RAFT IDEAS

Topics: Solar Energy, Energy Conversion

Materials List

(For each “cell”)

- ✓ Reflective Mylar (best) or foil
- ✓ Transparency
- ✓ Rectangular solid of foam or a box at least 6 cm (2-1/2”) on a side and about 2 cm (¾”) thick
- ✓ Plastic wrap
- ✓ Black and dark blue permanent markers
- ✓ Tape

This activity can be used to teach:
Next Generation Science Standards:

- Energy can be transferred /converted (Physical Science, Grade 4, 3-2 & 3-4; High School, 3-3)
- Energy, natural resources, & the environment (Grade 4, Earth & Space Science 3-1)
- Human Impacts (Middle School, Earth & Space Science 3-3; High School, Life Science 2-7)

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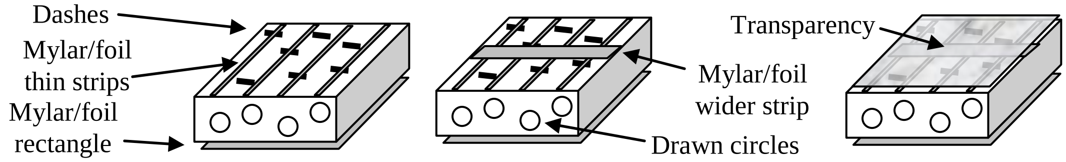
Solar Cell Sandwich

Layer up the learning by creating a model of a solar cell



Create a model to learn about how the most common type of solar cell is constructed.

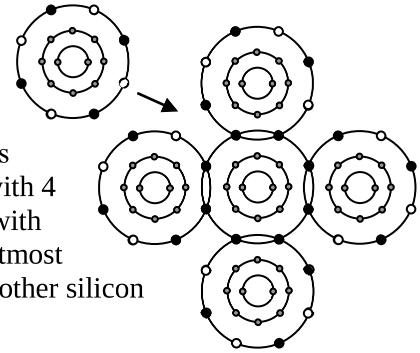
Preparation

1. Cut a section from the transparency that will cover the largest side of the block of foam. Optionally the transparency could be colored blackish blue with markers.
2. Cut a rectangle of reflective Mylar, or aluminum foil, the same size as the transparence rectangle cut in step 1.
3. Cut a second piece of reflective Mylar, or aluminum foil, to make 4 strips 2 mm (1/16”) wide that are slightly shorter than the longest dimension of the block of foam. Cut additional strips if the block is wider than 6 cm (2-1/2”) so that there is a strip for each additional cm (or ½”) of width.
4. Cut a third piece of reflective Mylar, or aluminum foil, to make a strip that is ½ cm (3/16”) wide and a little longer than the foam block is wide.

To Do and Notice (plus information about silicon and processing silicon)

1. The block of foam represents a piece or slice of silicon that is the basis for building the most common type of solar cell. Silicon, while the 2nd most common element in the Earth’s crust, is rarely found in a pure state. Silicon dioxide is usually refined from sand or quartz. To create a solar cell the silicon must be 99.9999% pure (no more than 1 part of impurity in a million parts of silicon).
2. To the purified silicon is added an element, such as boron, that has 1 less electron than silicon in the outermost electron band. This addition, called a dopant, is invisible to the eye. In a process called doping a tiny amount of dopant (parts per 100 million) is added. To model the adding of the dopant draw small circles on a narrow side of the foam block, representing the “missing” electron.
3. To provide “extra” electrons another element, such as phosphorus, is added in equally tiny amounts to a thin top layer of the silicon. Phosphorus has 1 more electron in the outermost electron band than silicon. This second doping can be modeled by writing black dashes on the top of the foam block. The dashes will represent the invisible extra electrons that each have a negative (-) charge.
4. To supply a conductive path for electrons to enter the bottom of the solar cell a layer of aluminum is added. To model the bottom conductive layer place the precut rectangle of Mylar or foil on the bottom of the foam block, see above.
5. To collect freed electrons the solar cell will have thin conductive electrodes called collector lines added to the top. To model the collector lines lay the thinner cut Mylar strips evenly across the length of the top of the foam block, see above.
6. The electrons conducted by the collector lines are “collected” by a wider conductor, called a bus bar. Model the adding of a bus bar by laying the wider strip of Mylar across the collector lines as show in the middle illustration. (Tape could be added across the strips to keep the bus bar and collector lines in place.)
7. To increase a solar cell’s efficiency an anti-reflective coating is applied to the top of the solar cell. Lay the transparency on the top of the foam block to model the anti-reflective coating, which gives solar cells their distinctive bluish-black color.
8. For protection solar cells can be encapsulated in epoxy. Use plastic wrap to wrap up the pieces to model this protection, as well as hold all the pieces together.

Developed and written by Michael Pollock (RAFT)



The Science Behind the Activity

While a silicon atom's outermost electron band (or shell) can "hold" 8 electrons there are actually only 4 electrons present. Each silicon atom can form bonds with 4 neighboring silicon atoms such that each neighboring atom shares an electron with the central silicon atom so that central silicon atom has all 8 positions in the outmost band filled. When this process is repeated each neighboring silicon atom has 4 other silicon atoms to share electrons. These groupings form crystals of silicon.

Silicon is considered a semiconductor because silicon does not have the free electrons of a conductor, such as copper, but is more conductive than glass, which is considered an insulator. Silicon can have impurities added which can either have less electrons or more electrons in the outermost electron band than silicon. The additions will change the silicon's electrical properties. See the RAFT idea sheet ***A Silicon Solar Cell – all Doped Up***.

When "doped" with an impurity that has **fewer** electrons in the outermost band than silicon, the silicon is labeled "P" type. The letter P stands for **p**ositive as the material will more easily accept electrons. The layer is often referred to as having "holes", places where electrons can be attracted. The process where the holes of neighboring atoms are in turn filled and emptied can be visualized as the "holes" moving from place to place.

When silicon is doped with an impurity that has **more** electrons in the outermost band than silicon then the silicon is labeled "N" type. The letter N stands for **n**egative as the material can more easily give up electrons.

The process where light strikes the solar cell and knocks free some electrons is covered in more detail in the RAFT idea sheet ***Moving around the Solar Cell***.

Some of the "freed" electrons, knocked loose by light striking the solar cell, will bump other electrons out of place in a cascade that leads to some electrons reaching the top surface of the solar cell. In a sense the process can be compared to falling dominoes as each electron only moves a short distance before displacing another electron. The excess electrons at the top surface are "collected" (conducted) by the collection lines and then "funneled" by the bus bar to the "load" (e.g., motor or light) that is in the circuit with the solar cell. A key factor to remember is that the electron originally knocked free only travels a short distance before bumping another electron out of place, which then bumps another electron out of place and on and on. The electrons will not go very far before switching places with another electron. The zigzag bumping is what is moving around and being funneled along the conductors, not the specific electron that was originally knocked loose. Each freed electron leaves a "hole" behind which can be filled by another electron in turn leaving another hole in the process. Electrons migrate toward the top layer of the solar cell. The "holes" migrate downward toward the bottom collector.

In a pattern similar to the electrons moving about, the holes migrate to the bottom of the solar cell to later be combined with the electrons that have been bounced and pulled out of the bottom conductive plate. Those electrons in turn have been bounced about by other electrons in the conductive path of the wire to the load, the load, and the wire coming from the bus bar in the top layers of the solar cell.
To block the least amount of light from reaching the inside of the solar cell light the collection lines are made very thin and the conductive lead (wire) from the top bus bar exit from the side or bottom of the cell.

Taking it Further

Mylar or foil could be cut to model the leads that connect to the bus bar and the bottom of the solar cell to allow making the electrical connections to an external circuit. Cut holes in the plastic wrap as needed for the "leads". Many solar panels (sometimes mislabeled as solar cells) contain several smaller solar cells connected together to increase the voltage output (using series connections) or current output (using parallel connections) of the solar panel. Create a model of a solar panel from several model solar cells. Solar panels can be combined into larger solar arrays to provide power for homes and business. Create a model of a solar array.

Web Resources (Visit www.raft.net/raft-idea?isid=609 for more resources!)

- More solar cell information and links - http://www.eere.energy.gov/basics/renewable_energy/pv_cells.html