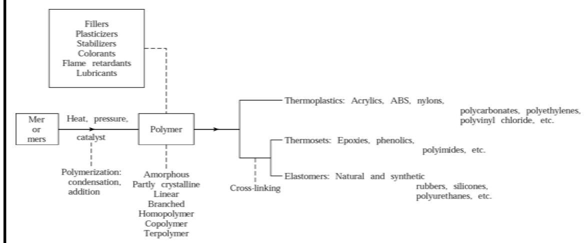
CH 13 and 28

Outline



A Brief History of Plastics – Plastic Processing

- 1860s: Small moldings made of cellulose nitrade in England.
- 1930s: Development of nylon and polyethylene – self-lubricating bearings and wire insulation.
- 1930s to1950s: Use of polymers in automotive industry.
- Today: 8% (by weight) of material used in a North-American, European, and Asian automobiles is plastics based: Engine intake manifolds, instrument panels, side doors, fuel lines, etc.:
  - Legislative recycling initiatives could keep usage at current levels, while fuel-economy initiatives could increase usage up to 15 to 20% in order to reduce vehicle weight.

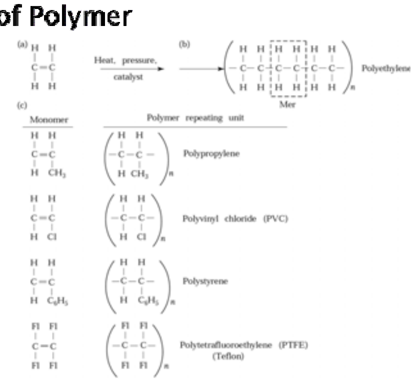
Advantages

- Corrosion resistance and resistance to chemicals
- Low electrical and thermal conductivity
- Low density
- High strength to weight ratio
- Noise reduction
- Wide choice of colors and transparencies
- Ease of manufacturing and complexity of design possibilities
- Low cost

Structure and Properties

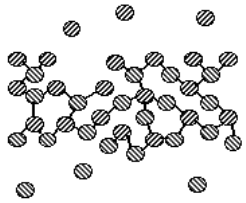
- Depend largely on the individual polymer molecules
  - Shape and size
  - Arrangement in the polymer structure
- Characterized by their size
  - Long chain molecules of monomers
    - polymerization

Structure of Polymer Molecules



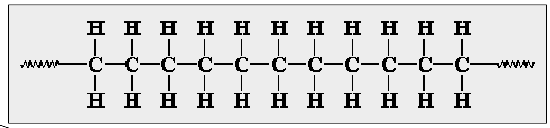
Polymerization

- Chemical reaction of linking monomers into repeating units
  - Addition
  - Condensation



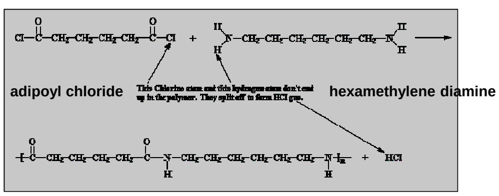
Addition Polymerization

You might say that an addition polymer is like a good friend who accepts everything about you, the pleasant and the unpleasant alike.



Condensation Polymerization

But a condensation polymer is more like a snotty social club that says, "Sure you can join, but only if you ditch those friends of yours".

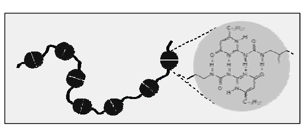


Molecular Weight

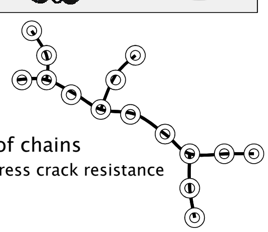
- Sum of the molecular weight of the mers in a polymer chain
- Higher the weight…….. Longer the chain
- Molecular weight distribution
  - Impacts the property of tensile and impact strength.

Polymer Chains

- <u>Linear</u>
  - Sequential structure
  - Thermoplastics
    - Acrylics, nylons



- <u>Branched</u>
  - Side branch chains
  - Interferes with movement of chains
    - Deformation resistance and stress crack resistance
  - Polyethylene



Engineering Plastics

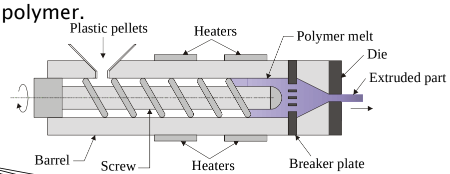
- Plastics refer to the family of polymers: Repeated collection of monomers produced through polymerization.
  - ***<u>Thermoplastics:</u>*** Linear chains – they can be solidified or molten reversibly. The four major thermoplastic polymers are: polyethylene (PE), polypropylene(PP), polystyrene (PS), and polyvinyl chloride (PVC):
    - *Polyethylene* has excellent chemical resistance to acids, bases, and salts, it is easy to process (mostly through injection molding or extrusion), free from odor and toxicity, and, reasonably, clear when in thin-film form: bottles, toys, food containers, and conduits and wires.

Engineering Plastics (cont.)

- ***Polypropylene*** has stiffness, heat resistance, and chemical resistance superior to those of PE. PP films can also be glass-clear: medical containers, luggage, and various auto parts (e.g., door frames).
- ***Polyvinyl chloride*** is always utilized with fillers/ plasticizers/ pigments – it is resistant to alkalis and dilute mineral acids, and a good electrical insulator: bathroom curtains, blood bags, and pipes and fittings.
- ***Polystyrene*** is rigid, transparent, and good electrical insulator: mouldings for appliances, containers, disposable cutlery/ dishes,lenses, and footwear heels.

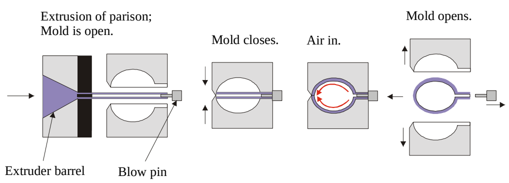
Thermoplastic Processes

- Extrusion is a continuous process. However, it is utilized in many discrete-parts plastics manufacturing processes to plasticize the polymer:
  - Frictional forces within the barrel are the primary contributors to the melting (plasticizing) of the polymer.



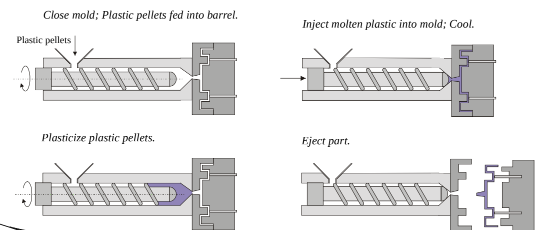
Thermoplastic Processes (cont.)

- Blow Molding: Production of thin-walled hollow products.



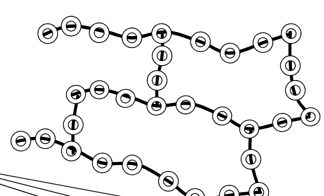
Thermoplastic Processes (cont.)

- Injection molding can be used for the fabrication of thermoplastic as well as thermoset discrete plastic parts:



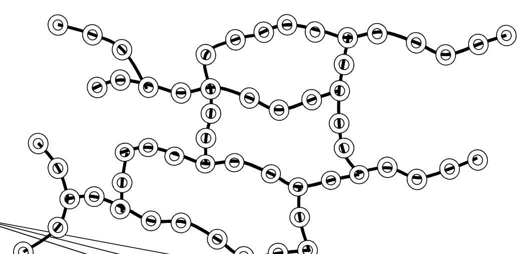
Polymer Chains

- <u>Cross linked</u>
  - Adjacent chains linked by covalent bonds
  - Thermosets (irreversible)
  - Characteristics given: hardness, strength, stiffness, brittleness….



Polymer Chains

- <u>Network</u>
  - Three or more active covalent bonds
  - Epoxies and phonics



Engineering Plastics (cont.)

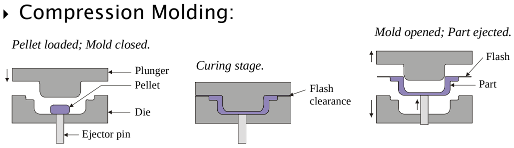
- *Thermosets:* Cross-linked chains – they cannot be re-melted, (e.g., *polyester, polyurethane, and phenolic).* They are almost always combined with fillers, for yielding reinforced plastics with good mechanical properties.

Engineering Plastics (cont.)

- Foam is a cellular polymer with gaseous voids less than 5 μm (≈200 μin) (cells).
  - The foaming process comprises three primary steps:
    - cell nucleation,
    - bubble growth (expansion),
    - and stabilization (coalescence) of the cells:
  - Automobile glove-box doors, water skis, pallets, speaker chassis, cushions, food trays and containers, refrigerator insulation, life preserver, automobile panels, etc.

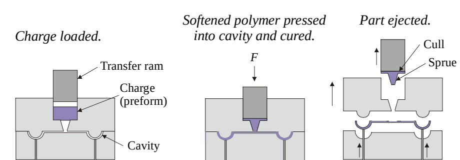
Thermoset Processes

- Thermoset resins require higher temperatures to initiate polymerization: Once processed, they are temperature and chemical resistant – though they are also very brittle; Thus, they are seldom used without a reinforcement agent.
- Compression Molding:



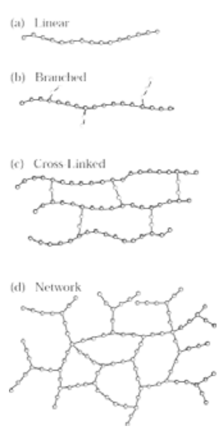
Thermoset Processes (cont.)

- Transfer Molding: In comparison to compression molding:
  - Good control of part thicknesses,
  - Production of intricate geometrical details, and
  - Better mechanical properties.



Polymer Chains

Schematic illustration of polymer chains. (a) Linear structure--thermoplastics such as acrylics, nylons, polyethylene, and polyvinyl chloride have linear structures. (b) Branched structure, such as in polyethylene. (c) Cross-linked structure--many rubbers or elastomers have this structure, and the vulcanization of rubber produces this structure. (d) Network structure, which is basically highly cross-linked--examples are thermosetting plastics, such as epoxies and phenolics.



What-polymer?

- Homopolymer
  - Repeating chain of the same material
- Copolymer
  - Two types of polymers
    - Styrene – butadiene (used for auto tires)

- Terapolymers
  - Three types
    - ABS (acrylonitrile – butadiene – styrene)
      - Helmets, telephones, refrigerator liners

Engineering Plastics (cont.)

- <u>Composites</u>
  - the polymer matrix and reinforcement fibers/flakes/fillers/etc. The modulus and strength of the reinforced plastic is determined by the stiffness and the strength of the reinforcements and the bonding between them and the polymer matrix.
    - Reinforcing materials: glass fiber, as continuous fibers (woven into a laminated structure) or as (chopped) short fibers (mixed with the liquid polymer prior to being processed), carbon fibers, synthetic polymer fibers (e.g., Kevlar 49), and silicon-carbide fibers.
    - Primary vehicle structures as a replacement for steel.

Additives

- Modify and improve certain characteristics
- <u>Plasticizers</u>
  - Reduce the strength of the secondary bonds
  - Add flexibility and softness
  - Polyvinyl Chloride (PVC) , shower curtains, inflatable mattress
- <u>Carbon black</u> (soot)
  - Absorbs the ultraviolet radiation

Additives

- <u>Fillers</u>
  - Wood flour, silica flour, clay, talc, glass, asbestos, powered mica
  - May improve strength, toughness, abrasion resistance
  - Lowers overall cost
- <u>Colorants</u>
  - Organic (dyes) , inorganic (pigments)
  - Selection depends on service temperature and exposure to light

Additives

- <u>Flame retardants (Stabilizers)</u>
  - Chlorine, bromine and phosphorus
  - Non burning
    - Fluorocarbons (Teflon)
  - Burning self extinguishing
    - Carbonate, nylon, vinyl chloride
- <u>Lubricants</u>
  - Linseed oil, mineral oil, waxes, metallic soaps (calcium stearate and zinc stearate)
- <u>Antistatic agents</u>
  - allow electrical charges to migrate to the surface and get discharged to the environment.

General Recommendations

General Recommendations for Plastic Products

Design requirement	Applications	Plastics
Mechanical strength	Gears, cams, rollers, valves, fan blades, impellers, pistons	Acetal, nylon, phenolic, polycarbonate
Functional and decorative	Handles, knobs, camera and battery cases, trim moldings, pipe fittings	ABS, acrylic, cellulosic, phenolic, polyethylene, polypropylene, polystyrene, polyvinyl chloride
Housings and hollow shapes	Power tools, pumps, housings, sport helmets, telephone cases	ABS, cellulosic, phenolic, polycarbonate, polyethylene, polypropylene, polystyrene
Functional and transparent	Lenses, goggles, safety glazing, signs, food-processing equipment, laboratory hardware	Acrylic, polycarbonate, polystyrene, polysulfone
Wear resistance	Gears, wear strips and liners, bearings, bushings, roller-skate wheels	Acetal, nylon, phenolic, polyimide, polyurethane, ultrahigh molecular weight polyethylene

Design for Plastics Processing

- The filling of the mold as well as the cooling of the part within the mold should be simulated using CAE analysis tools:
  - Sudden wall-thickness changes should be avoided to prevent shrinkage problems.
  - Tapers should be used for ease of removal from the mold.
  - Undercuts should be avoided for low-cost molds.
  - Holes must not be placed too near to edges to avoid fracture.
  - Fine screw threads should be avoided in composite part design, since even short fibers (less than 3 mm in length) would not be present at the threads.