Introduction of Polymers

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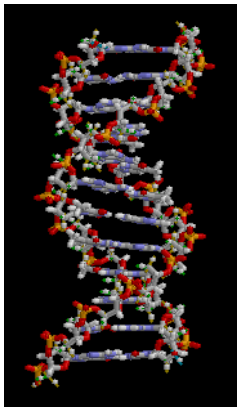
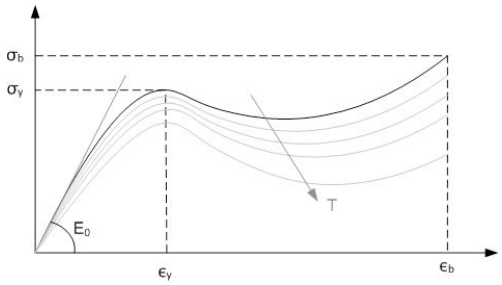
Definition of Polymer

- A substance composed of molecule which have long sequences of one or more species of stoma or groups of atoms linked to each other by primary bonds.
- Because of the extraordinary range of properties of polymeric materials, they play an essential and ubiquitous role in everyday life. This role ranges from familiar synthetic plastics and elastomers to natural biopolymers such as nucleic acids and proteins that are essential for life.



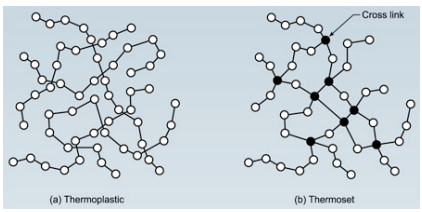
General Classes of Polymer

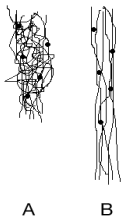
- Thermoplastics (ABS, PMMA, PC, PE, PS)
  - Thermoplastics are elastic and flexible above a glass transition temperature, T_g.
  - Most thermoplastics are high-molecular-weight polymers whose chains associate through weak Vander Waals forces; stronger dipole-dipole interactions and hydrogen bonding; or even stacking of aromatic rings.



General Classes of Polymer

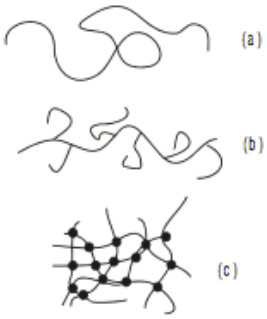
- Thermosets (two-part epoxy)
  - Polymer material that irreversibly cures.
  - The cure may be done through heat (generally above 200°C), through a chemical reaction, or irradiation such as electron beam processing.
- Elastomers (PDMS)
  - A polymer with the property of viscoelasticity, generally having notably low Young's Modulus and high yield strain compared with other materials.





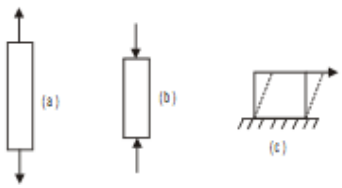
Molecule Architectures

- (a) Linear Chain:
  - A long chain of monomers.
- (b) Branched Molecule:
  - Branches are covalently attached to the main chain.
- (c) Cross-linked network
  - Three-dimensional network; molecules are linked through covalent bonds; the network extends over the whole sample which is a giant macromolecule.
  - Elastomers are loosely cross-linked networks.
  - Thermosets are densely cross-linked networks.



Mechanical Behaviors of Polymers

- Whenever a force is exerted on a solid material, the material will deform in response to the force. Depending on the particular orientation of the force with respect to the material surface different types of forces can be identified.
- A mechanical test using tensile forces is called a tensile test.
  - (a) Tensile force
  - (b) Compressive force
  - (c) Shear force

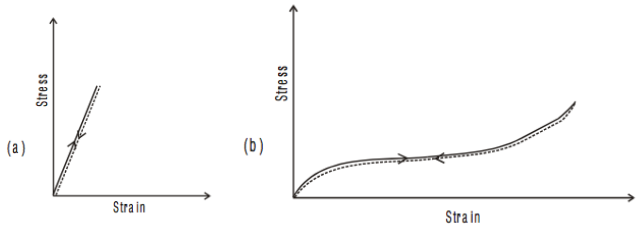


Elastic Behavior

- A material is elastic, if upon an applied force, its deformation is instantaneous and constant, and upon the removal of the force, its recovery is instantaneous and complete.
- The stress-strain relationship is given by:

$$\sigma = E\varepsilon$$

where $\sigma = F/A$, $\varepsilon = \Delta l / l_0$ and E is the Young's modulus [units N/m^2 = Pa].



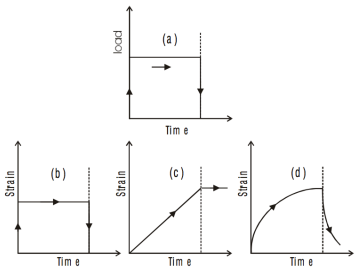
Viscous Behavior and Viscoelasticity

- Fluids show a characteristic resistance to movement (flow), which is called *viscosity*. Viscosity results in a frictional energy loss, which dissipates in the fluid as heat. Polymeric materials behave both as viscous fluids and elastic solids. They are *viscoelastic* materials. The most important characteristic of viscoelastic materials is that their mechanical properties depend on time.
- The deformation of a material over time due to the application of a constant load is called *creep*.

Creep

- A purely elastic material responds instantaneously to the load and the deformation remains the same, in addition, it will recover its initial shape upon the removal of the load. On the contrary, a viscous liquid will deform as long as the load contin- ues to be applied. Upon the removal of the load, the fluid does not return to its initial position. The response of a viscoelastic material is intermediate between the solid and the liquid.

  Creep depends on the applied load, molecular characteristics, microstructure and temperature.



Creep

- Combinations of springs (linear elastic behavior) and dashpots (linear viscous behavior) in order to quantify the mechanical behavior of polymeric materials.

  $\sigma = \sigma_1 + \sigma_2$

  $\varepsilon = \varepsilon_1 = \varepsilon_2$

- Elastic: $\sigma_1 = E\varepsilon_1$; Viscous: $\sigma_2 = \eta\, d\varepsilon_2/dt$

  $\sigma = E\varepsilon + \eta\, d\varepsilon/dt$

$$\varepsilon(t) = \frac{\sigma}{\eta}[1 - \exp(Et/\eta)]$$

- For the recovery ($\sigma = 0$)

$$\varepsilon(t) = \varepsilon_0 \exp(-Et/\eta)$$

$$\boxed{\varepsilon(t) = K\sigma t^n}$$