# PETE Processing Activity

## Pre-Activity Reading and Discussion Questions

Plastic materials are composed of a tangled collection of polymer molecules or "chains". Each polymer chain is made of a series of repeating units that are connected by covalent (chemical) bonds in an end-to-end fashion to form one long, flexible, string-like polymer molecule (see Figure 1).

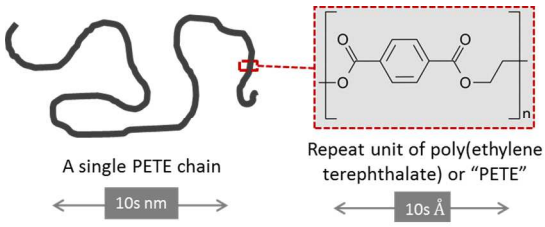


*Figure 1: Simple schematic of a polymer chain (left), illustrating the chemical structure of PETE (right) and the relative length scales.*

Plastic objects contain millions of polymer chains, tangled together in a similar fashion to a tangled collection of spaghetti noodles (see Figure 2). When a force is applied to the collection of chains, the chains can move and reorient in response to the applied force. If the applied force is great enough in magnitude, the long axis of the molecules can reorient in the direction of the applied force (as shown in Figure 2). Chain reorientation takes less energy and is thus more likely to occur when the plastic is heated.

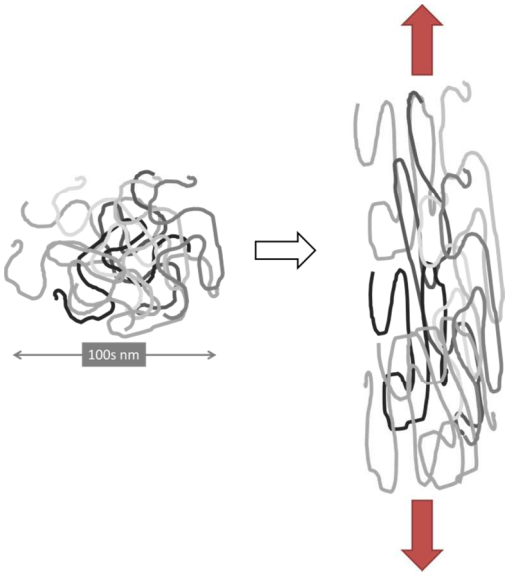


*Figure 2: Simple schematic of the microstructure of a plastic material, composed of a tangled collection of polymer chains (left). When the chains are exposed to a tensile force (red arrows), the chains can reorient and align in the direction of the applied force (right).*

The long axis of the aligned molecules can store elastic energy within its covalently bonded "backbone", resulting in a strong mechanical response from the deformed collection of aligned chains. Thus, a plastic material in which the chains are aligned is very strong in response to forces applied

parallel to the chain alignment direction but can behave in a mechanically weak manner in response to forces applied perpendicular to the chain alignment direction. This is because only the relatively weak Van der Waals interaction forces between the different chains act to resist forces applied perpendicular to the alignment direction as compared to the relatively strong covalent bonds in the chains' backbones that resist forces applied parallel to the alignment direction.

When a block of plastic is heated to a high temperature and becomes mechanically soft, it can be molded and processed into a variety of different physical forms, such as plastic cups, plastic forks, and plastic cords. A quick online search for "How plastic forks (or cups or cords) are made" will result in a number of videos that illustrate different industrial plastic processing techniques, such as sheet extrusion, injection molding, compression molding, and thermoforming.

Focusing on disposable plastic cups, cups are commonly manufactured by a process known as thermoforming (see Figure 3). In Step 1, a heated film of plastic is positioned above a cooled metal mold containing a cup-shaped cavity. In Step 2, a metal punch is brought into contact with the hot plastic by applying a downward force and the plastic subsequently deforms around the punch. Typically, this process is also assisted by a vacuum to aid in mold-filling. In Step 3, the punch is pushed further into the plastic, causing the plastic film to stretch and deform, ultimately filling the mold and creating the cup. After the cup is formed in Step 3, it is cooled and removed from the mold. There are excellent videos of this process at the industrial scale available online.

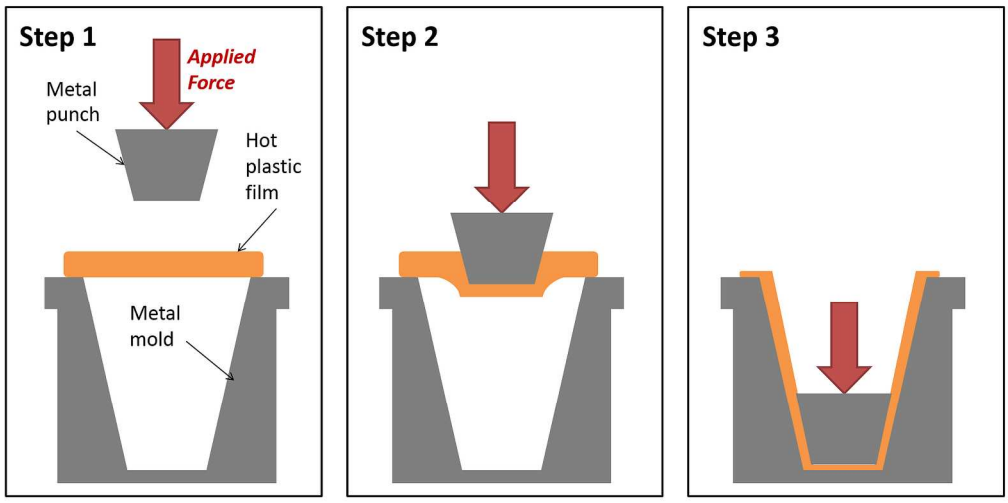


*Figure 3: Simple schematic (side-view) illustrating a thermoforming process to make a plastic cup.*

**Pre-Activity Discussion Questions**

(1) If you were to "zoom-in" on the microstructure of the hot plastic film in Step 1 and were able to see the individual polymer chains, what would the collection of chains look like? Draw a sketch to explain your answer.
(2) When the hot plastic film is stretched into the cup-shaped mold in Step 2 and 3, how would this stretching affect the polymer chains within the plastic? Draw a sketch of the cup's microstructure to explain your answer.
(3) How do you think the mechanical properties of the finished cup are affected by the thermoforming process? How might you confirm your ideas experimentally?