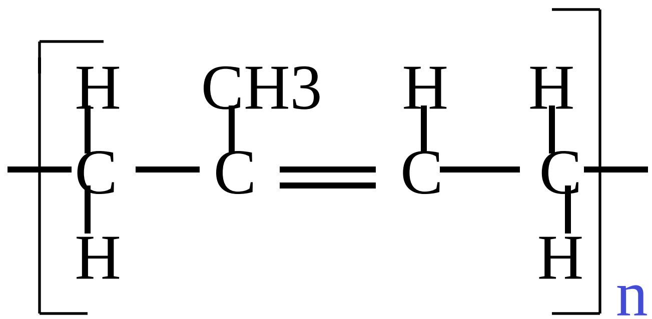
MSE200
Lecture 18 (CH. 10.9, 10.11)
Polymeric Materials
Instructor: Yuntian Zhu

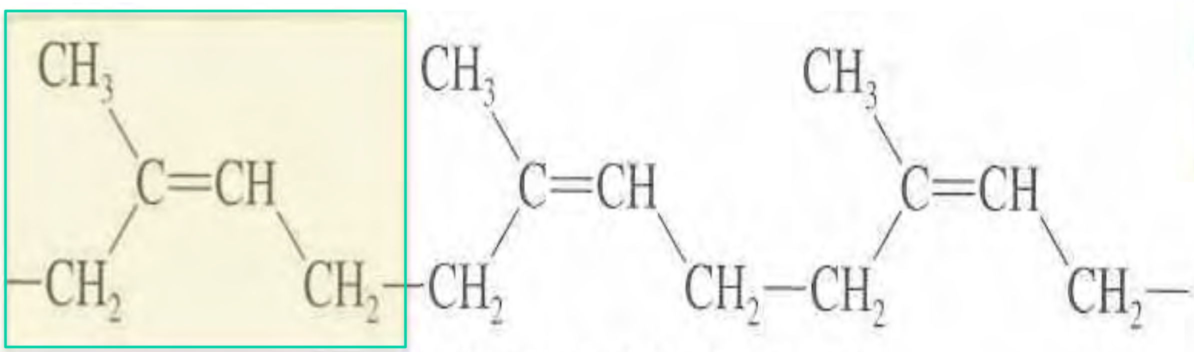
Objectives/outcomes: You will learn the following:

- Elastomers and vulcanization.
- Mechanical properties of polymeric materials in relation to structure
- Stress relaxation

Elastomers (Rubbers)

- **Natural rubber: Produced from latex (sap) of Havea Brasiliensis tree**

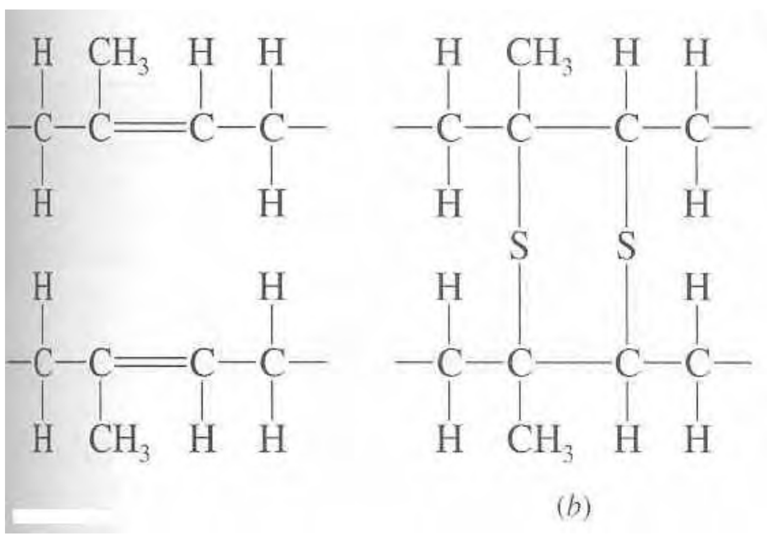


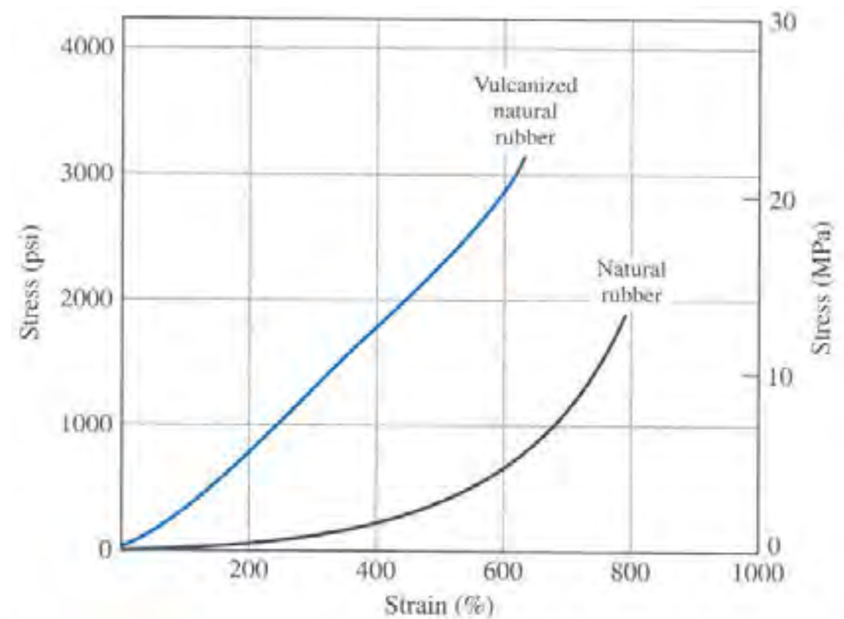


Segment of natural rubber polymer chain

Vulcanization:

- **Heating rubber with sulfur and lead carbonate**
  - **Increases tensile strength**
  - **Increase stiffness**
  - **Restricts molecular movement by crosslinking of molecules**



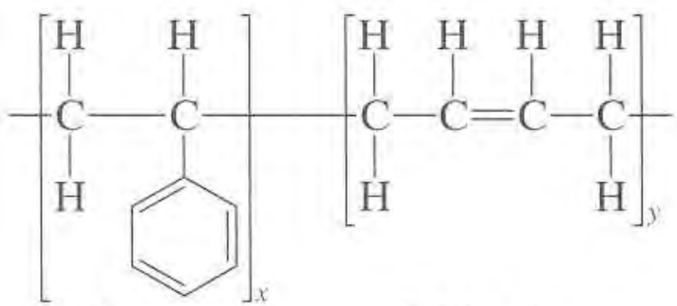


Natural and Synthetic Rubbers - Properties

Elastomer	Tensile strength (ksi)[†]	Elongation (%)	Density (g/cm^3)	Recommended operating temp. °F	°C
Natural rubber* (*cis*-polyisoprene)	2.5–3.5	750–850	0.93	−60 to 180	−50 to 82
SBR or Buna S* (butadiene-styrene)	0.2–3.5	400–600	0.94	−60 to 180	−50 to 82
Nitrile or Buna N* (butadiene-acrylonitrile)	0.5–0.9	450–700	1.0	−60 to 250	−50 to 120
Neoprene* (polychloroprene)	3.0–4.0	800–900	1.25	−40 to 240	−40 to 115
Silicone (polysiloxane)	0.6–1.3	100–500	1.1–1.6	−178 to 600	−115 to 315

Synthetic Rubbers

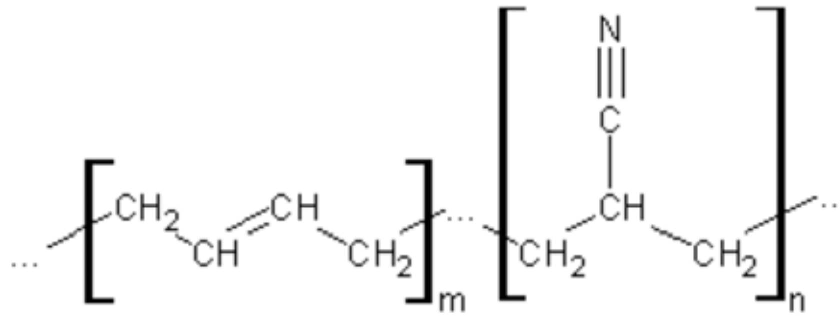
- **Styrene-Butadiene rubber (SBR): Most widely used.**
  - **Greater elasticity than natural rubbers.**
  - **Tougher and stronger, wear resistant.**
  - **Absorbs organic solvents and swell.**



Polystyrene   Polybutadiene

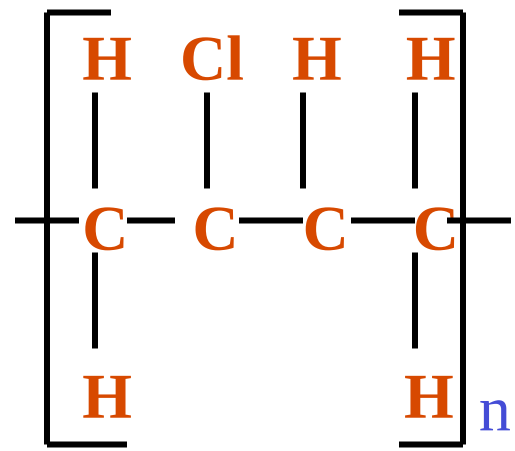
Nitrile Rubbers

- **55-82% Butadiene and 45-18% acrylonitrile.**
  - **Resistance to solvents and wear**
  - **Less flexible.**



Polychloroprene

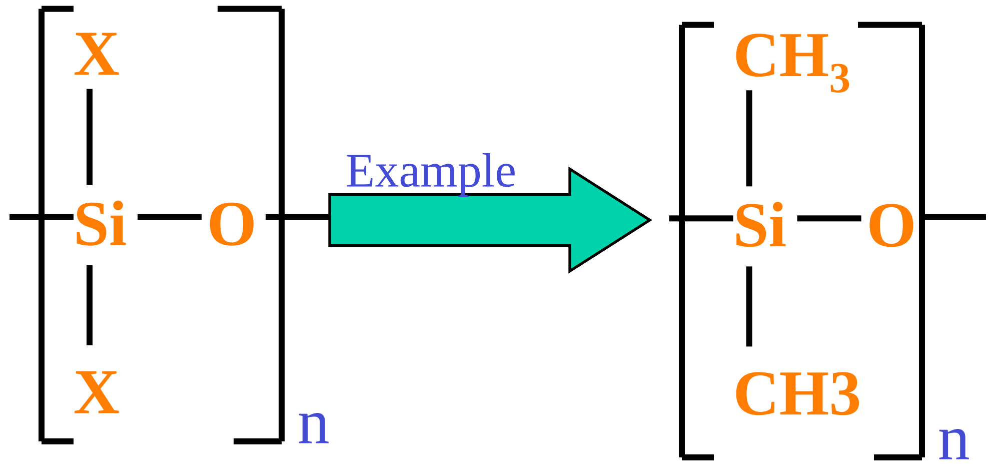
- **Increased resistance to oxygen, ozone, heat and weather.**
- **Low temperature flexibility, high cost.**



Silicone Rubbers:

Wide temperature range.

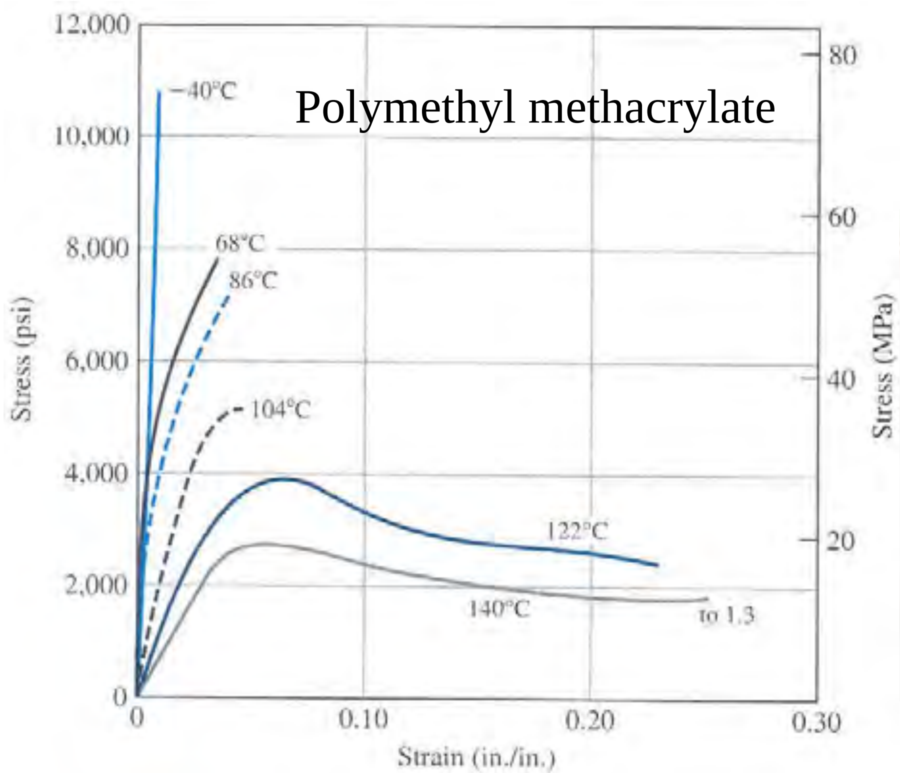
Used in gaskets, electric insulation etc.



http://video.google.com/videosearch?q=silicone+rubber&hl=en&sitesearch=

Deformation of Thermoplastics

- **Below T_g: Elastic deformation.**
- **Above T_g: Plastic deformation.**

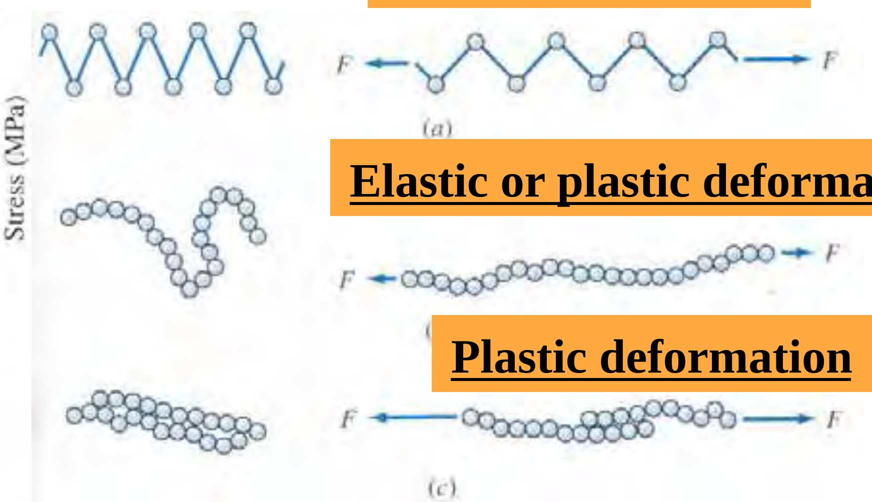


Deformation mechanisms

Elastic deformation

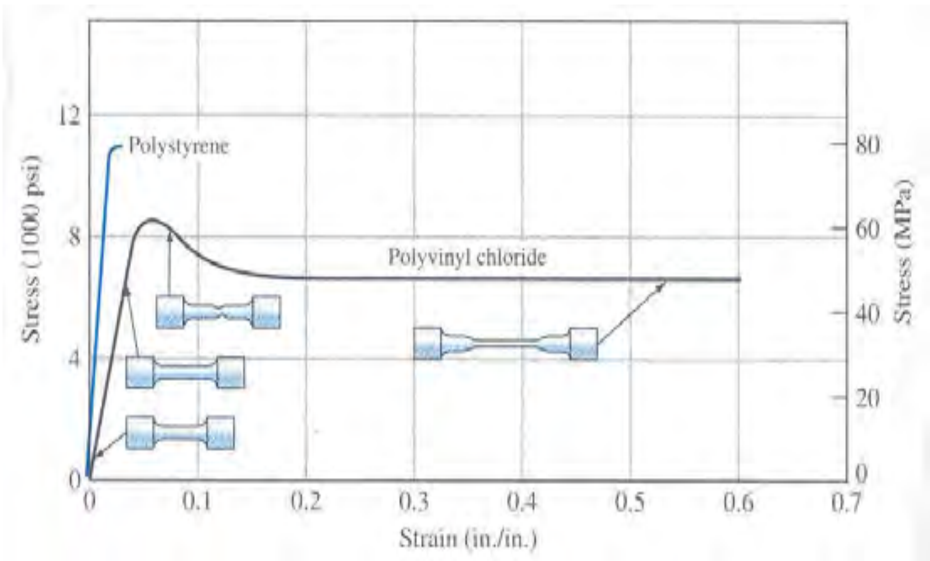
Elastic or plastic deformation

Plastic deformation



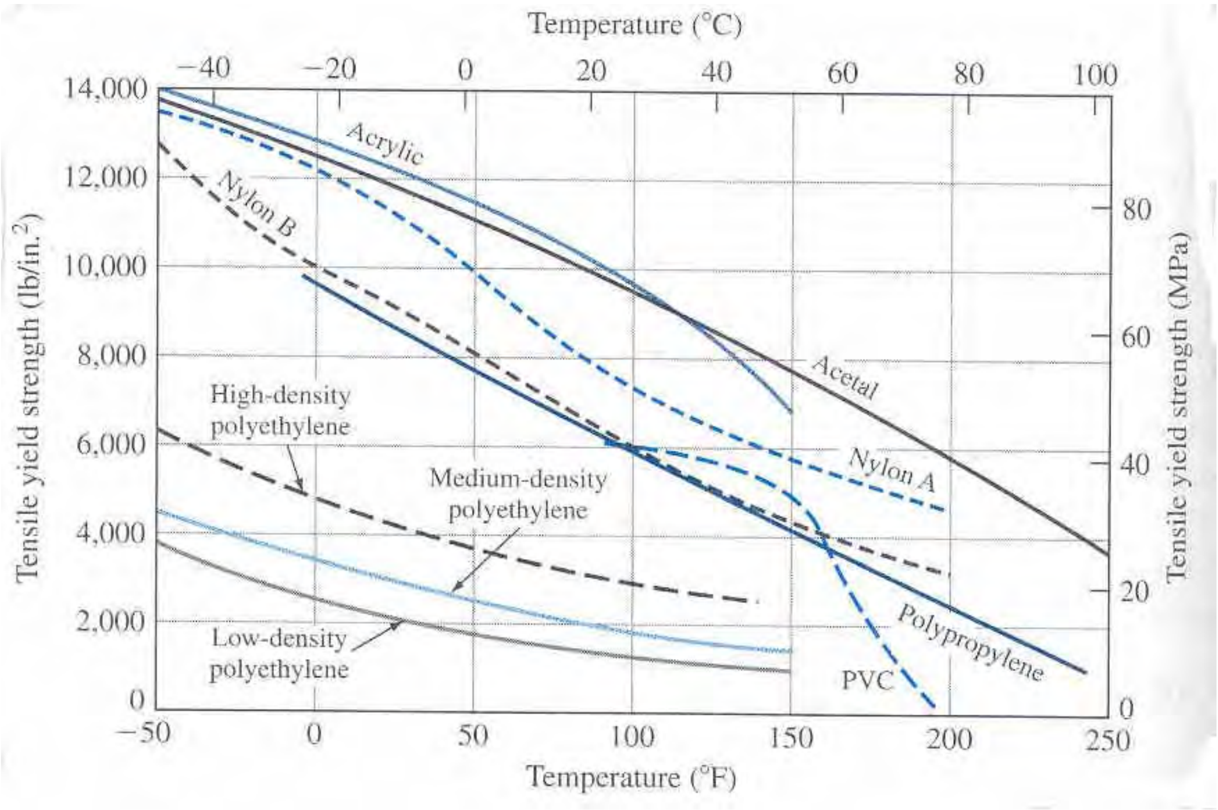
Strengthening of Thermoplastics

- Increasing average molecular mass increases strength up to a certain critical mass.
- Increasing the degree of crystallinity increses strength, modulus of elasticity and density.
- Introducing pendant atomic groups to hinder chain slippage during permanent deformation
- Making composites by adding fibers/particles



Effects of Temperature on Strength

- **Thermoplastics**
- **Thermosets**



Creep and Stress Relaxation of Polymers

- **Creep increases with increased tensile stress and temperature.**

- **Stress relaxation: Decrease in stress at constant strain.**

$$\sigma = \sigma_0 e^{\frac{-t}{\tau}}$$

σ = Stress after time t.

σ_0 = Initial stress

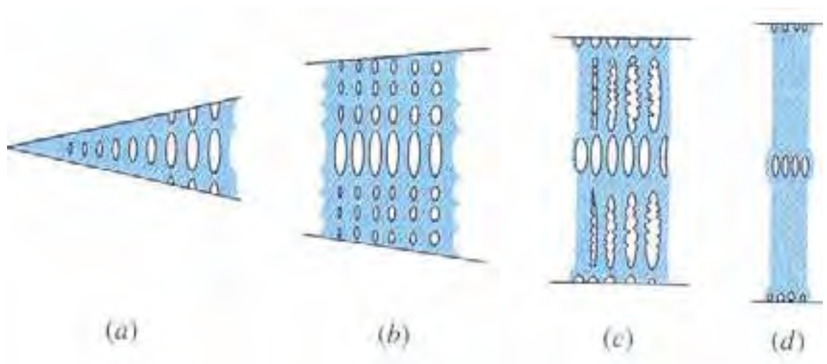
$$\frac{1}{\tau} = Ce^{\frac{-Q}{RT}}$$

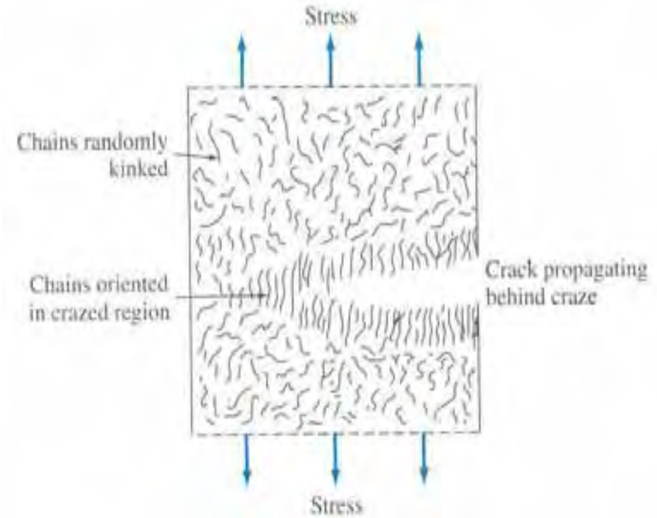
τ = relaxation time.

T= temperature, R= molar gas constant.

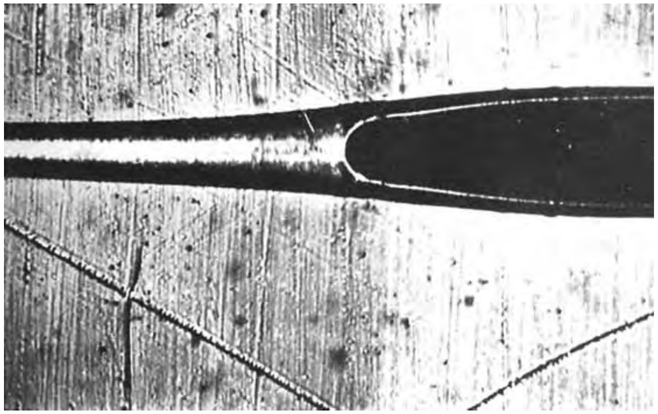
Fracture of Polymers

- **Thermosetting plastics: Primarily brittle mode.**
- **Thermoplastics: ductile or brittle *depending* on the temperature.**

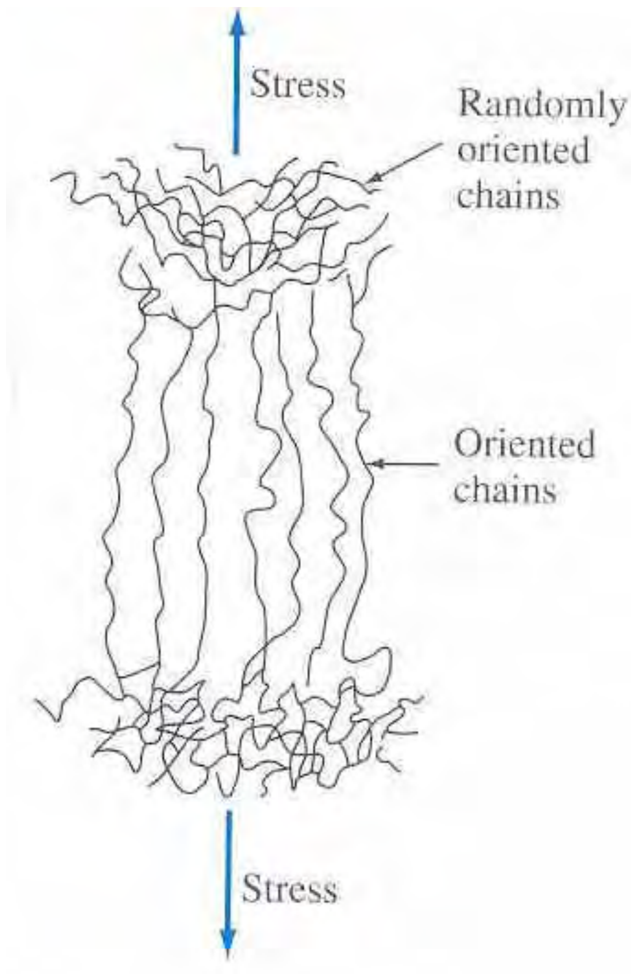




Craze microstructure in a glassy thermoplastic



Ductile Fracture of polymer



HW

Chapter 10: 9, 13, 14, 20,

Example problems: 10.1, 10.2, 10.3, 10.4, 10.5, 10.6, 10.7, 10.8, 10.9, 10.11

Reading assignment: 11.1-11.3