There will be a Quiz on Monday

January ~~24~~, 27, 2025

* From the Hitchhikers Guide to the Galaxy – Douglas Adams

EMAC 276 - Homework Assignment #1

Due: Friday January 24, 2025

Dr. Olah

We have spent some time on the Hierarchical Structure concept within several disciplines; i.e., biology, polymer science, mechanical engineering, management, etc.

Other than the examples we have provided in class, your assignment is to identify one ***additional*** example of the hierarchical structure concept.

In your description you must:

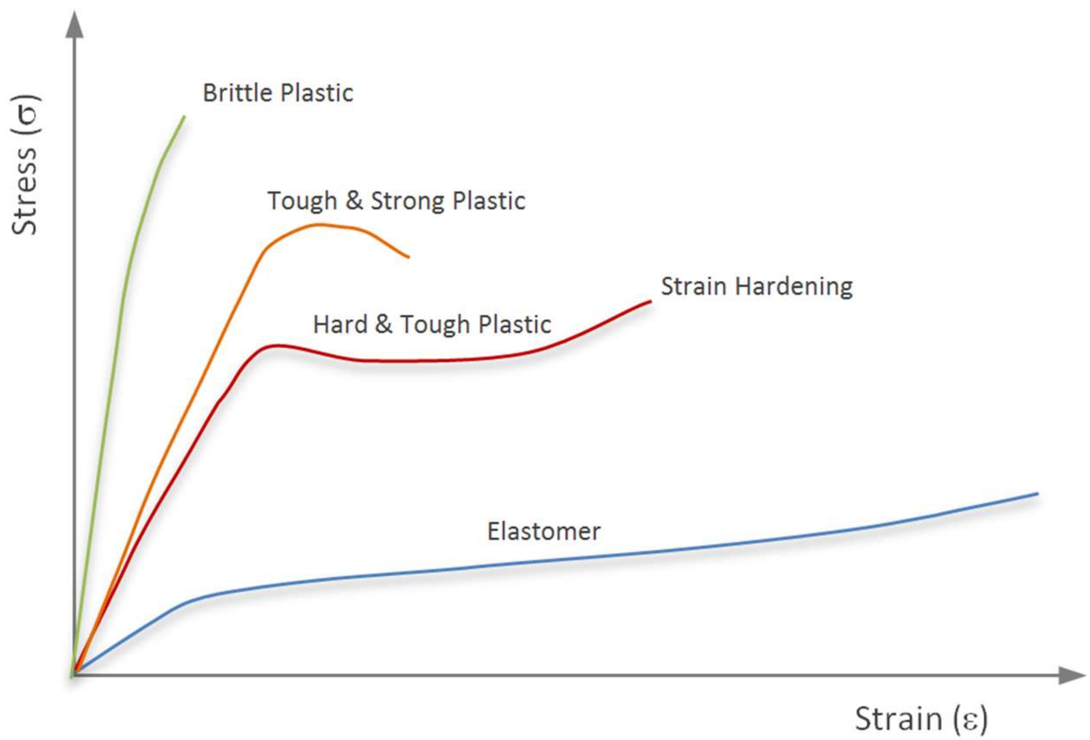
1. Identify the example and the discipline it involves.
2. Explain the number of hierarchical levels and the scale of each level.
3. Identify the relationship in your example of the three concepts of hierarchical structures:
    a. Scale
    b. Interaction
    c. Architecture
4. Please keep your answer to one page.

EMAC 276

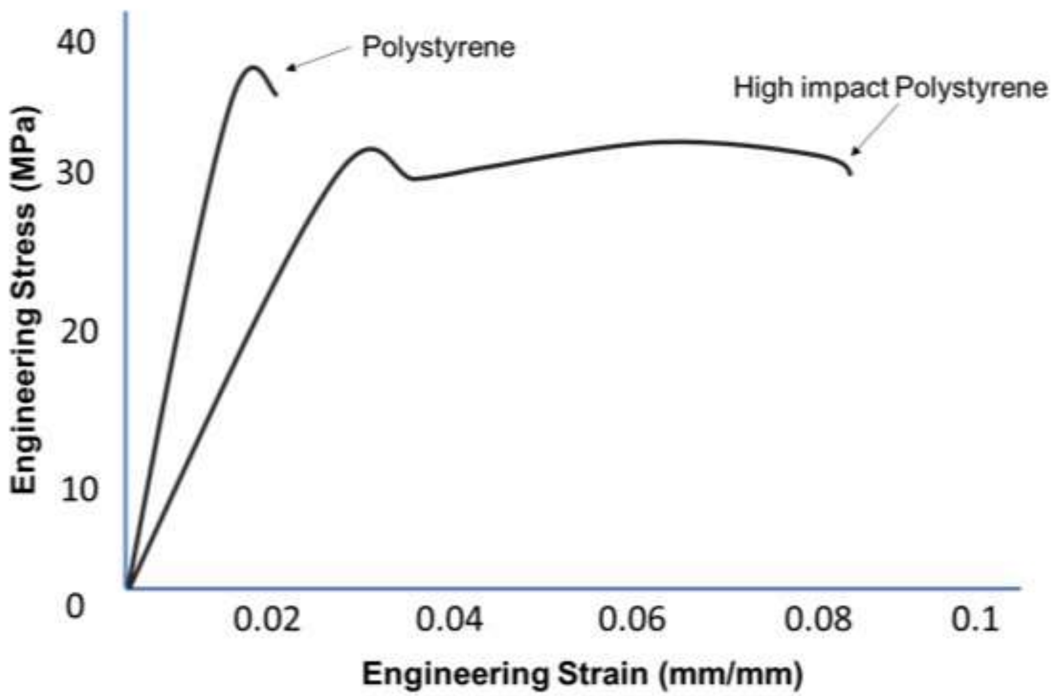
Lesson 4: SAN, ABS, HIPS

Andy Olah, Ph.D.
January 22, 2025

Variations on the Theme - Polystyrene



Unmodified Polystyrene is a Brittle Material



Tensile Testing and Relationship to The Tensile Properties of Plastics

Instron® 3300 Floor Model

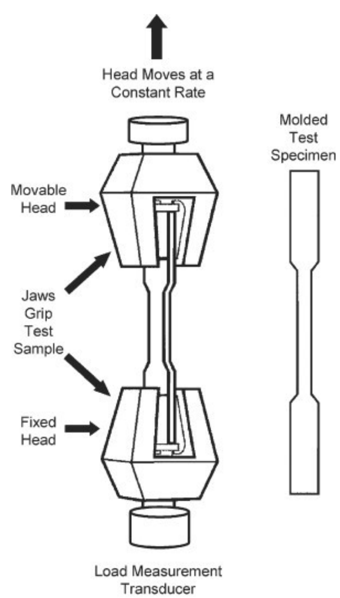
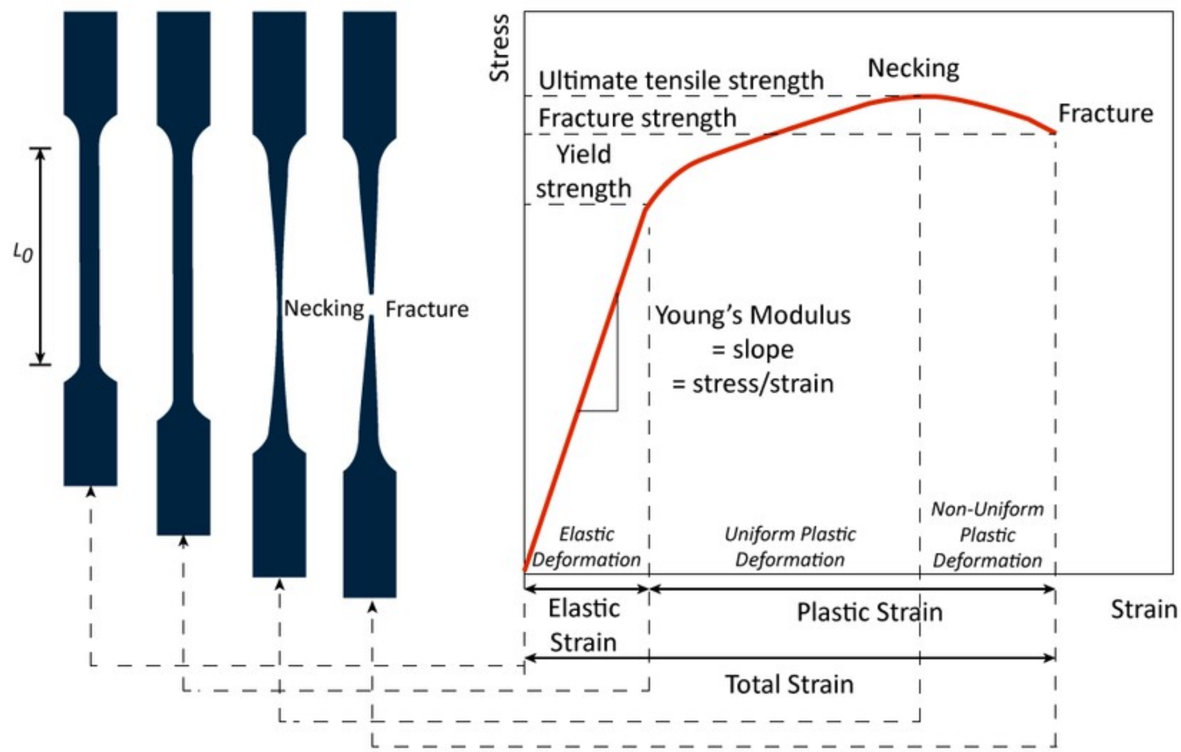
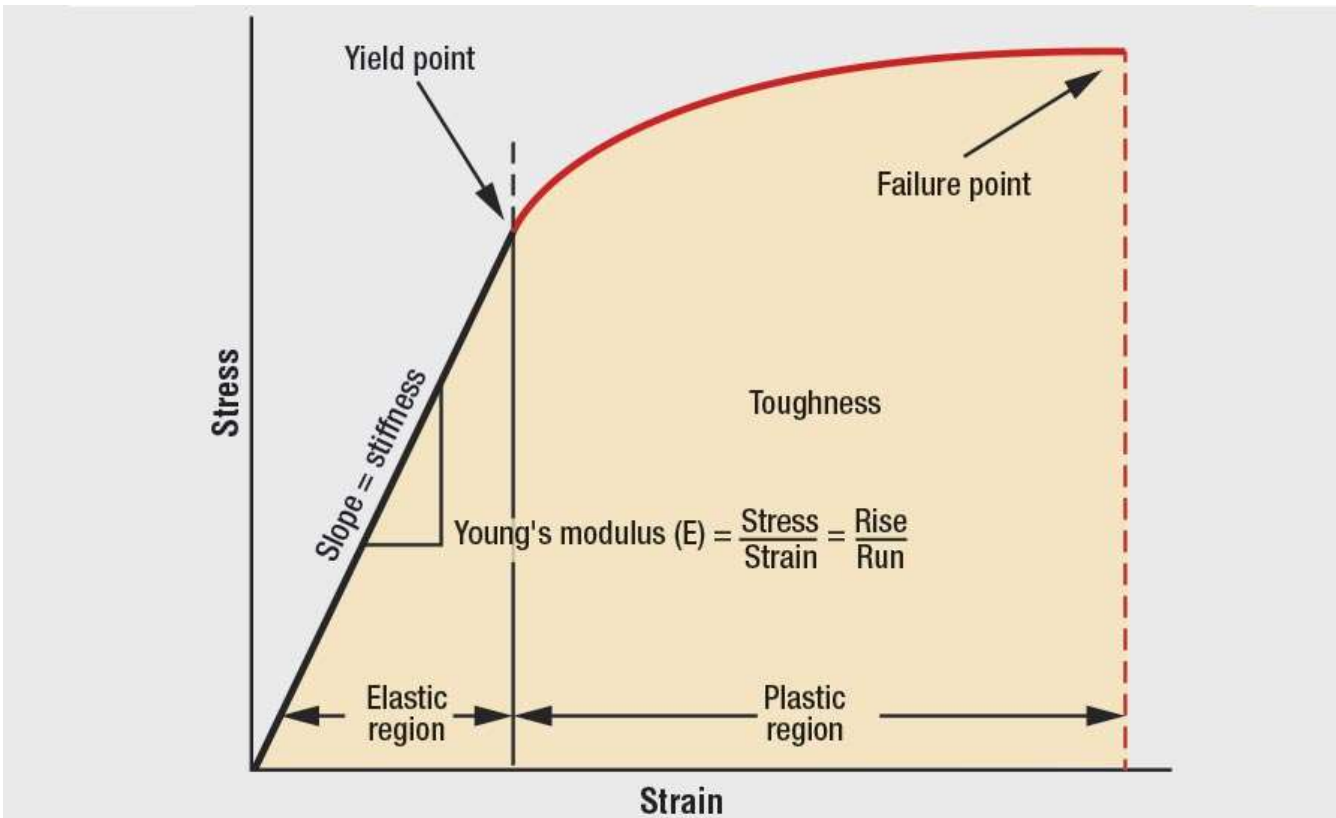


Diagram of Test Specimen and Mounting Jaws

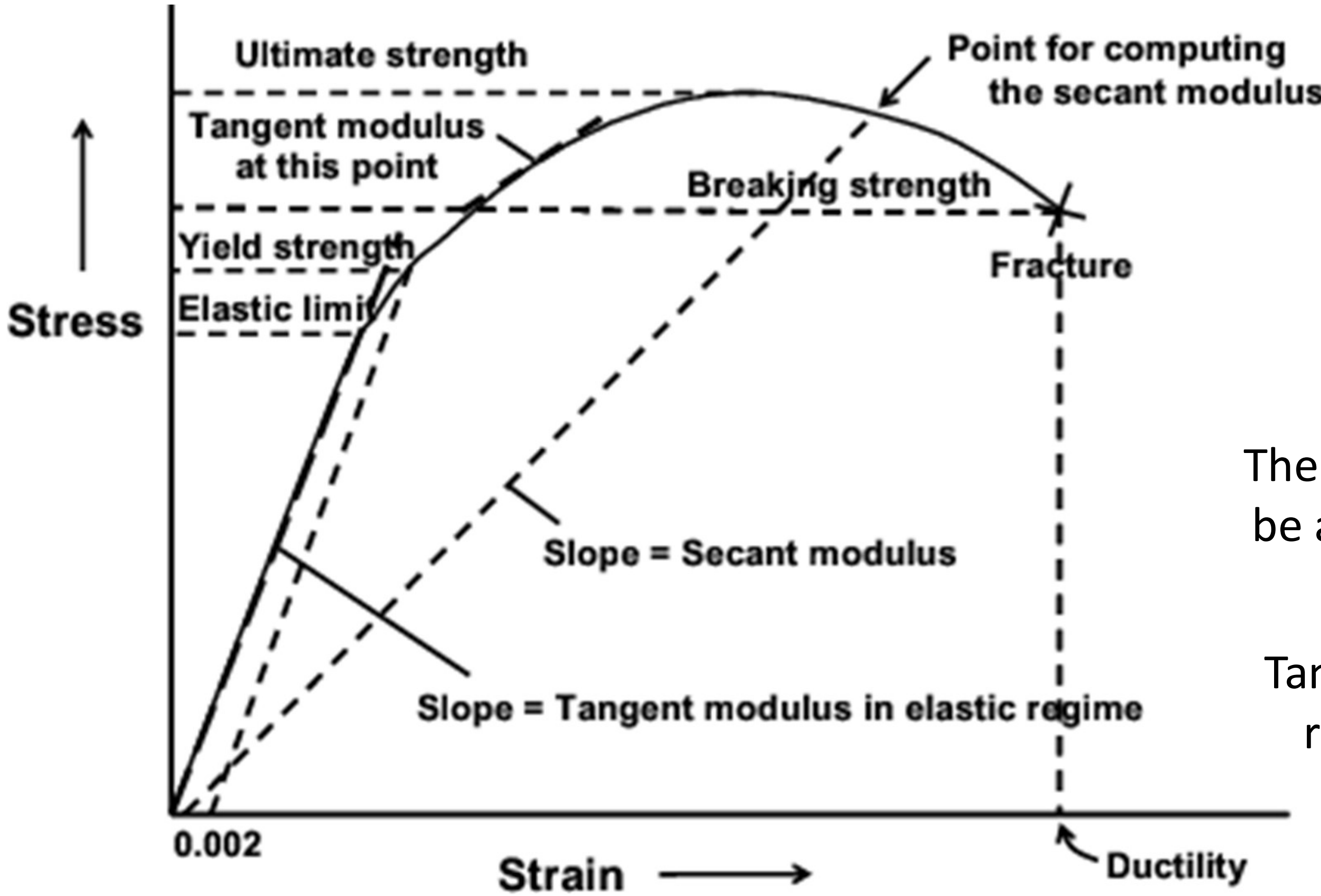


ASTM D638: Standard Test Method for Tensile Properties of Plastics

Tensile Properties of Plastics is a Fingerprint of the Mechanical Performance



Tensile Properties of Plastics is a Fingerprint of the Mechanical Performance

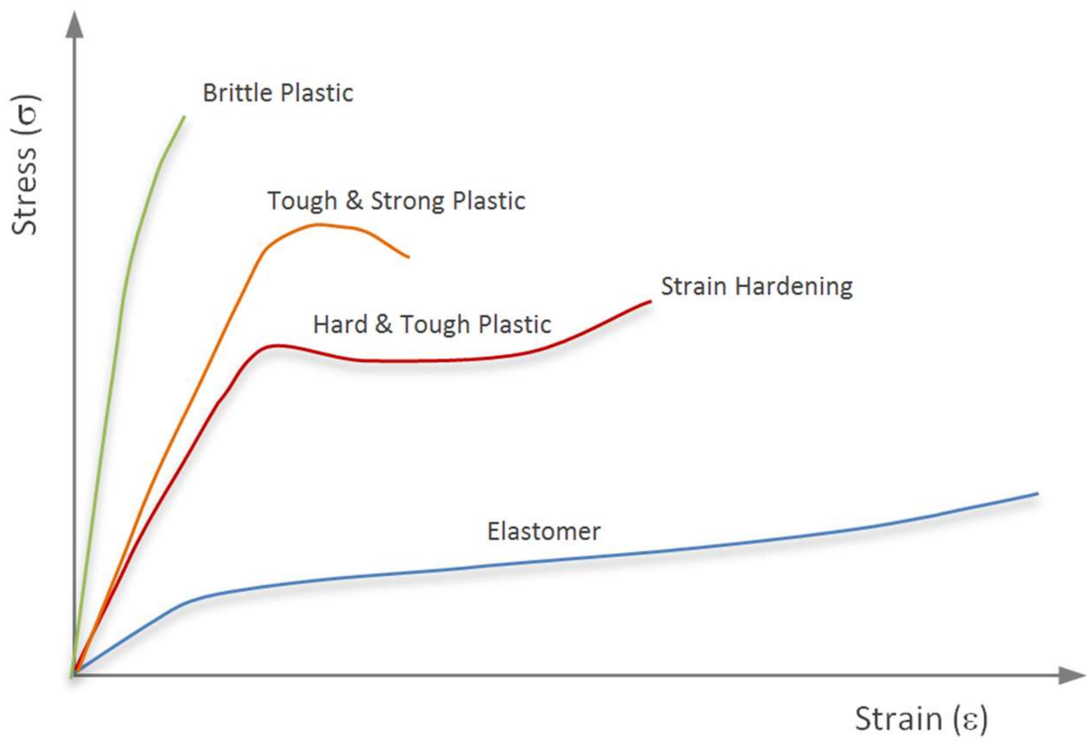


$$\frac{\text{Secant Modulus}}{\text{Tangent Modulus}} \leq 1$$

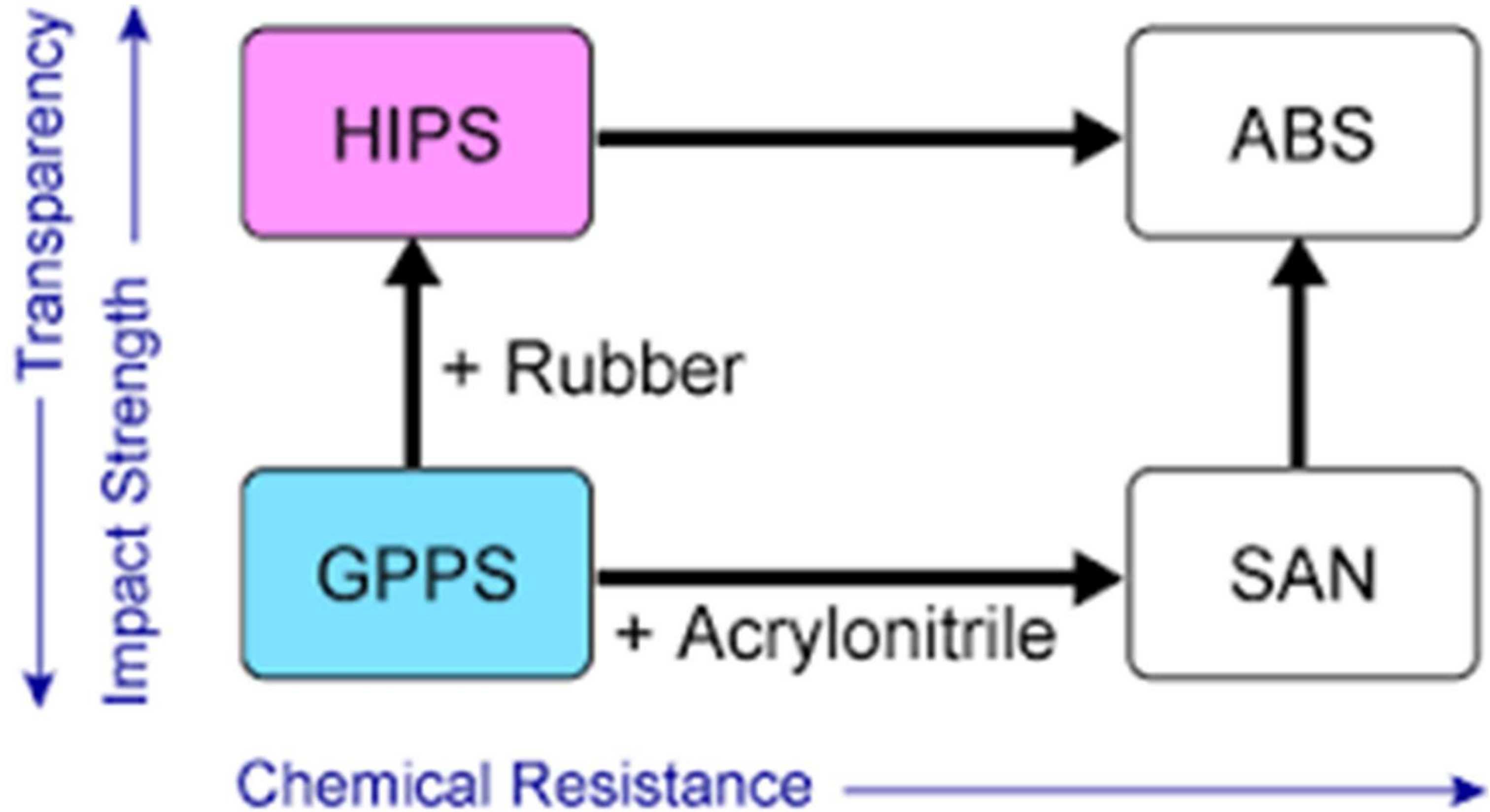
The Secant Modulus must always be associated with a strain level.

Tangent Modulus in the elastic regime is Young's Modulus.

Tensile Properties of Polymers can Vary Greatly



Polystyrene Derivatives for Improved Performance

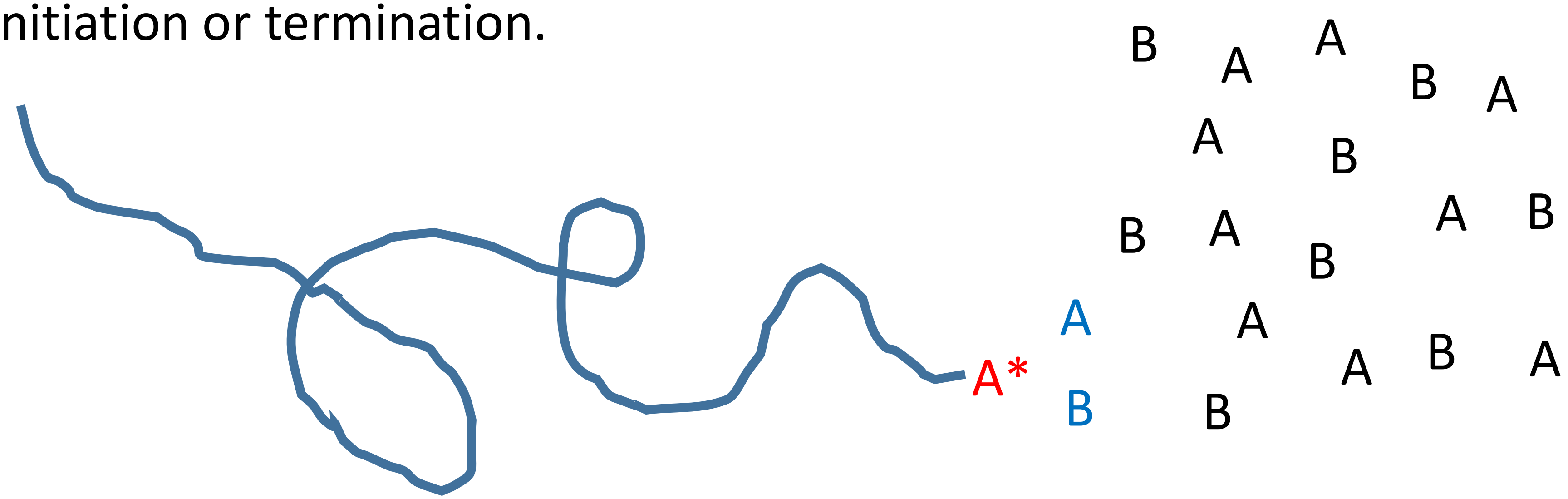


GPPS = general purpose polystyrene

Reactivity Ratios for Free Radical Polymerization

Assumptions:

1. Concentration of free radicals doesn't change over time.
2. Only the last monomer unit on a polymer chain determines reactivity.
3. Chain propagation is the only reaction of importance; i.e., disregard initiation or termination.



Reactivity Ratios for Free Radical Polymerization

$$A\cdot + A \xrightarrow{k_{11}} A\cdot$$

$$A\cdot + B \xrightarrow{k_{12}} B\cdot \qquad \text{A, B} = \text{monomers A and B}$$

$$B\cdot + B \xrightarrow{k_{22}} B\cdot \qquad A\cdot, B\cdot = \text{growing chains ending in groups A and B}$$

$$B\cdot + A \xrightarrow{k_{21}} A\cdot$$

Rate of consumption (disappearance) of monomers A and B:

$$-\frac{d[A]}{dt} = k_{11}\,[A\cdot]\,[A] + k_{21}\,[B\cdot]\,[A]$$

$$-\frac{d[B]}{dt} = k_{12}\,[A\cdot]\,[B] + k_{22}\,[B\cdot]\,[B]$$

Reactivity Ratios for Free Radical Polymerization

The reactivity ratios r_1 and r_2 are defined as:

$$r_1 = \frac{k_{11}}{k_{12}}$$ The ratio of reactivity of monomer 1 (A) toward itself to the reactivity of monomer 1 toward monomer 2 (B).

$$r_2 = \frac{k_{22}}{k_{21}}$$

If the product of r_1 and r_2 is:

a) $r_1 * r_2 \sim 1$ – Random Copolymer – A A B B B A A A B A B A A A A
b) $r_1 * r_2 < 1$ – Alternating Copolymer – A B A B A B A B A B A B A B
c) $r_1 * r_2 >> 1$ – Block Copolymer – A A A A A A A A B B B B B B B B

Reactivity Ratios for Free Radical Polymerization

TABLE 2.11
REACTIVITY RATIOS FOR COPOLYMERIZATION AT 60°C

M_1	M_2	r_1	r_2
Styrene	Acrylonitrile	0.4 ± 0.05	0.04 ± 0.04
Styrene	Methyl methacrylate	0.52 ± 0.02	0.46 ± 0.02
Styrene	Butadiene	0.78 ± 0.01	1.39 ± 0.03
Styrene	Vinyl acetate	55 ± 10	0.01 ± 0.01
Styrene	Maleic anhydride	0.02	0
Methyl methacrylate	Acrylonitrile	1.2 ± 0.14	0.15 ± 0.07
Methyl methacrylate	Vinyl acetate	20 ± 3	0.015 ± 0.015
Methyl methacrylate	Methyl acrylate	1.69	0.34
Vinyl acetate	Acrylonitrile	0.061 ± 0.013	4.05 ± 0.3
Vinyl acetate	Vinyl chloride	0.23 ± 0.02	1.68 ± 0.08
Vinylidene chloride	Isobutene	3.3	0.05

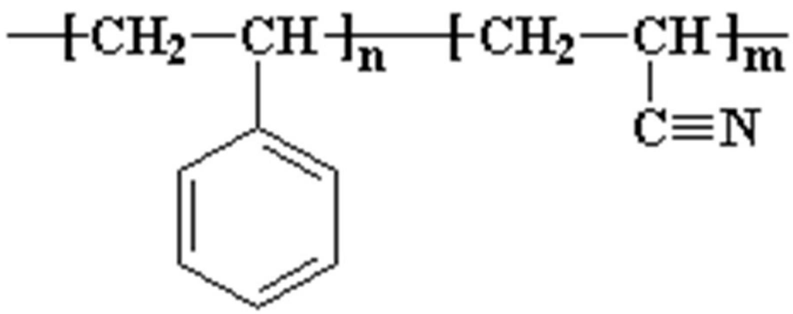
Reactivity Ratios for Free Radical Polymerization

Products of Monomer Reactivity Ratios in Copolymerization

Butadiene							
1.0	Styrene						
0.71	0.55	Vinyl Acetate					
0.30	0.34	0.39	Vinyl Chloride				
0.19	0.24	0.30	1.0	Methyl Methacrylate			
0.10	0.16	0.12	0.96	0.61	Vinylidene Chloride		
0.04	0.14	0.90	0.75	0.96	0.80	Methyl Acrylate	
0.02	**0.02**	0.25	0.13	0.24	0.34	0.84	Acrylonitrile

$r_1 * r_2 << 1$ – Alternating Copolymer

Styrene Acrylonitrile Copolymer - SAN



SAN

Commonly having 70% styrene and 30% Acrylonitrile.

Tensile Strength of SAN to Polystyrene

thermoplastic	tensile strength (MPa)	elongation at break (%)
polystyrene	46	2.2
styrene–acrylonitrile	72	3
acrylonitrile–butadiene–styrene (ABS)	48	8
flame-retardant ABS	40	5.1
polypropylene	32	15
polyethylene	30	9

Styrene Acrylonitrile Copolymer

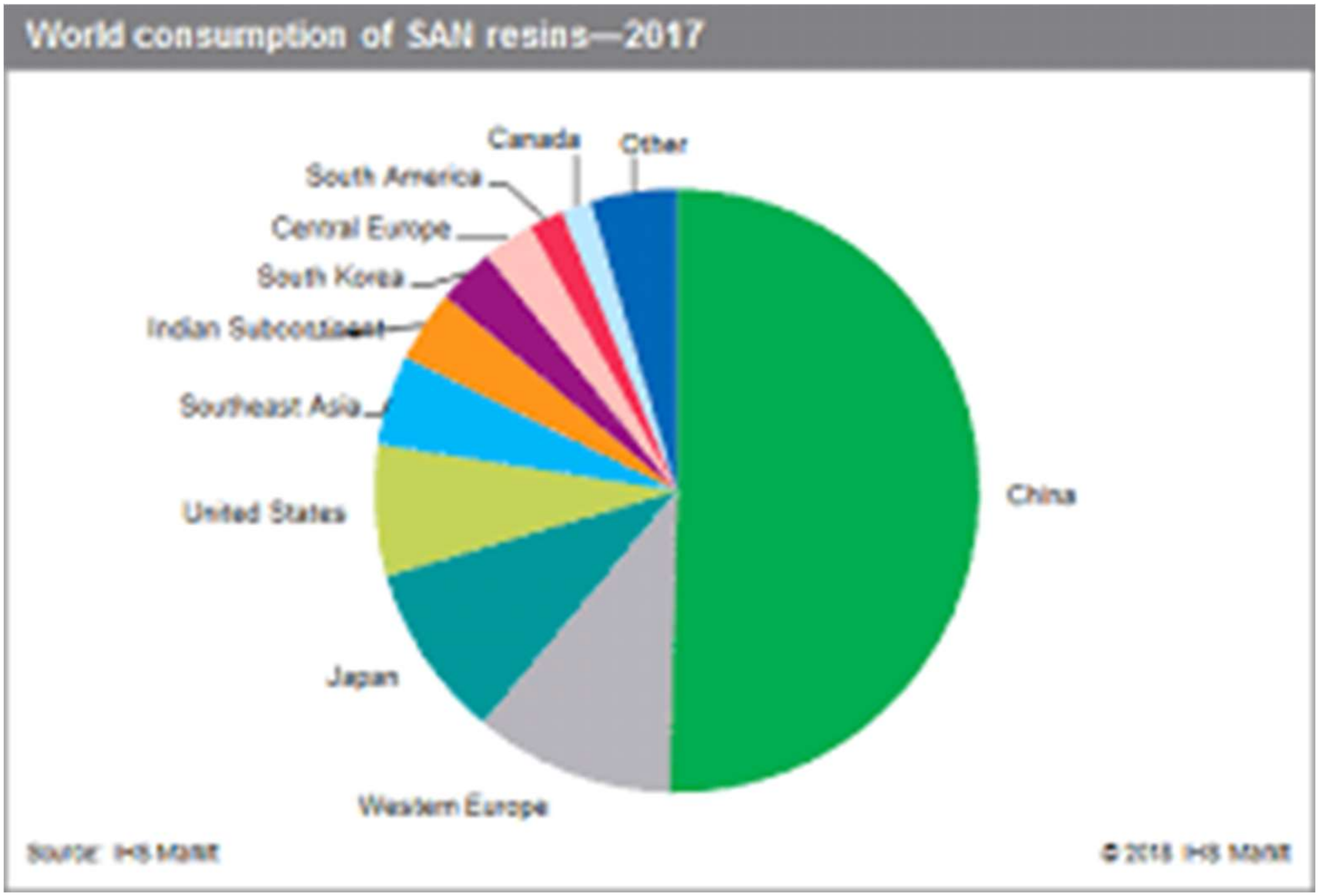
Some of the advantages of SAN include:

- Excellent Rigidity/Stiffness.
- Excellent Load-Bearing Capacity.
- Excellent Chemical **Resistance**.
- High Flexural **Strength**.
- Good Appearance.
- Good Clarity.
- Good Thermal **Resistance**.

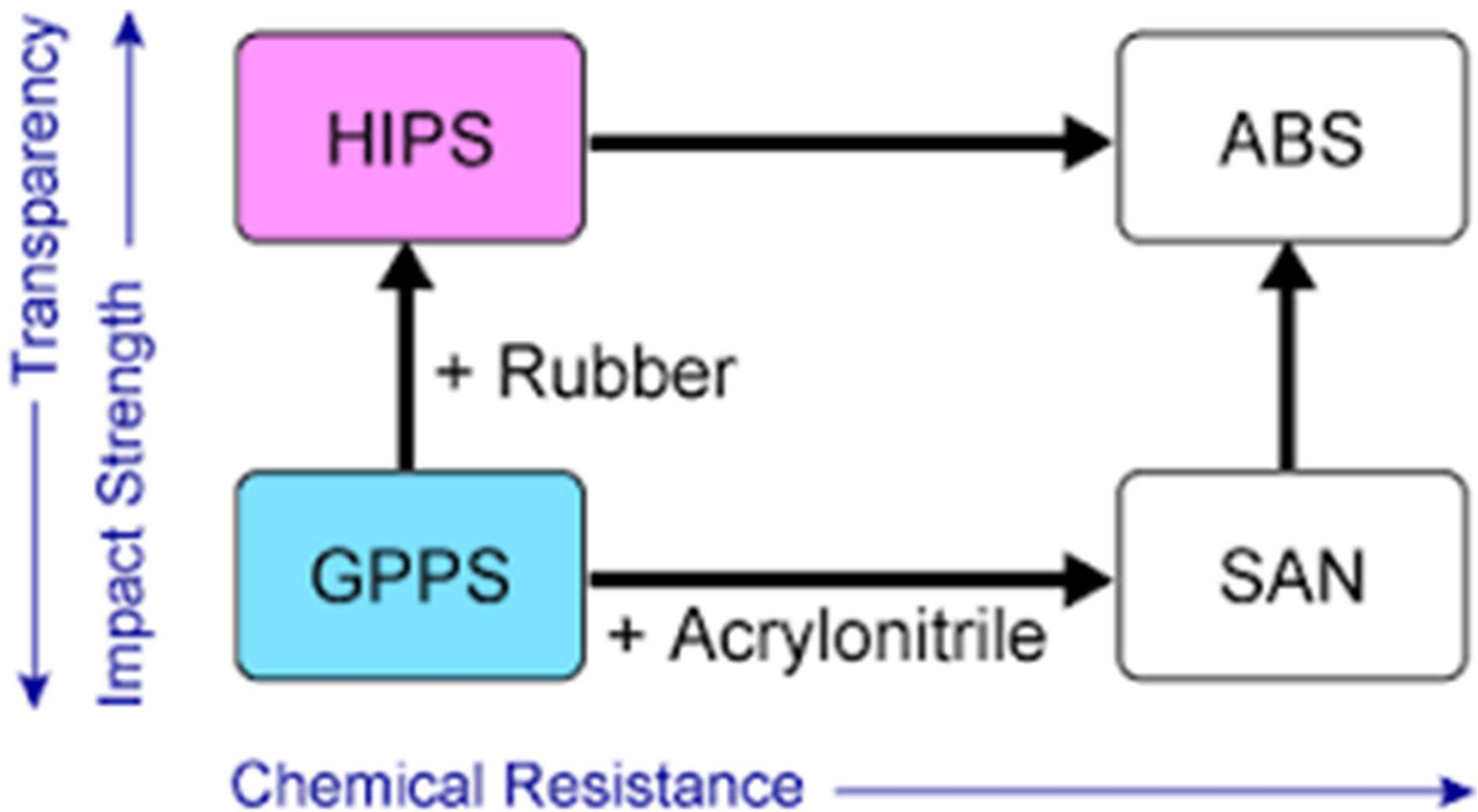
Uses

Electrical/Electronic Applications , Household Goods , Appliances, Cosmetic Packaging, Compounding, Automotive Applications, General Purpose, Stationary Supplies, Cups, Containers.

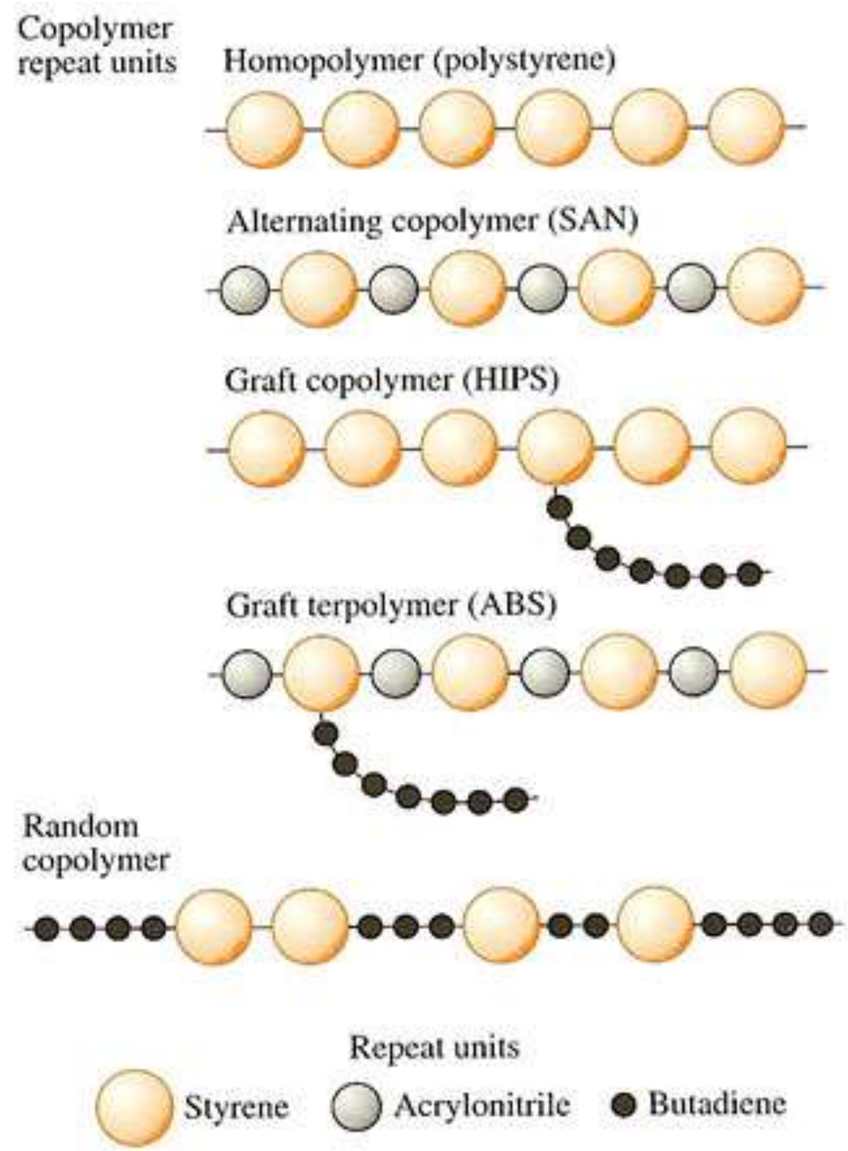
Styrene Acrylonitrile Copolymer



Polystyrene Derivatives for Improved Performance



ABS – Acrylonitrile, Butadiene, Styrene Copolymer



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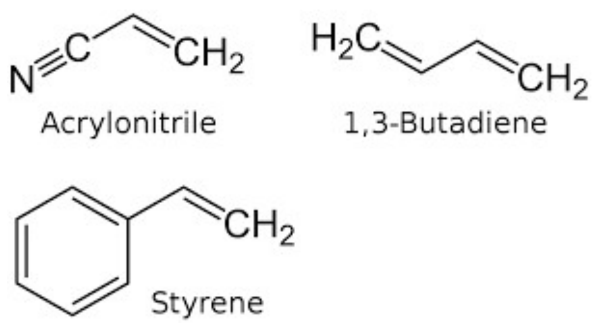
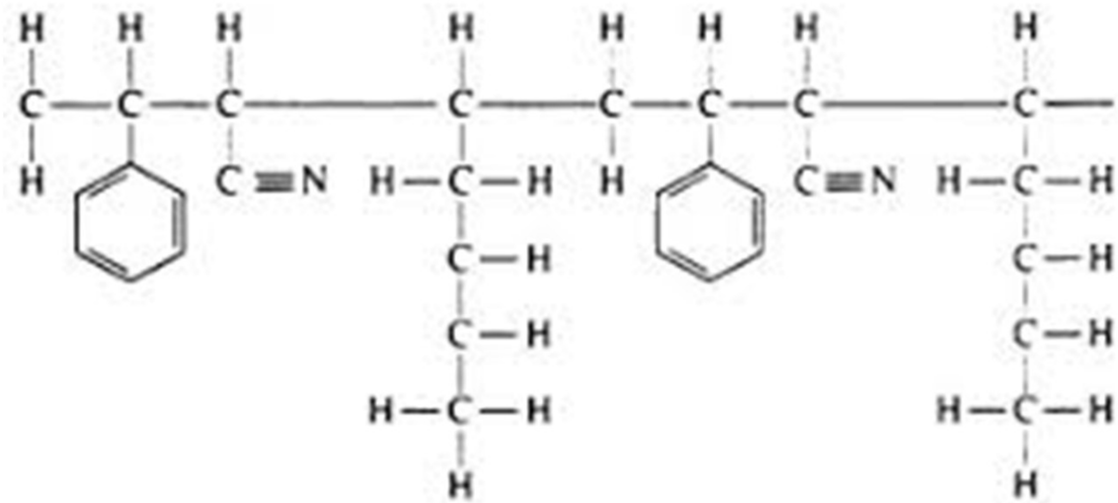
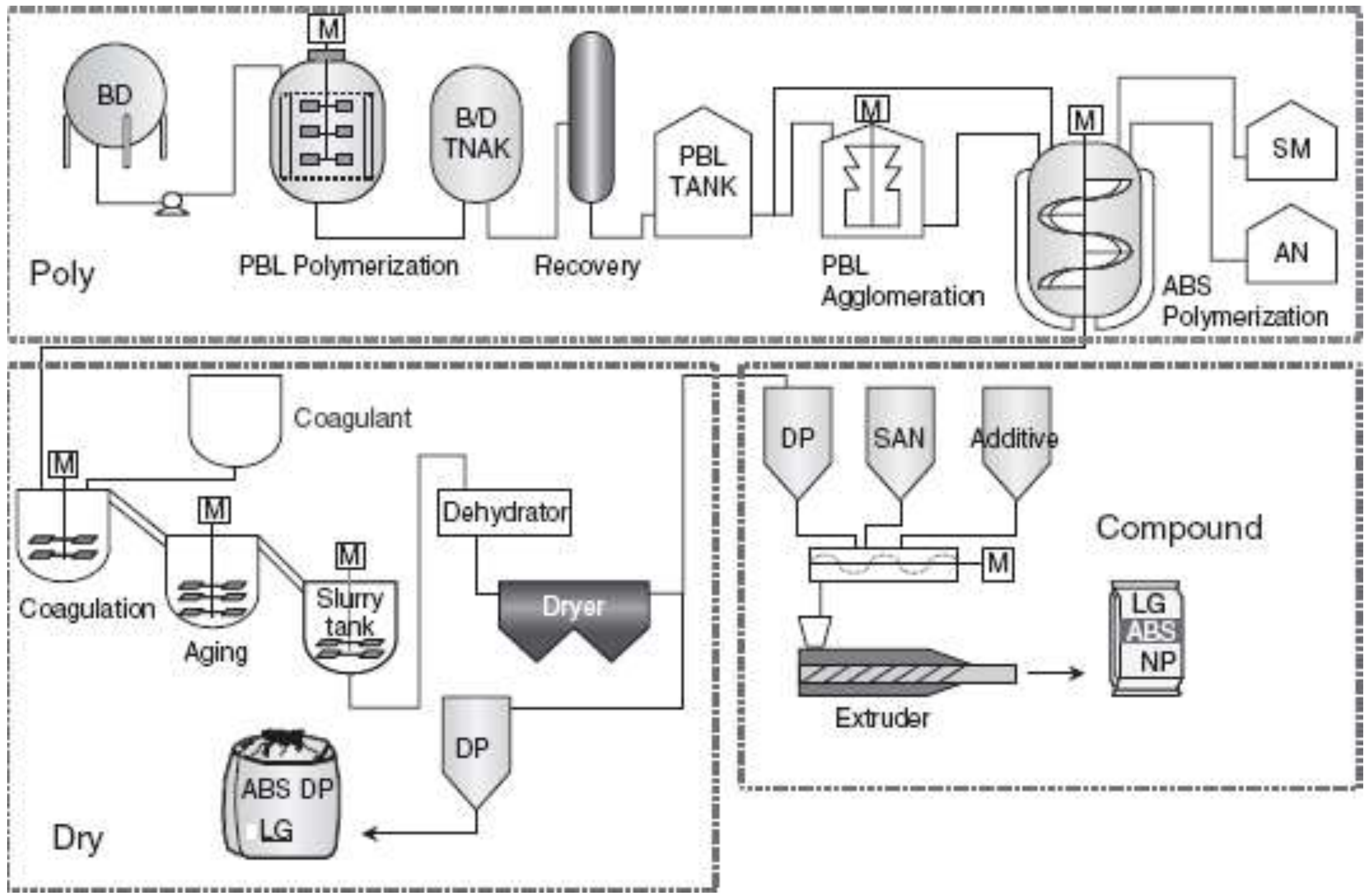




Borg-Warner Patent – 1948
B-W Commercialized - 1954

Production of ABS Polymer

40 – 60% Polystyrene
15 – 35% Acrylonitrile
5 – 30% Butadiene



ABS – Acrylonitrile, Butadiene, Styrene Copolymer

A Word of Caution on Recycling

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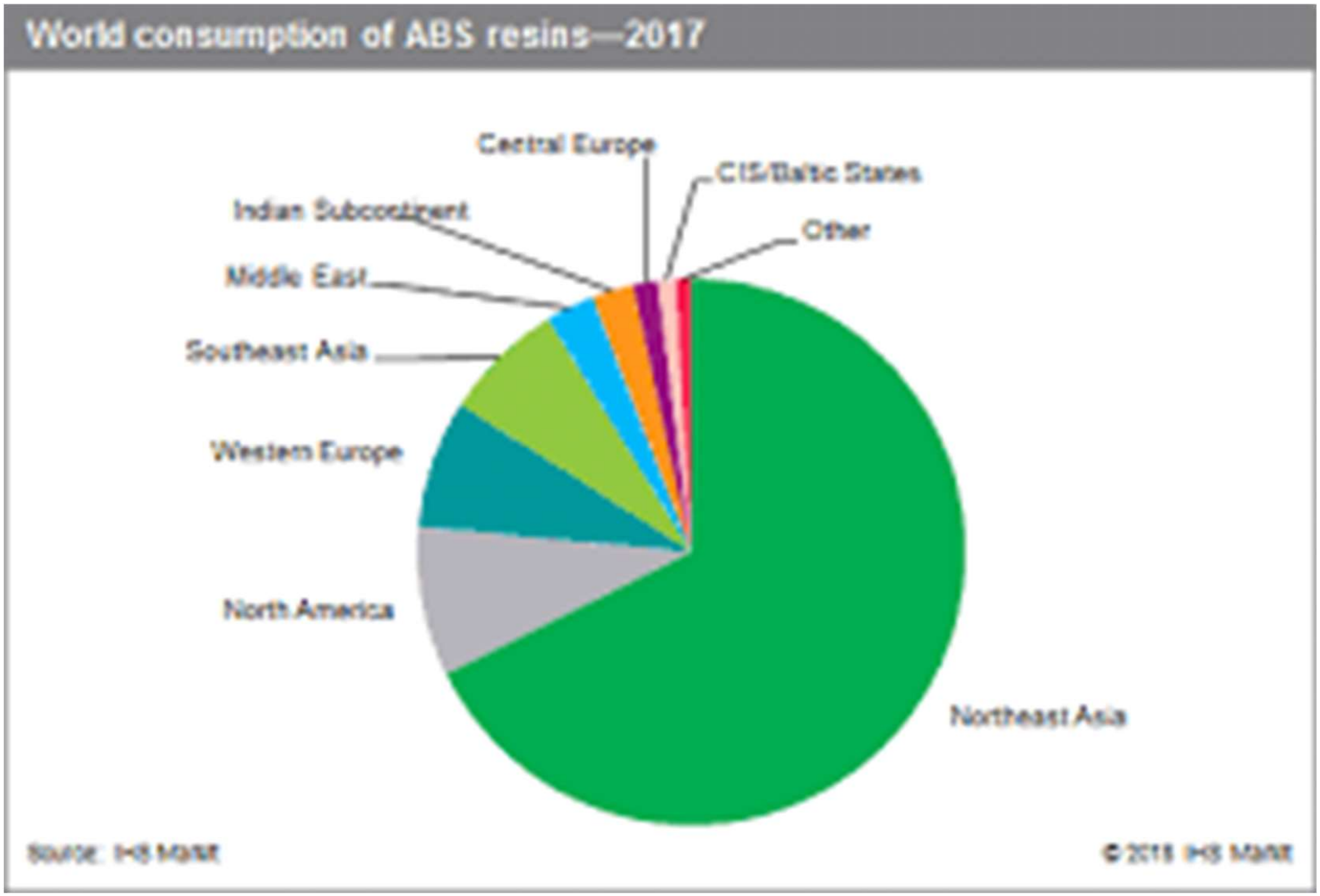
"All Black" defective black ABS plastic waste pipe manufactured in the mid 1980's failed by cracking. The result was litigation and some damage settlements.
ABS drain pipe material failures were reported for pipe made between 1985 and 1988. [1][2][5][6][7] below

ABS – Acrylonitrile, Butadiene, Styrene Copolymer



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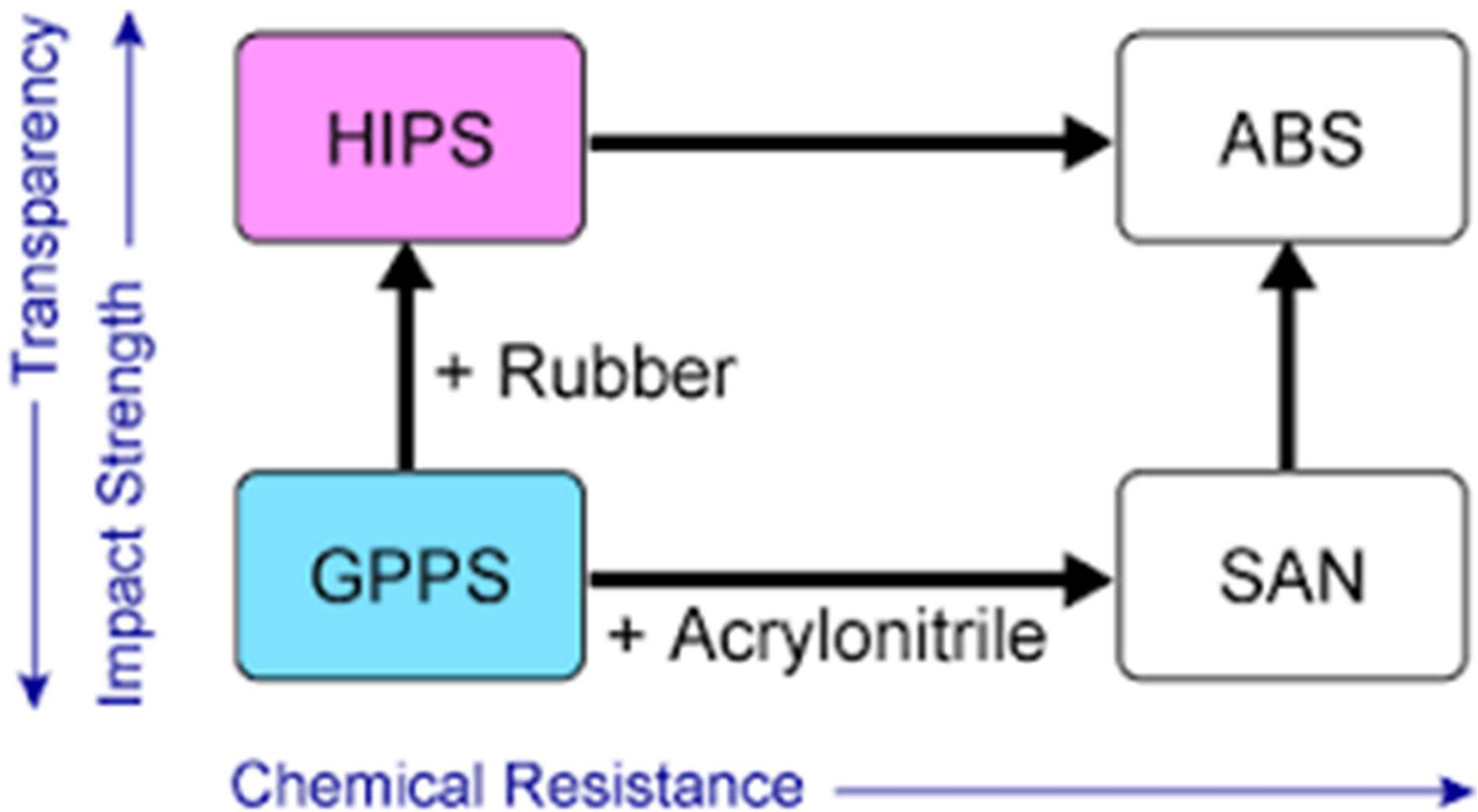
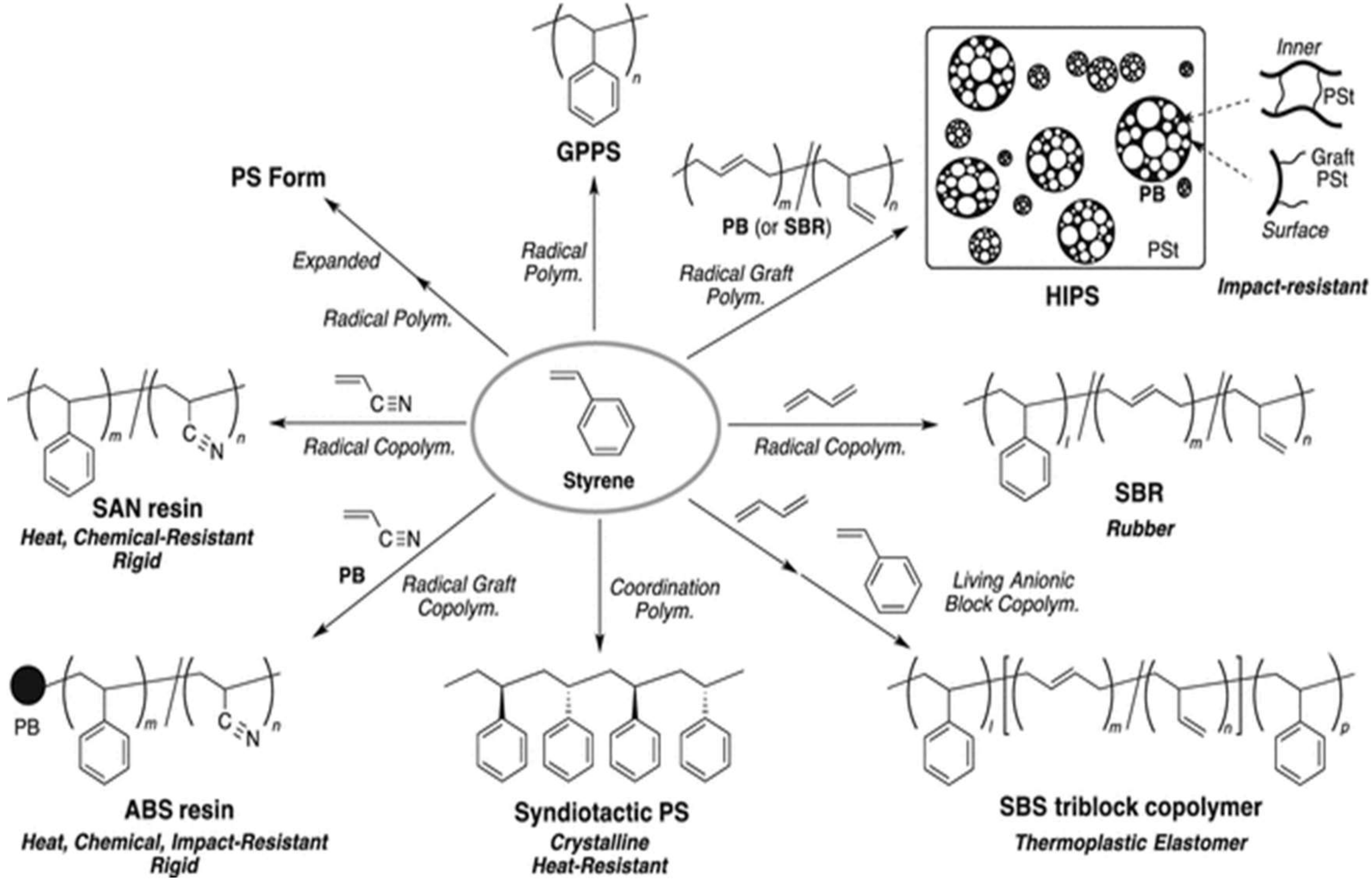


Styrenic Forms



Lesson 3: SAN, ABS, HIPS

Questions?

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“When I was a kid, I wanted to be older . . . . . **This is not what I expected!**