Organic Solar Cells

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)

Goal

- In the past year the price of fossil fuels has increased more than anytime in recent memory. Because of this fact, the race for alternate energy sources to replace or lessen the use of fossil fuels has risen. This activity of creating electricity through the use of organic solar cells is an example of one way scientists are trying to alleviate some of the dependence on non-renewable resources. It is the purpose of this activity for students to see that with a little human ingenuity, other ways to create energy can be attained.

Safety

- In the initial stages of this lab, when using the powered TiO_2 care should be taken not to inhale this compound. Massing, grinding, and heating should be done in a fume hood or a well ventilated area. If this is not possible, a ventilation mask should be worn.
- Goggles and gloves are also recommended throughout the lab.

Procedure

Prepare the TiO_2 Suspension

- In 1 mL increments, add 9 mL of very dilute acetic acid solution (0.1 mL concentrated acetic acid to 50 mL of distilled or deionized water.) to 6 g of TiO_2 powder in a mortar and pestle while *grinding*.
- The grinding process mechanically separates the aggregated TiO_2 particles due to the high shear forces generated.
- Add each 1 mL addition of the dilute acid solution only when the previous mixing and grinding has produced a uniform and lump-free suspension with a consistency of a thick paint.
- The grinding process requires about 30 minutes and should be done in a well-ventilated area. (a Fume hood if you have one)

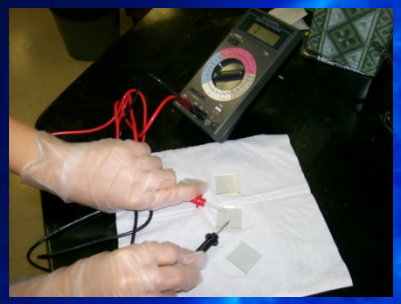
Procedure

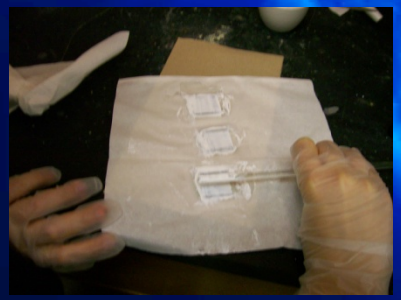
Prepare the TiO_2 Suspension

- To the TiO_2 paste, add a drop of Triton X or two drops of clear dish washing detergent, and swirl.
- This allows the final suspension to more uniformly coat the glass plates. So as not to produce foam, the TiO_2 suspension should not be ground or agitated after the surfactant is added.
- Transfer half of the TiO_2 suspension in to each of the 2 provided small dropper bottles and allow it to equilibrate for at least 15 minutes (if not overnight) for best results. These bottles will need to be shared with the entire class.

Procedure

Preparation of the TiO_2 slide

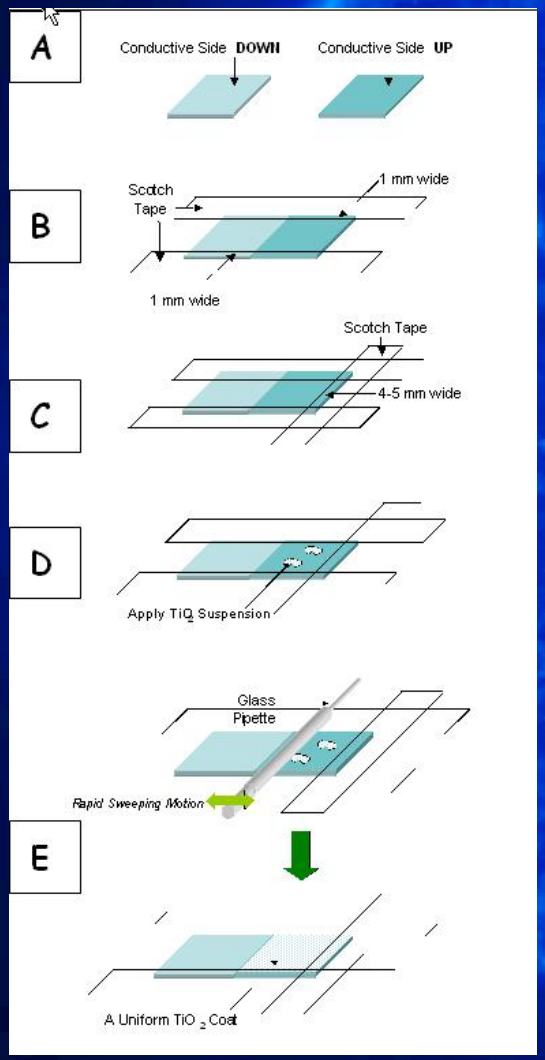




- Obtain 2 glass plates and clean with ethanol. Do not touch the faces of the plates once they are cleaned!
- Determine which side of each glass plate is conducting with a multimeter (set it to measure resistance).
- Put the glass plates side by side with one conducting side up and one conducting side down.
- Cover **1mm** of each long edge of the plates with Scotch tape.
- Cover **4-5 mm** of the short edge of the conductive side up with Scotch tape.
  Add 2 drops of the white TiO_2 solution on the conductive side up glass.
- Quickly spread the white TiO_2 solution evenly with a glass pipette, sweeping first away from the second slide, then sweeping the extra TiO_2 onto the second glass slide.

Procedure

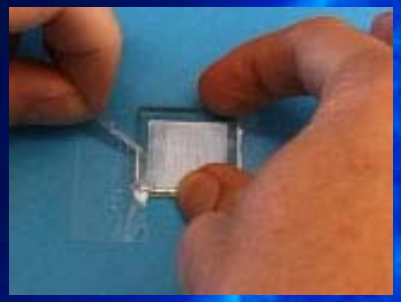
Preparation of the TiO_2 slide

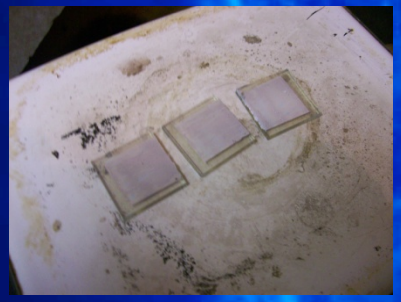


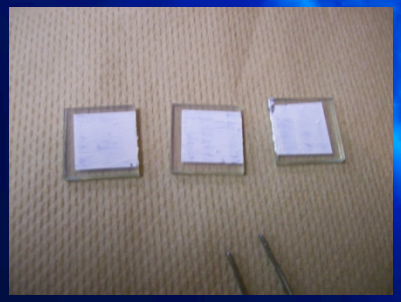
- Obtain 2 glass plates and clean with ethanol. Do not touch the faces of the plates once they are cleaned!
- Determine which side of each glass plate is conducting with a multimeter (set it to measure resistance).
- Put the glass plates side by side with one conducting side up and one conducting side down. (A)
- Cover **1mm** of each long edge of the plates with Scotch tape. (set it to measure resistance). (set it to measure resistance). (B)
- Cover **4-5 mm** of the short edge of the conductive side up with Scotch tape. (C)
- Add 2 drops of the white TiO_2 solution on the conductive side up glass. (D)
- Quickly spread the white TiO_2 solution evenly with a glass pipette, sweeping first away from the second slide, then sweeping the extra TiO_2 onto the second glass slide. (E)

Procedure

Preparation of the TiO_2 slide







- Remove the tape and place the TiO_2-coated glass on the hot plate, keeping track of where your plate is.
- Clean the TiO_2 from the other glass plate with ethanol and save it for the next part of the lab.
- Heat the glass on a hotplate turned to high 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: this requires a plate that gets quite hot.)
- Allow the glass to slowly cool by turning off the hotplate.

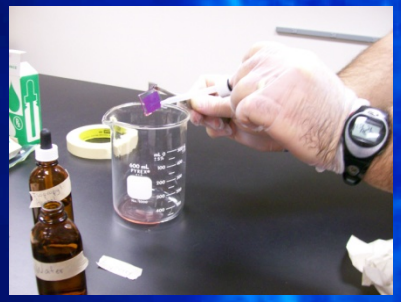
Procedure

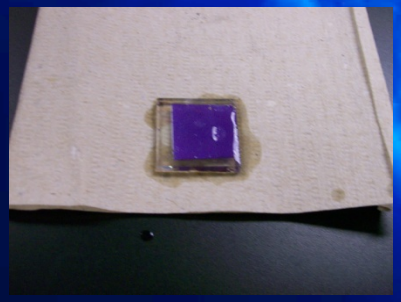
Staining the TiO_2 slide

- Crush fresh or frozen raspberries, blackberries, pomegranate seeds, bing cherries, or red Hibiscus tea into a Petri dish.
- Soak the slide for 10 minutes in this liquid to stain the slide to a deep red-purple color. If slide the slide is not uniformly stained, then put it back in the juice for 5 more minutes.
- Wash the film in ethanol and gently blot it dry with a tissue.

Procedure

Staining the TiO_2 slide

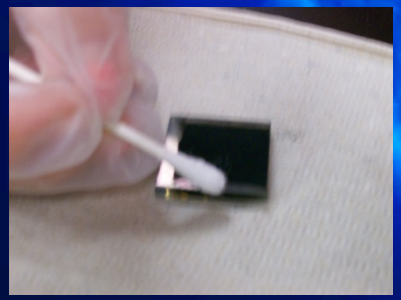




- Soak the slide (face down) for 10 minutes in this liquid to stain the slide to a deep red-purple color. If the slide is not uniformly stained, then put it back in the liquid for 5 more minutes.
- Wash the slide first with distilled water then ethanol and gently blot it dry with a tissue.
- While the TiO_2 slide is soaking in the liquid, use this time to prepare the graphite slide. (Do not remove the TiO_2 slide from the liquid until you have finished the graphite slide.)

Procedure

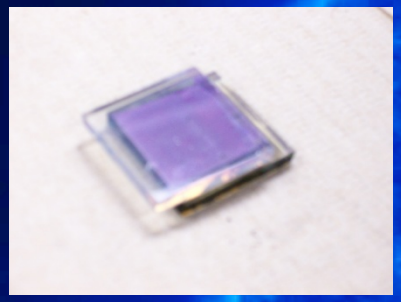
Preparation of the graphite slide

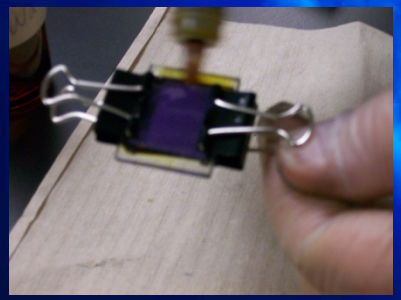


- Pass the other piece of tin oxide glass, conducting side down, through a candle flame to coat the conducting side with carbon (soot).
- For best results, pass the glass piece quickly and repeatedly through the middle part of the flame.
- Wipe off the carbon along the perimeter of three sides of the carbon-coated glass plate using a cotton swab.

Procedure

Assembling the Solar Cell

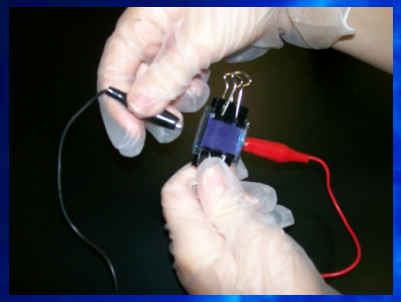




- Place the carbon-coated glass plate face down on the TiO_2-coated glass plate.
- The two glass plates must be slightly offset (5 mm) .
- Hold the plates together with binder clips on each side of the longer edges.
- Add 2 drops of the iodide solution on an offset side and allow it to soak through.
- Alternately open and close each side of the solar cell by releasing and returning the binder clips to help the iodide solution move through.
- Make sure that all of the stained area is contacted by the iodide solution.
- Wipe off excess iodide solution on the exposed area (important) with tissue paper.

Procedure

Assembling the Solar Cell



- 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).
- Make sure the light is shining through the TiO_2 coated glass first.
- Test the current and voltage produced by solar illumination, or an overhead projector.

Data

- Using your readings from the multimeter complete the following table.

Group	Overhead Projector Off		Overhead Projector On		Sunlight	
	Voltage (V)	Current (mA)	Voltage (V)	Current (mA)	Voltage (V)	Current (mA)
1.						
2.						
3.						
4.						
Average						

Materials

- **Reusable Supplies**
- Plates of Conductive Glass
- Mortar & Pestle
- Dropper Bottles for TiO_2
- Dropper Bottles for Iodide Solution
- Petri Dishes with Lids
- Pasteur Pipettes
- Multimeter
- Alligator Clips
- Binder Clips
- Coffee filter (for squeezing raspberry juice)
- Hot Plate
- Overhead Projector

- **Consumable Supplies**
- nanocrystalline TiO_2
- Triton X or clear liquid dish soap
- Aqueous Acetic Acid Solution
- Iodide Solution
- Frozen Raspberries (allow to thaw in refrigerator overnight)
- Ethanol (Rubbing Alcohol may be substituted)
- Distilled or Deionized Water
- Scotch Tape
- Absorbent Tissue or Cotton Swabs

Most of these can be purchased in a classroom kit at http://ice.chem.wisc.edu/catalogitems/ScienceKits.htm#SolarCell

Conclusion

- Is making Organic solar cells a viable alternate to fossil fuels?
- What is the efficiency of your solar cell?

  (hint, Estimate the efficiency of your solar cells. Measure the power they produce while driving a motor by measuring the voltage across the terminals and the current through the solar cell. Multiply the voltage times the current to get the power of the solar cell Po.

  Po = V x

  Now estimate the power from the sun which hits the solar cell. To do this multiply the area of the solar cell, A, in square meters times the power of sunlight ,Ps, which is about 1000 watts per meter squared, W/m^2. If your solar cell is 4 cm by 6 cm then its area is 0.04 m x 0.06 m = 2.4×10^{-3} m^2. So the power input is

  $Pi = A * Ps = 2.4 \times 10^{-3} * 1000 = 2.4$ watts

  The ratio of the power delivered by the solar cell to the power input from the sun is the efficiency of the solar cell, e, which is usually expressed as a percent.

  e = (Po/Pi) * 100
- Can you think of any ways to change the solar cell to make it more efficient?

Resources

Websites for more ideas and activities with Solar Cells:

Nanocrystalline Solar Cell Kit- place to purchase prepared kits for lab.

Clean Energy: Converting Light to Energy- contains a similar solar cell lab, and power points and videos to support alternate energies.

Titanium Dioxide Raspberry Solar Cell- Instructions , pictures and video clips for making organic solar cell.

Solar-energy research heats up- interview with Greg Smestad, the developer of the Ti02 solar cell kit.

SOL IDEAS- Greg Smestad's web site.

Organic Solar Cells- 7 minute video using carbon nanotubes to build cells.

Solar Cells- shows how solar cells can be connected in Series and parallel.

How Solar Cells Work – HowStuffWorks, lots of information.