Titanium Dioxide Raspberry Solar Cell

Greg Smestad (http://www.solideas.com/solrcell/cellkit.html) developed this experiment. See the Nanocrystalline Solar Cell Kit: Recreating Photosynthesis, Institute for Chemical Education, Madison, WI (1998)
Additional information and procedures added by David A. Katz, Department of Chemistry, Pima Community College

Using a dye found in raspberries to absorb sunlight, a tin oxide electrode, a graphite electrode, and nanocrystalline titanium dioxide, makes a solar cell that will produce a voltage.

Materials Needed

Nanocrystalline titanium dioxide, TiO_2, Degussa P25 or equivalent
Acetic acid solution, $HC_2H_3O_2$, 0.035 M. (Prepared by diluting 0.1 mL concentrated acetic acid to 50 mL with distilled or deionized water.)
Triton X-100 surfactant
Scotch brand Magic™ Tape, 19.0 mm (3/4 inch)
Tin oxide coated conductive glass, 2 pieces (Note: This glass is supplied in the Nanocrystalline Solar Cell Kit available from ICE, Madison, WI or can be prepared using procedure for Preparation of Surface Conductive Glass by E. Eibergen and G. Lisensky)
Ethanol, 95%
KI_3 electrolyte solution (The KI_3 electrolyte solution consists of 0.5 M KI and 0.05 M I_2 in anhydrous ethylene glycol.)
Raspberries, frozen (Note: Blackberries, pomegranate seeds, and Bing cherries can also be used)
Evaporating dish or watch glass
Mortar and pestle
Glass stirring rod, 5 mm diameter x 10 cm length
Crucible tongs
Candle
Cotton swabs
2 Binder clips, small
Lab tissues, Kimwipes or equivalent
LED, low energy
Alligator lead jumper cables with alligator clips on both ends
Multimeter with alligator clip test leads
Hot plate

Safety Precautions

Wear approved eye protection at all times in the laboratory.

Titanium dioxide can be a skin and eye irritant. Individuals may want to wear protective gloves. In the event of contact wash skin with soap and water, flush eyes with water.

KI_3 solution contains both iodine and potassium iodide. Iodine is an irritant to the eyes, skin and respiratory system. Flush affected areas with water.

Disposal

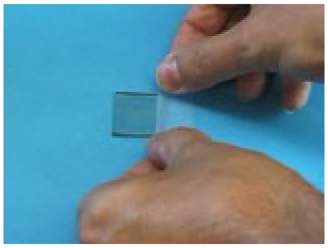
Dispose of all materials in the proper waste containers.

Procedure

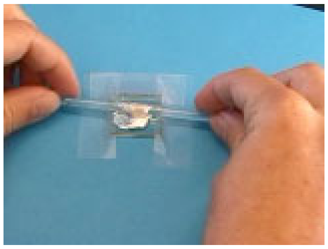
Grind about 2 grams of nanocrystalline titanium dioxide (TiO_2) in a mortar and pestle with a few drops of very dilute acetic acid. Alternate grinding and addition of a few drops of very dilute acetic acid (0.035 M) until you obtain a slightly soupy colloidal suspension with a smooth consistency.

Add a few drops of Triton X-100 surfactant or clear dishwashing detergent and mix some more.

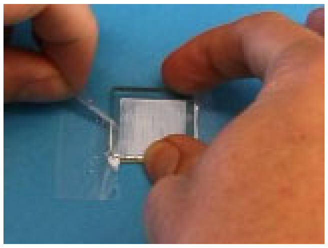
Identify the conducting side of a tin oxide-coated piece of glass by using a multimeter to measure resistance. The conducting side will have a resistance of 20-30 ohms.



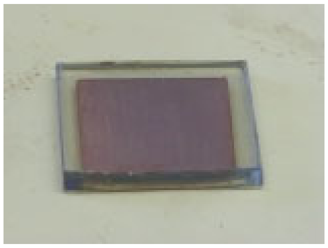
With the conducting side up, tape the glass on three sides using one thickness of Scotch brand Magic™ tape. Wipe off any fingerprints or oils using a tissue wet with ethanol.



Add some of the titanium dioxide paste and spread using a glass rod. The tape serves as a 40-50 micrometer spacer to control the thickness of the paste layer.

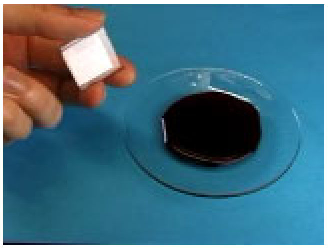


Carefully remove the tape without scratching the TiO_2 coating.



Heat the glass on a hotplate in a hood for 10-20 minutes. The surface turns brown as the organic solvent and surfactant dries and burns off to produce a white or green titanium dioxide coating. (NOTE: If the coating is too thick, it will crack and peel from the glass surface. If that occurs, allow the glass to cool, clean it, and recoat with a thinner TiO_2 laver.)

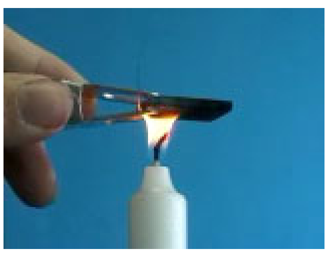
Allow the glass to cool.



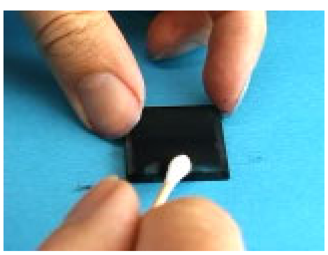
Immerse the coating in a source of anthocyanins, such as raspberry juice. The raspberry juice may be obtained most easily from frozen raspberries. (Blackberries, pomegranate seeds, and Bing cherries can also be used.)

The white TiO_2 will change color as the dye is absorbed and complexed to the Ti(IV).

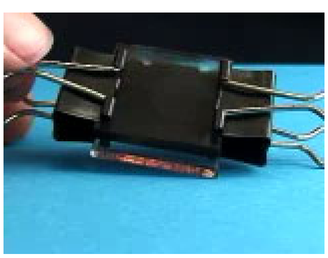
Rinse gently with water and then with ethanol. (The ethanol serves to remove water from the porous TiO_2.)



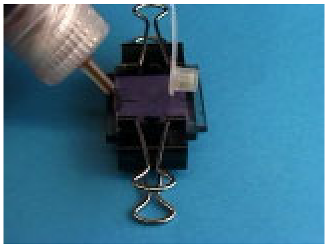
Pass a second piece of tin oxide glass, conducting side down, through a candle flame to coat the conducting side with carbon (soot). For best results, pass the glass piece quickly and repeatedly through the middle part of the flame.



Wipe off the carbon along the perimeter of three sides of the carbon-coated glass plate using a cotton swab.



Assemble the two glass plates with coated sides together, but offset so that uncoated glass extends beyond the sandwich. Do not rub or slide the plates. Clamp the plates together.



Add a few drops of a triiodide solution to the edge of the plate. Capillary action will cause the KI_3 solution to travel between the two plates.

Connect a multimeter using an alligator clip to each plate (the negative electrode is the TiO_2 coated glass and the positive electrode is the carbon coated glass).

Measure the current and voltage produced by the solar cell under normal room illumination.

Current ____________________

Voltage ____________________

Measure the current and voltage produced by solar illumination,
or...
measure the current and voltage produced by illumination from an overhead projector.

Current ____________________

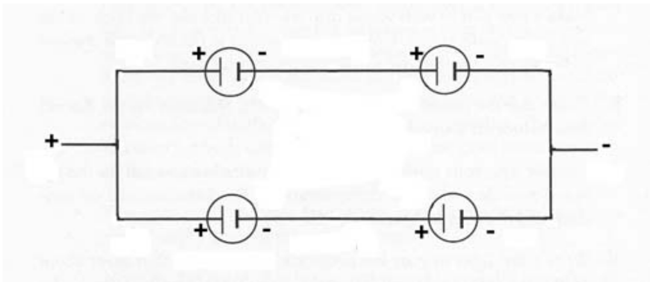
Voltage ____________________

Which side of the solar cell is the active side (i.e., the light sensitive side)?

Use alligator lead jumper cables to connect a low energy LED to your solar cell and expose it to solar illumination or light from an overhead projector. Is there sufficient current and voltage to light the LED?

Connect two solar cells in series and expose them to solar illumination or light from an overhead projector. Is there sufficient current and voltage to light the LED?

If four solar cells are available, they can be combined in a solar array by placing two series cells in parallel with each other:



What is the current and voltage of the solar cell array?

Is there sufficient current and voltage from the solar cell array to light an LED?

Carefully store the solar cell in your chemistry locker or drawer, or as directed by your instructor, until the next class. Measure the current and voltage produced by either solar illumination or illumination from an overhead projector. Is the solar cell still functioning as it had previously? If it is not functioning, can you suggest a reason why? (Note: materials may be available to attempt a rejuvenation of the solar cell.)

Do you have any suggestions for improving this solar cell or for possibly extending its useful life?