

Nanocrystalline Solar Cells

Pre-Lab Materials

- Colloidal titanium dioxide powder (TiO_2)
- Dropper bottle
- Surfactant (such as Triton X100 or clear dish detergent)
- 10 mL Graduated cylinder
- 0.1M Acetic Acid
- Mortar and pestle
- Pipettes
- Graduated cylinder
- Scale
- Weigh boats
- Spatula
- Distilled water
- Labels (tape and marker)

Safety

Safety goggles and gloves should be worn throughout the experiment. Any waste chemicals should be disposed of in a waste container. Preparation of the TiO_2 suspension should be done in a hood or a well-ventilated area.

Pre-Lab Procedure

Preparing the TiO_2 Suspension

1. Weigh 6 g of colloidal TiO_2 powder and place in a mortar.
2. Using a mortar and pestle, grind the TiO_2 powder.
3. Measure 10 mL of 0.1 M acetic acid in a 10 mL graduated cylinder.
4. One milliliter at a time, add the acetic acid to the TiO_2 . Before adding each additional milliliter, grind the solution until it is uniform and lump-free. This should take about 20 minutes.
5. Measure 1 mL of distilled water in a 10 mL graduated cylinder. Add one drop of surfactant to the water. Add this solution to the TiO_2 paste. Do not grind or agitate the paste after the surfactant is added.
6. Put the TiO_2 in the dropper bottle provided and label.



Nanocrystalline Solar Cells

Materials

- 2 Conductive (tin dioxide, SnO_2 , coated) transparent glass plates
- Iodide electrolyte solution in dropper bottle
- Binder clips
- Dropper bottle containing TiO_2 suspension
- Soft graphite pencil
- Overhead projector with (integral) parabolic reflector
- Hot plate
- Ethanol in wash bottle
- Deionized water in wash bottle
- Blackberries, raspberries, pomegranate seeds, or Bing cherries
- Multimeter, capable of measuring volts and ohms
- Hookup wire (black and red)
- Alligator clips (large – should exert a large pressure when closed)
- Tongs
- Plastic tray
- Transparent tape
- Glass stirring rod
- Absorbent tissue paper
- Cotton swabs
- Buchner funnel
- Safety goggles
- Gloves
- Aqueous waste container
- Organic waste container



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Pre-Lab Questions

The dye is deep in color. What do you think is the purpose of the dye?

What properties are important for the surface of the solar cell (the SnO_2 coated glass) to have?

What is the role of the electrolyte?



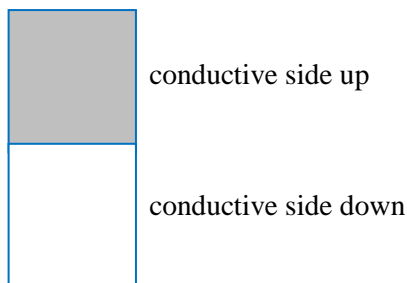
Safety

Safety goggles and gloves should be worn throughout the experiment. Any waste chemicals should be disposed of in the waste containers. Never leave the hot plate unattended while it is on. Be careful when removing the glass plate from the hot plate and while it is cooling.

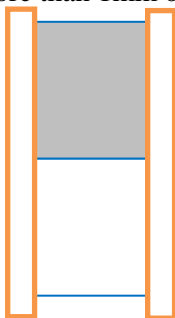
Procedure

Deposition of the TiO₂ Film

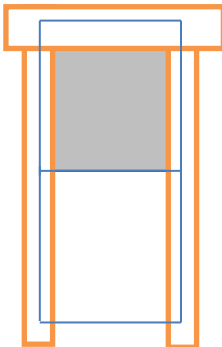
1. Rinse two of the conductive glass plates in ethanol and dry with a soft tissue. When handling the glass plates, take care to touch just the edges of the plates.
2. Set a multimeter to ohms (Ω). Place the ends of the black and red wires on the face of one of the glass plates to determine which side of the plate is conductive. If the side you are testing is conductive, the multimeter will read between 10 and 30 ohms. Repeat with the other plate.
3. Place one glass plate conductive side up. Place the other plate directly next to the first one but with the conductive side down.



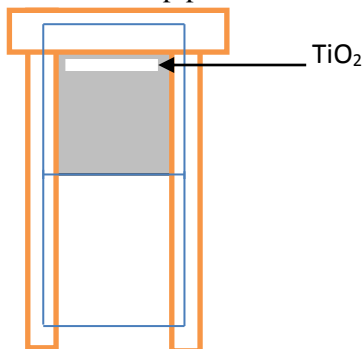
4. Take two pieces of transparent tape. Keeping the glass plates together (one with the conductive side up, one with the conductive side down), tape the two longer edges of the plates directly to the table while only covering no more than 1mm of the plates with tape. This will help to secure the plates as you coat them.



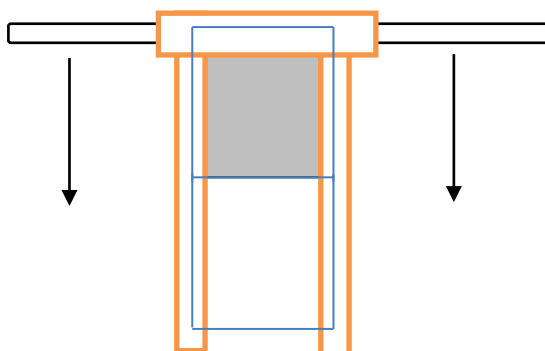
5. Place another piece of tape along the top edge of the conductive plate. This piece of tape should cover 4 - 5mm of the plate.



6. To coat the conductive glass plate, apply a thin line of TiO_2 suspension to the edge of the plate near the tape using the dropper bottle or a pipette.



7. Use a clean glass stirring rod to spread the TiO_2 as uniformly as possible over the plate with the conductive side up. Slide the stirring rod toward the bottom of the plates without lifting the stirring rod. (The plate that is conductive side down does not need to be fully coated. It is used to aid in making it easier to coat the plate with the conductive side up.)



8. If the coating is not uniform, the TiO_2 can be cleaned off the plates with a lab tissue and reapplied with a clean stirring rod.
9. Carefully remove the tape.
10. Using the ethanol wash bottle and lab tissue, clean the plate that had the conductive side down.
11. Anneal (heat and then slowly cool), the TiO_2 film on the conductive glass by placing the plate on a hot plate. Heat for 10-15 minutes in a hood or well-ventilated area. The film **may** turn light brown, then black, then white.
12. After annealing, allow the TiO_2 to cool to room temperature (about 15 minutes). The glass could crack if the plate is not cooled completely. While waiting for the plate to cool, move on to the next step.



Staining the TiO₂ with Anthocyanin Dye

1. In the Buchner funnel, crush 5-6 berries in about 2 mL of deionized water with the stir rod and filter into a plastic tray. This filtered solution is an anthocyanin dye solution.
2. Place the TiO₂ coated plate in the solution with the TiO₂ coating face down.
3. As the film is soaking for 10 minutes, move on to the steps for carbon coating the counter electrode.
4. After 10 minutes, if white can be seen upon viewing the stained film from either side of the glass, place the plate back in the dye for 5 more minutes.

Carbon Coating the Counter Electrode

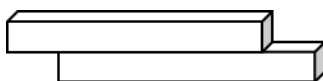
1. While the TiO₂ electrode is being stained in the berry juice, the counter electrode can be made from another piece of conductive SnO₂ coated glass.
2. Clean the glass plate with a lab tissue and ethanol like you would clean glasses. Be sure not to touch the faces of the plate.
3. Use the multimeter to determine which side of the glass plate is conductive, as done previously in this lab.
4. Holding the edges of the plate, use a graphite pencil to apply a light carbon film to the entire conductive side of the plate. Be careful not to miss any spots.
5. The carbon coating on the counter electrode should not be touched. It should not be rubbed or slid against the TiO₂ electrode or any other surface.

Assembling the Solar Cell Device

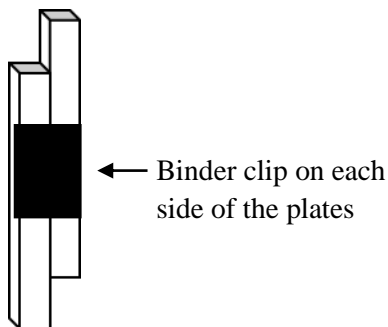
1. Using wash bottles, rinse the TiO₂ /dye-coated plates in distilled water and then in ethanol. Note: the rinse water should be disposed of in the **aqueous waste** and the rinse ethanol should be disposed of in the **organic waste**.
2. Gently blot dry the TiO₂ film with a lab tissue. Do not rub the film; doing so will remove the film from the plate.
3. Place the dried electrode on a flat surface so that the TiO₂ film side is face up. Place the carbon coated counter electrode on top of the TiO₂ plate so that the carbon coated side faces down.



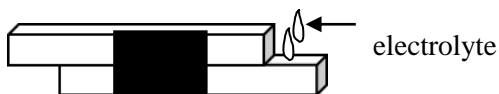
4. Gently lift the counter electrode and offset the two plates so that all of the TiO_2 is covered by the carbon coated counter electrode and the 4-5 mm strip without any TiO_2 is exposed.



5. Carefully pick up the assembly while it is in this orientation. Place two binder clips on the longer edges to hold the plates together.



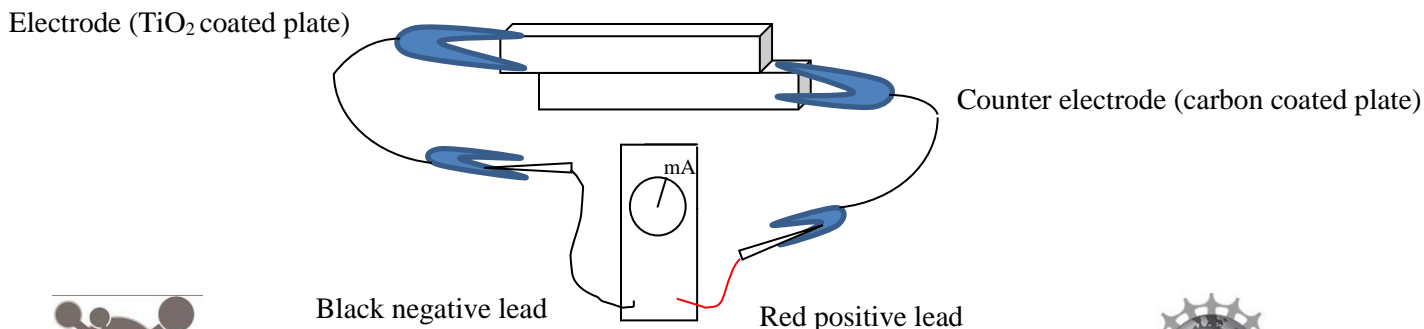
6. Carefully place one or two drops of the iodide electrolyte solution at one edge of the plates.



7. The liquid is drawn into the space between the electrodes by capillary action and wets the stained TiO_2 film. Make sure that all of the stained area is contacted by the electrolyte. If needed, alternately open and close each side of the solar cell by releasing and returning the binder clips.
8. Wipe off the excess electrolyte from the exposed areas of the glass using cotton swabs and lab tissues dampened with ethanol. It is important that the electrolyte is completely removed from the two exposed sides of the cell.

Testing your Solar Cell

1. Attach an alligator clip to each exposed end of the glass plates.
2. Attach the other end of the negative electrode, the TiO_2 coated glass, alligator wire to the negative wire (black) of the multimeter.
3. Attach the other end of the positive counter electrode, the carbon coated glass, alligator wire to the positive wire (red) of the multimeter.



4. Holding the TiO_2 side up so as to absorb the light, measure the amount of electricity produced when light from an overhead projector is absorbed by the solar cell. Record your results.
5. Measure the amount of electricity produced when the solar cell is exposed to the sun.



Data and Discussion Questions

Record your results

	Current (mA)	Voltage (V)
Projector		
Sun		

Does the amount of current produced changed if you bring the solar cell closer or farther away from the light source? Describe your observations.

Which produces more energy the projector or the sun?

How can you use your solar cell to produce more electricity?

Why is the nanostructure of the TiO_2 film important to the solar cell?

How could you make your solar cell more efficient?



Label the different parts of the solar cell below and sketch the path of the electrons through the circuit.

