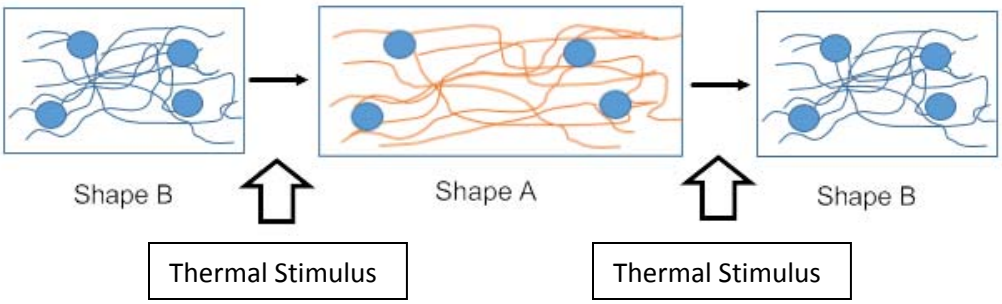
Creating Shape Memory Polymers

Background

Shape memory polymer is an emerging class of polymers that has the capability of changing into a different programmed shape and then back to its original shape. This shape change is usually caused by some outside stimulus like heat, light, magnetism or electricity. Because shape memory polymers can exist in different shapes, they have many potential uses such as self-tying sutures, medical implants and other high tech applications. In this activity, you will transform a homemade rubber band into a shape memory polymer using latex and lauric acid. The outside stimulus will be heat. Shape B will be the original shape of the rubber band. Shape A will be the stretched shape after the stimulus. See figure 1 below.

Shape Memory Figure 1



Safety

Caution should be used in working with latex as some students have allergic reactions to it. Students should wear non-latex gloves for this activity. Students should also use caution working with lauric acid as it is flammable. Do not use open flames for this activity. Students should wear safety goggles for this activity.

Materials

Petri dishes, Lauric acid, Latex (Holden's HX-80), Vinegar, Forceps, Dixie Cups, 2 – 250 mL Beakers, Ethanol, Small Cookie Cutter Shapes (optional)

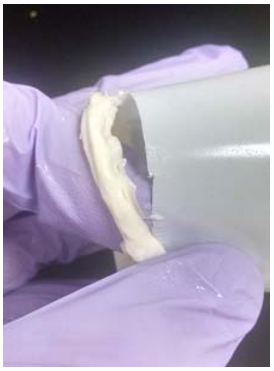
Procedure

Day 1 – Using latex to make rubber bands.

1. Obtain a Dixie cup with the bottom cut out of it, or use another form. Cookie cutters work, but the size of the shape should fit in the Petri dish. Whatever shape is used will be the initial shape of the polymer/rubber band.

2. Pour enough liquid latex into a Petri dish until the bottom of the dish is covered. The latex should be no more than ¼ inch deep. Also, obtain another Petri dish and fill it with household vinegar. The vinegar should completely cover the latex layer on the forms.

3. Dip the cut out bottom of the Dixie cup in latex. Make sure that the latex layer is even. If a latex bubble forms, be sure to pop it.
4. Carefully, dip the latex coated cup in household vinegar. The latex will coagulate within seconds. Leave the cup in vinegar for 30 seconds and remove. Pat the latex band dry with paper towels.
5. Repeat the coating process by dipping the latex ring in latex one more time. Coagulate the coating in vinegar again for 30 seconds.
6. Carefully remove the ring from the bottom of the cup. Be sure not to tear the latex. Use your fingers to form it into a smooth rubber band. Test the elasticity of the rubber band. Does it stretch like a normal rubber band? Record your observations in your data table.
7. Repeat the coating/coagulating process two more times for a total of three homemade rubber bands. These bands will be transformed in to shape memory polymers tomorrow. Record your observations in your day 1 data table.
8. Cure the rubber bands overnight by letting them sit out.
9. Excess latex can be coagulated by mixing vinegar into the Petri dish. The latex can be formed into a rubber bouncy ball. Be careful not to squeeze the latex ball too much as liquid latex can squirt out from the inside.



Day 2 – Creating the Shape Memory Polymer

1. Before beginning the experiment, test the elasticity of the home made rubber band. Is it more or less elastic than yesterday? Record your observations in your data table.
2. Make a 250 mL, 50 ^{o}C hot water bath using a hot plate and prepare a 250 mL room temperature water bath.
3. Using another Petri dish, heat lauric acid to 50 ^{o}C until it melts. Be sure to have enough lauric acid to completely submerge the rubber band.
4. Once the lauric acid melts, place the rubber bands into the melted lauric acid for 5-7 minutes.
5. Remove the band from the lauric acid and rinse the excess with ethanol.
6. Pat dry the band with a paper towel.
7. To program the shape memory polymer, place the lauric acid/latex band in the hot water bath (around 50 ^{o}C) for 1 minute. Stretch the polymer into the desired shape.
8. Lock the stretched shape by plunging the stretch shape into the room temperature bath for 1 minute. Make a rough sketch of your programmed shape in your data table.
9. Repeat the procedure two more times with the other rubber bands.
10. Students should be able to program their shape memory polymer in a variety of ways and it should return to its original shape. Each lab group should be able to make the following shapes; triangle, square and spring shape (coil). Record your observations and data in your data table.
11. Additional shapes can be programmed into your polymer. Forms can be used to program different shapes or the rubber band can be cut to make linear shapes. Develop at least two more creative shapes and have them return to their original shape. Record your observations & sketches of your work in your data table.

Experimental Observations

Data Table	Day 1	Day 2
Observations	*Students should write observations about the coagulation process observed in lab.* *Students should also note that the relative strength of the rubber band is less than normal because it is not cured*	*Students should observe that the strength of the rubber band increases with curing.* *Students should observe the shape memory polymer has the ability to be manipulated and return to the original shape.*

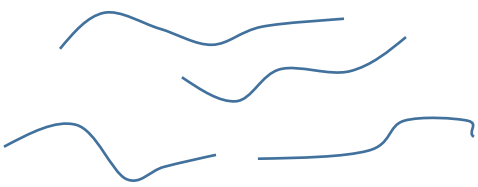
Sketch of Programmed Shapes

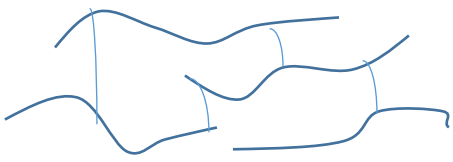
Square	Triangle	Coil	Created Shape #1	Created Shape #2
Results may vary	Results may vary	Results may vary		

Post Lab Questions

1. Why does latex coagulate in vinegar? Explain.
   Latex coagulates because alkaline latex form micelles of latex polymer surrounded by a natural protein. When acid is added the micelles are destroyed and the polymer chains combine into larger chains. Latex can also be coagulated by leaving it out in the air. Bacteria in the latex produce acid, which also causes it to coagulate.

2. Cross linking is the chemical joining of several polymer chains.
   Uncross linked rubber **Cross linked rubber**





   Which of the above forms of rubber has more elasticity? How does elasticity relate to cross linking?

The cross linked rubber is more elastic because it has more bonding. The more bonding in a polymer, the greater the strength of the material. In rubber, the elasticity increases as the rubber cures. More curing, means more cross linking.

3. Why does the shape memory polymer need to be heated to program the shapes?
   The shape memory polymer should be heated to above the temperature of the lauric acid (around 50^{o}C). At this temperature the lauric acid melts inside of the polymer and it can be easily manipulated. When the material is cooled below the melting point of lauric acid, the shape is frozen or programmed into the material.
4. Rank the success of your group. Were you able to create new shapes and return them to the original shape? How could you improve the experiment?

   Results may vary

5. Discuss potential uses for shape memory polymers. In what ways can it be used?

   Shape memory polymers are an emerging field in polymer science. Many of the current uses are biomedical (like self-suturing sutures and surgical implants that expand or contract in blood vessels). Students may be able to come up with new uses with some creative thought. Just as silicone rubber bands shaped into common shapes made millions as Silly Bandz, so too could shape memory polymers take off into something special. Sometimes students have the best ideas because they can think outside-the-box. Challenge them to come up with a creative use. Who knows they may be able to develop a million dollar product.

For more information on shape memory polymers, see this article below.

Behl, M., & Lendlein, A. (2007). Shape-Memory Polymers. *Materials Today, 10*(4), 20-28