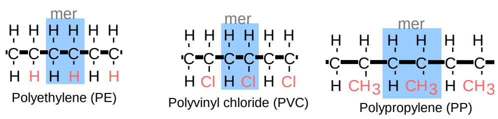
Class 3: Introduction to Polymers



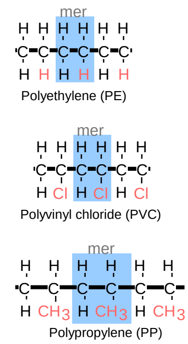
PRIME Modules
Project-based Resources for Introduction to Materials Engineering

Long, C based chain made up of repeatable sub units (monomers)

A polymer is a long C based chain.

It is made up of individual units, monomers.

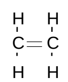
The monomers are tailor-able, we can easily change the side groups. This is what gives polymers the range of properties including mechanical, aesthetic, and electrical.



Adapted from Fig. 14.2, *Callister 6e.*

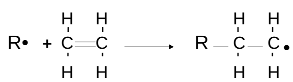
One way a polymer can grow is by breaking the double bonds in a monomer

A common synthesis method is addition polymerization.

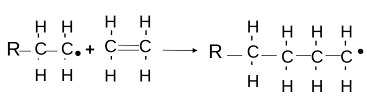


The monomers exist as stable units with a double or triple C bond in them.

A catalyst (R•) comes along and breaks the double bond.



This leaves a reactive bond that then breaks the double bond of another monomer and adds that to the chain.

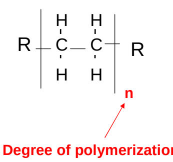


The chains stops growing when a catalyst reacts with the end of the chain

The process stops when a catalyst reacts with the other end

The chain length is determined by the rates of

- initiation: fast initiation would give a lot of chains forming at once
- propagation: fast propagation would give long chains
- termination: fast termination would give short chains



The polymer is defined by the average molecular weight

The chain length varies between chains in a sample.

larger M_w

smaller M_w

The polymer sample is defined by either the number- average molecular weight

$$\overline{M}_n = \sum x_i M_i$$

Fraction of the total number of chains that have that MW

Or the weight average molecular weight

$$\overline{M}_w = \sum w_i M_i$$

Fraction of the total weight that have that MW

Figure from Callister overheads

Homogeneous polymers are classified by how the chains interact

Linear polymers are long straight chains with secondary bonding forces between the chains

Branched chains form when monomers attach in different directions. There is a reduced density and a reduced interaction between the chains.

HDPE (high density polyethylene) is liner LDPE is branched

Cross-linked is when chains connect in a 3-D nature. The chains become locked together.

Networked is a chemical connection forms between chains as part of the polymerization process.

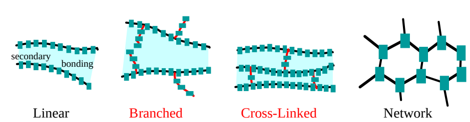
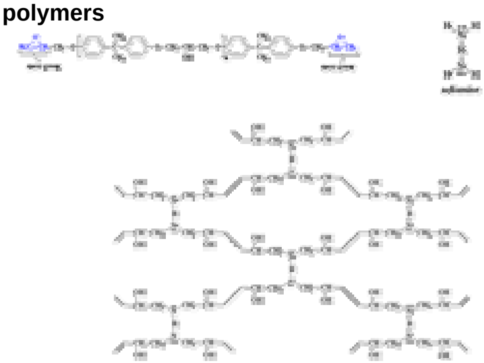


Figure from Callister overheads

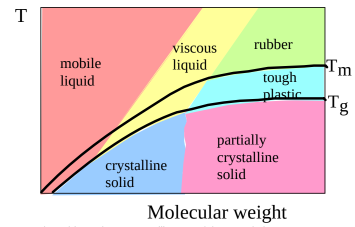
Epoxies are examples of networked polymers



Polymers are also defined by their thermal response (thermoset vs thermoplast)

Thermoplastics:
- little cross linking
- ductile
- soften w/heating
  - -polyethylene (#2)
  - -polypropylene (#5)
  - -polycarbonate
  - -polystyrene (#6)

Thermosets:
- large cross linking (10 to 50% of mers)
- hard and brittle
- do NOT soften w/heating
- -vulcanized rubber, epoxies, polyester resin, phenolic resin



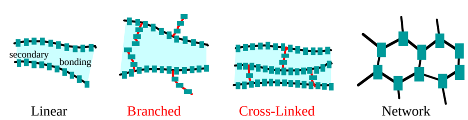
Adapted from Fig. 15.18, *Callister 6e*. (Fig. 15.18 is from F.W. Billmeyer, Jr., *Textbook of Polymer Science*, 3rd ed., John Wiley and Sons, Inc., 1984.)

Overhead from Callister

The tensile strength increases as it gets harder to untangle the chains

Higher tensile strength (lower ductility) is achieved by making the chains harder to untangle

- **Bulky side groups**
- **Longer chains**
- **Linear > branched (more secondary bonding between chains)**
- **Networked > Cross Linked > Linear**



In summary, a polymer is a long C based chain with tailorable properties

Monomers with double or triple C bonds link up when a catalyst breaks the bond.

The length of the chains in a polymer sample vary.

The lengths are controlled by the rate of initiation, propagation, and termination.

Polymers are classified by how the chains interact (linear, branched, cross-linked, and networked).

A polymer has a higher tensile strength and lower ductility if it is harder to untangle the chains. This occurs with bulky side groups, longer chains, and cross linked and networked polymers.