EMAC 276

Lesson 5: ABS & HIPS: Basis for Impact Modification

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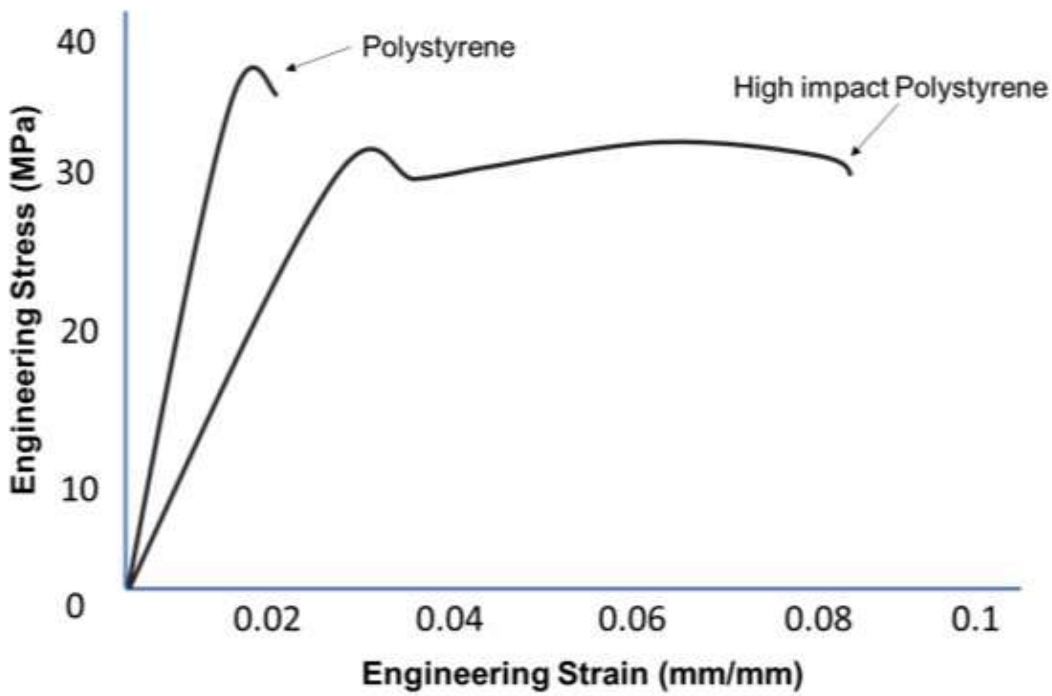
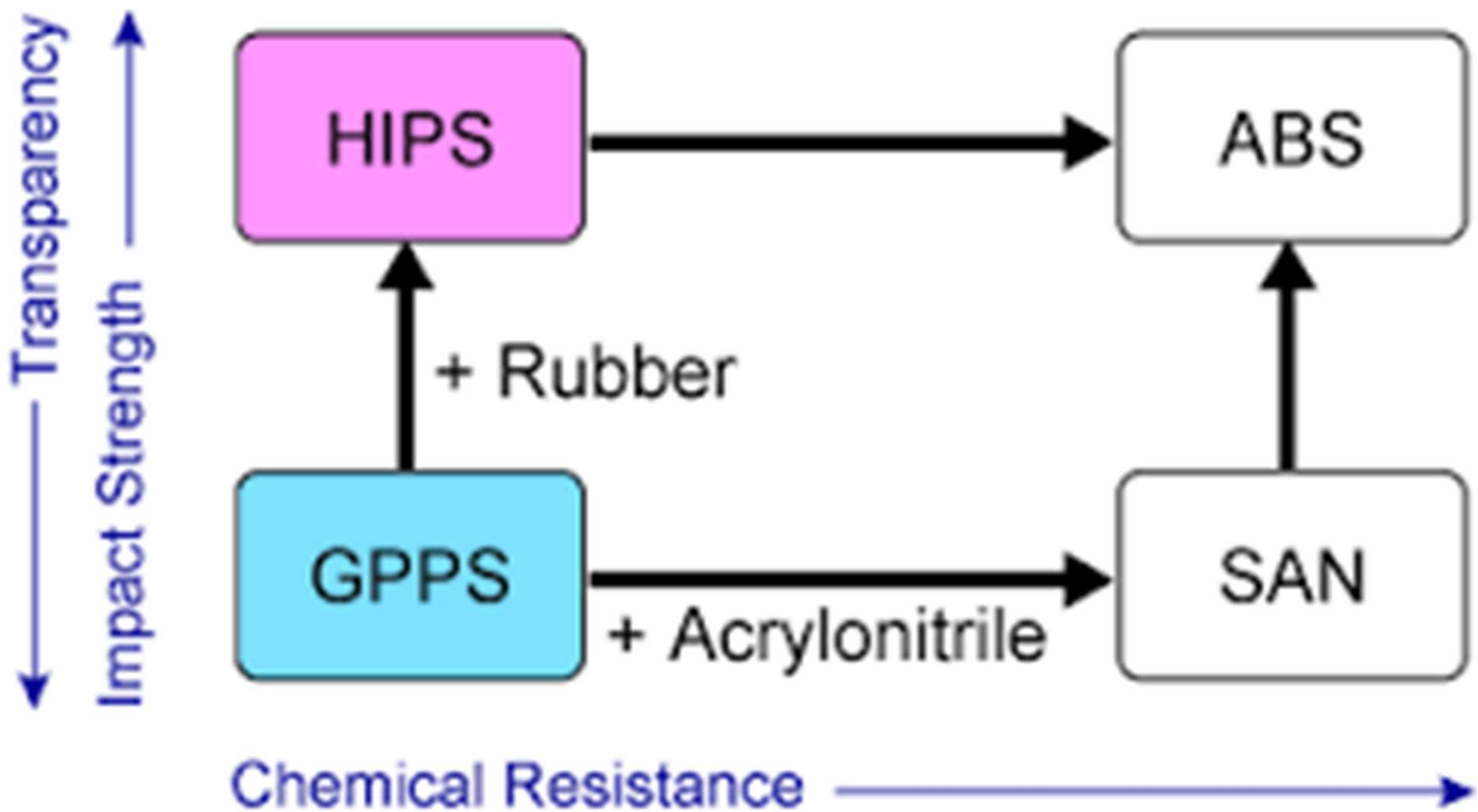
January 27, 2025

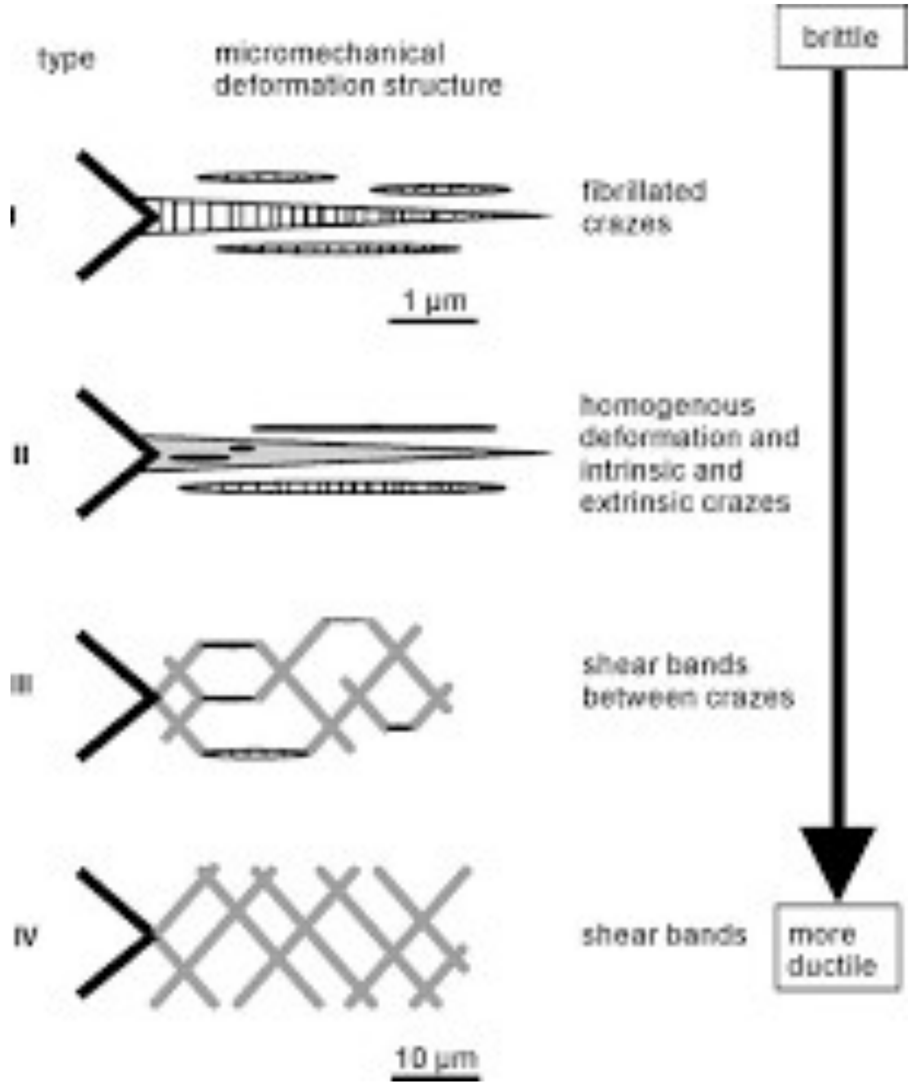
Unmodified Polystyrene is a Brittle Material



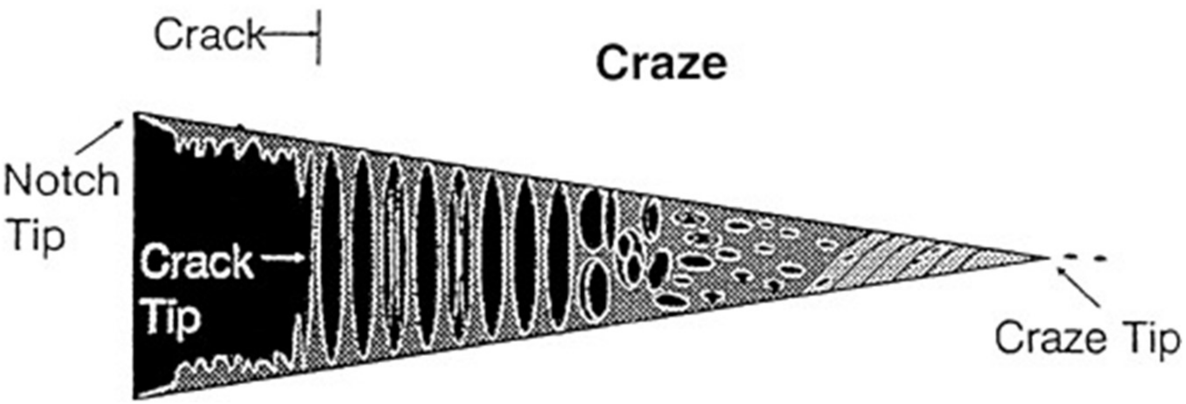
ABS and HIPS for Improved Impact Performance

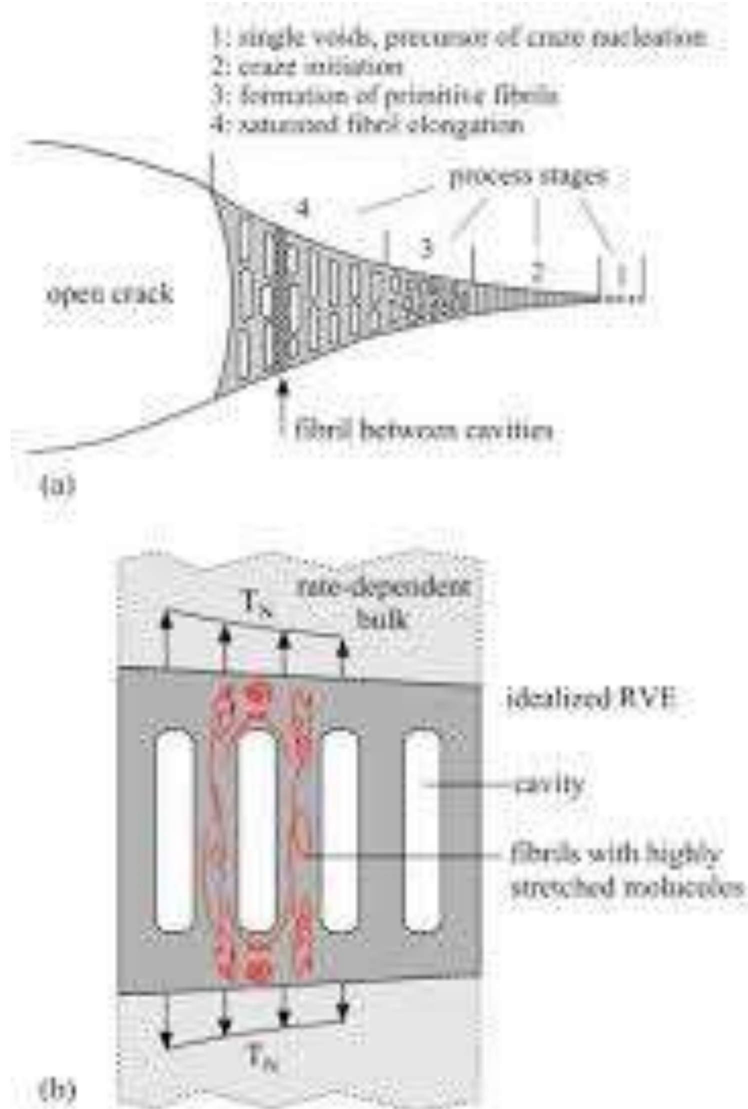


Failure Mechanism Difference Crazing and Shear Banding

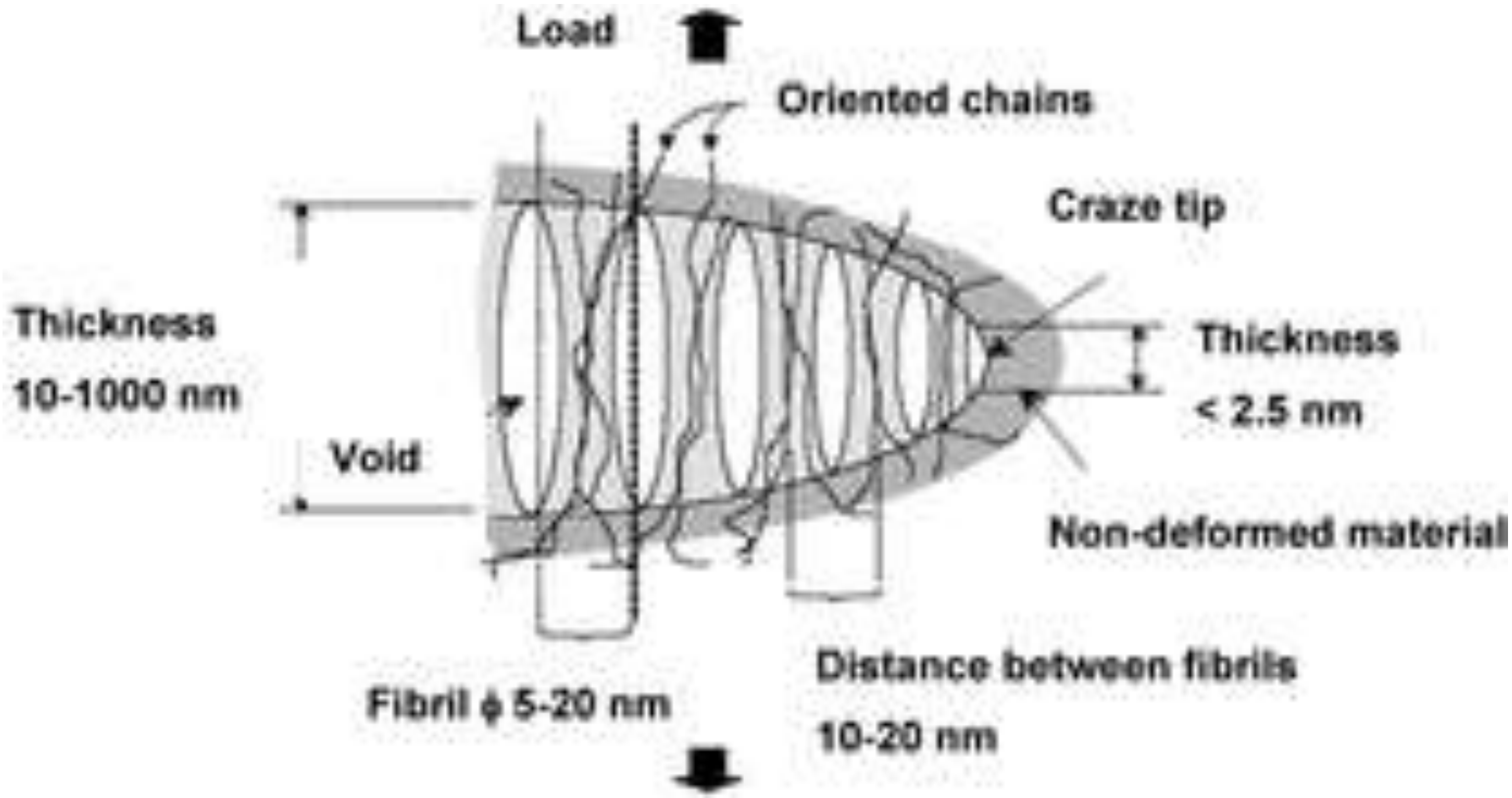


Crack-Craze Morphology in PS

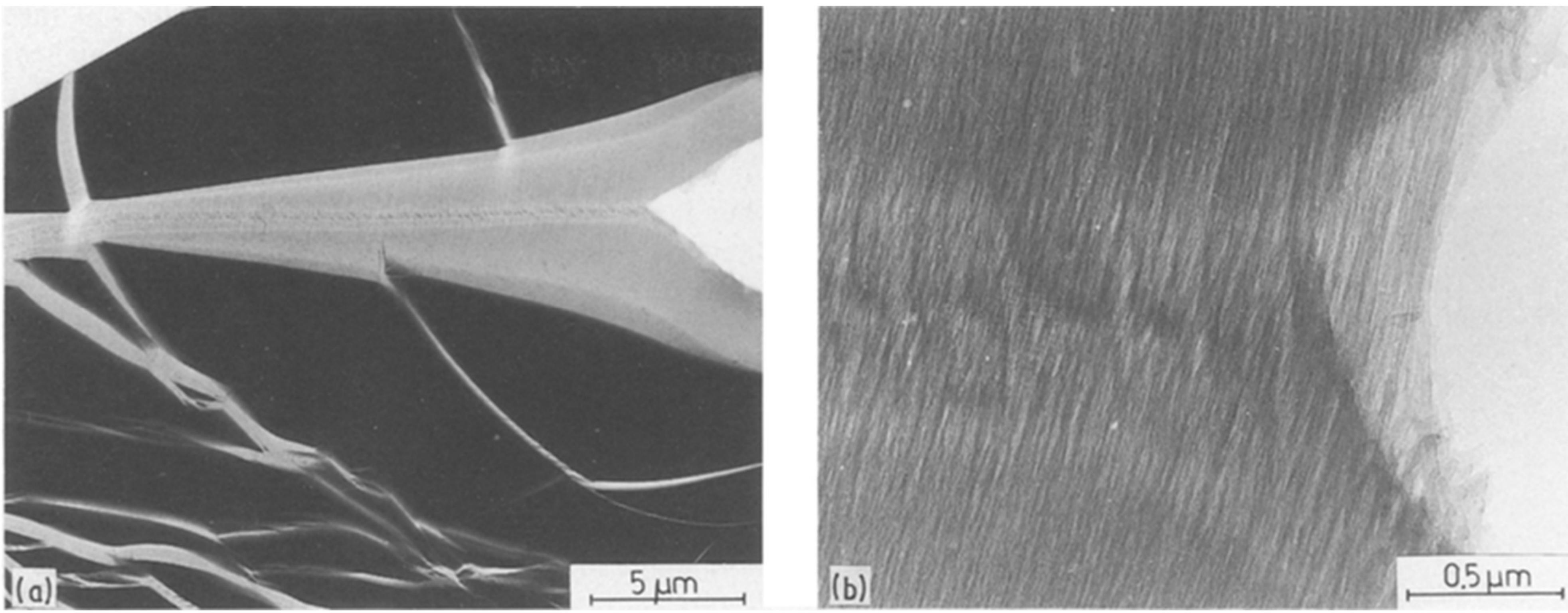




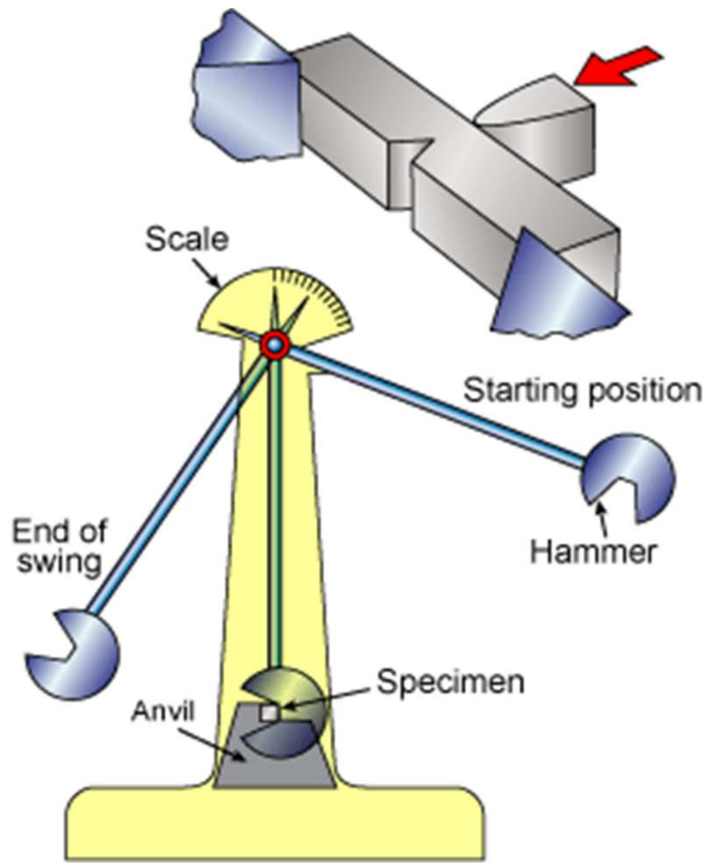
Morphology and Scale of a Craze

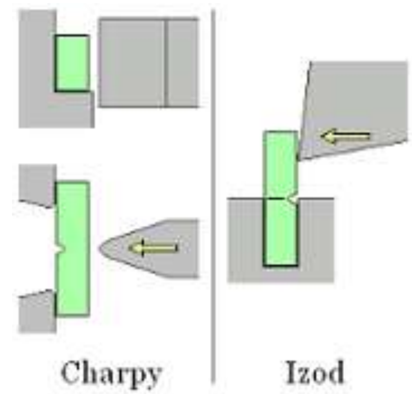


Craze Fibril Formation in PS at Crack Tip



Charpy and Izod Impact Test Method

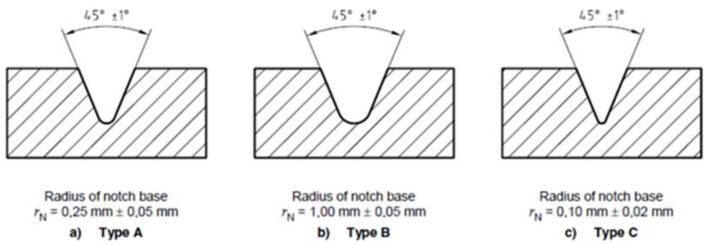


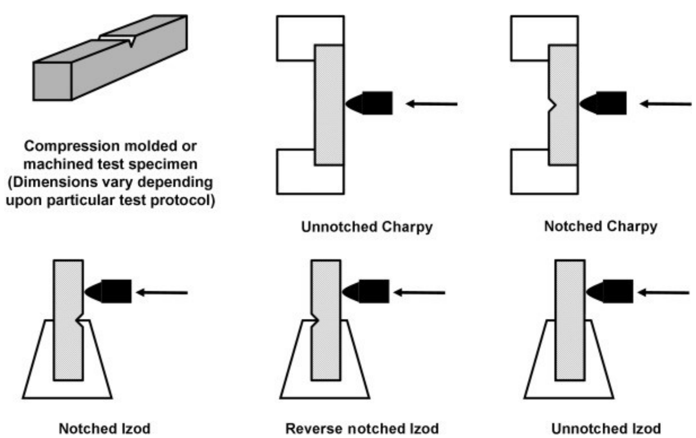


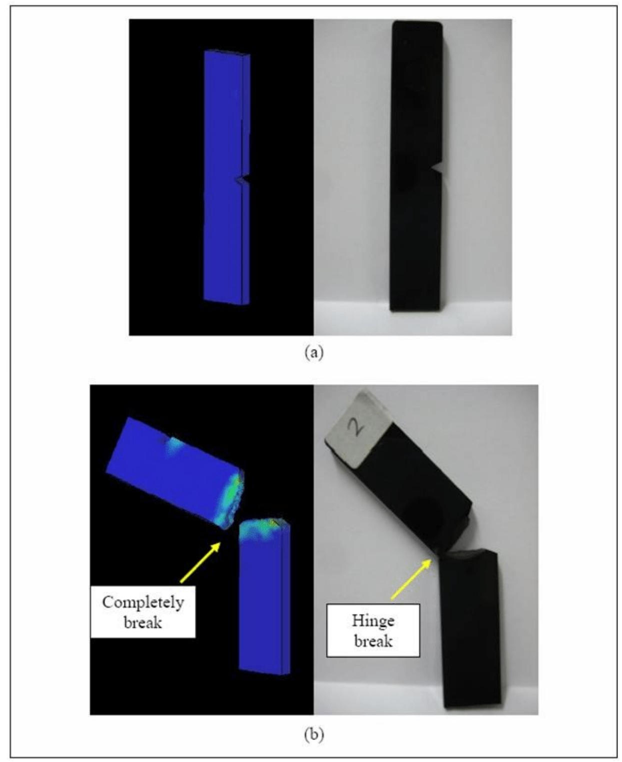
ASTM D6110: Standard Test Method for Determining the Charpy Impact Resistance of Notched Plastics

ASTM D256: Standard Test Method for Determining the Izod Pendulum Impact Resistance of Plastics

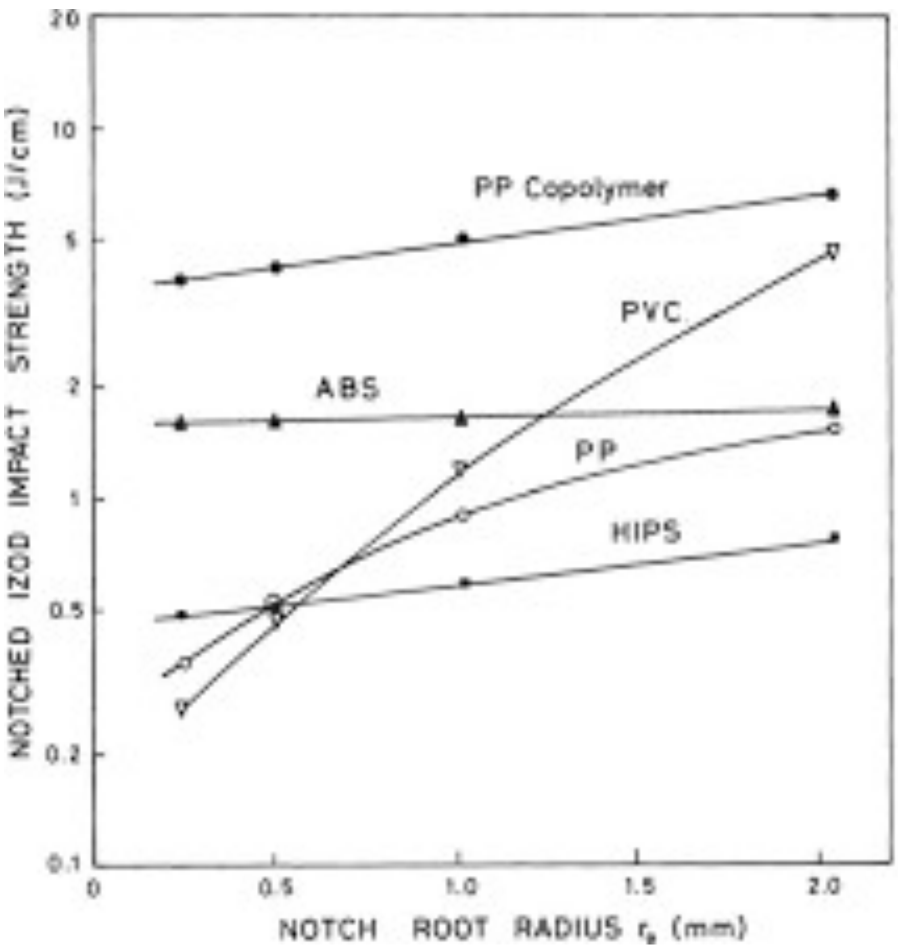
Details of Notch Geometry, Position and Break



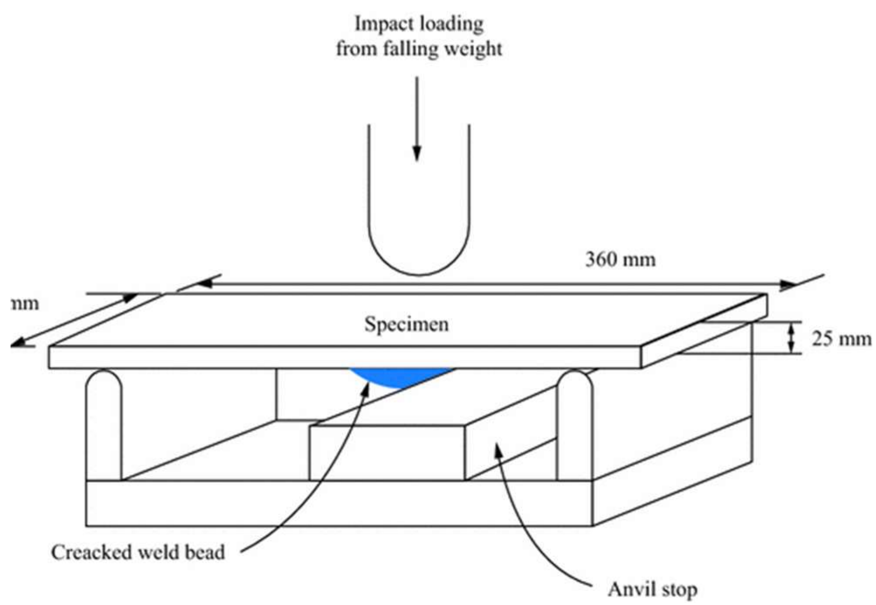




Izod Impact Test Results for ABS & HIPS

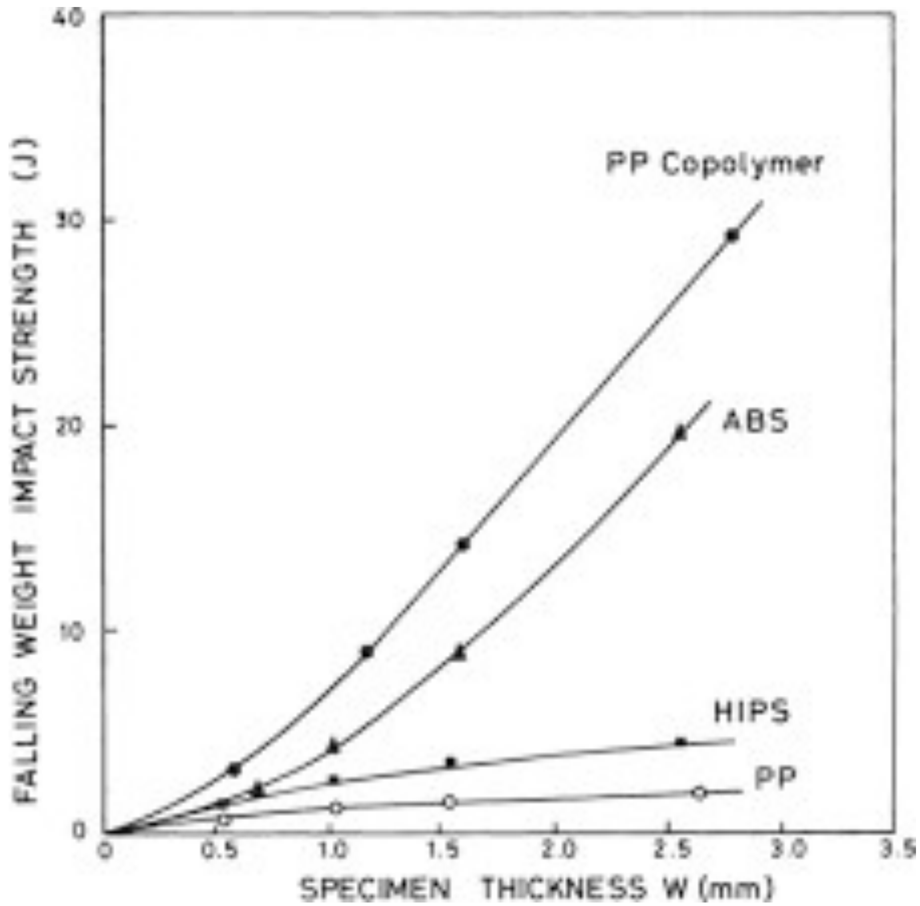


Falling Weight Impact Test Method

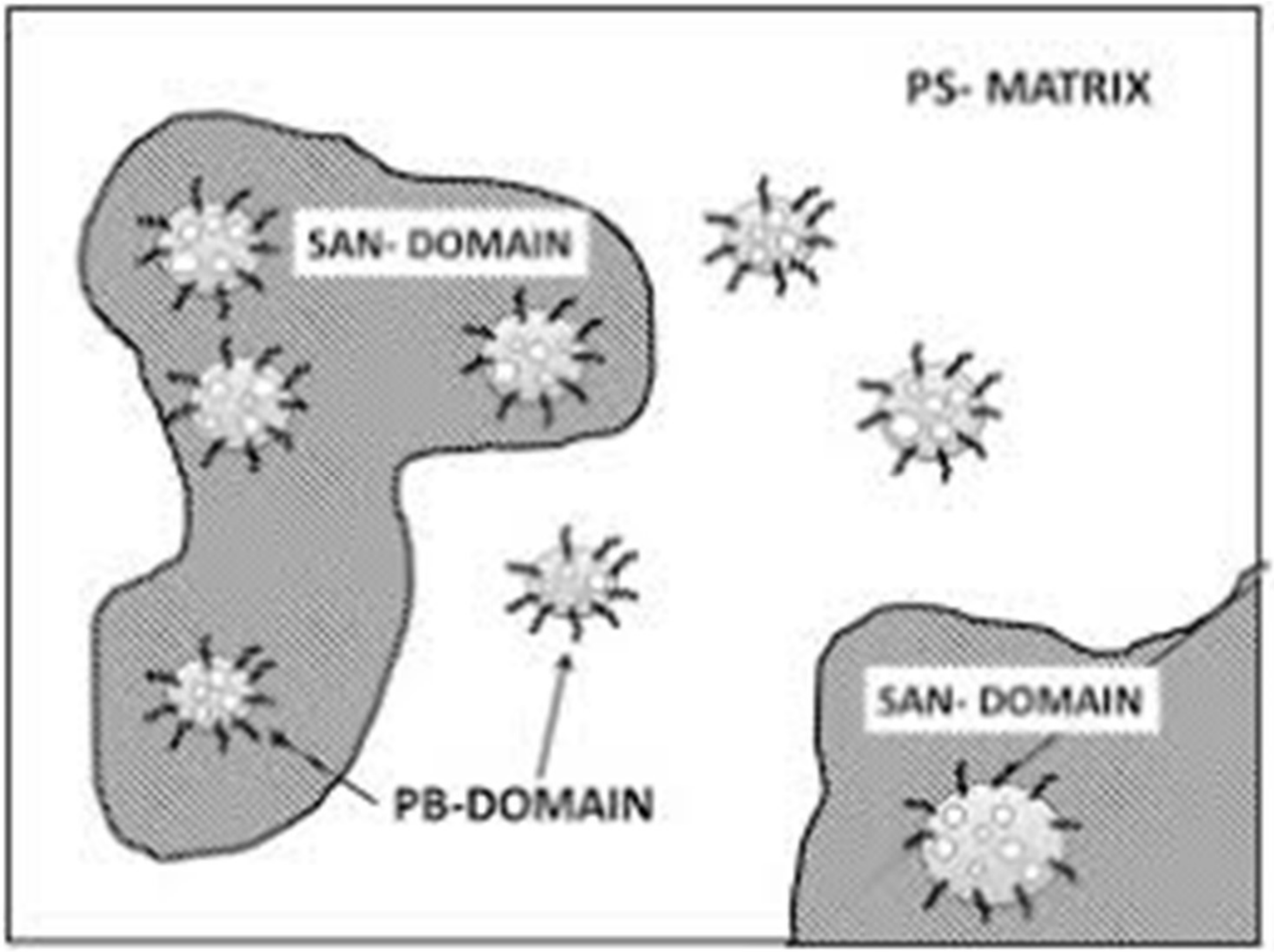


ASTM D5420: Standard Test Method for
Impact Resistance of Flat, Rigid Plastic Specimen by Means
of a Striker Impacted by a Falling Weight (Gardner Method)

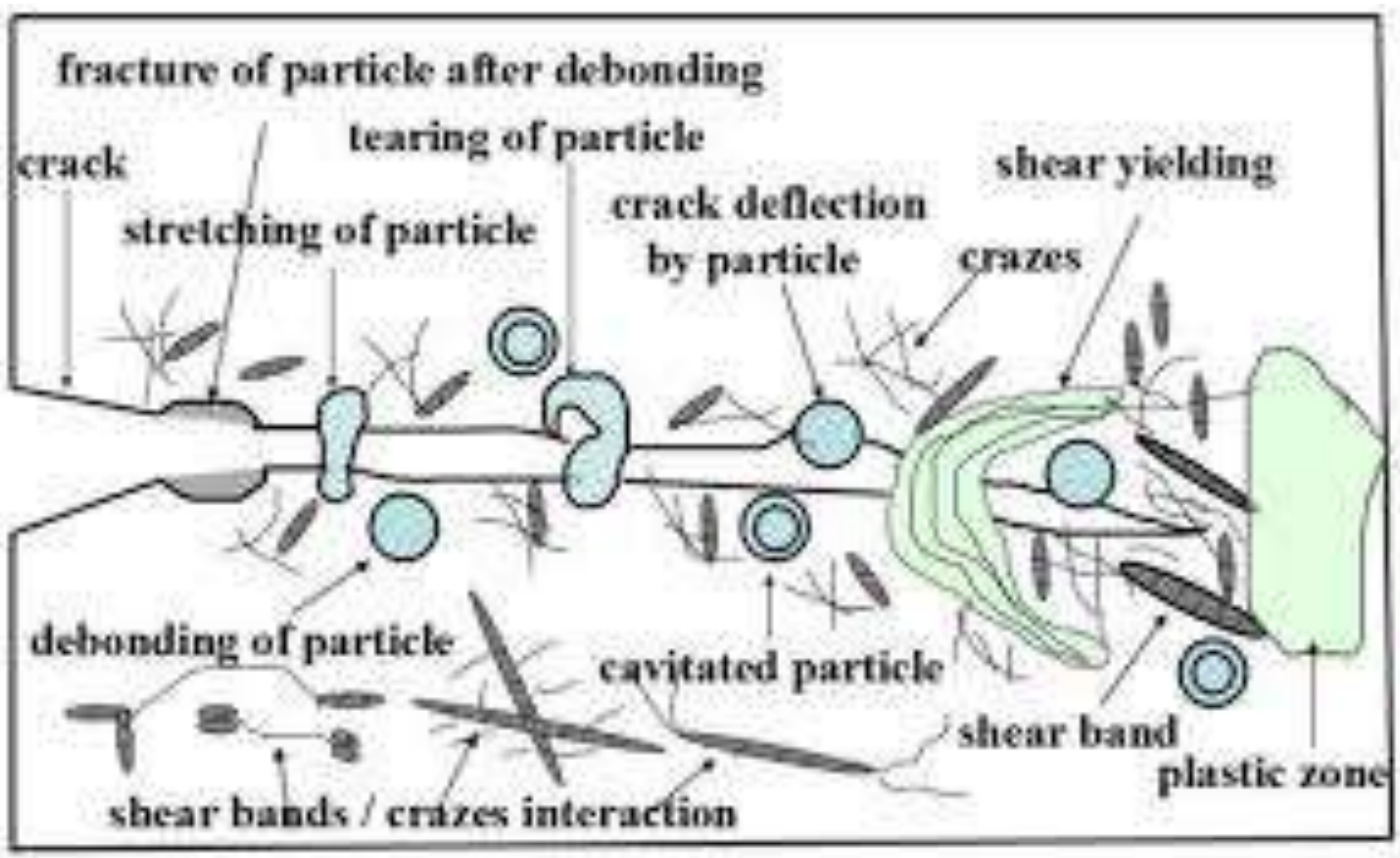
Falling Weight Impact Test Results for ABS & HIPS



Domain Morphologies Common to both ABS and HIPS



Energy Dissipation Mechanisms in Rubber Modified Styrenics



Impact Modification in ABS and HIPS

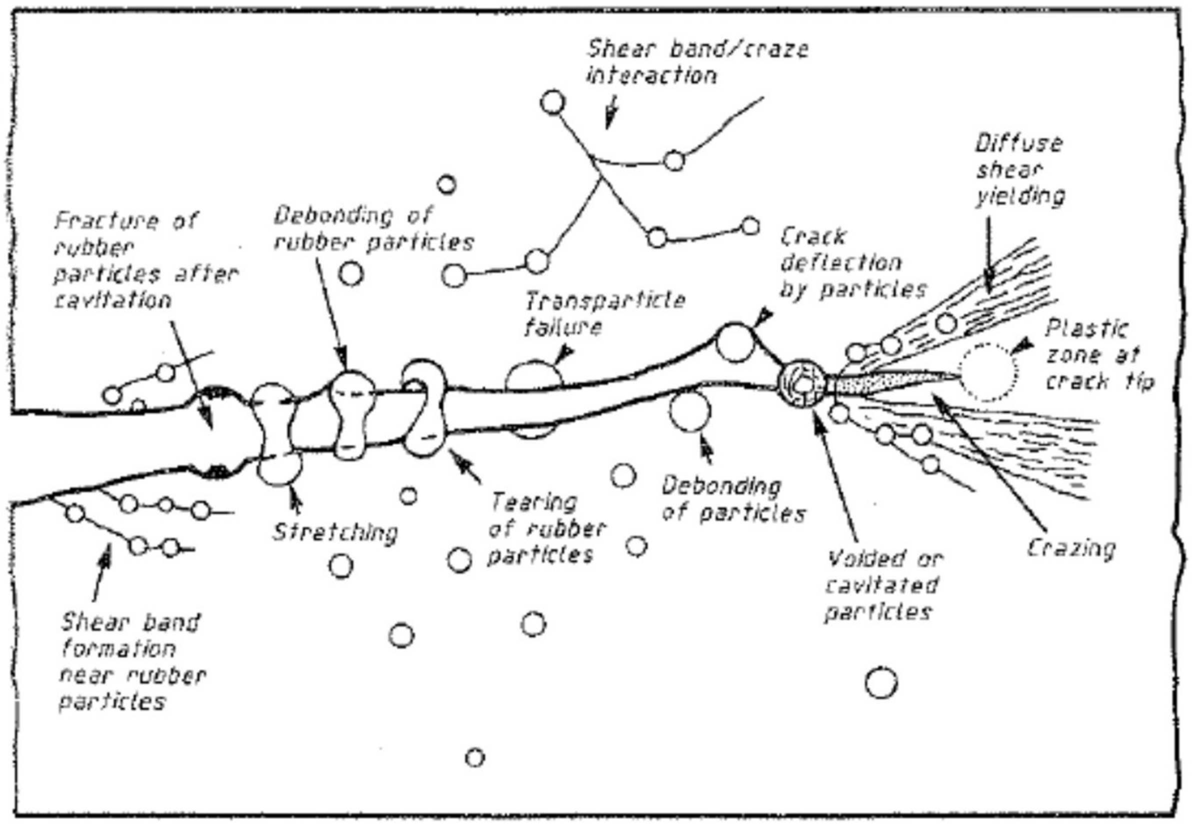
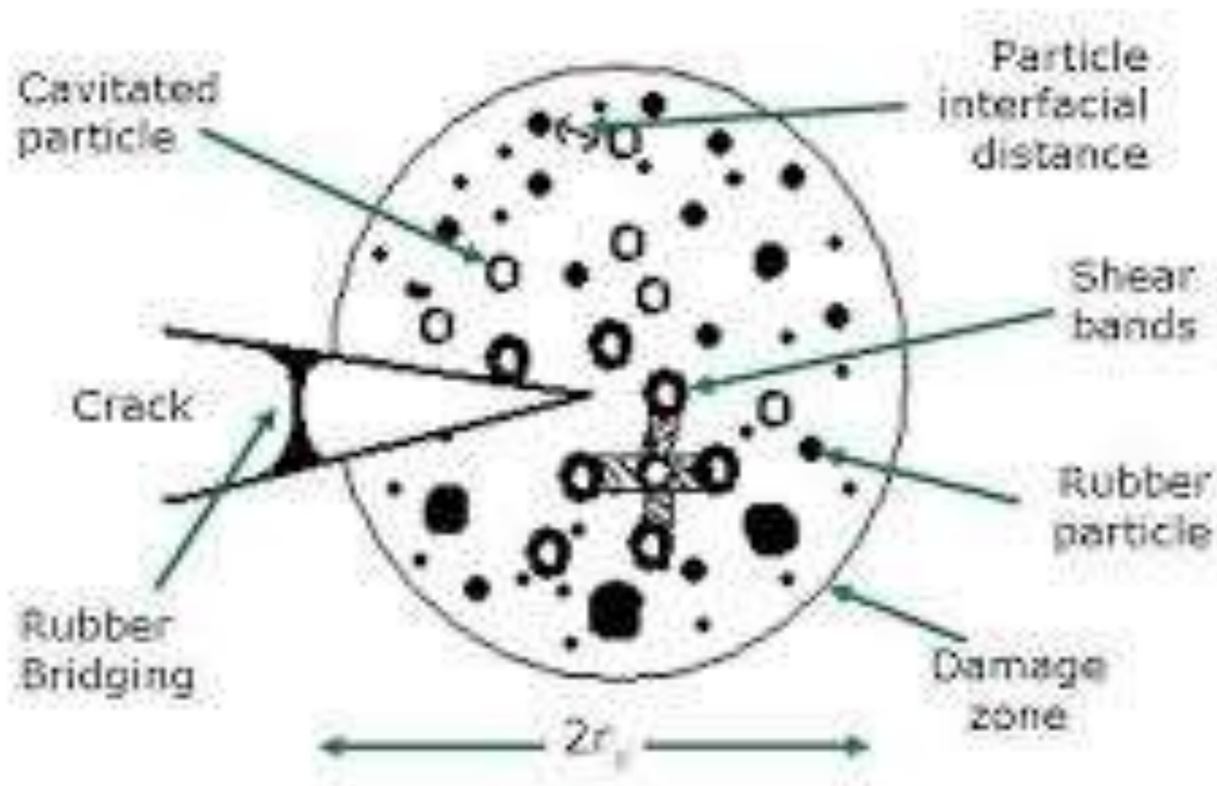


Fig. 3.1 Crack toughening mechanisms in rubber filled modified polymers.

Energy Dissipation by Occluded Rubber in ABS and HIPS



Energy Dissipation by Occluded Rubber in ABS and HIPS

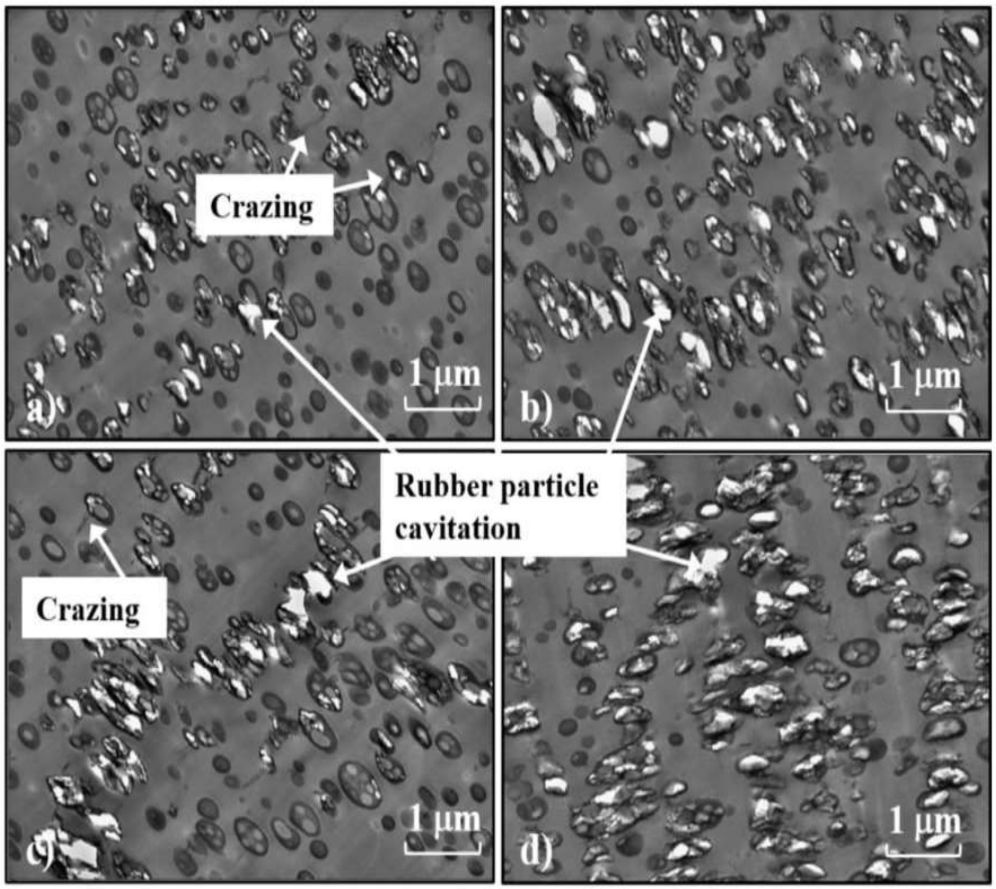


Fig. 10. TEM images taken to the inner region of specimens tested up to 0.2 of u_{pl}/W at different conditions: (a) 23 °C and 0.3 mm/min, (b) 23 °C and 300 mm/min, (c) 60 °C and 0.3 mm/min, (d) 60 °C and 300 mm/min. Rubber particle cavitation and matrix crazing are indicated.

Reaction Sequence for ABS

PB

SAN-g-PB

SAN

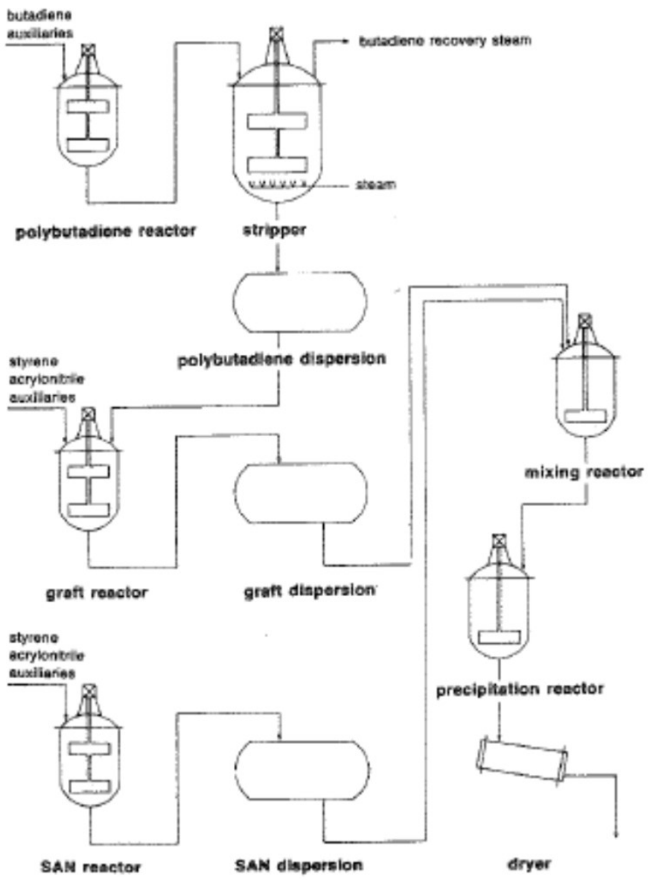
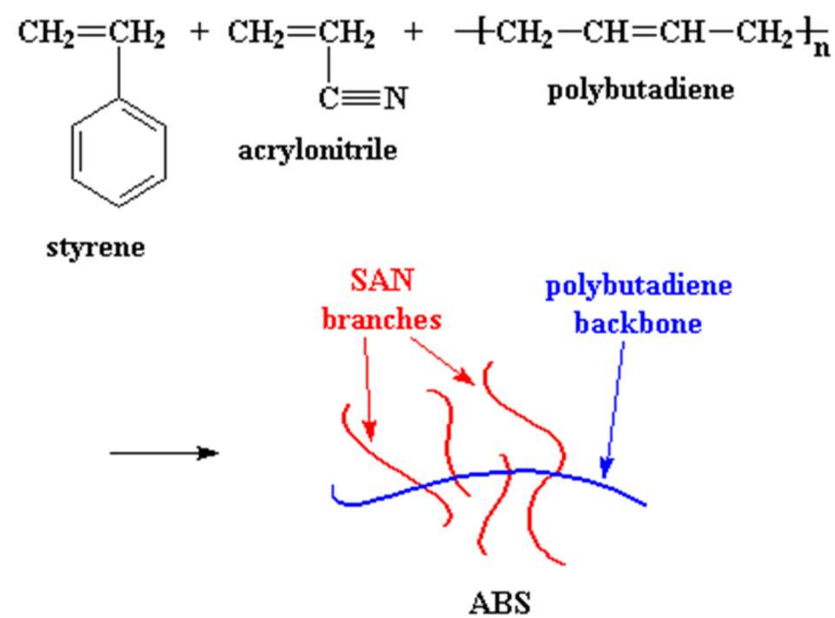
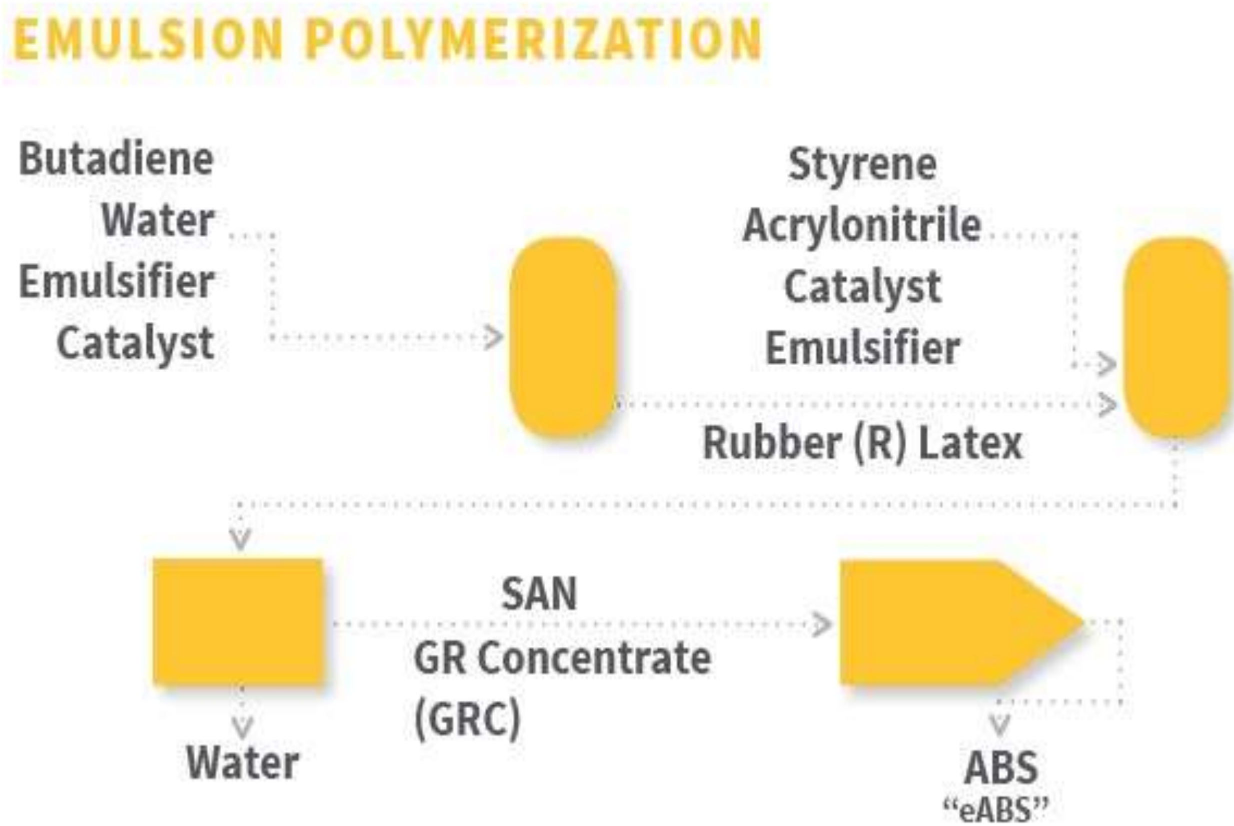


Figure 30. Production of ABS in emulsion.

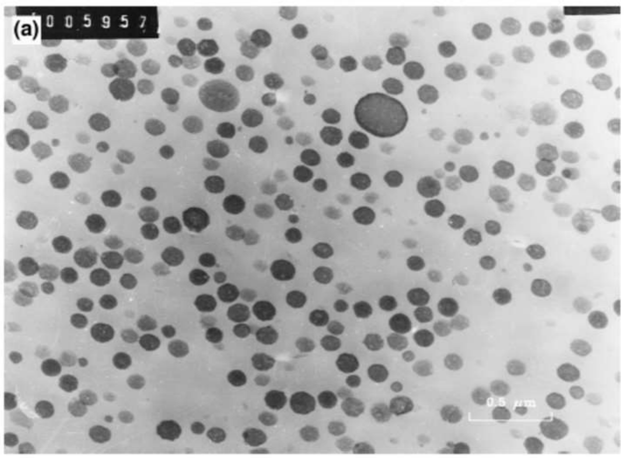


Emulsion Polymerization of ABS

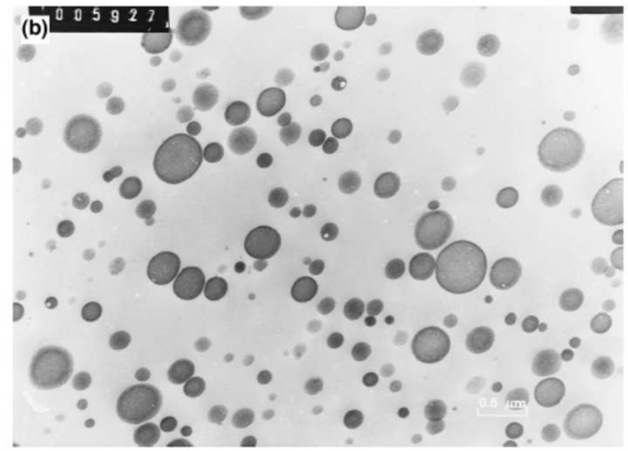


Emulsion polymerization *uses a batch reaction process requiring emulsifiers and salts that remain in the ABS at detectable levels.*

Morphology and Craze Structure in Emulsion ABS



E1:
PB ~ 49%
ST ~ 38%
AN ~ 12%



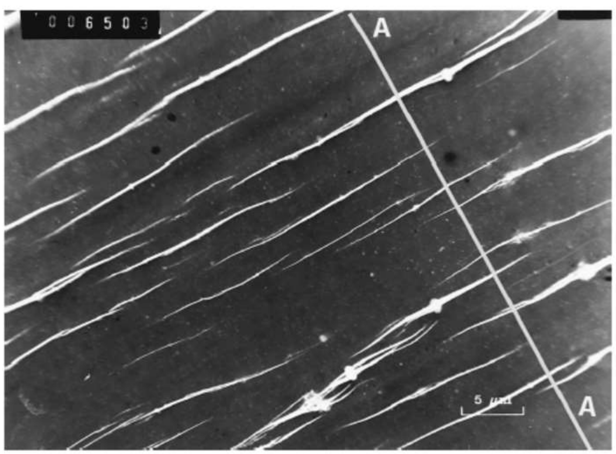


Figure 8 TEM micrograph of sample E1/2.5 after plastic deformation

E2:
PB ~ 68%
ST ~ 24%
AN ~ 8%

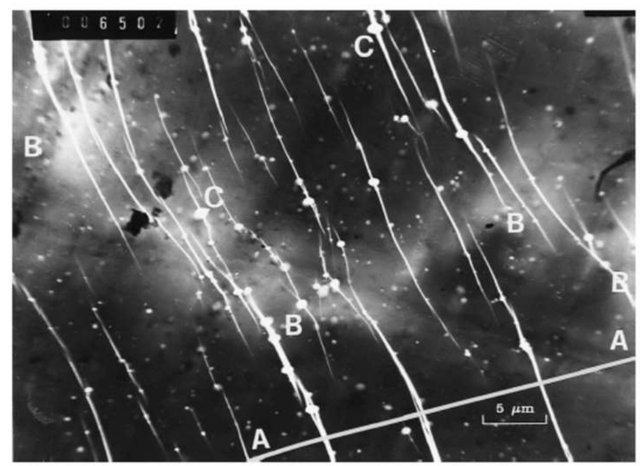
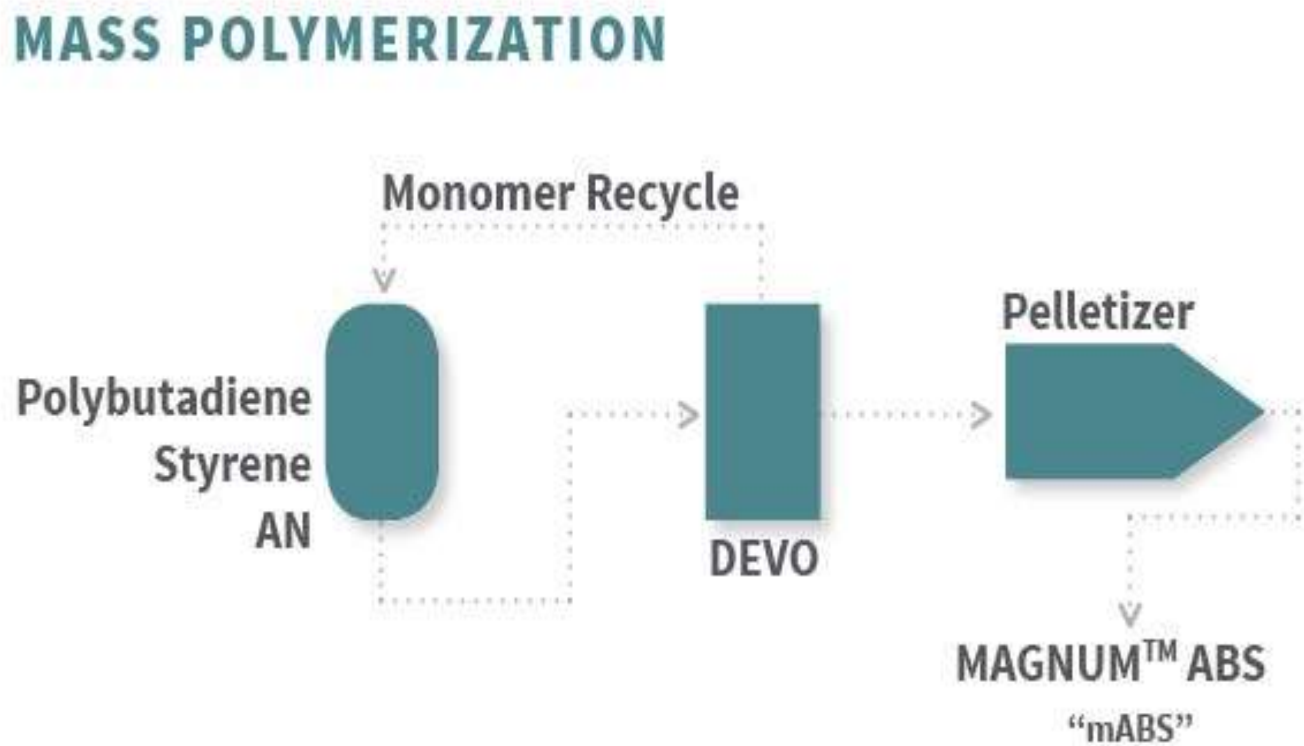


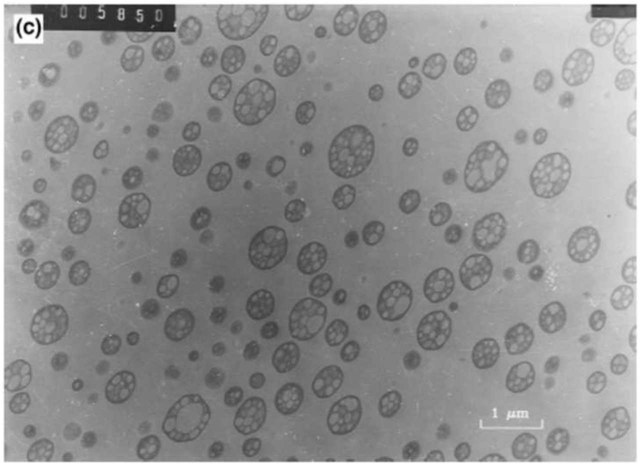
Figure 9 TEM micrograph of sample E2/2.5 after plastic deformation

Mass Polymerization of ABS



***Mass polymerization** is a continuous process that uses few additives, resulting in clean, pure ABS material with high consistency.*

Morphology and Craze Structure in Mass ABS



M1:
PB ~ 11%
ST ~ 65%
AN ~ 23%

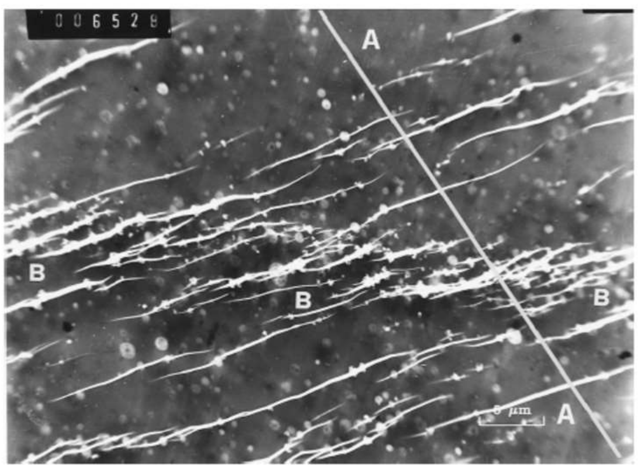
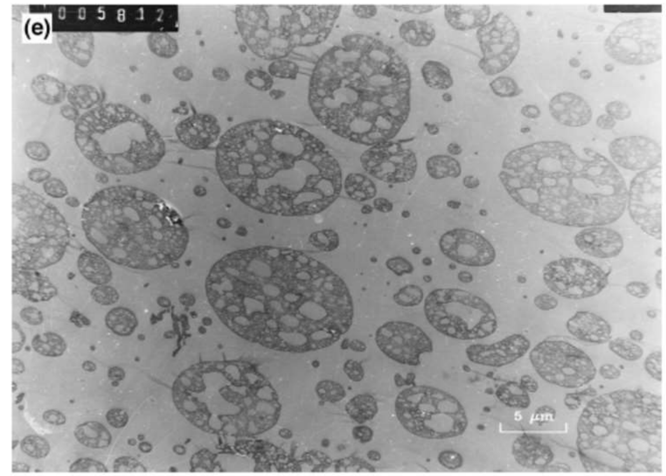


Figure 10 TEM micrograph of sample M1/2.5 after plastic deformation



M3:
PB ~ 11%
ST ~ 66%
AN ~ 23%

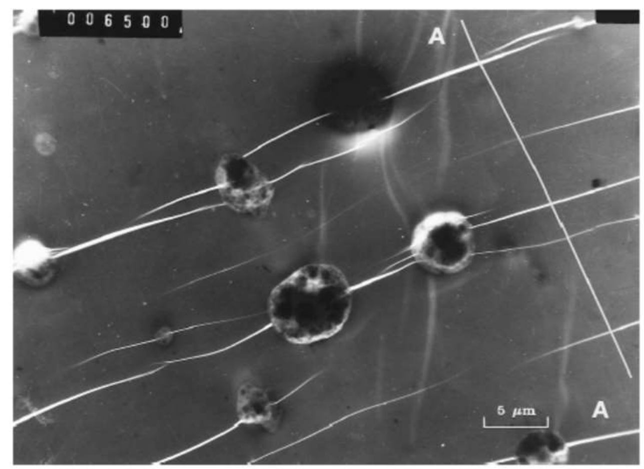
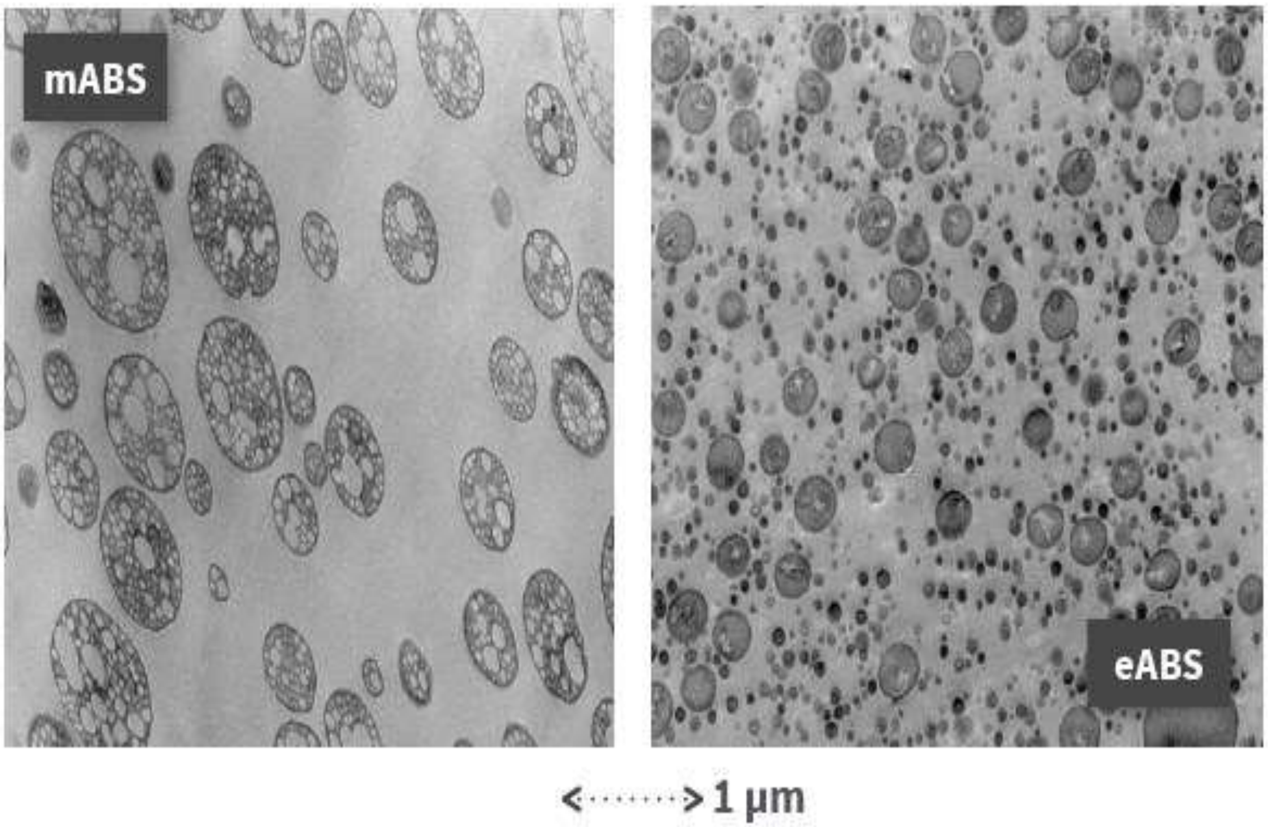


Figure 12 TEM micrograph of sample M3/2.5 after plastic deformation

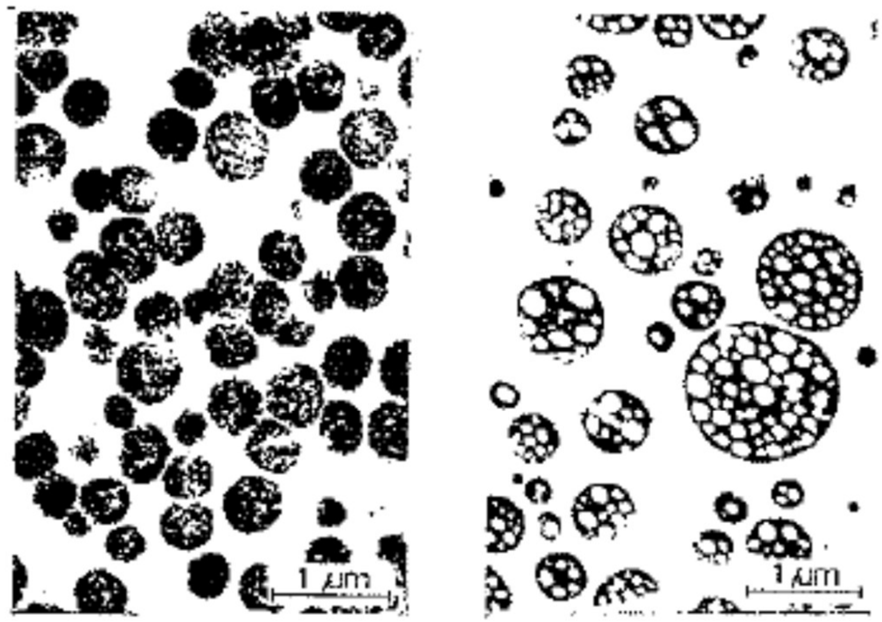
Comparison of Mass and Emulsion Polymerized ABS



Morphology is the result of in situ formation of rubber particles during the SAN matrix polymerization. Pictured below are examples where:

- Light gray background = SAN matrix polymer
- Dark gray spherical particles = rubber particles
- Darker color is the result of a sample pre-treatment process, called staining, and this staining process works specifically on carbon-carbon double covalent bonds that are present in the rubber.

Comparison of Mass and Emulsion Polymerized ABS



Emulsion ABS　　Bulk ABS

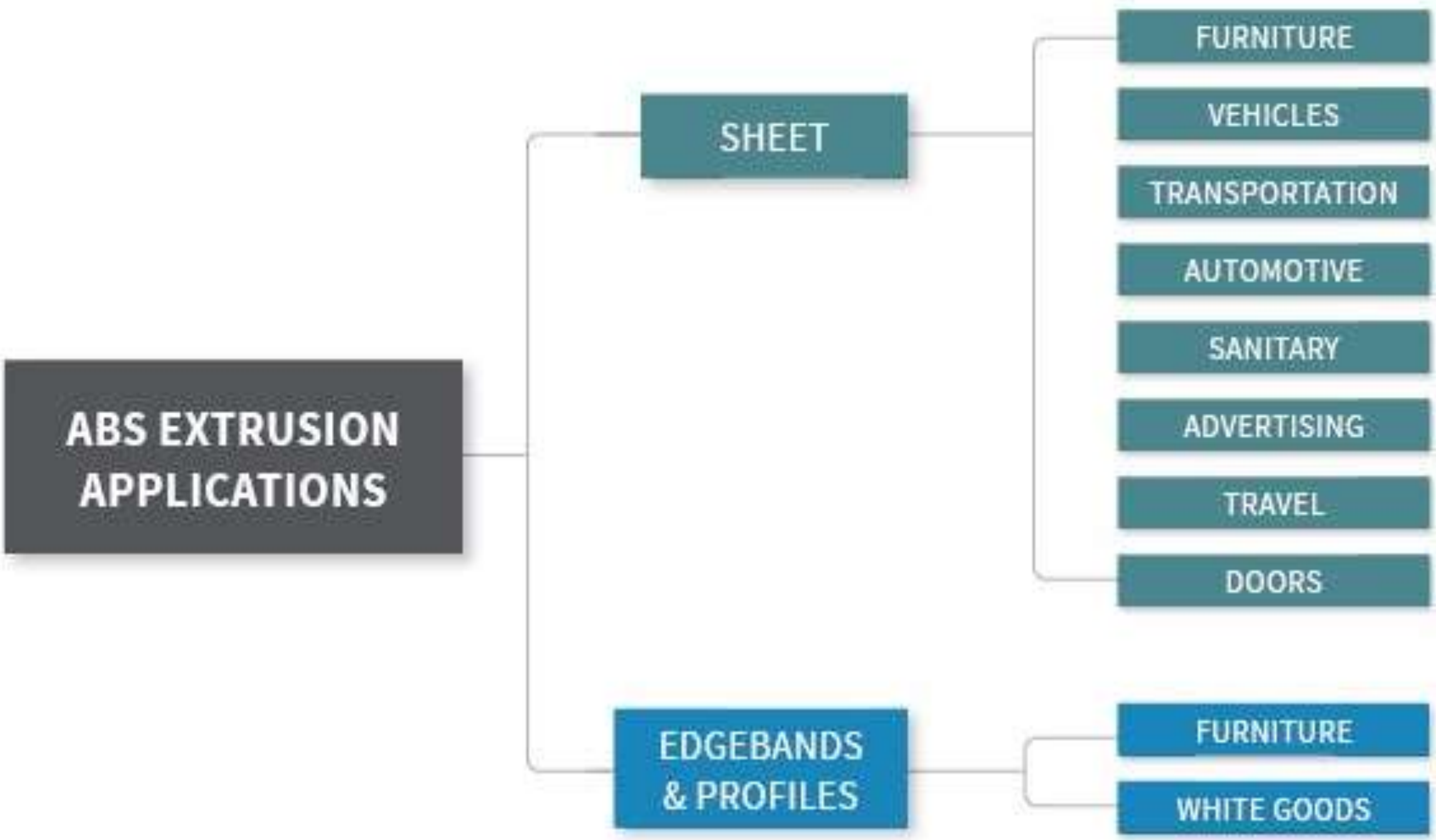
Figure 3. Morphology of ABS polymerized in emulsion or in bulk. (Reproduced with permission from ref. 4. Copyright 1979 Verlag Chemie.)

Comparison of Mass and Emulsion Polymerized ABS

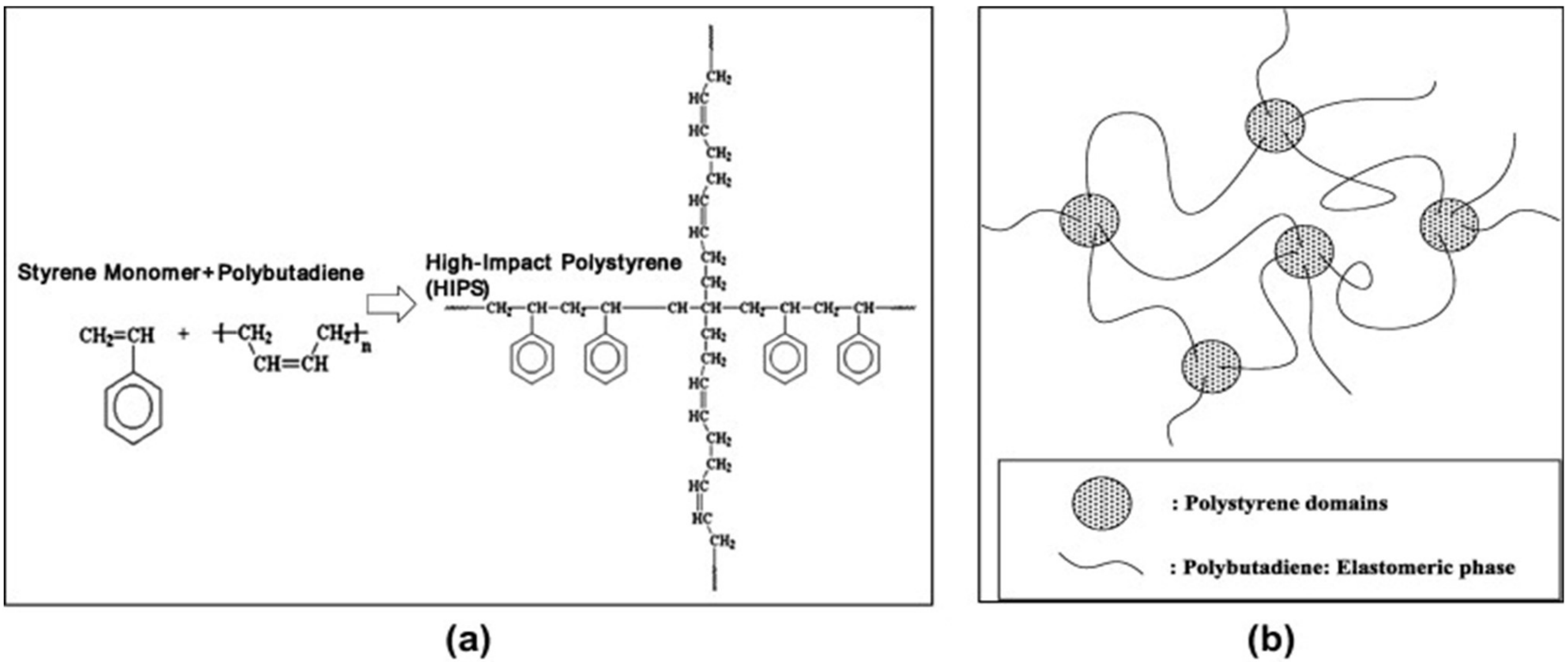
mABS: rubber particles are larger and contain SAN occlusions, therefore the ABS rubber particle morphology is characterized by a high rubber efficiency, which makes it less sensitive to rubber degradation.

eABS: rubber particles are smaller and dense because they are in essence produced in a separate process (rubber latex and GRC production) from the SAN matrix polymerization. This allows a higher control on the rubber particle size and hence the possibility to produce smaller rubber particles, which can be beneficial in case one seeks the highest gloss levels.

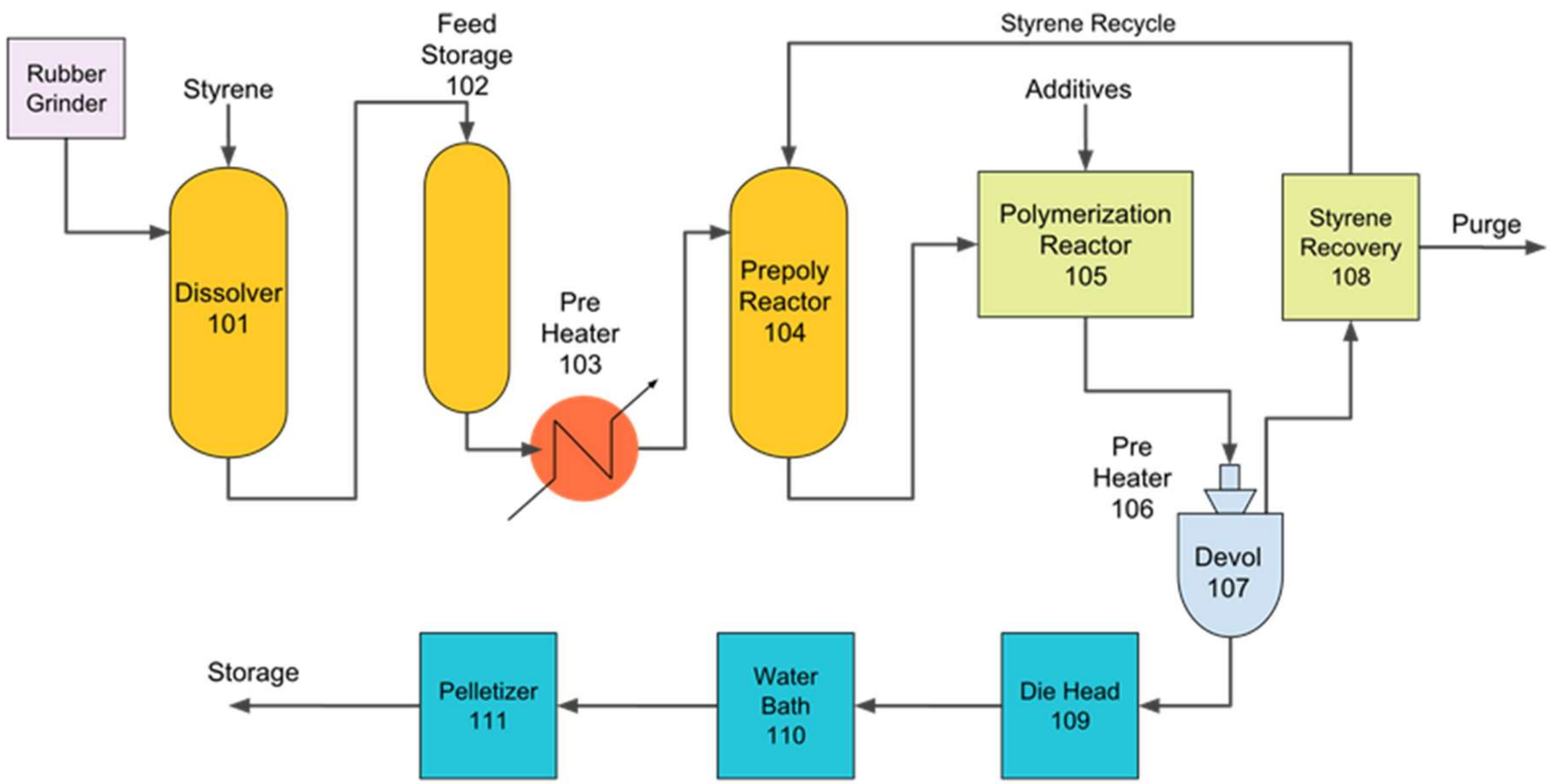
Applications for ABS



HIPS Structure and Morphology



One Reaction Sequence for HIPS



Various Reaction Sequences for the Polymerization of HIPS

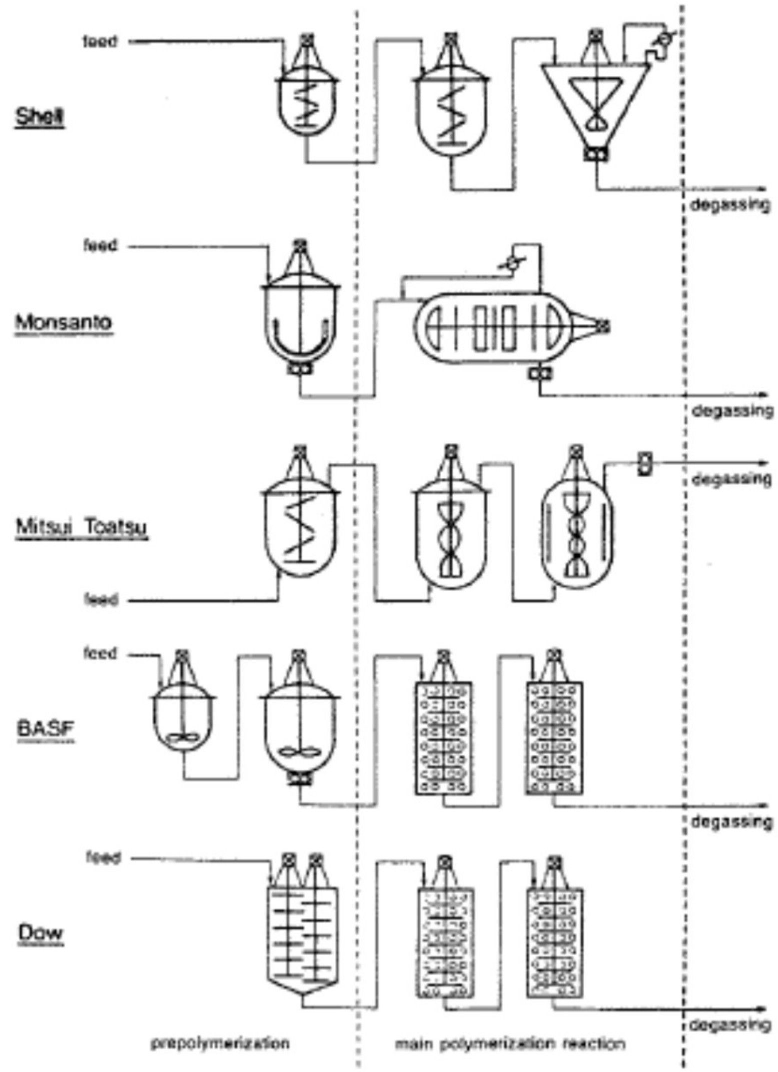


Figure 27. Reactor cascades for HIPS production. (Reproduced with permission from ref. 32. Copyright 1982 Hanser.)

Varying Morphologies can be Imparted into HIPS

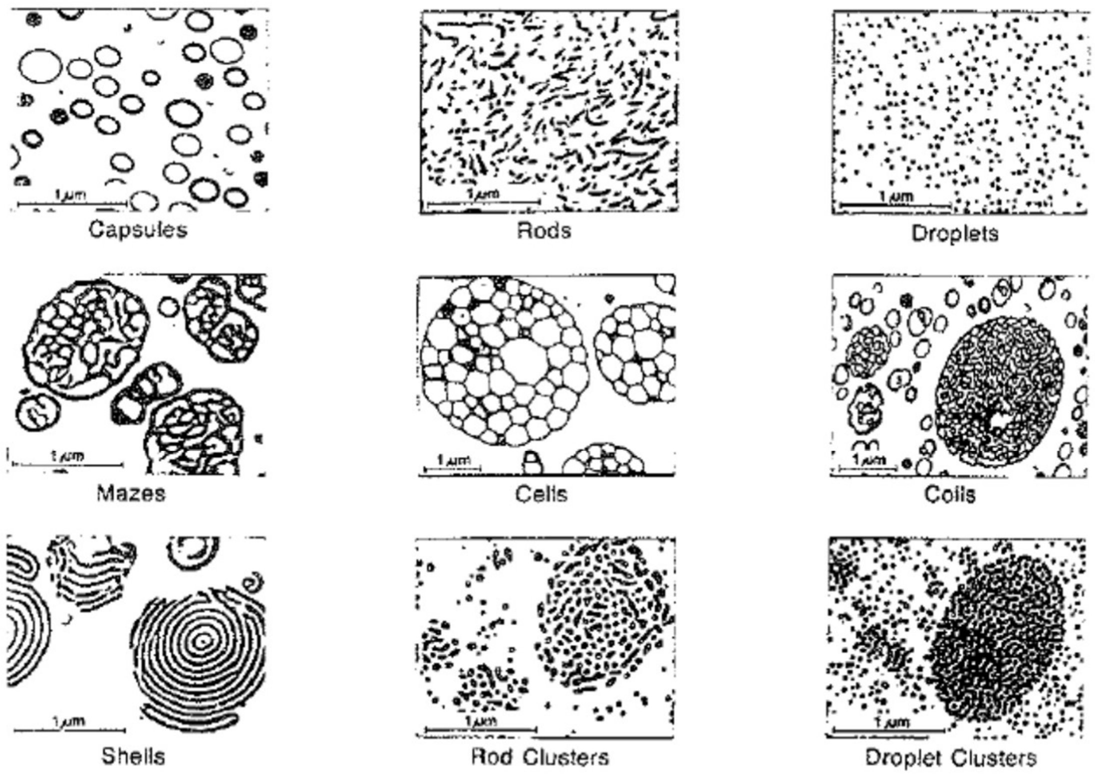


Figure 14. Particle structures observed in HIPS. (Reproduced with permission from ref. 32. Copyright 1982 Hanser.)

Typical properties of ABS and applications

Grade			Good Flow	Middle Impact	Heat Resistance	For Extrusion Standard	For Extrusion High Impact
Item	Unit	Test Method	UT61	MT81	GT-10	ET-70	ST-55
Rheologocal Properties							
Melt Flow Rate	cm^3 /10min	ISO 1133	35	23	20	9	15
Mechanical Properties							
Tensile Stress at Yield	MPa	ISO 527	50	48	52	43	49
Flexural Modulus	MPa	ISO 178	2,400	2,300	2,500	2,100	2,100
Flexural Strength	MPa	ISO 178	76	72	81	66	74
Charpy Notched Impact Strength	kJ/m^2	ISO 179	15	20	15	18	25
Rockwell Hardness	R Scale	ISO 2039	116	113	118	110	110
Thermal Properties							
Temperature of Deflection under Load	deg.C	ISO 75	81	78	85	81	82
Ball Pressure registration Temperature	deg.C	*1	90	90	95	-	-
Flammability	-	UL-94	HB	HB	HB	HB	HB
Other Properties							
Density	g/cm^3		1.05	1.04	1.05	1.05	1.04
Application			Housewares, Electrical appliences (injection)	←	Machinery Parts (Injection)	Sheets, Housing-related materials	←

*1 : Electrical Appliance and Material Safety Law

[redacted]

HIPS Properties

[redacted]

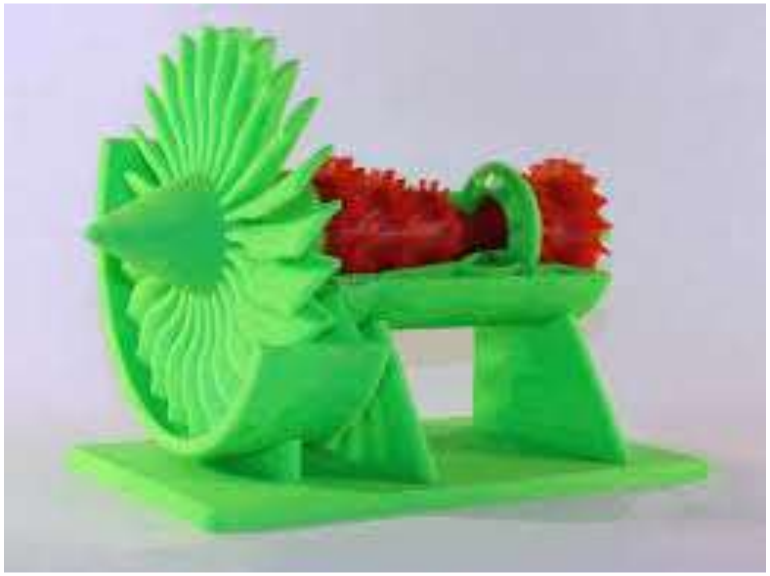
Properties	Unit	Test Method	High Performance Grades (Note.1)				Conventional Grades				
			ESCR	High Gloss	Super High Impact	Super High Flow	Standard for Injection	Sheet	High Heat	High Impact Sheet	High Strength High Heat
Melt Index (200°C, 5,000 g)	(g/10 min.)	ISO-1133	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Tensile Strength (Yield)	(MPa)	ISO-527	22	38	37	23	25	30	35	27	37
Elongation	(%)	ISO-527	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Charpy (notched, t = 4.0 mm, +23deg.C)	(kJ/m2)	ISO-179	12	14	22	17	15	14	12	16	10
Charpy (notched, t = 4.0 mm, -30deg.C)	(kJ/m2)	ISO-179	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Vicat Softening Point (49N)	(°C)	ISO-306	88	94	96	84	86	91	96	90	96
Gloss 60°	(%)	ISO-306B	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
Cyclopentane Resistance	(%)	TEC/MCI	70	-	-	-	-	-	-	-	-
Main Application			[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

Comparison of ABS and HIPS Mechanical Properties

Polymers	HIPS			ABS			PLA		
	OV	SD	$SE\overline{x}$	OV	SD	$SE\overline{x}$	OV	SD	$SE\overline{x}$
MFI (g/10 min)	7.5 ± 0.20	0.16	0.11	8.76 ± 0.16	0.13	0.09	13.52 ± 0.11	0.09	0.06
Young's modulus (MPa)	112.5 ± 0.12	0.09	0.06	175 ± 0.11	0.09	0.06	47.9 ± 0.10	0.08	0.05
Yield stress (MPa)	3.44 ± 0.21	0.17	0.12	0.49 ± 0.21	0.17	0.12	0.27 ± 0.16	0.13	0.09
Glass transition temp (°C)	100.41 ± 0.16	0.13	0.09	109.76 ± 0.2	0.16	0.11	62.57 ± 0.21	0.17	0.12
Peak load (N)	80.8 ± 0.11	0.08	0.06	207 ± 0.2	0.16	0.11	282.4 ± 0.20	0.16	0.11
Peak strength (MPa)	4.21 ± 0.16	0.13	0.09	10.78 ± 0.11	0.09	0.06	14.71 ± 0.16	0.13	0.09
Peak elongation (mm)	1.9 ± 0.20	0.16	0.11	4.75 ± 0.16	0.13	0.09	5.13 ± 0.16	0.13	0.09
Percentage elongation at peak (%)	3.0 ± 0.11	0.09	0.06	6.0 ± 0.15	0.12	0.08	7.0 ± 0.10	0.08	0.05

ABS is used in 3D Printing



HIPS is used in 3D Printing

Questions?

I may not be that funny or athletic or good looking
or smart or talented. . . . . I forgot where I was going with this.