MSE200
Lecture 16 (CH. 10.1,10.2, 10.4.1-10.4.4)
Polymer Materials

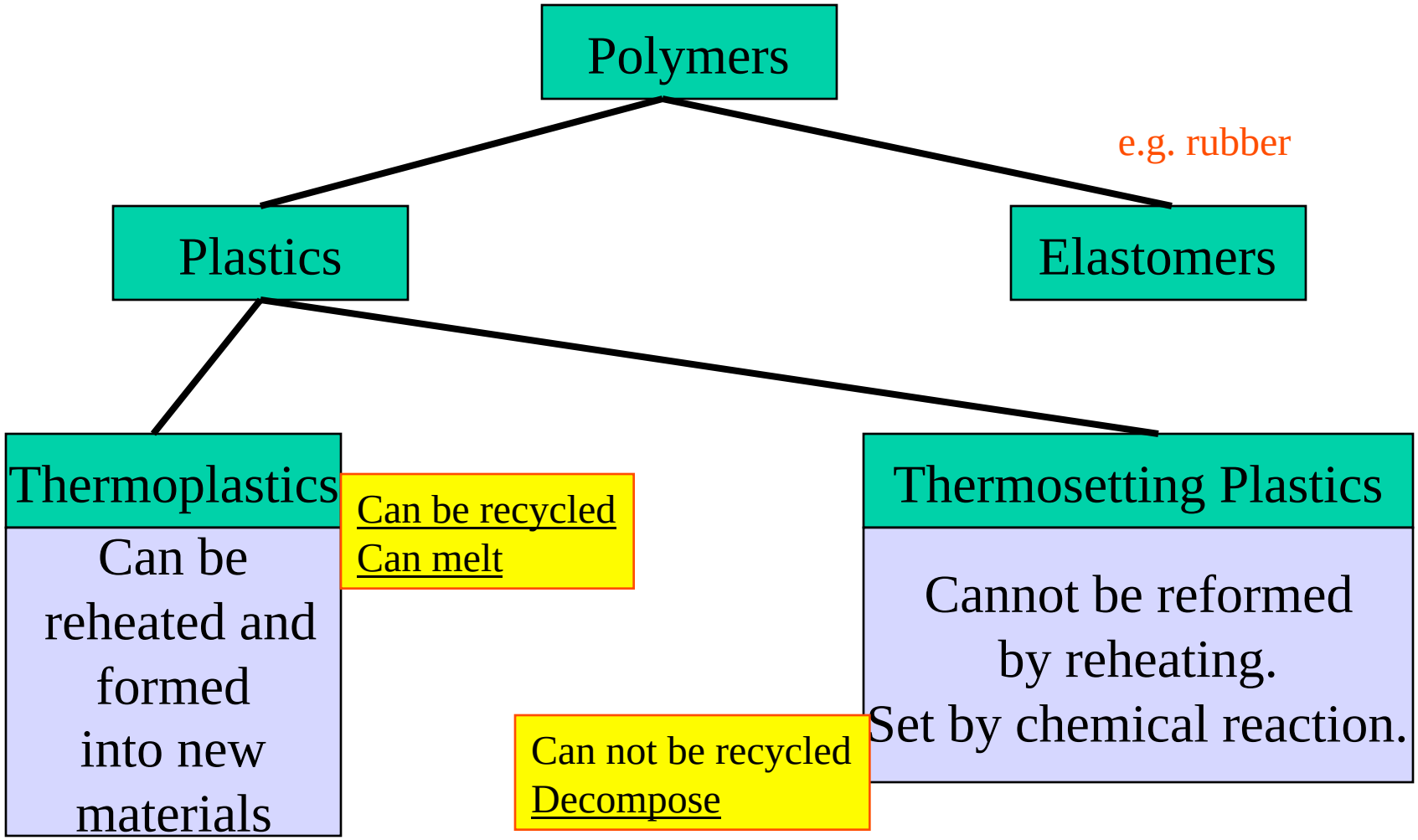
Instructor: Yuntian Zhu

Objectives/outcomes: You will learn the following:

- Polymerization reactions
- The degree of polymerization
- Addition polymerization and copolymers
- Structure of partly crystalline polymers
- Stereoisomerism
- Linear and network polymers.

Introduction to Polymers

- **Polymers ⇒ many parts (Poly-mers = many mers)**



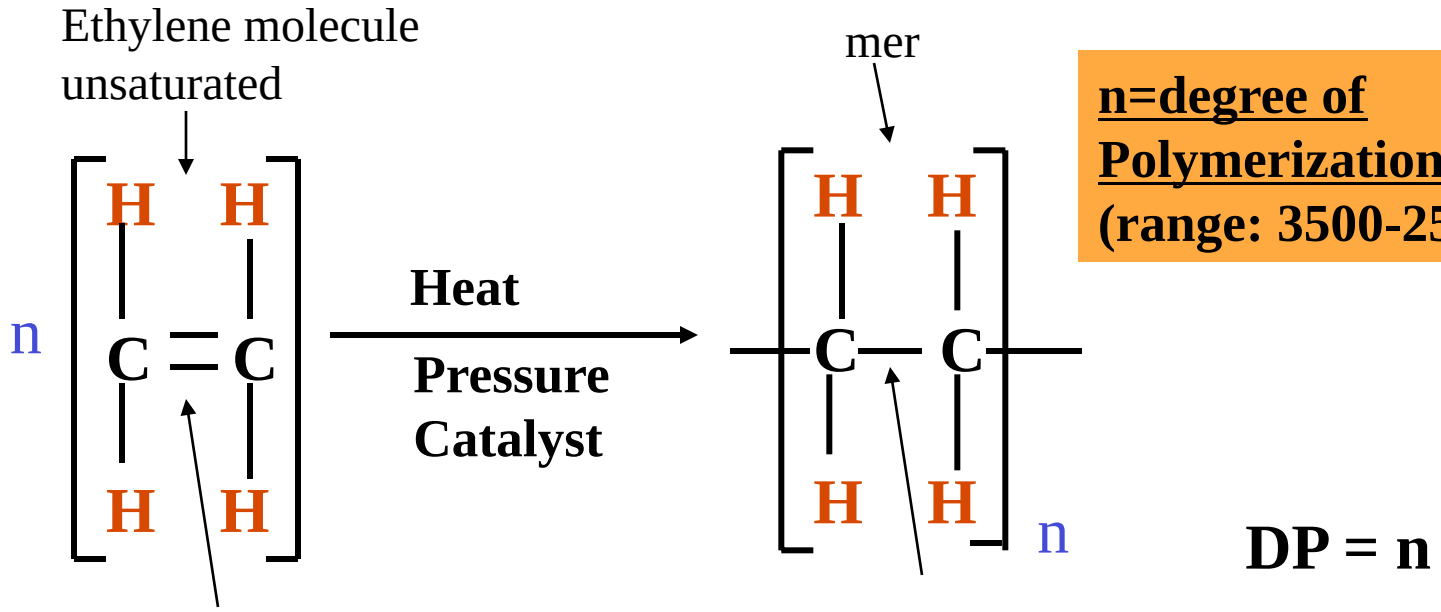
Plastics - Advantages

Advantages	Disadvantages
• Minimum finishing. • Good insulation. • Light weight. • Noise Reduction.	• Low strength

Polymerization

http://video.google.com/videosearch?hl=en&q=plaastics&ndsp=18&ie=UTF-8&sa=N&tab=iv#q=polymerization&hl=en&emb=0

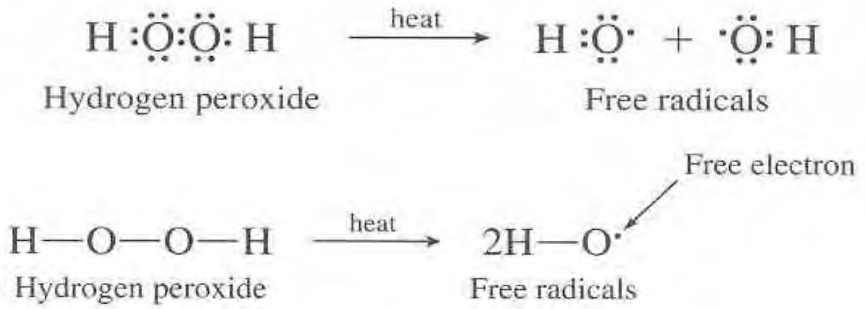
- **Chain growth polymerization: Monomers link together to form long chains (polymers)**
- **Example: Ethylene**



Functionality: Number of active bonds in a monomer.

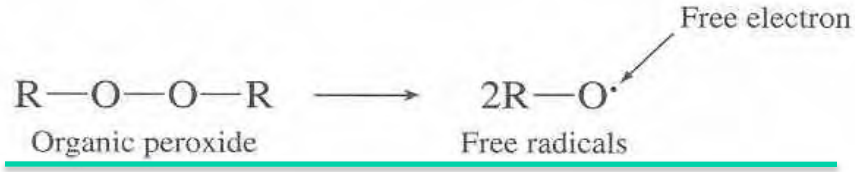
Chain Polymerization - 3 Steps

- **Step 1: Initiation:**
  - **A Radical is needed.**
  - **Example H_2O_2**

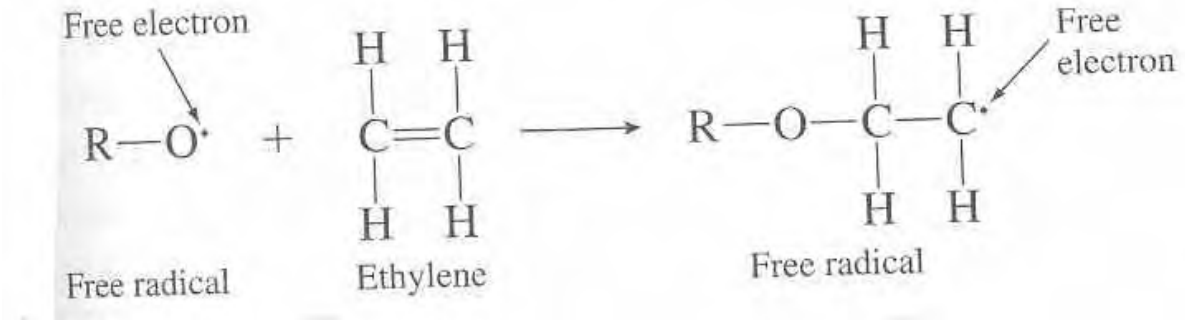


In General

R is a chemical group



- **One of free radicals react with ethylene molecule to form new longer chain free radical**



Chain Polymerization – Steps (cont..)

- **Step 2: Propagation: Process of extending polymer chain by addition of monomers.**

- **Energy of system is lowered by polymerization.**
- **Step 3. Termination:**
  - **By addition of termination free radical.**
  - **Combining of two chains**
  - **Impurities.**

Coupling of two chains

Average Molecular Weight

- **Average molecular weight**

$$\overline{M_m} = \sum f_i M_i$$

$\overline{M_m}$ = **average molecular weight of thermoplastics.**

M_i = Mean molecular weight of each molecular range selected.

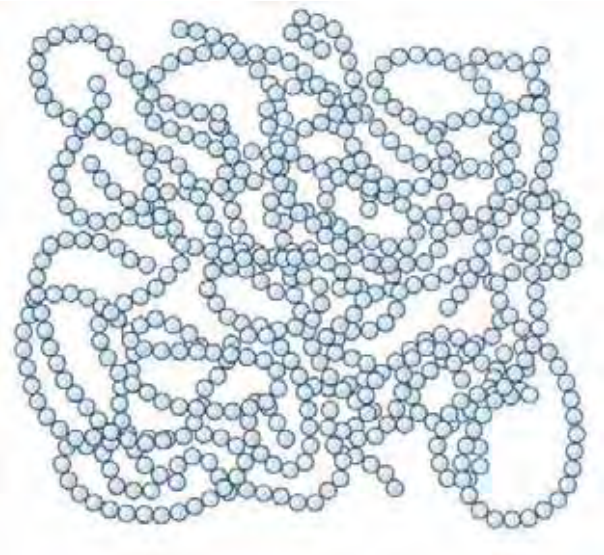
f_i = Weight fraction of the material having Molecular weights of a selected molecular Weight range.

- **Example:**

Molecular Weight Range, g/mol	M_i	f_i	$f_i M_i$
5,000–10,000	7,500	0.11	825
10,000–15,000	12,500	0.17	2,125
15,000–20,000	17,500	0.26	4,550
20,000–25,000	22,500	0.22	4,950
25,000–30,000	27,500	0.14	3,850
30,000–35,000	32,500	0.10	3,250
		$\sum = 1.00$	$\sum = 19,550$

Structure of Noncrystalline Linear Polymers

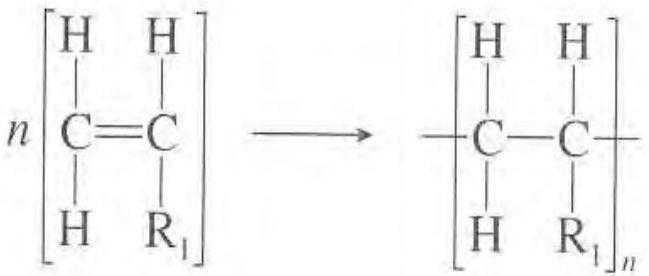
- **Zig-Zag configuration in polyethylene due to 109^{o} angle between carbon covalent bonds.**

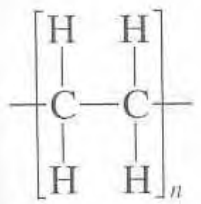


- **Chains are randomly entangled.**
- **Entanglement increases tensile strength.**

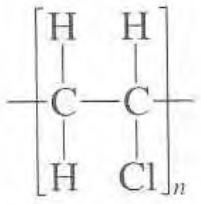
Vinyl and Vinylidene Polymers

- **Vinyl polymers: One of the hydrogen atom is replaced by another atom or group of atoms.**

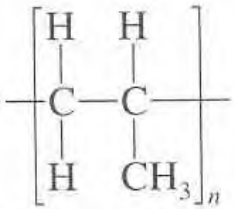




Polyethylene
mp: 110–137°C
(230–278°F)

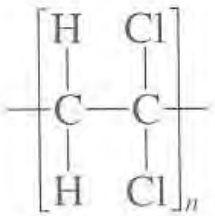


Polyvinyl chloride
mp: ~204°C
(~400°F)

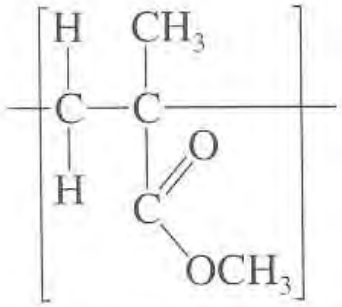


Polypropylene
mp: 165–177°C
(330–350°F)

- **Vinylidene Polymers: Both hydrogen on a carbon are replaced by another atom or group of atoms.**



Polyvinylidene chloride
mp: 177°C (350°F)



Polymethyl methacrylate
mp: 160°C (320°F)

Homopolymer and Copolymers

- **Homopolymers: Polymer chain is made up of single repeating units (mers).**

  Example: AAAAAAAA

- **Copolymers: Polymer chains made up of two or more repeating units.**
  - **Random copolymers: Different monomers randomly arranged in chains: ABBABABBAAAAABA**
  - **Alternating copolymers: Definite ordered alterations of monomers: ABABABABABAB**
  - **Block copolymers: Different monomers arranged in long blocks: AAAAA…….BBBBBBBB……**
  - **Graft copolymers: One type of monomer grafted to long chain of another: AAAAAAAAAAAAAAAAAAA**

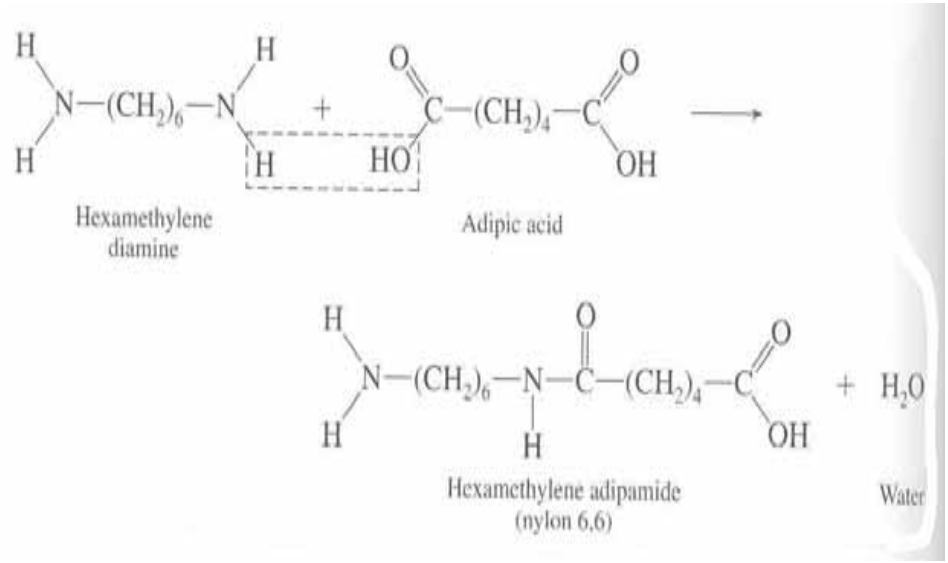
    B B

    B B

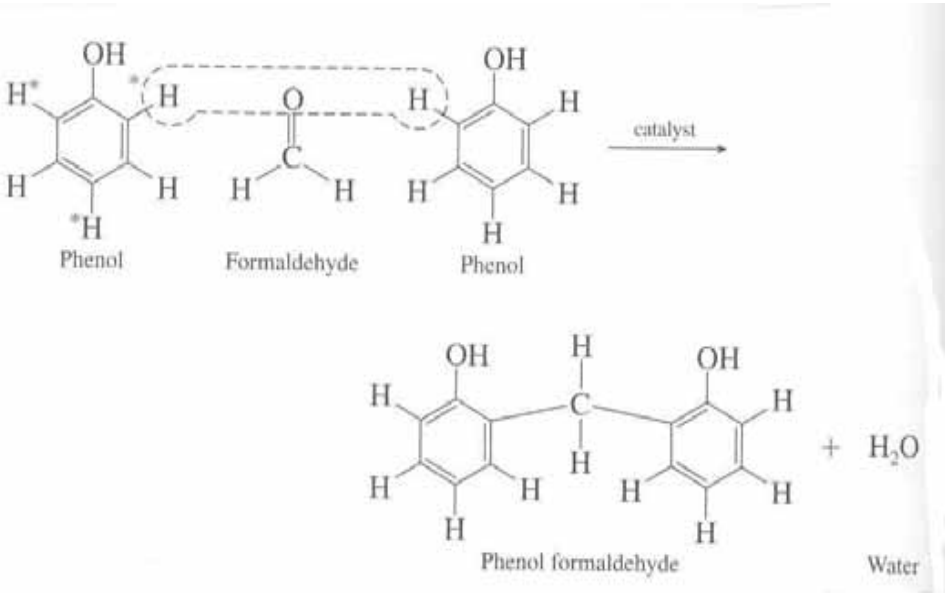
    B B

Other Methods of Polymerization

- **Stepwise Polymerization:** **Monomers chemically react with each other to produce linear polymers and a small molecule of byproduct.**

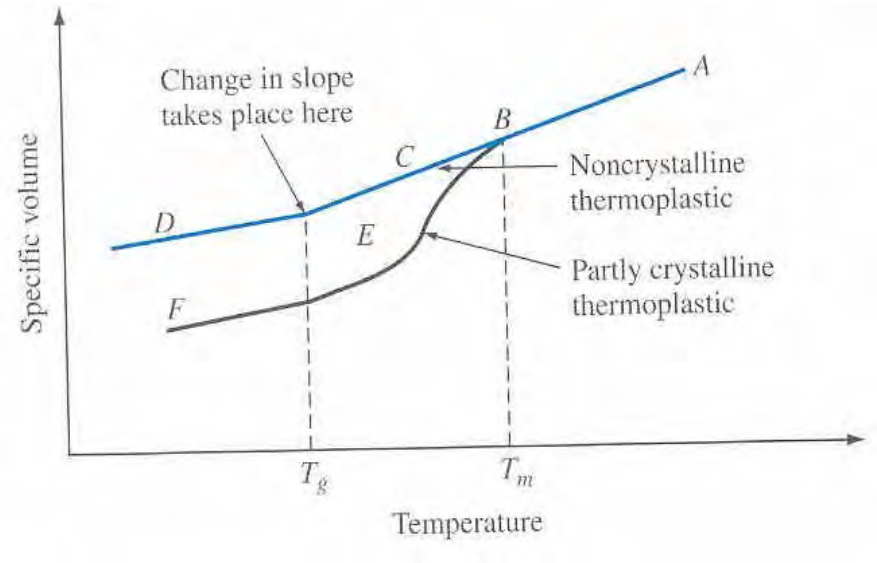


- **Network polymerization:** **Chemical reaction takes place in more than two reaction sites (3D network).**



Solidification of Thermoplastics.

- **There is no sudden change in specific volume on cooling in noncrystalline thermoplastics.**



T_g = glass transition temperature.

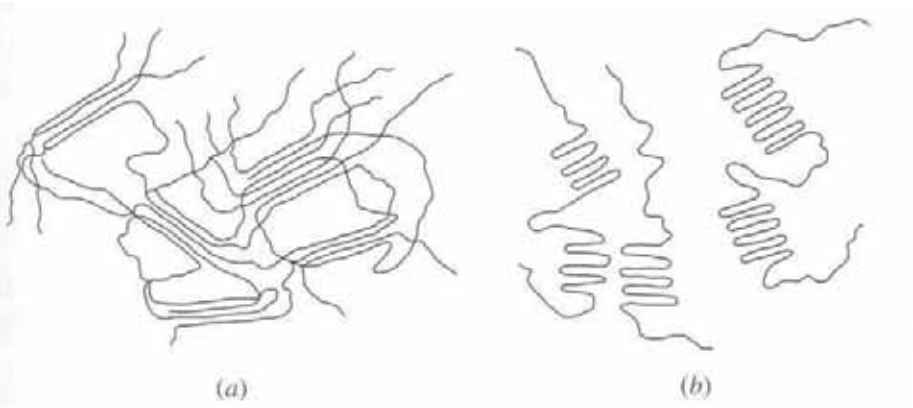
Glass brittle ← **below** **T_g** **above** → **Rubbery**

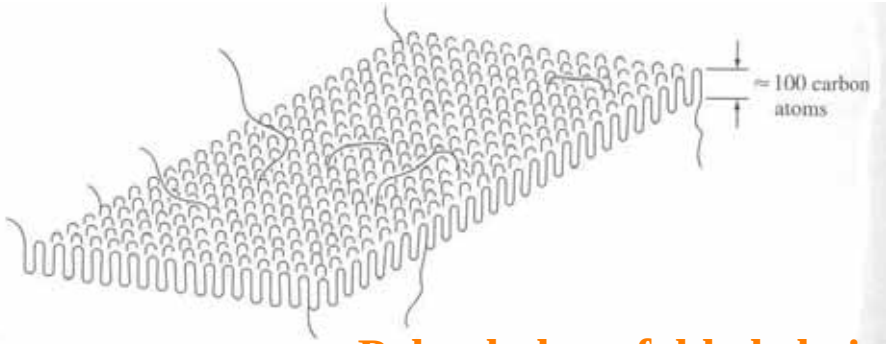
T_g for polyethylene is -110^0C
For PVC it is 82^0C

- **In crystalline thermoplastics, sudden decrease in specific volume occurs due to more efficient packing of polymer chains.**

Structure of Partly Crystalline Thermoplastics

- **Longest dimension of crystalline region is 5-50 nm.**
- **Fringed micelle model: Long polymer chains of 5000 nm wandering successively through a series of disordered and ordered region.**
- **Folded chain model: sections of molecular chains folding on themselves.**

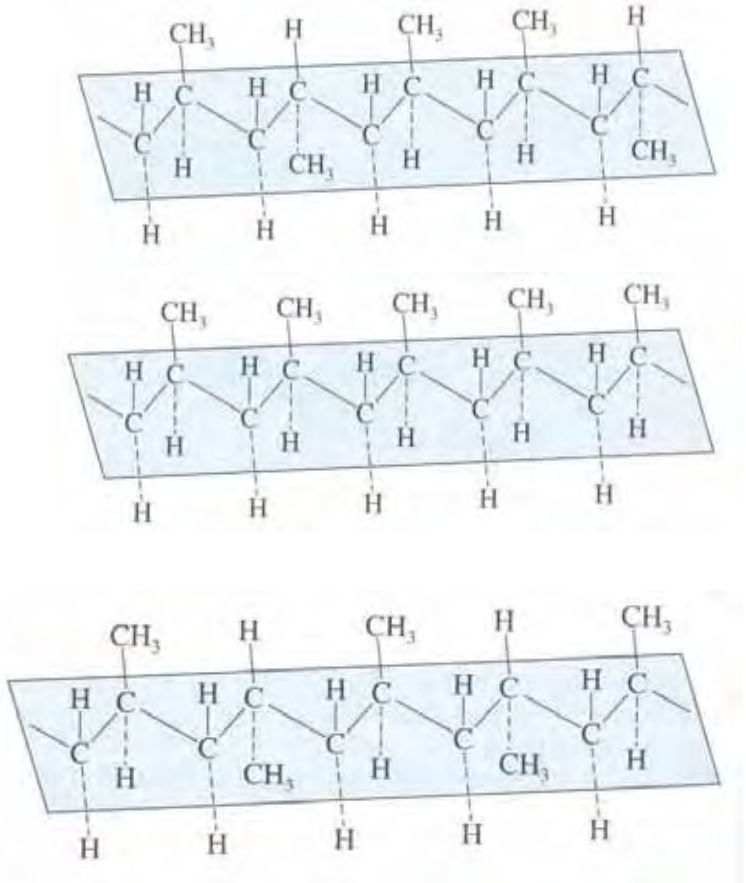




Polyethylene-folded chain

Stereoisomerism in Thermoplastics

- **Stereoisomer:- Same chemical composition but different structural arrangements.**
  - **Atactic stereoisomer:- Pendent methyl group of polypropylene is randomly arranged on either side of main carbon chain.**
  - **Isotactic stereoisomer:- The pendent methyl group is always on same side of the carbon chain.**
  - **Syndiotactic stereoisomer:- The pendant group regularly alternates from one side of the chain to the other side.** Polychlorotrifluroethylene (PCTFE)



Homework

- Chapter10: 7
- Example problems: 10.1, 10.2, 10.3, 10.4, 10.5,
- Reading assignment: 10.9, 10.11

http://video.google.com/videosearch?q=polymer&hl=en&sitesearch=

- Video and Popquiz