Fabricating and Testing the Electrical Potential of a Photovoltaic Cell

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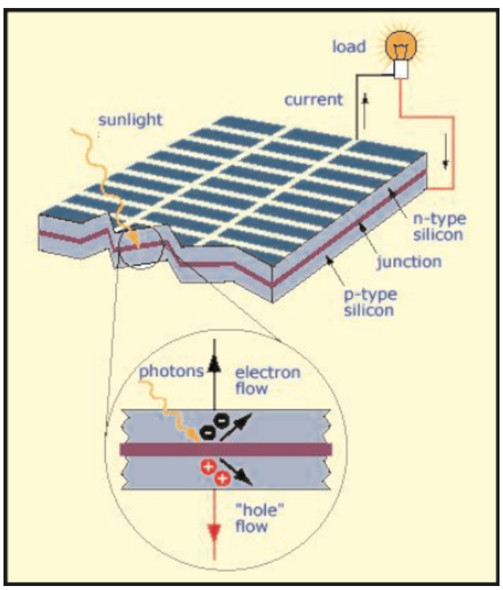
Source: http://www.energyeducation.tx.gov/renewables/section_3/investigations_activities/53bainv.pdf

Comptes rendus de l'Académie des Sciences - A. E. Becquerel

ABSTRACT:
Fossil fuels are a fantastic source of energy, however prolonged use on a mass scale has had serious negative impacts on the environment. Renewable and non carbon emitting sources of energy are crucial to the sustainability of the planet. This lab explores the sun as a source of renewable energy. The methods of making the sun's energy available for use is in the form of an electrical electrical potential is demonstrated in this lab. An electrical potential is generated when a photovoltaic cell is exposed to direct sunlight. A photovoltaic cell is comprised of two oppositely charged semiconductors and a conductive medium connecting them. When a cell is exposed to sunlight (photons), the electrons of the negatively charged semiconductor are freed via the photovoltaic effect and create an electrical potential as they move through the medium and collect on the positive semiconductor. The photovoltaic effect is the process of photons exciting electrons to the point of free conduction. The photovoltaic effect is demonstrated through the fabrication and testing of a photovoltaic cell made of two sheets of Copper, with one being oxidized. These act as the two semiconductors of the cell. The cell also contains salt water, which acts as the medium in which electrons can flow from one semiconductor to the other. A multimeter was used to measure the differences in voltage generated by different semiconductor surface areas. The highest recorded voltage of 115 mV was achieved with the configuration of 7.67 cm^2 copper and 23.01 cm^2 cuprous oxide. When an object was placed in front of the cuprous oxide of each configuration, voltage dropped significantly proving the sun as its source.

Figure 1.



INTRODUCTION:
In order to use the sun as a renewable resource, its energy must be transformed into something useable/storable. There are two major ways of harnessing the sun's energy (excluding wind) in the form of electricity. Solar thermal, which uses the sun's energy to heat water into steam in order to generate electricity, is the least efficient method. The second, and more efficient method, is to use the photovoltaic effect to generate electricity. The photovoltaic effect is the process of photons energising valence electrons to the point of conduction. In 1839, A. E. Becquerel was one the first people to observe and study the photovoltaic effect. He observed "the production of an electric current when two plates of platinum or gold diving in an acid, neutral, or alkaline solution are exposed in an uneven way to solar radiation." - Comptes rendus de l'Académie des Sciences. A circuit known as a photovoltaic cell uses two oppositely charged semiconductors and a conductive medium to generate an electrical current via the photovoltaic effect. Electrons of the negatively charged semiconductor are freed by the energy from the sun's photons. These electrons generate an electrical current as they move through the conductive medium and on to the positively charged semiconductor. The current method of fabricating high efficiency solar panels uses 180 to 350 micrometer wafers of silicon. The wafers have impurities added in a process called doping.

Phosphorus atoms are scarcely distributed in a silicon lattice to form a n-type (negative) semiconductor because each phosphorus atom binds with three silicon atoms leaving its 4th electron free for conduction. P-type (positive) silicon semiconductors are doped with boron which is missing an electron in its valence shell. The addition of boron creates electron holes which contributes to the semiconductors affinity for electrons. The construction of photovoltaic cells used for industrial application require a number of resources and specialized equipment. However, copper can be used to demonstrate the photovoltaic effect. Cells made with copper and cuprous oxide semiconductors, with salt water as a medium, will theoretically generate an electrical potential when exposed to sunlight. If the photovoltaic effect is real, electrons will be freed from the cuprous oxide semiconductor and generate an electrical potential as they move through the water and onto the positively charged copper semiconductor.

MATERIALS:

Uniform Copper Strips
Table salt or sodium chloride
Two alligator clip leads
Fine sandpaper
Multimeter
Goggles or galvanometer gloves
Electric hot plate
600 ml or larger beaker
Shallow clear plastic container
Tray to carry assembly

HAZARDS:

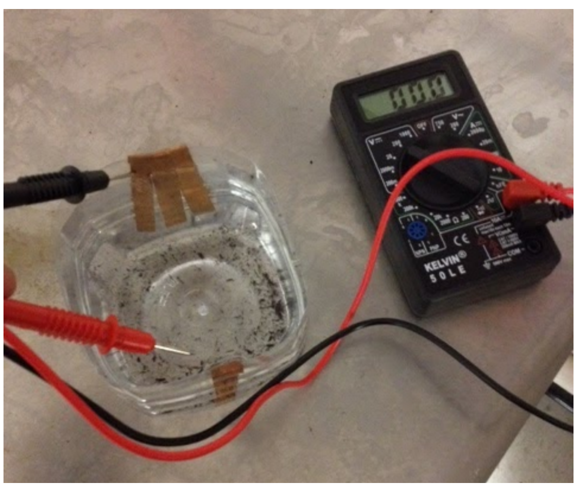
This lab involves high heat and sharp objects. Wear goggles and gloves while working with the copper and heated surfaces. All other aspects of the lab are not a hazard.


PROCEDURE: To begin preparing the copper strips, Wash your hands thoroughly. Now, wash all copper strips with soap or cleanser to remove all traces of oil or grease. Dirt and oil on the sheets will prevent proper coatings from forming. Continue cleaning the copper strips by using fine sandpaper. They should be a light pink color. Dry the copper strips thoroughly. Carefully, curl over 0.5cm of each copper strip so they each have a hooked end. Place half of the copper strips on the burner, hookside up, and turn the burner to its highest setting. Set the other half of the strips aside to be used later. As the copper starts to heat up, oxidation patterns will begin to form. You will see the oxidation patterns as shades of orange, purple, and red covering the copper. Continue to allow the copper strips to heat for about thirty minutes, until the copper is covered with a thick, black coating. This black coating is cupric oxide. Turn off the burner, but leave the copper strips on the burner and allow them to cool slowly. As it cools, differential shrinkage will cause the cupric oxide to flake off, exposing a coating of cuprous oxide underneath. Clean up the black flakes that collect and discard. Do not try to scrape off any remaining black flakes, as this might damage the cuprous oxide coating.

Begin the assembly of the first cell by filling the plastic container with tap water so that the water level is 2 cm below the rim. Pour this water into an appropriately sized beaker. Mix in one tablespoon of salt for every 300 ml of water. Place on magnetic-stir equipped hot plate and heat and stir until the salt is completely dissolved. Now, empty beaker into plastic container. Hang a strip of copper and CuO_2 on opposite sides of the plastic container so that the majority of the strips are suspended in water. Attach the two alligator clip leads, one to the clean copper strip, and one to the oxide-coated strip. Connect the lead from the clean copper strip to the positive terminal of the meter. Connect the lead from the copper oxide-coated strip to the negative terminal of the meter.

In order to test the cell, you must locate an appropriately sunny test location. Take the assembled photovoltaic cell outside and face the oxide-coated strip towards the sun. Starting with the highest voltage setting, keep decreasing the voltage settings until the reading can be easily measured. Be sure to look for voltage change with light variation i.e. when you move your hand in front of the cuprous oxide. Once the circuit has been successfully tested, the voltage reading of the first scenario can be recorded. There should be one testing scenario for each unique ratio of copper strips to cupric oxide. For testing scenarios requiring multiple Cu or CuO_2 strips, be sure to suspend each strip so that the maximum amount of surface area is exposed while maintaining contact between strips of the same composition like in Figure 2.

Figure 2.



RESULTS:

Chart 1: Voltage as a function of Semiconductor Surface Area

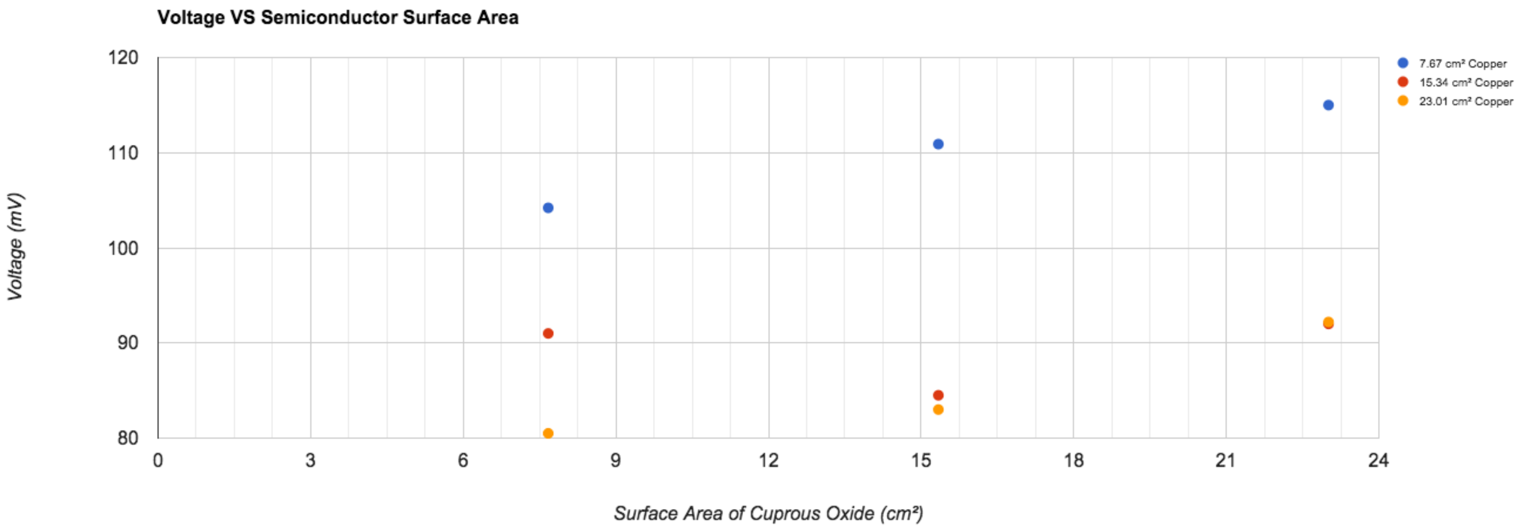


Table 1: Completed Voltage Test Matrix

	7.67 cm² Copper	15.34 cm² Copper	23.01 cm² Copper
7.67 cm² Cuprous Oxide	104.2 mV	91 mV	80.5 mV
15.34 cm² Cuprous Oxide	110.9 mV	84.5 mV	83 mV
23.01 cm² Cuprous Oxide	115 mV	92 mV	92.2 mV

Both Table 1 and Chart 1 show distinct trends in data. Both figures show that highest recorded voltages were achieved in trials configured with 7.67 cm² of Copper. Trials configured with 15.34 cm² Copper all resulted in lower voltages. The lowest recorded voltages occurred during trials configured with 23.01 cm² Copper. Chart 1 displays the trend that increases in surface area of the positively charged copper semiconductor results in loss of voltage. Chart 1 also indicates that increases in surface area of the negatively charged cuprous oxide semiconductor generally result in increased voltage.

DISCUSSION:

The photovoltaic effect is used to generate an electrical potential from sunlight within a photovoltaic cell. It was expected that an electrical potential would be created between the two semiconductors. This hypothesis was confirmed upon the testing of the first cell configuration. When exposed to sunlight. A photovoltaic cell made with 7.67 cm^2 copper and 7.67 cm^2 cuprous oxide, generated 104.2 mV of electricity. The voltage dropped significantly when the cell was shaded and increased when the cell was reintroduced to direct sunlight. This proves that sunlight is responsible for an increase of voltage generated by the cell and thus confirms the existence of the photovoltaic effect. Although there were sources of uncertainty such as variations in sunlight intensity, there was no source of error that could have affected the direct observation of the photovoltaic effect. Fabricating a working photovoltaic cell out of copper, cuprous oxide and salt water proves how easy it is to generate electricity from sunlight. The next step toward powering the earth completely off the sun is the development of hyper efficient photovoltaic cells. To continue this investigation, I propose a study be done on the efficiency of copper and cuprous oxide semiconductors and research into other potential semiconductors. This experiment could be redone with the addition of measuring current along with voltage to give an actual power output which could be compared to the cells power input to determine efficiency.