Chapter 16  Polymer properties

- Stress-strain behavior
- Deformation of polymers
- Factors that influence the mechanical properties of polymers
- Polymer applications

Polymers stress-strain behavior

![Stress-strain graph with labels for Brittle, Plastic, and Highly elastic regions.](image)
Deformation of semicrystalline polymers

- Mechanism of elastic deformation
- Mechanism of plastic deformation
- Stress-strain curve relation

Tensile response brittle & plastic

[Diagram showing stress-strain curve and deformation mechanisms]

- Initial aligned, networked cross-linked case
- Near failure
- Brittle failure
- Plastic failure
- Onset of necking
- Unload/reload
- Crystalline regions slide
- Semi-crystalline case
- Amorphous regions elongate
- Crystalline regions align
Tensile response: elastomer case

- **Initial:** Amorphous chains are kinked, heavily cross-linked.
- **Final:** Chains are straight, still cross-linked.

- Deformation is reversible!

- Compare to responses of other polymers:
  - Brittle response (aligned, cross-linked & networked case)
  - Plastic response (semi-crystalline case)

Deformation of semicrystalline polymers

- Detailed structure of a spherulite
Factors that influence the mechanical properties of polymers

- **Molecular weight**
  - $\sigma_{TS}$ often increase with Mw
  - Longer chains are entangled or anchored better

- **% crystallinity: % of material that is crystalline**
  - $\sigma_{TS}$ and $E$ increase with %crystallinity
  - Annealing increases with %crystallinity

Predeformation by drawing

- **Drawing**: aligns polymer chains to the stretching direction
  - $E$ and TS increases in the direction of tension and reduces in other directions
  - Ductility is reduced

- **Annealing after drawing**
  - Alignment decreases
Deformation of elastomers

- Polymeric structures
  - amorphous, highly twisted, kinked and coiled
  - free rotation of chain bonds
- Deformation of elastomers
  - rubberlike elasticity
  - driving force for elastic deformation: entropy

Polymer applications

- Plastics, elastomers, fibers, coatings,
- Polymer additives
  - fillers
  - plasticizers
  - stabilizers
  - colorants
  - flame retardants
- Advanced polymers
  - ultrahigh molecular weight polyethylene
  - liquid crystal polymers
  - thermoplastic elastomers
Polymer applications

Summary

- General drawbacks to polymers
  - $E$, $\sigma_y$, $K_c$, $T_{application}$ are small
  - $T$-dependent deformation
  - Result: polymers benefit from composite reinforcement

- Thermoplastics (PE, PS, PP, PC)
  - smaller $E$, $\sigma_y$, $T_{application}$
  - larger $K_c$
  - easier to form and recycle

- Elastomers (rubber)
  - large reversible strains

- Thermosets (epoxies, polyesters)
  - larger $E$, $\sigma_y$, $T_{application}$
  - smaller $K_c$