/s **Fiber Diameter:** $3.73 \pm 1.37\mu m$ **Distance between adjacent fibers:** $5.13 \pm 6.67\mu m$	[7]
Poly(Vinylidene Fluoride) (PVDF; MW = 534,000 g/mol)	Acetone and Dimethyl Sulfoxide (DMSO)	3D Electrospinning	**Solution Concentration:** $17wt\%$ PVDF; $1.7g$ of PVDF, $5g$ of acetone, $0.5g$ of Capstone FS-66, $5g$ of DMSO **Nozzle:** Needle inner diameter of $100\mu m$ **Solution deposition rate:** $14\ nL/min$ **Nozzle-to-substrate distance:** $750\mu m$ **Substrate composition:** A4 size commercial printing paper (Double A) **Applied voltage:** $1.9kV$ **x-y stage velocity:** $10mm/s$ **Fiber Diameter:** *Not determined* **Distance between adjacent fibers:** *Not determined*	[8]

Continued on next page

Table 1 continued

Poly(9-Vinyl Carbazole) (PVK; MW = 1,100,000 g/mol)	Styrene	Typical NFES process	**Solution Concentration:** 3.96$wt\%$ PVK in styrene **Nozzle:** Needle inner diameter of 100μm **Solution deposition rate:** 500nL/min **Nozzle-to-substrate distance:** around 2.5mm **Substrate composition:** Si/SiO2 **Applied voltage:** 3-4kV x-y stage velocity: 13.3cm/s **Fiber Diameter:** 289.26 $\pm$ 35.37nm **Distance between adjacent fibers:** 50μm **Notes:** 15m yield in 2min	[9]
Polystyrene (PS; MW *Not determined*)	1,2,4-Trichloro benzene	Electrohydrodynamic (EHD) jet printing	**Solution Concentration:** 1 to 5$wt\%$ PS **Nozzle:** Glass nozzle inner diameter of 2μm and outer diameter of 2.66μm **Solution deposition rate:** *Not determined* **Nozzle-to-substrate distance**: 20, 30, 40μm **Substrate composition:** Si **Applied voltage:** 500 to 400V in 25V increments **x-y stage velocity:** 0.01-10mm/s **Fiber Diameter:** about 60-170μm **Distance between adjacent fibers:** *Not determined*	[10]
Poly(ethylene oxide) (PEO; MW = 300,000 g/mol)	*Not determined*	Typical NFES process	**Solution Concentration:** 3$wt\%$ PEO **Nozzle:** *Not determined* **Solution deposition rate:** *Not determined* **Nozzle-to-substrate distance:** 500μm **Substrate composition:** Si **Applied voltage:** 1000V **x-y stage velocity:** 20cm/s **Fiber Diameter:** 300nm **Distance between adjacent fibers:** 25μm	[11]

Continued on next page

Table 1 continued

Poly(ethylene oxide) (PEO; MW = 2,000,000 g/mol)	Distilled water	Multinozzle NFES	**Solution Concentration:** $5wt\%$ **Nozzle:** four-nozzle and six-nozzle array with needle spacing changes from $1.5mm$ to $3.5mm$ **Solution deposition rate:** 1-3$\mu L/min$ **Nozzle-to-substrate distance:** $2mm$ **Substrate composition:** *Not determined* **Applied voltage:** 1.7-2.7kV **x-y stage velocity:** *Not determined* **Fiber Diameter:** $5.47\mu m$ **Distance between adjacent fibers:** 3-5 mm	[12]
Poly(ethylene oxide) (PEO; MW = 2,000,000 g/mol)	Distilled water	Multinozzle NFES	**Solution Concentration:**$5wt\%$ **Nozzle:** Dual-28G-needle array with needle inner diameter of $0.18mm$ and outer diameter of $0.36mm$; with needle spacing changes from $2.0mm$ to $3.0mm$ **Solution deposition rate:** $0.2\mu L/min$ **Nozzle-to-substrate distance:** 3.0-4.0mm **Substrate composition:** *Not determined* **Applied voltage:** 2.0-3.0kV **x-y stage velocity:** $20mm/s$ **Fiber Diameter:** *Not determined* **Distance between adjacent fibers:** 218-326μm	[13]

Continued on next page

Table 1 continued

Poly(ethylene oxide) (PEO; MW = 2,000,000 g/mol)	Distilled water	Multinozzle NFES	**Solution Concentration:**5 $wt\%$ **Nozzle:** Dual-28G-needle array with needle inner diameter of 180μm and outer diameter of 360μm; with needle spacing changes of 2.0mm **Solution deposition rate:** 0.2$\mu L/min$ **Nozzle-to-substrate distance:** 4.0mm **Substrate composition:** chromium-plated glass **Applied voltage:** 2.5kV **x-y stage velocity:** 20mm/s **Fiber Diameter:** *Not determined* **Distance between adjacent fibers:** 2.3002-2.7224mm	[14]
Poly(ethylene oxide) (PEO; MW = 4,000,000 g/mol)	*Not determined*	Typical NFES process	**Solution Concentration:** 2$wt\%$ **Nozzle:** G30 needle with inner diameter of 0.15mm **Solution deposition rate:** *Not determined* **Nozzle-to-substrate distance:** 1-3mm **Substrate composition:** Silicon **Applied voltage:** 1250V **x-y stage velocity:** *Not determined* **Fiber Diameter:** *Not determined* **Distance between adjacent fibers:** 20μm	[15]

Continued on next page

Table 1 continued

Gelatin (porcine skin; MW *Not determined*)	Acetic Acid and Ethyl Acetate	Typical process	NFES	**Solution Concentration:** $11wt\%$ gelatin, $30wt\%$ water, $35.4wt\%$ acetic acid, $23.6wt\%$ ethyl acetate **Nozzle:** 19G needle tip with outer diameter of $1.08mm$ **Solution deposition rate:** *Not determined* **Nozzle-to-substrate distance:** $1.25mm$ **Substrate composition:** Poly(Dimethylsiloxane) (PDMS) films **Applied voltage:** $1000V$ **x-y stage velocity:** *Not determined* **Fiber Diameter:** around 2-3μm **Distance between adjacent fibers:** $40\mu m$	[16]
Poly(ethylene oxide) (PEO; MW = 300,000 g/mol)	Water/Ethanol (v/v = 60/40)	Typical process	NFES	**Solution Concentration:** PEO concentrations of 16% and 18% **Nozzle:** $40\mu m$ **Solution deposition rate:** *Not determined* **Nozzle-to-substrate distance:** $1mm$ **Substrate composition:** Planar silicon **Applied voltage:** $1.7kV$ **x-y stage velocity:** $0.36m/s$ **Fiber Diameter:** $5.15\mu m$ **Distance between adjacent fibers:** *Not determined*	[17]

Continued on next page

Table 1 continued

Poly(ethylene oxide) (PEO; MW = 300,000 g/mol)	Water/Ethanol (v/v = 3/1)	Electrohydrodynamic Direct-Write (EDW)	**Solution Concentration:** $14wt\%$ PEO **Nozzle:** Stainless needle with inner diameter of $210\mu m$ and outer diameter of $400\mu m$ **Solution deposition rate:** $50\mu L/h$ **Nozzle-to-substrate distance:** $2mm$ **Substrate composition:** Poly(ethylene terephthalate) (PET) **Applied voltage:** $3kV$ **x-y stage velocity:** $700mm/s$ **Fiber Diameter:** 15-35μm **Distance between adjacent fibers:** $70\mu m$	[18]
Poly(ethylene oxide) (PEO; MW = 300,000 g/mol)	Deionized water	Mechano-Electrospinning	**Solution Concentration:** $3wt\%$ PEO **Nozzle:** Stainless steel nozzle with inner diameter of $160\mu m$ and outer diameter of $310\mu m$ **Solution deposition rate:** $50nL/min$ **Nozzle-to-substrate distance:** 2-5mm **Substrate composition:** Silicone **Applied voltage:**polymer jet initiated at $2kV$ and dispensed at $1kV$ **x-y stage velocity:** 200-400mm/s **Fiber Diameter:** from 344±32 to 214±27nm **Distance between adjacent fibers:** *Not determined*	[19]

Continued on next page

Table 1 continued

Poly(co-Glycolic) acid (PLGA; MW *Not determined*)	Dimethyl Carbonate (DMC)	Tethered Pyro-Electrohydrodynamic Spinning (TPES)	**Solution Concentration:** *Not determined* **Nozzle:** nozzle-free **Solution deposition rate:** The drop reservoir is placed directly on a flat substrate **Nozzle-to-substrate distance:** Taylor's cone is focused and put in direct contact with the collector **Substrate composition:** Poly(tetrafluoroethylene) (PTFE) coated glass slide **Applied voltage:** pyro-electric field of between 2.7 $x10^7$ V/m and 5.5$x10^7$ V/m **x-y stage velocity:** *Not determined* **Fiber Diameter:** 304.7nm **Distance between adjacent fibers:** *Not determined*	[20]
Poly(ethylene oxide) (PEO; MW = 4,000,000 g/mol) with Tetrabutylammonium tetrafluoroborate (TBF; MW *Not determined*) and SU-8 2002	N,N Dimethylformamide (DMF)	Typical NFES process	**Solution Concentration:** SU-8/PEO/TBF blend with 0.75wt% PEO, 1wt% TBF; the blend is diluted with 30vol% DMF $\mu m \mu m$ **Solution deposition rate:** *Not determined* **Nozzle-to-substrate distance:** *Not determined* **Substrate composition:** Brass disk with a diameter of 38mm **Applied voltage:** 980V **x-y stage velocity:** *Not determined* **Fiber Diameter:** *Not determined* **Distance between adjacent fibers:** *Not determined*	[21]

Continued on next page

Table 1 continued

Poly(ethylene oxide) (PEO; 200,000 g/mol)	Water:Ethanol (3:2)	Suspension NFES	**Solution Concentration:** $14wt\%$ PEO **Nozzle:** stainless steel needle (25 G) with inner diameter of $0.25mm$ **Solution deposition rate:** $3nL/s$ **Nozzle-to-substrate distance:** between 0.5 and $10mm$ with $0.5mm$ increments **Substrate composition:** Planar silicon electrodes **Applied voltage:** $1.6kV$ **x-y stage velocity:** 50, 150, and $250mm/s$ **Fiber Diameter:** $300nm$ **Distance between adjacent fibers:** 0.1 and $0.5mm$	[22]
Poly(ethylene oxide) (PEO; MW = 400,000 g/mol)	Deionized water	Typical NFES process	**Solution Concentration:** $10wt\%$ PEO **Nozzle:** 32G metal needle **Solution deposition rate:** (Jet impact speed of $5mm/s$) **Nozzle-to-substrate distance:** $0.5mm$ **Substrate composition:** p-type silicon wafer **Applied voltage:** $400V$ **x-y stage velocity:** $5mm/s$ **Fiber Diameter:** *Not determined* **Distance between adjacent fibers:** $50\mu m$	[23]

December 1, 2020