TEACHER INSTRUCTIONS

Piezoelectric Materials

Objective: To demonstrate the piezoelectric effect in several materials and explain why this property exists in certain materials.

Background Information: Piezoelectric materials are everywhere. Piezoelectric materials are used in a wide variety of applications. Sensors, amplifiers, and ultrasonic transducers are just a few examples. They are a necessary component in all electronics and can be made very small (so your electronics can be compact as well).

The piezoelectric effect describes the relationship between a mechanical stress and an electric voltage in solids. Certain materials (e.g. quartz and barium titanate ($BaTiO_3$)) exhibit this effect. When a mechanical stress is applied to these materials, they generate a voltage. This is shown schematically in Figure 1. The effect is reversible as well. When a voltage is applied to the material, the shape of the material will change by a small amount (up to 4% in volume change).

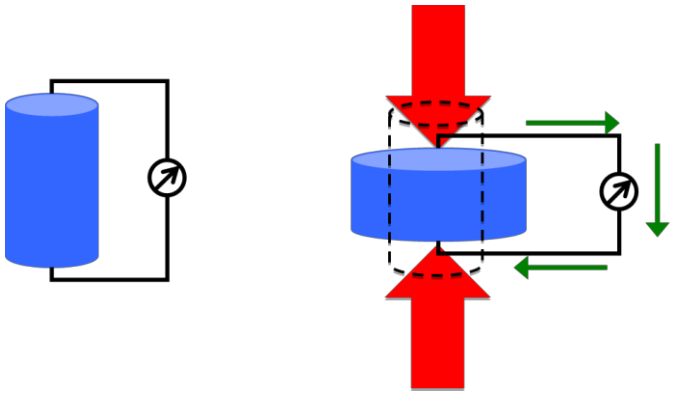

Figure 1. Schematic of the piezoelectric effect. When a force is added to the material (red arrows), it generates a voltage (green arrows). It also works in reverse.

This is how the speaker in a greeting card or the speaker in an mp3 player's headphones works. The material is electrically vibrated at certain frequencies that we then hear as sound. This sound can be amplified with the use of a diaphragm.

The piezoelectric effect is caused from the structure of the material. Sometimes atoms are arranged in such a way that they can be physically forced towards each other when the material experiences a compressive force. The change in the material's structure causes an electric dipole, or change in potential (voltage). The opposite is also true. When a potential is applied to the material, like a battery, then the atoms are driven apart and a force is created. See the

introductory PowerPoint presentation on the flash drive in the kit for examples of how the piezoelectric effect is used in real-world applications.

Demo Description: In this demo, the piezoelectric effect of a ceramic disk and a polymer film will be demonstrated through the use of LEDs. Two of each piezoelectric material have been included in the kit so that you may keep one to demonstrate and pass one among the students.

Keywords:

· piezoelectric – the effect of generating electric charge from applied force; "piezo" comes from the Greek for "pressure."
· ceramic – classification of materials which are inorganic, non-metal solids.
· polymer – classification of materials which are characterized by long, chain-like molecules that typically have repeating sub-units.
· structure – the arrangement of atoms within a material.
· potential – difference in electric charges resulting in the capacity to do work.
· force – influence exerted on an object, such as pressure or tension.
· transducer – a device that converts small amounts of energy from one kind into another.

Materials List:

Items provided in the kit:

· two piezoelectric ceramic disks
· two piezoelectric polymer films
· four LEDs
· eight alligator clip sets

Items to be provided by the teacher/school:

· musical greeting card
· voltmeter

Safety Precautions: Too much force on either piezoelectric material can permanently damage them.

Instructions:

1. Test both piezoelectric materials prior to starting the demonstration to make sure neither is damaged or needs to be replaced.
2. Connect one LED to a piezoelectric polymer film so that the long wire of the LED is connected to one leg of the piezoelectric material, and the short wire on the LED is connected to the other leg of the piezoelectric film. Use the supplied alligator clips to make these connections (Figure 2).

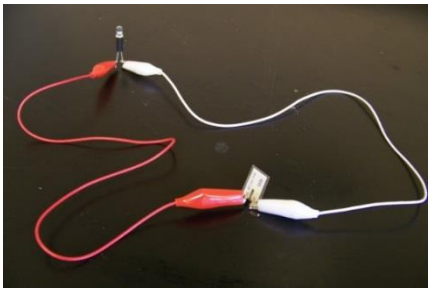

Figure 2. LED and piezoelectric polymer film connected by alligator clips

3. Connect 1 LED to a piezoelectric ceramic disc so that the long wire of the LED is connected to the red wire coming from the disk and the other wire of the LED is connected to the black wire of the disk.

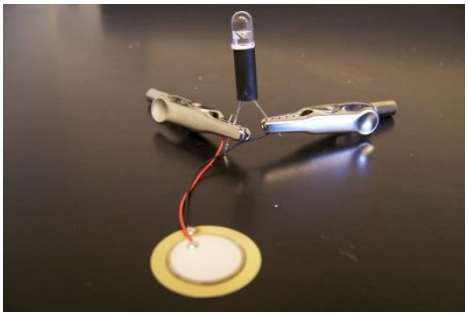

Figure 3. Piezoelectric disk ready to be tested

4. With a very light tap, slowly increase the force until the LED visibly flashes with each tap. Show effect to students. It is important to simply tap the disk and to not apply steady pressure. ***NOTE***: The room must be fairly dark to see the LED light.
5. Bend the polymer film back and forth slowly (Figure 4). Increase the speed at which you are bending the material until the LED lights up with each bending motion.

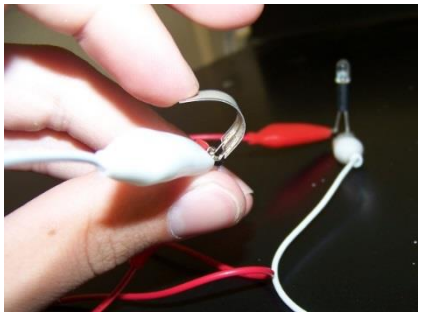

Figure 4. Bending the polymer film

6. Open the musical greeting card and explain the use of piezoelectric materials as a speaker. Take apart the card so that students can see the actual piezoelectric "buzzer." Supply students with the background information on piezoelectric materials. A reproduction of Figure 1 should be created as a demonstration aid, linking it to the ceramic disk and polymer films used.

OPTIONAL ADDITIONS TO THE DEMO

7. Use a voltmeter in place of the LED to measure the voltage generated by the piezoelectric. This provides a better indication of the piezoelectric effect as the light generated by the LED is very minimal.
8. Connect the two piezoelectric materials in series and try to generate more voltage by simultaneously activating both materials.
9. Create a simple circuit by connecting the ceramic disk directly to the polymer film. Attempt to make the polymer film bend by striking the ceramic disk.

Demo Delivery Hints: Interest is key. This demonstration can be boring if you are not interested in it yourself. Try to be excited about the piezoelectric affect. The video "How a quartz watch works" can be used as an introduction: http://www.youtube.com/watch?feature=player_embedded&v=1pM6uD8nePo

Troubleshooting: If either piezoelectric material is damaged or not working, then replacements should be purchased. If the demonstration isn't functioning, then the piezoelectric materials are most likely the cause (the LEDs are nearly indestructible).

Clean-up/Replacement Parts: Disconnect the LEDs from the piezoelectric materials and return all materials to the kit. LEDs can be found at any electronics store for very little cost if they are lost or stolen. Piezoelectric ceramic disks can be purchased from online electric suppliers, including eBay. They are typically referred to as "transducers." It is recommended to purchase the disks with wires already attached (for ease of use). Piezoelectric polymer films can also be purchased from online electronic suppliers. They are commonly referred to as "piezoelectric vibration sensors." It is also recommended to purchase films with wires already attached (for ease of use).

TEACHER DISCUSSION QUESTIONS

Piezoelectric Materials

Discussion Questions to Ask Before the Demo

1. How do we, as a society, make electricity?

   Discussion: We typically use generators powered by water or steam pressure, wind, solar, coal, or nuclear power.

2. What objects or materials generate electricity?

   Discussion: Magnets (generator), batteries (chemical reaction)

Discussion Questions to Ask During the Demo

1. Why does the LED have to be polarized (red and black wires)?

   Discussion: The charge only moves in one direction when the material is compressed.

2. What do these piezoelectric materials have in common?

   Discussion: A similar structure that allows atoms to be forced together.

3. What is generating the charge observed as light from the LED?

   Discussion: The movement of atoms within the material causing an electric dipole to light the LED.

Discussion Questions to Ask After the Demo

1. What are potential applications this material could be used for?

   Discussion: Sensors, speakers, actuators, buzzers, switches, and power generation.

2. Is human hair a piezoelectric material?

   Discussion: It is . . . did you ever statically charge a balloon by rubbing it on your head?

STUDENT QUESTION HANDOUT

Piezoelectric Materials

1. What is the piezoelectric effect?

2. What causes the piezoelectric effect?

3. Name a type of material that can have the piezoelectric effect.

4. Name one current use of this material property.

5. What is a potential application of this material? Where could you use the piezoelectric effect?