Engineering Polymers (Plastics)

Thermoplastics

A key descriptive of thermoplastic polymers is reversible. Engineering thermoplastics are typically flexible or rigid at room temperature. When heated, they become viscous liquids, and it is in this state that they are usually formed. Then, they are cooled back to room temperature. These plastics are recyclable, as this heating and cooling can be repeated.

A concern with thermoplastics is that, when cooled below room temperature, many become glassy. Material that was flexible or resilient at room temperature may become unacceptably brittle at low temperatures. Many thermoplastics do not melt with a discontinuous volume change like metals. Rather, they continuously change from glassy to viscous liquid at a temperature, referred to by the scientist as the *glass transition temperature* and by the engineer as the *softening temperature*.

Thermoplastics are the long-chain molecules mentioned in the unit introduction. If a polymer molecule would be scaled up so that its diameter would be 1 mm, then its length might be 3 m. These numbers depend on particular chemistry and molecular weight. Some flexible thermoplastics can be made more rigid by forming covalent bonds between molecules, referred to as *cross-linking*.

Our selected plastics that we will use for comparisons in Unit 3 are all thermoplastics:

- Polyethylene (PE): This is the most widely used plastic. The grocery store plastic bag, as well as many other packaging materials, such Ziploc® bags, are PE. Wikipedia reports that one-third of all plastic toys are PE.

- Polypropylene (PP): Second most widely used, PP finds use in climbing ropes and carpets. Better at elevated temperatures than PE, it's the material of dishwasher-safe plastic ware. Resistant to fatigue failure, it is used for flip-top plastic lids.

- Polyvinylchloride (PVC): Third in amount of use, rigid PVC is the white plastic pipe buried underground for municipal water and sewer systems. Flexible PVC is a common insulating sheath around electrical wires.

- Polystyrene (PS): Pure PS is colorless and found in disposable cutlery and DVD cases. It can be colored with additives and used in products such as disposable razors. PS can be a thermoset (discussed in the next section), as well as a thermoplastic. It can also be foamed, as with the familiar Styrofoam®.

- Polymethylmethacrylate (PMMA): Clear and rigid, it is referred to as acrylic glass and sold under trade names Plexiglas® and Lucite®. One application is the protective barrier at the hockey rink.

- Polycarbonate (PC): Also transparent, it is harder than PMMA. One trademark PC is sold as Lexan®. It is used as the cockpit canopy material in fighter planes, as an example.

Thermosets

Thermosetting polymers start out as small organic molecules, often in powdered form. These molecules have double bonds, which when heated, usually under pressure, can break and recombine with neighboring molecules. The result is a 3D network of strong double bonds that forms a rigid material. The process is irreversible. Once the polymer has reacted (set), further heating and cooling produces no further changes.

Thermosets are among some of the most rigid plastics, and include Bakelite®, Formica®, melamine, and various epoxy resins. The figure below compares the two types of polymers.