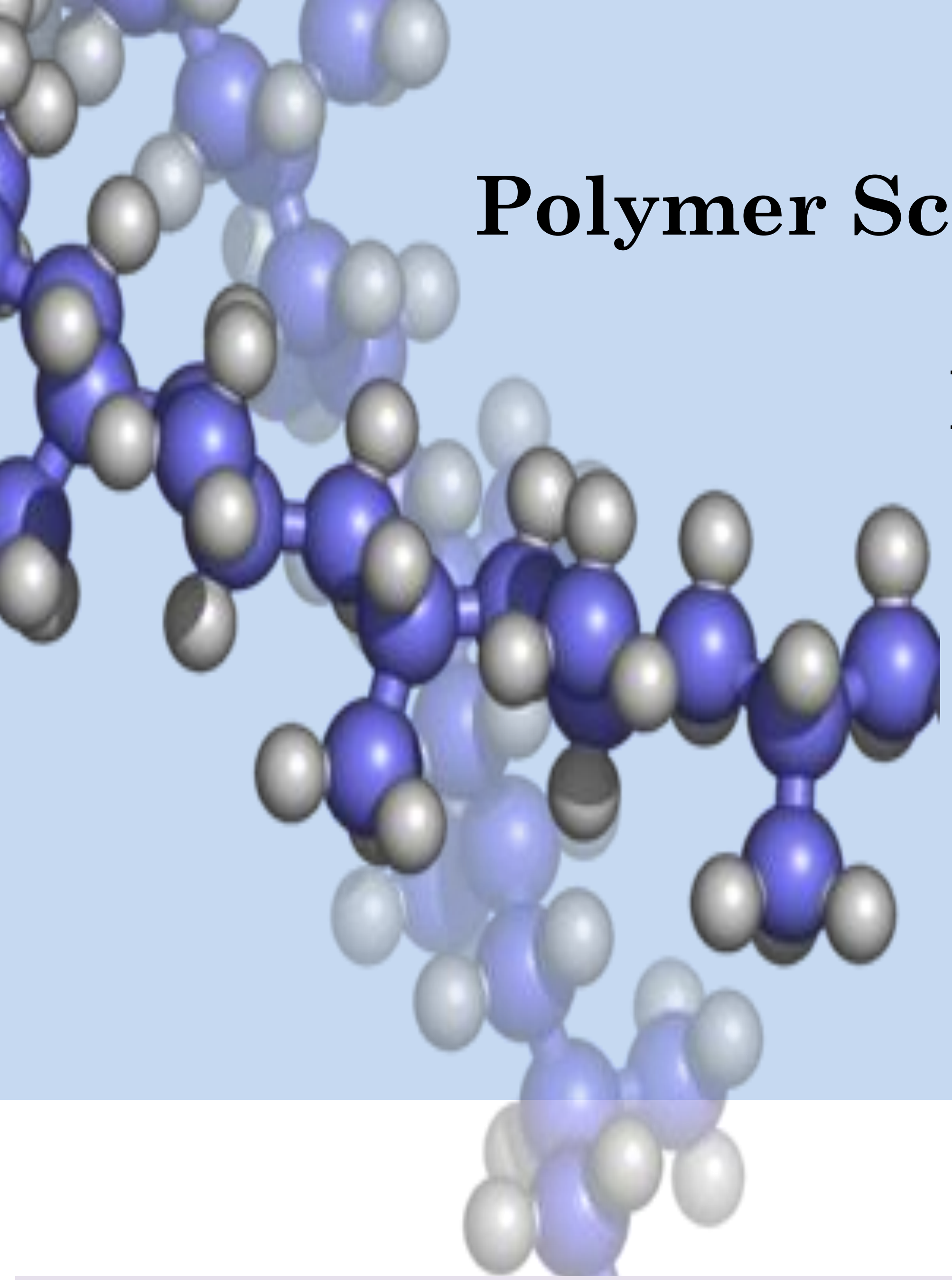

Polymer Science & Engineering

Mechanical Analysis

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Tensile strength, tensile modulus, elongation.

Important and useful mechanical property.

1) Tensile stress :

$$\sigma = \frac{F}{A}$$

2) Tensile strain :

$$\varepsilon = \frac{\Delta l}{l}$$

3) Tensile modulus :

$$E = \frac{\sigma}{\varepsilon}$$

Units of tensile strength :

1) CGS : dyne / cm2

2) SI : N / m2 (Pa)

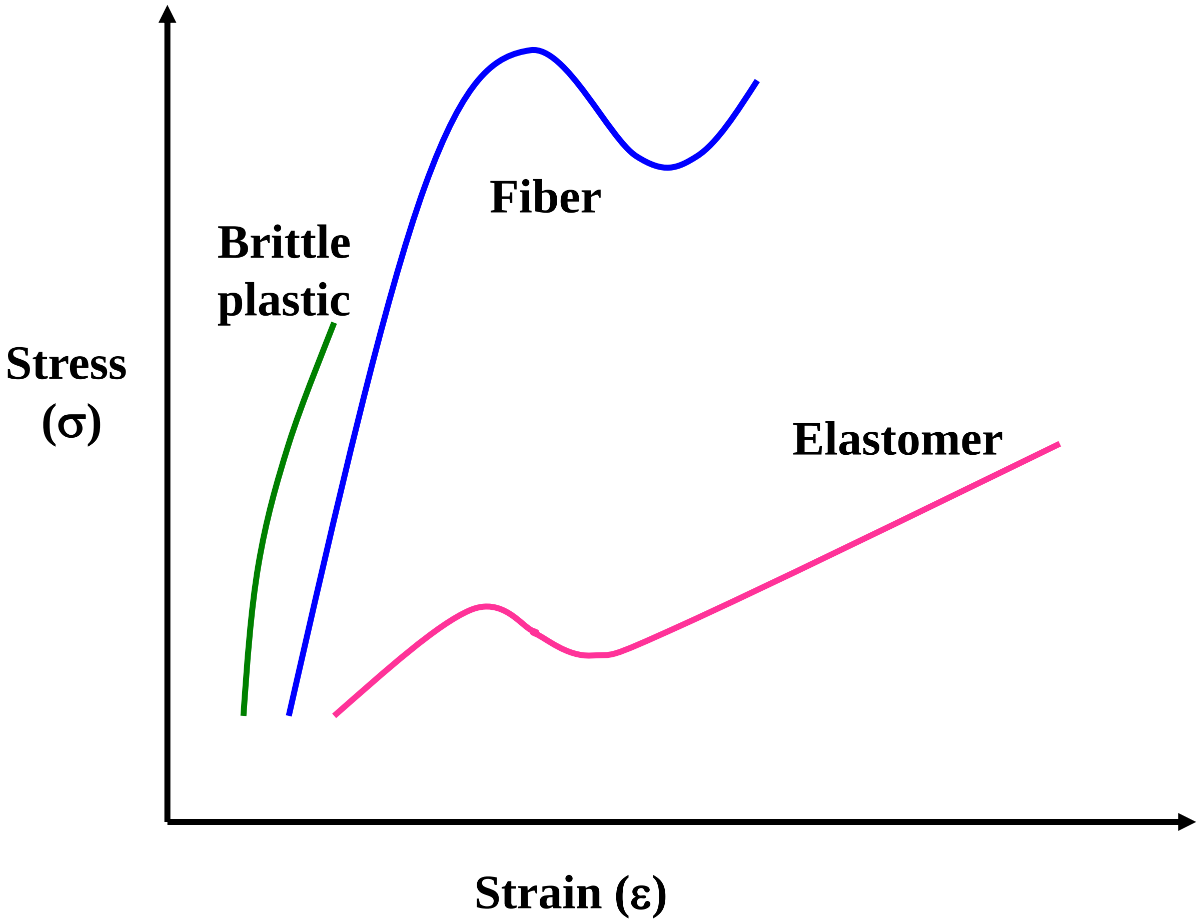
3) pounds per square inch (psi)

Unit of modulus

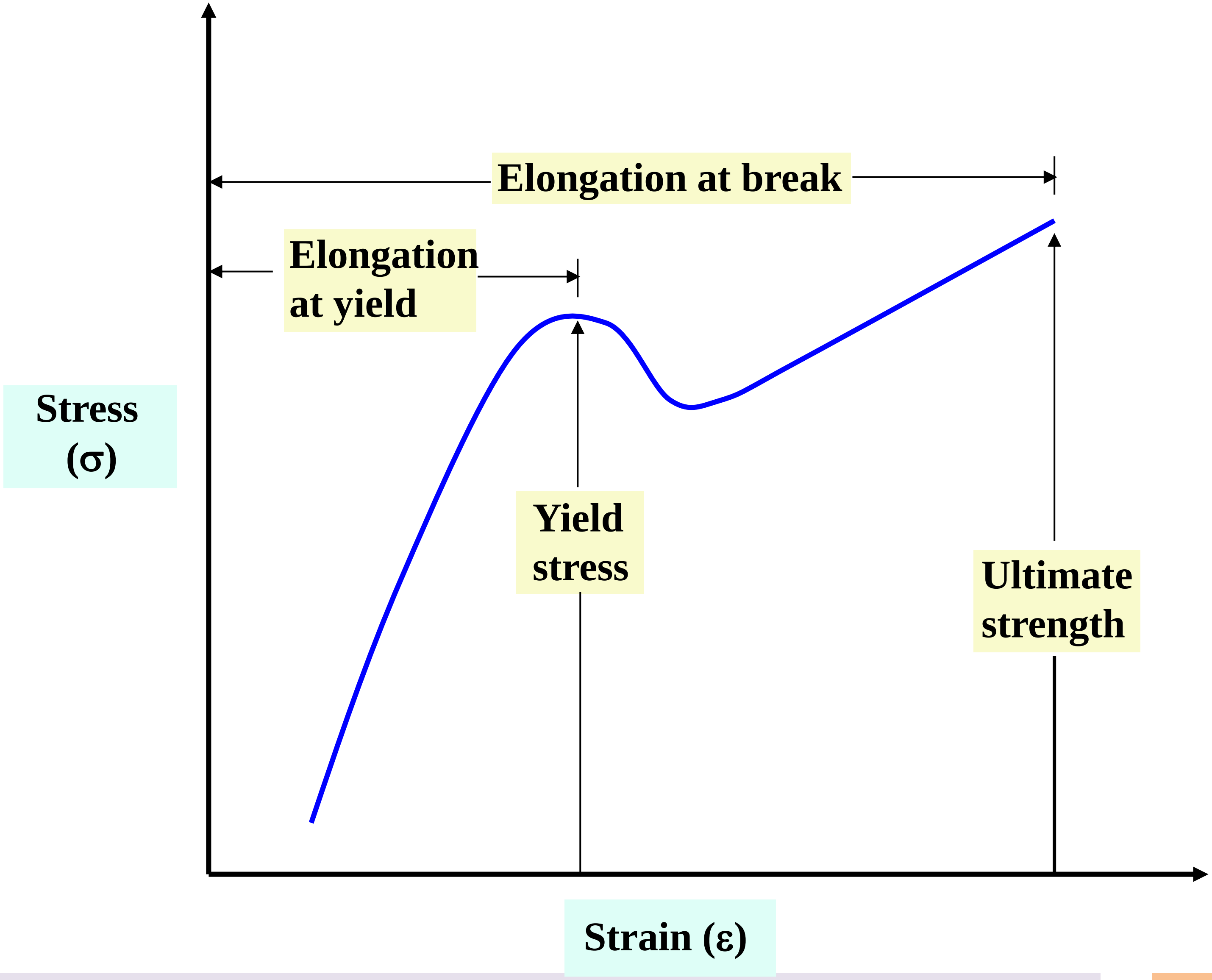
same unit of tensile strength.

Unit of elongation : No dimension.

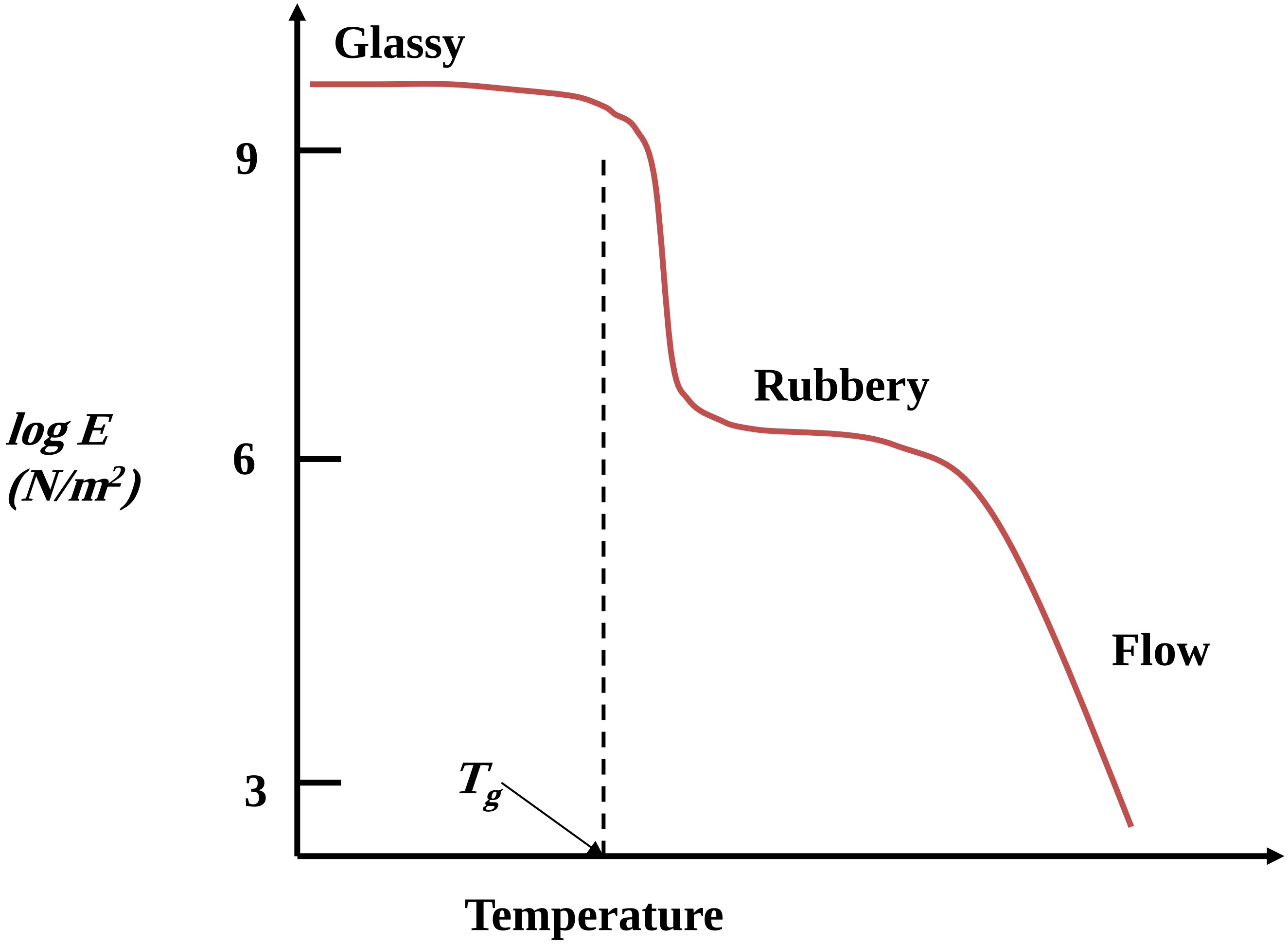
Tensile stress-strain behavior



General tensile stress-strain curve for a typical thermoplastic

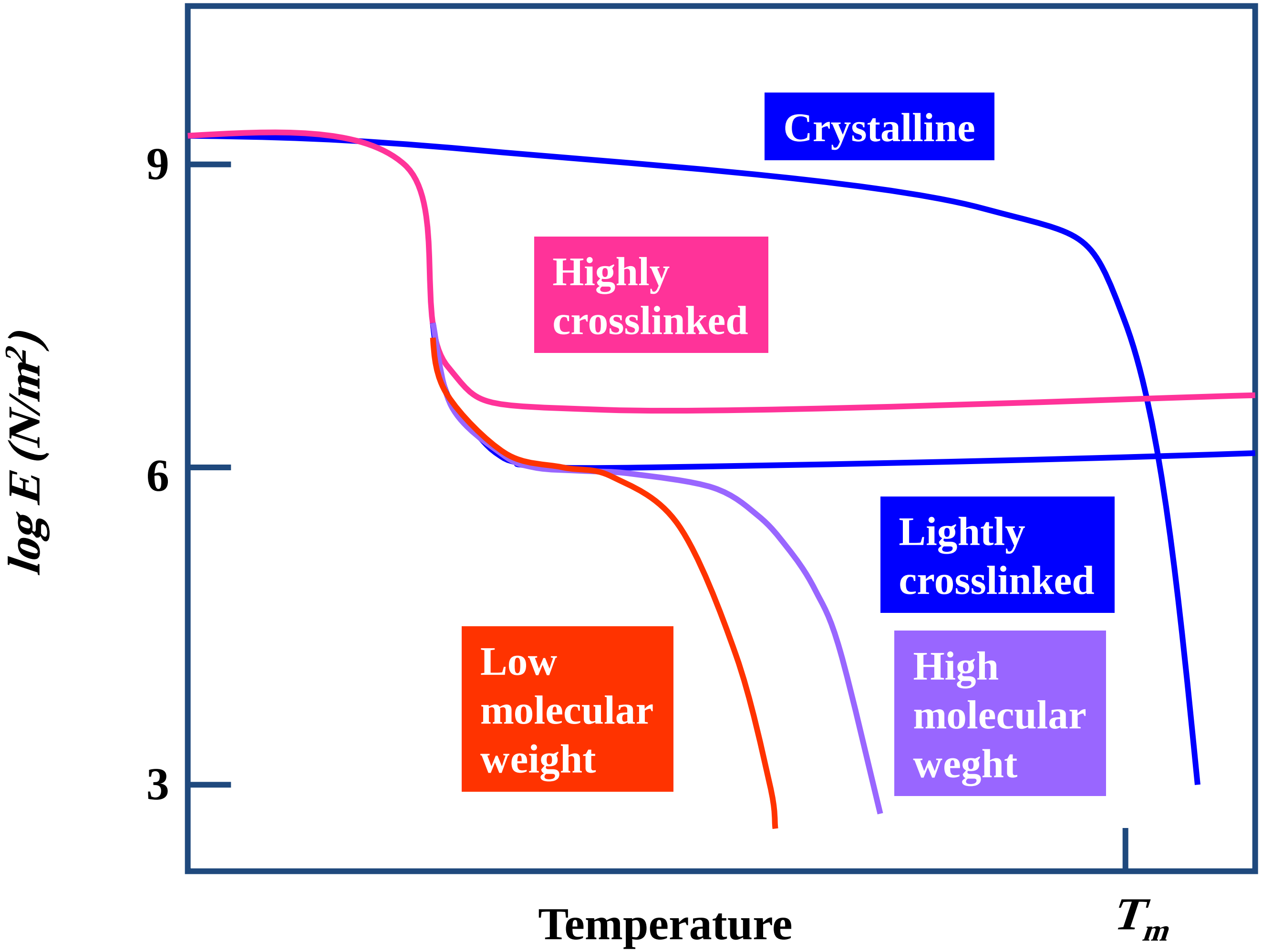


Effect of temperature on tensile modulus of an amorphous thermoplastic

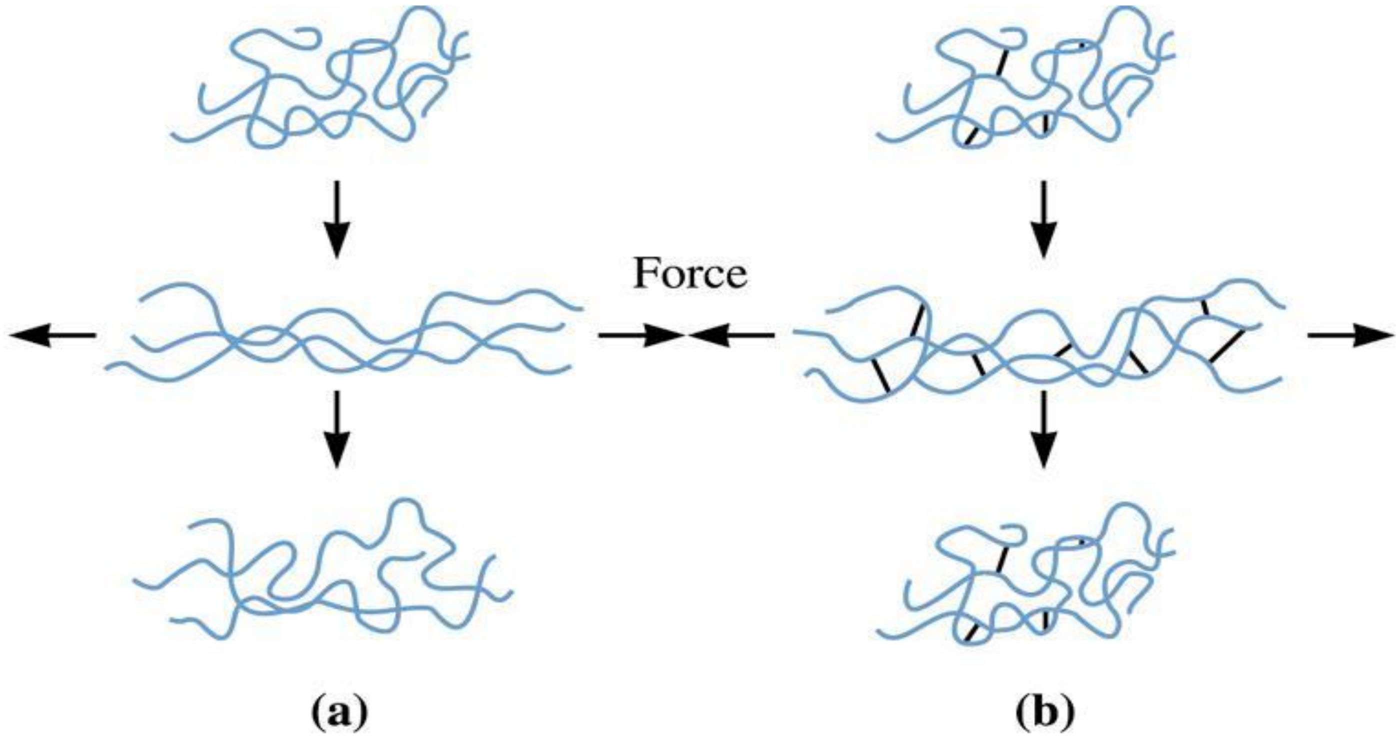


log *E*, modulus scale; T_g glass transition temperature.

Effect of temperature on tensile modulus (log E scale) of various polymers



Micro-deformation behaviors



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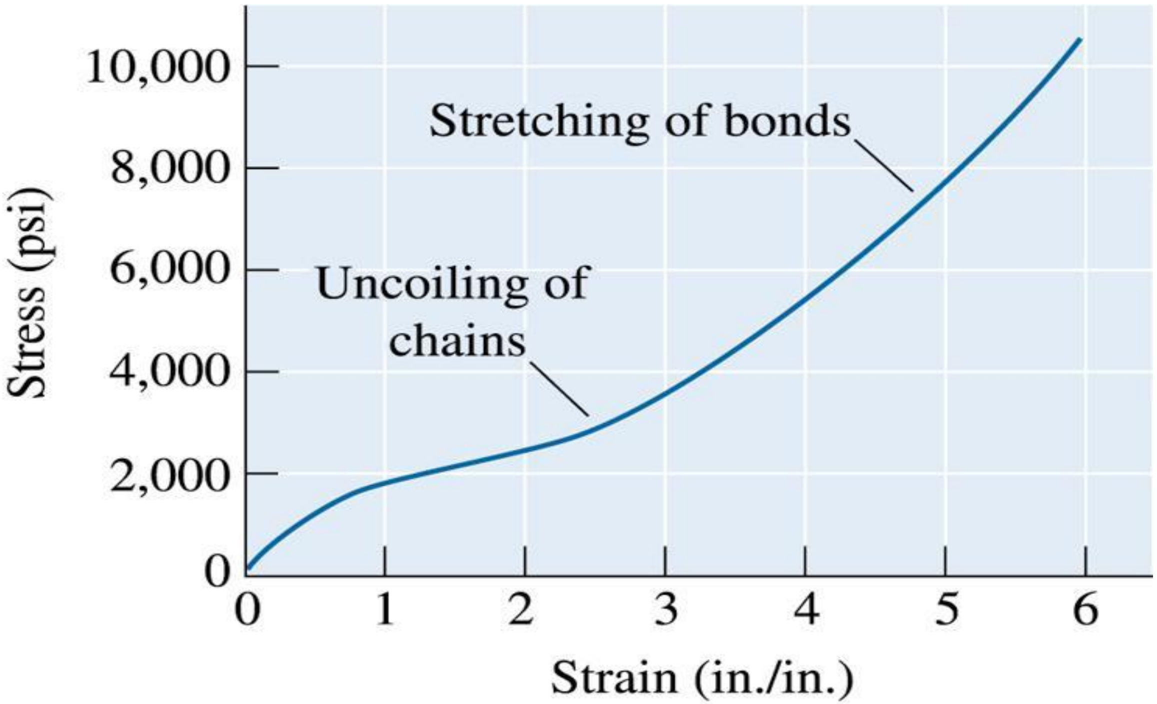
(a) When the elastomer contains no cross-links, the application of a force causes both elastic and plastic deformation; after the load is removed, the elastomer is permanently deformed.
(b) When cross-linking occurs, the elastomer still may undergo large elastic deformation; however, when the load is removed, the elastomer returns to its original shape.



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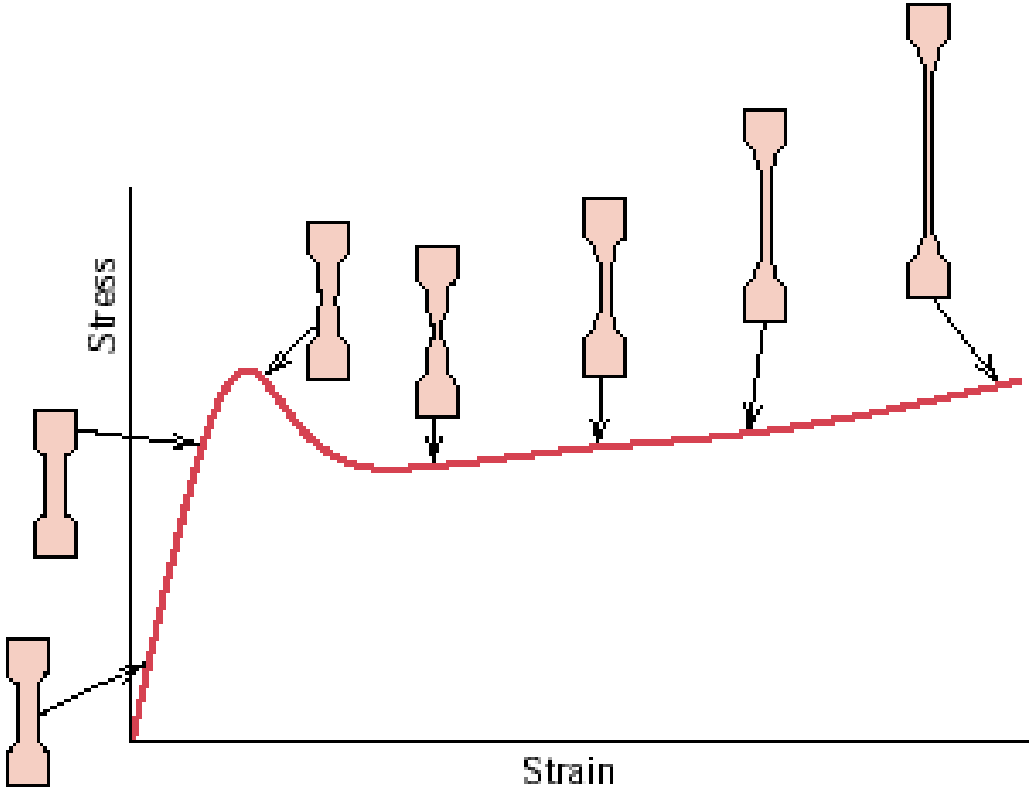
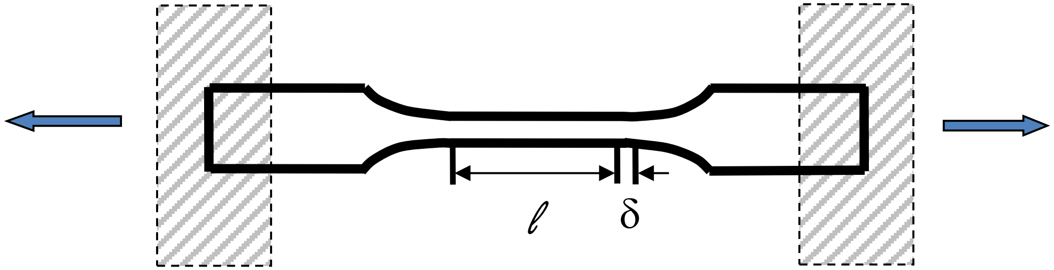
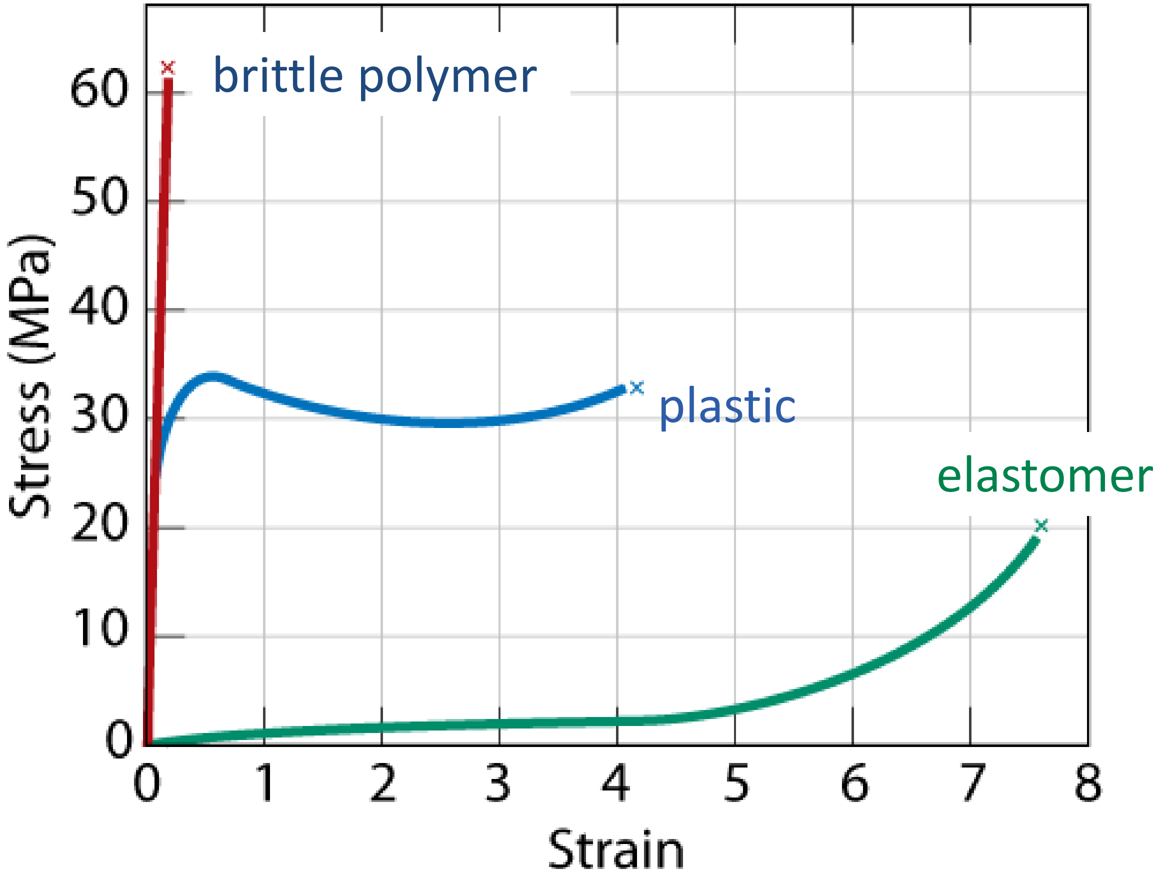
The stress-strain curve for an elastomer. Virtually all of the deformation is elastic; therefore, the modulus of elasticity varies as the strain changes.

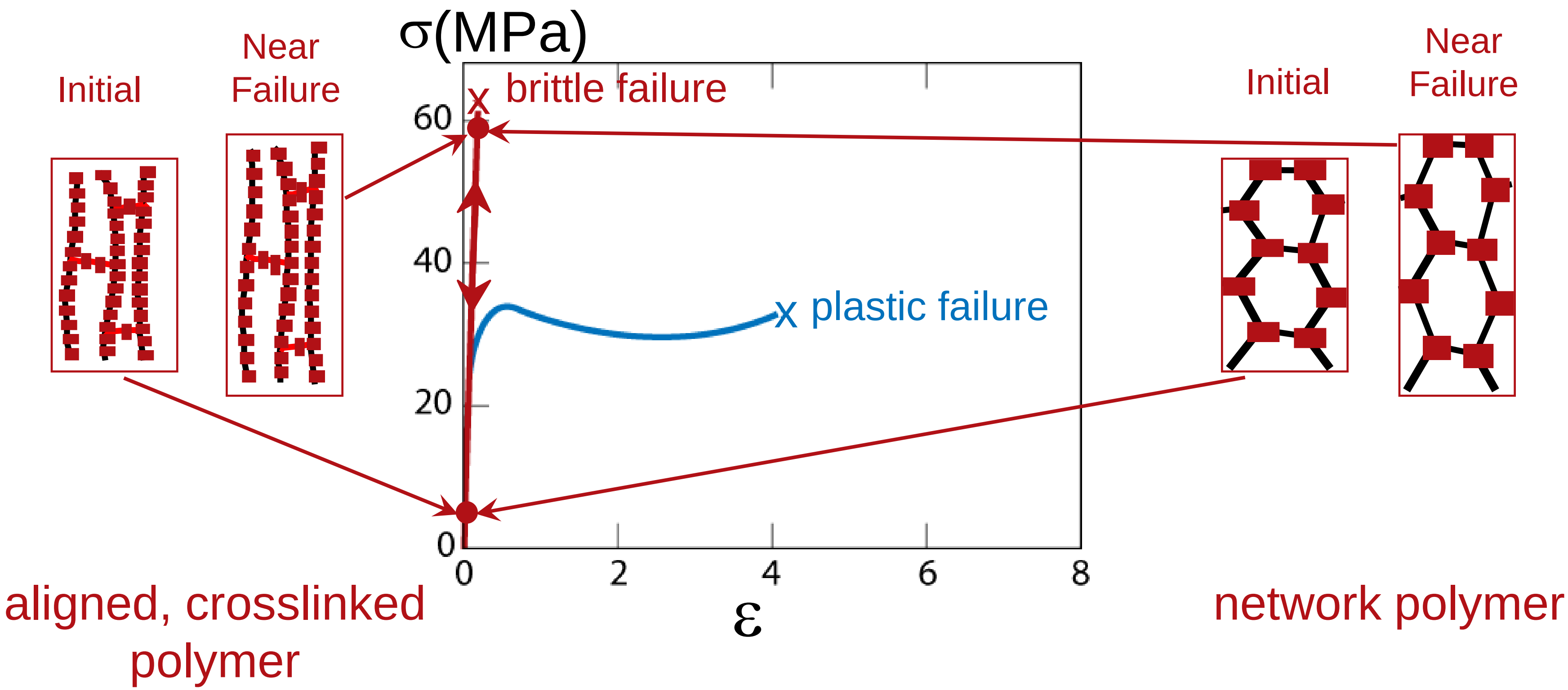
Deformation illustration





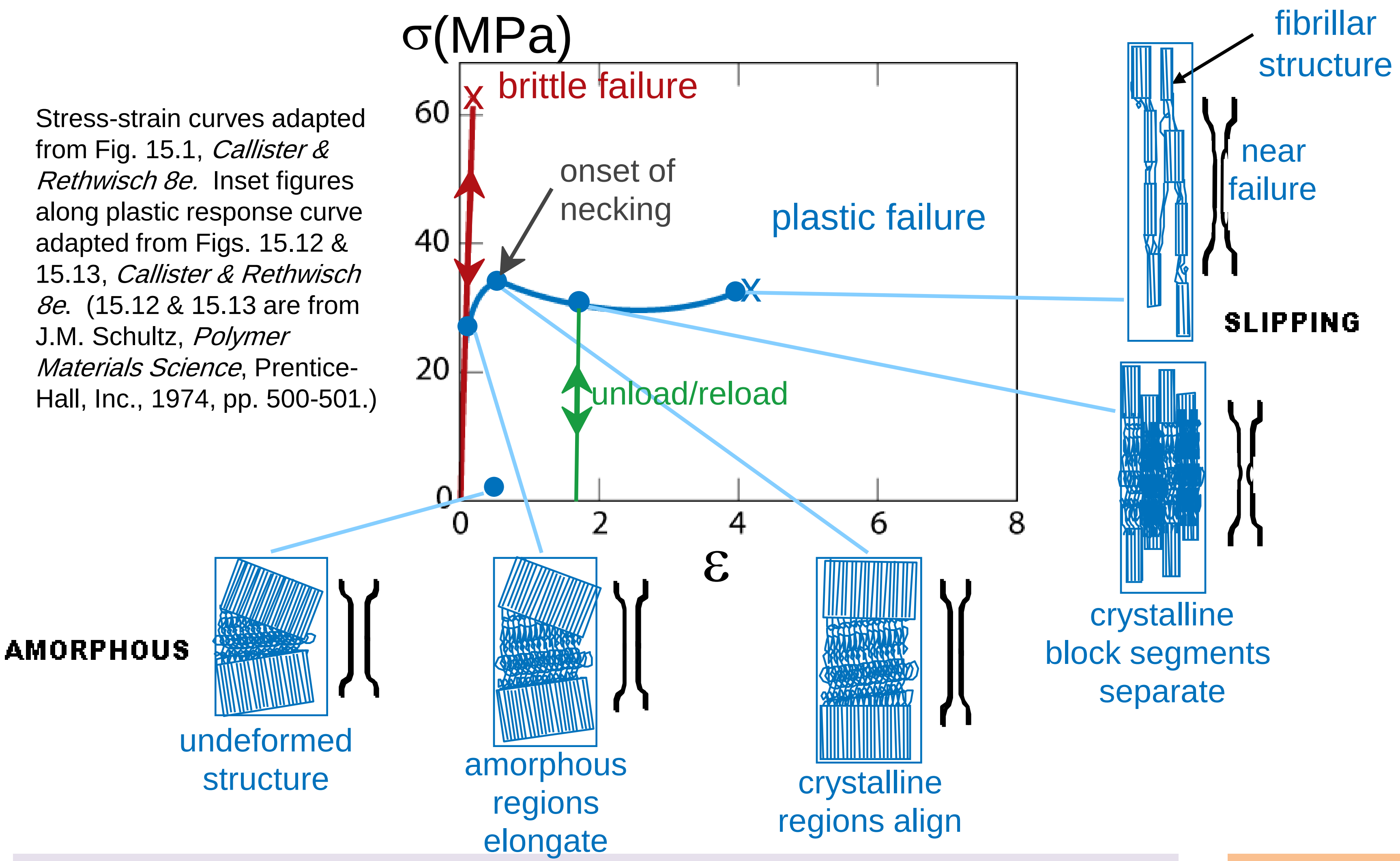
Polymers – Stress-Strain Behavior



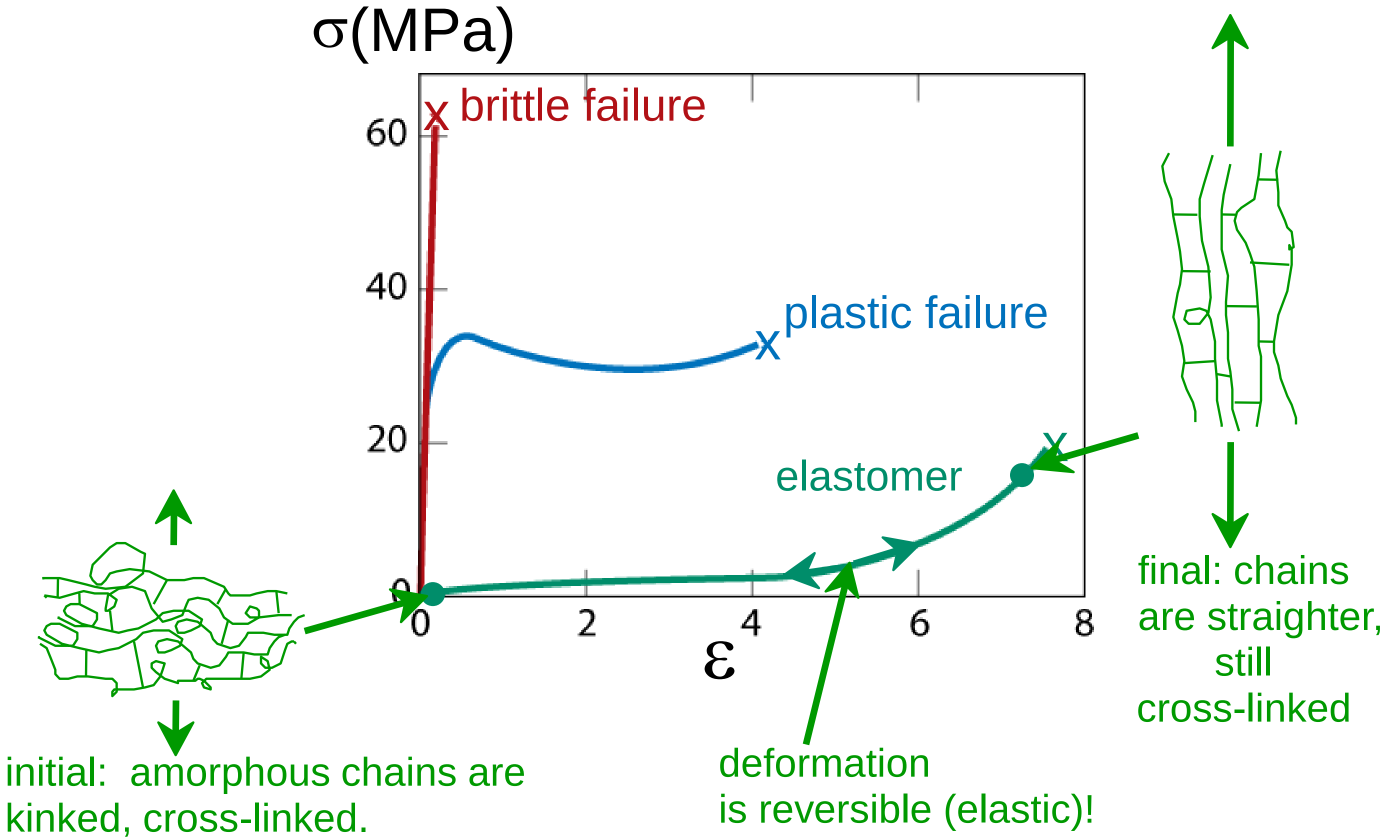

Initial
Near Failure
σ(MPa)
x brittle failure
60
40
20
0
x plastic failure
0
2
4
6
8
ε
Initial
Near Failure
aligned, crosslinked polymer
network polymer

Mechanisms of Deformation — Semicrystalline (Plastic) Polymers

Stress-strain curves adapted from Fig. 15.1, *Callister & Rethwisch 8e.* Inset figures along plastic response curve adapted from Figs. 15.12 & 15.13, *Callister & Rethwisch 8e*. (15.12 & 15.13 are from J.M. Schultz, *Polymer Materials Science*, Prentice-Hall, Inc., 1974, pp. 500-501.)



Mechanisms of Deformation—Elastomers



Stress-strain curves adapted from Fig. 15.1, *Callister & Rethwisch 8e.* Inset figures along elastomer curve (green) adapted from Fig. 15.15, *Callister & Rethwisch 8e*. (Fig. 15.15 is from Z.D. Jastrzebski, *The Nature and Properties of Engineering Materials*, 3rd ed., John Wiley and Sons, 1987.)

- Compare elastic behavior of elastomers with the:

  -- brittle behavior (of aligned, crosslinked & network polymers), and

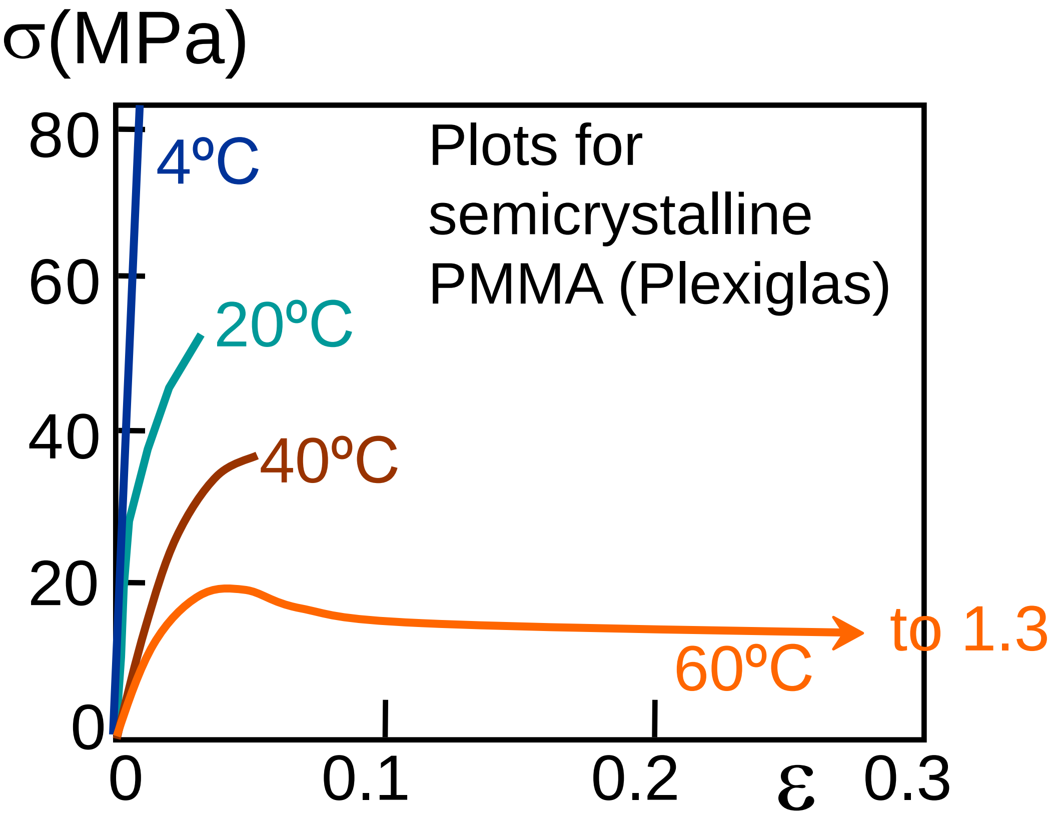
  -- plastic behavior (of semicrystalline polymers)

  (as shown on previous slides)

Influence of *T* and Strain Rate on Thermoplastics

- Decreasing *T*...
  - -- increases *E*
  - -- increases *TS*
  - -- decreases %*EL*

- Increasing strain rate...
  - -- same effects as decreasing *T*.



Adapted from Fig. 15.3, *Callister & Rethwisch 8e*. (Fig. 15.3 is from T.S. Carswell and J.K. Nason, 'Effect of Environmental Conditions on the Mechanical Properties of Organic Plastics", *Symposium on Plastics*, American Society for Testing and Materials, Philadelphia, PA, 1944.)

Rubberlike-materials