Amy R. Densborn
Duke Energy Lesson Plan
Photovoltaic Cells

Goal
Students will understand the composition and operation of a photovoltaic cell.

Grade Level
Middle School and High School students.

Time Frame
Two fifty minute class periods.

Assessment
Informal assessments will be completed throughout the lab as students work within their groups. The formal assessment will be based upon the outcome of the lab worksheet.

Objective
Students will build a representative model of a photovoltaic cell. Students will analyze the amount of solar power that can be generated from the roof of our high school.

Standards

9-10.RS.7, 9-10.RS.8, 9-10.RS.9, 9-10.WS.2, 9-10.WS.3, 9-10.WS.4, 9-10.WS.5, 9-10.WS.6, 9-10.WS.7, ES 2.3, ES.3.3, 7.1.1, 7.4.1, 7.4.2, 7.4.3, 7.4.4

Materials

- Duracell battery
- Various types of batteries
- Light bulb
- Wire
- Multimeter
- Photovoltaic cell
- Vanilla sugar wafer cookie
- Shoestring licorice
- Broch's butterscotch disk
- McCormick chocolate cake decorating confections

Key Terms

- Photon
- Electron
- Ion
- Anode
- Cathode
- Load
- Silicon

Background Information

Photovoltaic Energy
Photovoltaic (fo-to-vol-ta-ik) systems are solar systems that produce electricity directly from sunlight. The term "photo" comes from the Greek "phos", meaning light, "Voltaic" is named for Alessandro Volta (1745-1825), a pioneer in the study of electricity for whom the term "volt" was named. Photovoltaics, then means "light electricity". Photovoltaic systems produce clean, reliable electricity without consuming any fossil fuels. They are being used in a wide variety of applications, from providing power for watches, highway signs, and space stations, to providing for a household's electrical needs.

Solar energy can be part of a mixture of renewable energy sources used to meet the need for electricity. Using photovoltaic cells (also called solar cells), solar energy can be converted into electricity. Solar cells produce direct current (DC) electricity and an inverter can be used to change this to alternating current (AC) electricity.
This electricity can be stored in batteries or other storage mechanisms for use at night. Batteries used for this purpose have a large storage capacity. Practical photovoltaic (PV) cells were discovered in 1954 when they were demonstrated by powering toys. In 1958 they found wide acceptance as part of the space program after initial success on the Vanguard I satellite. PVs are made from silicon and other semiconductor materials.

Silicon has some special chemical properties, especially in its crystalline form. An atom of silicon has 14 electrons, arranged in three different shells. The first two shells, each which hold two and eight electrons respectively, are completely full. The outer shell, however, is only half full with just four electrons. A silicon atom will always look for ways to fill up its last shell, and to do this, it will share electrons with four nearby atoms. It's like each atom holds hands with its neighbors', except that in this case, each atom has four hands joined to four neighbors. That's what forms the crystalline structure, and that structure turns out to be important to this type of PV cell.

Silicon crystals have all four valence electrons bound with other silicon valence electrons. When silicon is "doped" with atoms of with fewer valence electrons is brought in contact with silicon doped with atoms with extra valence electrons, an electric field is created the electrons from atoms with extra valence electrons fill "holes" created by atoms with fewer electron.
When sunlight enters a PV cell, the light can separate an electron from an atom and the electric field helps move the electrons to charge collecting areas. The electrons are then gathered on the surface of the solar cell by a grid of metal connected to a circuit. The circuit allows the electrons to flow to the electron-poor back of the cell from the electron-rich front of the cell. Photovoltaic panels are oriented to maximize the use of the sun's light, and the system angles can be changed for winter and summer. When a panel is perpendicular to the sunlight, it intercepts the most energy. Students are familiar with the PV cells used in most calculators.

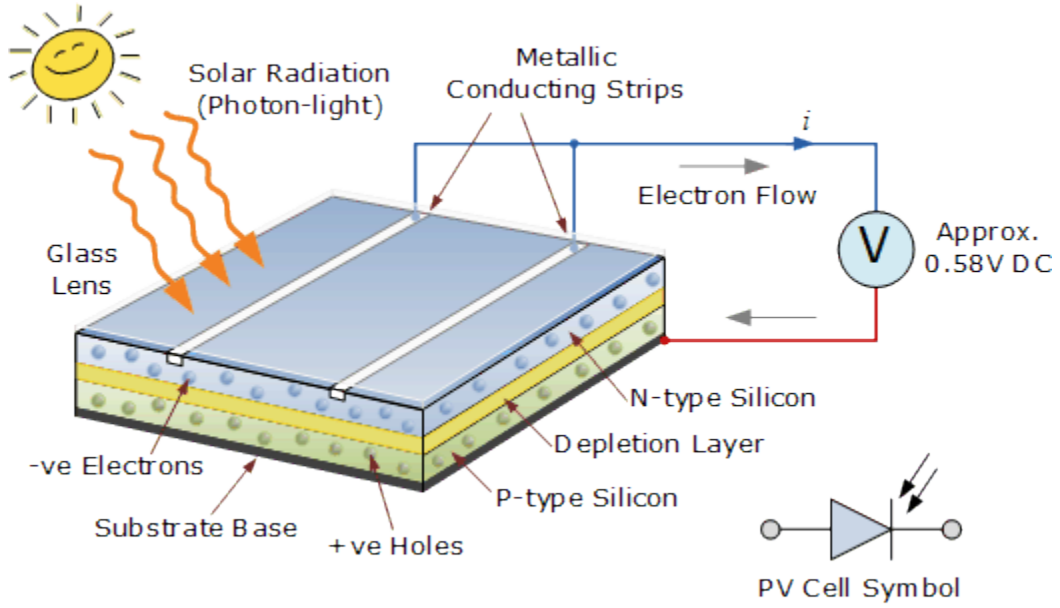
Photovoltaic (PV) cells are made up of at least 2 semi-conductor layers. One layer containing a positive charge, the other a negative charge.

Sunlight consists of little particles of solar energy called photons. As a PV cell is exposed to this sunlight, many of the photons are reflected, pass right through, or absorbed by the solar cell.

When enough photons are absorbed by the negative layer of the photovoltaic cell, electrons are freed from the negative semiconductor material. Due to the manufacturing process of the positive layer, these freed electrons naturally migrate to the positive layer creating a voltage differential, similar to a household battery.

When the 2 layers are connected to an external load, the electrons flow through the circuit creating electricity. Each individual solar energy cell produces only 1-2 watts. To increase power output, cells are combined in a weather-tight package called a solar module. These modules (from one to several thousand) are then wired up in serial and/or parallel with one another, into what's called a solar array, to create the desired voltage and amperage output required by the given project.

Due to the natural abundance of silicon, the semi-conductor material that PV cells are primarily made of, and the practically unlimited resource in the sun, solar power cells are very environmentally friendly. They burn no fuel and have absolutely no moving parts which makes them virtually maintenance free, clean, and silent.



Introduction

Familiarize students with a voltaic cell through the use of batteries. Show the students a Duracell battery and point out the "Copper Top". Review cathode, anode, load, electrons, ions and anion flow.

Once students understand the flow of the electrons have them complete a "circuit" using two wires and a light bulb (load). After students have successfully completed a circuit have them measure the voltage of the battery they are using to complete the circuit with a voltage meter. Have students test the voltage, with the multimeter and lightbulb, of at least two other types of batteries and have them record their data in chart on the Lab Sheet.

Procedure

Working with a partner, you will construct a photovoltaic solar panel and show the movement of electrons using common food items.

On your lab table you will find two vanilla sugar wafer cookies, shoestring licorice, McCormick chocolate cake decorating confections, Brach's Butterscotch disk.

Step 1. Place two vanilla sugar wafers side by side on your lab sheet where it is labeled photovoltaic cell. Pay close attention to the layering of the cookies; identify with your partner the P-type Silicon, depletion layer, N-type Silicon. Answer question one on your lab sheet.

Step 2. Place the Brach's butterscotch disk in the diagram labeled Sun.

Step 3. Separate the shoestring licorice; place licorice on diagram where the light rays are located and the metallic conducting strips should be (refer to above diagram if needed). Answer question two and three on your lab sheet.

Step 4. Use the McCormick cake decorating confections to show the flow of electrons; press confections on sides of photovoltaic cell (sugar wafer) where appropriate. Answer question four and five on your lab sheet.

Step 5. Once you have constructed your photovoltaic cell and answered lab questions one through five you may eat the food components of the lab.

Step 6. Now we will make some suggestions as to how much solar energy we could claim from our school's roof. We need to make some decisions first based upon observations. We are going outside to look at the school's roof. Observe the shape and style of our roof line. Answer questions six and seven on the lab sheet.

Name_____

Solar Energy- Photovoltaic Lab

Battery Type	**Voltage (Amps)**

A. What was the multimeter used for in this experiment?

B. Did the light have the same brightness regardless which battery was attached to it?

Photovoltaic Cell

1. Why is Silicon used in photovoltaic cells?

2. Define Photon.

3. How is a photon converted to electrical energy? (Answer using more than one sentence.)

4. Explain why electrons flow toward a positive terminal.

5. Explain why we used a sugar wafer to represent the photovoltaic cell. (Answer using more than one sentence.)

6. What do you notice about the roof as you look at it?

7. Which area of the school appears to be the better suited for installing solar panels? Explain the observations that influenced you reaching this hypothesis.

8. We are faced with the challenge of putting solar panels on our roof that will meet the needs of Mrs. Densborn's room. The lights in our room require 1.44 Kw / hr of energy. If a standard solar panel which is 2.2 feet by 2.2 feet (4.8 ft^2) produces 50 watts of power, how many square feet of roof space will be needed to supply Mrs. Densborn's room with the energy to keep the lights on?

Lab Sheet- Photovoltaic Diagram