# Chapter 11

# Photochemical Solar Cells

*My sincerest thanks to Dr. Greg P. Smestad for the information and images he has provided, on which this chapter is based.*

In addition to the photovoltaic solar cells that we have seen earlier in this book, there are other ways of generating electricity directly from the sun. We saw how photovoltaic solar cells rely on the photovoltaic effect that occurs at semiconductor junctions, and how the semiconductor performs the two jobs of absorbing the light and separating electrons.

One of the problems with this approach is that, because of the sensitive nature of the cells, they must be manufactured in ultra-clean conditions in order to be clean and free from defects which might impede their operation.

This works effectively; however, it is expensive.

The thing about photochemical solar cells is that they use cheap technology. Titanium dioxide is not some rare chemical that requires expensive processing, it is already produced in large quantities and used commonly; furthermore, you don't need an awful lot of it—only around 10 g per square meter. When you figure that this 10 g only costs two cents, you begin to realize that this is a solar technology with a lot of promise for the future.

In an attempt to make solar technology cheaper and more accessible, Michael Grätzel and Brian O'Regan from the Swiss Federal Institute of Technology decided to explore different approaches to the problem.

> **Note**
>
> The photochemical solar cell is sometimes also referred to as the "Grätzel" cell after Michael Grätzel who worked on developing the cell.

The photochemical solar cell has grown out of an expanding branch of technology—biomimickry, looking at how we can mimic natural processes to make more advanced technologies.

Rather than having a single thing to do all of the jobs, as in a conventional photovoltaic cell, photochemical solar cells mimic processes that occur in nature.

Electron transfer is the foundation for all life in cells; it occurs in the mitochondria, the powerhouses of cells which convert nutrients into energy.

Titanium dioxide, while not immediately springing to mind as a household name, is incorporated in a lot of the products that we use every day. In paints, as a pigment, it is known by its name titanium white. It is also used in products such as toothpaste and sunscreen. Titanium dioxide is great at absorbing ultraviolet light.

> **Tip**
>
> You might find titanium dioxide referred to as "Titania" in some references.

## How do photochemical solar cells work?

Take a peek at Figure 11-1, in the top image, we can see the energy transfers taking place—the light striking our photochemical solar cell, generating energy and turning the shaft of the electric motor, which is connected to our cell. The radiated energy from the sun in the form of light, is being transformed through a chemical process into electrical energy, which travels through the circuit to the motor, where electromagnets turn the electrical energy into movement (kinetic energy).

We need to look at the cell in a little more depth to understand the chemical processes that are taking place in it in order to generate the electricity.

The dye when it is excited by light injects an electron into the titanium dioxide with which the plates are coated and semiconducts.

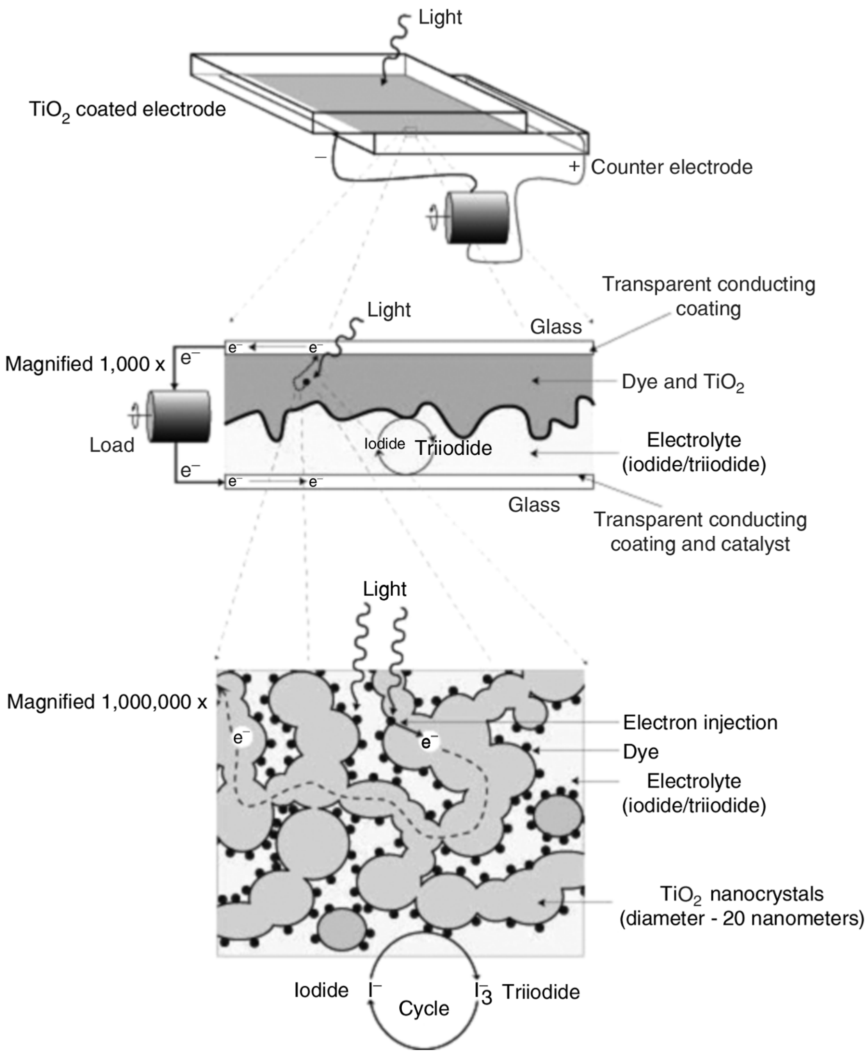


Figure 11-1 *How a photochemical solar cell works.* Image courtesy Greg P. Smestad.

# Project 29: Build Your Own Photochemical Solar Cell



## Online resources

Point your browser toward
www.solideas.com/solrcell/cellkit.html
for more information on dye sensitized photochemical solar cells and where you can obtain a kit of the parts featured in this project.

## You will need

- Berries
- Motor
- Alligator clips
- Wires
- Nanocrystalline $TiO_2$ Degussa P25 powder in mortar and pestle
- Glass plates

## Tools

- Petri dishes
- Tweezers
- Pipette
- Pencil

We need to get our titanium dioxide ground down so that the particles are as small as possible—this maximizes surface area, and so allows our reactions to take place quickly. To do this, we will need the mortar and pestle mentioned in our "tools" list (Figure 11-2). Be careful not to inhale any of the fine titanium dioxide powder as you are grinding, as it won't do you any good!

Now that we have prepared our suspension of titanium dioxide, we need to coat it onto our glass plate using a glass rod. This is shown in Figure 11-3.

**Figure 11-2** *Grinding the nanocrystalline titanium dioxide.* Image courtesy Greg P. Smestad.

The next thing that we need to do is sinter the titanium dioxide film in order to reduce its resistivity. This is shown in Figure 11-4. To do this, we hold it in a Bunsen flame and allow the gas to do the work! We need to hold the plate at the tip of the flame where the temperature is approximately 450°C or 842°F.

Hold it steady for around 10–15 minutes.

Now you need to produce the dye which will sensitize our photochemical solar cell. There are

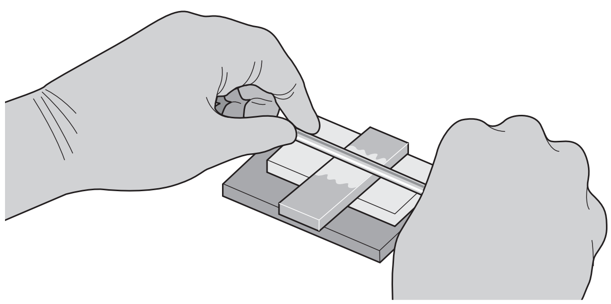

**Figure 11-3** *Using a glass rod to spread the suspension onto the plate.* Image courtesy Greg P. Smestad.

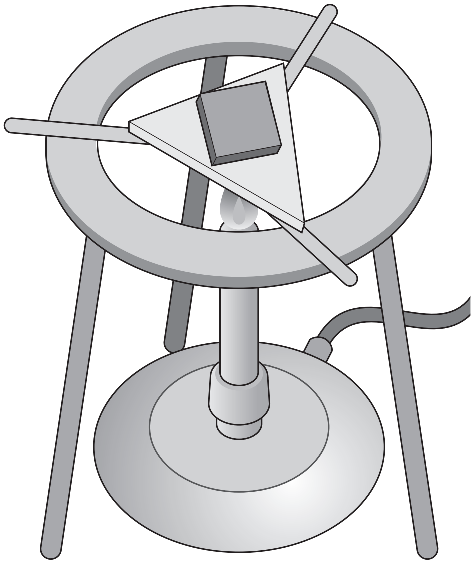

Figure 11-4 *Firing the film of titanium dioxide in order to sinter it.* Image courtesy Greg P. Smestad.

a number of suggestions for different substances which can be used for this cell. You can try:

- Blackberries
- Raspberries
- Pomegranate seeds
- Red hibiscus tea in a few ml of water

To produce the dye, you need to take the substance you are going to make the dye from, and crush it in a small saucer or dish. Once this has been done and a nice fluid has been produced, take the plate which has been coated in titanium dioxide, and immerse it in the dye. The titanium dioxide film should now be stained a deep red to purple color and the color distribution should be nice and even. If this is not the case, you can immerse the plate in the dye again. Once you have finished staining the plate, take a little ethanol and wash the film and then with a tissue, blot the plate dry. This is illustrated in Figure 11-5.

Now we need to prepare the other electrode. To do this you will need another of the coated glass plates (the one with the conductive tin oxide coating—not the one with a titanium dioxide coating). You need to find which is the conductive surface. There are two ways of doing this—the tactile method is to simply rub the plate. It should feel rougher on the coated side. The other involves

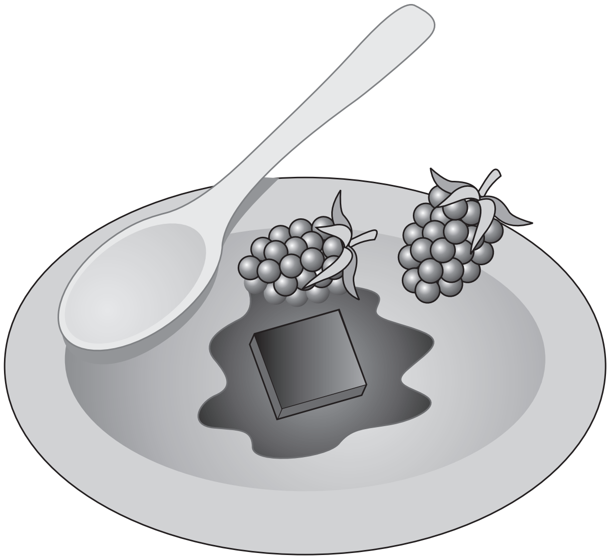

Figure 11-5 *Coating the plate in berry juice.* Image courtesy Greg P. Smestad.

a voltmeter or continuity tester. The conductive side is the one which yields a positive reading when tested for continuity.

We now need to deposit a layer of graphite. The easiest way to do this is take a soft pencil, and simply scribble on the surface until a nice even coating of graphite is obtained. This is shown in Figure 11-6. Just note that you need to do this with a plain pencil not a colored one!

Now if you have got this far, you are on the home run! The next thing we need to do is take some of the iodine/iodide mixture, and spread a few drops evenly on the plate that was stained with the dye (Figure 11-7). Once you have done this,

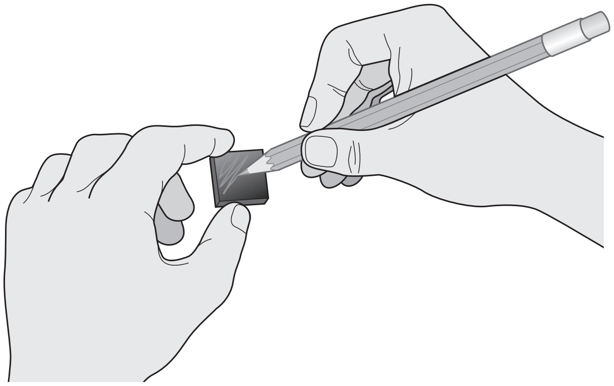

Figure 11-6 *Applying a graphite film to one electrode.* Image courtesy Greg P. Smestad.

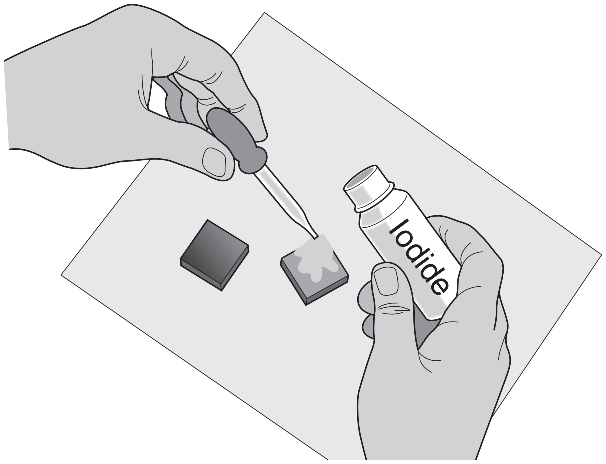


Figure 11-7 *Applying the iodine/iodide mixture.* Image courtesy Greg P. Smestad.

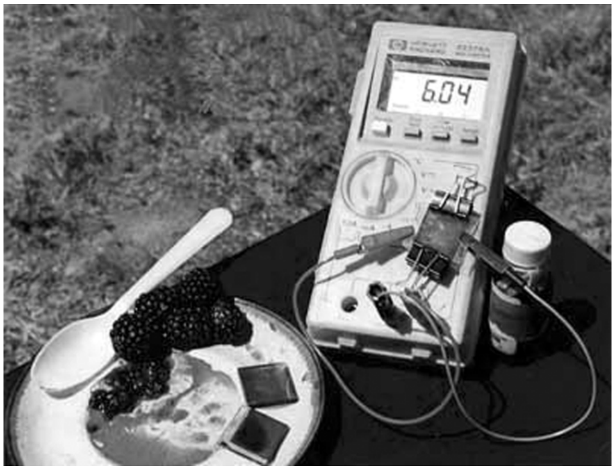


Figure 11-9 *The cell yields 6.0 mA.* Image courtesy Greg P. Smestad.

take the other electrode and place it on top of the dyed electrode. Stagger the junction between the two plates in order that you leave a little of each exposed at either end—you can then use a couple of crocodile clips to connect the cell to a multimeter.

Now clip the sheets of glass together carefully to ensure they stay together (Figure 11-8).

Now connect a multimeter—we can start to think about doing some really cool stuff now! You might like to try a few different experiments—like seeing what way to shine the light through the cell for the most effective operation. You might like to repeat some of the experiments in the section on photovoltaic solar cells, and see what results you obtain with a photochemical solar cell.

Another educational idea is to use a multimeter to measure the amount of power from both a photovoltaic solar cell, and the photochemical solar cell you have made, and compare the results—now work out their relative efficiencies taking into account the area of the cells.

Now we can take some measurements! Figure 11-9 shows a photochemical cell yielding 6.0 mA! Apparently, the juice in this picture is from Californian blackberries!

Figure 11-10 shows a photochemical cell being used to drive a small motor and fan.

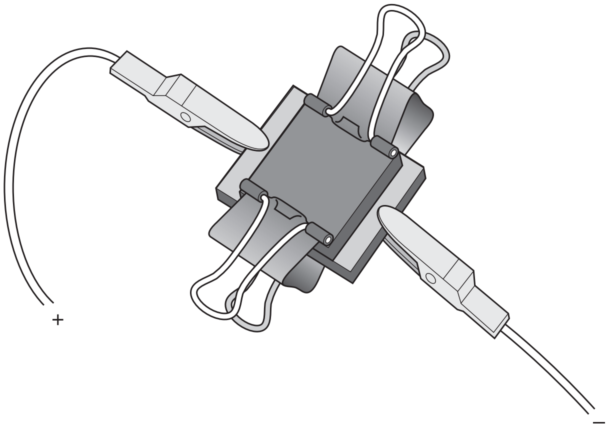


Figure 11-8 *Clipping the cell together with bulldog clips.* Image courtesy Greg P. Smestad.

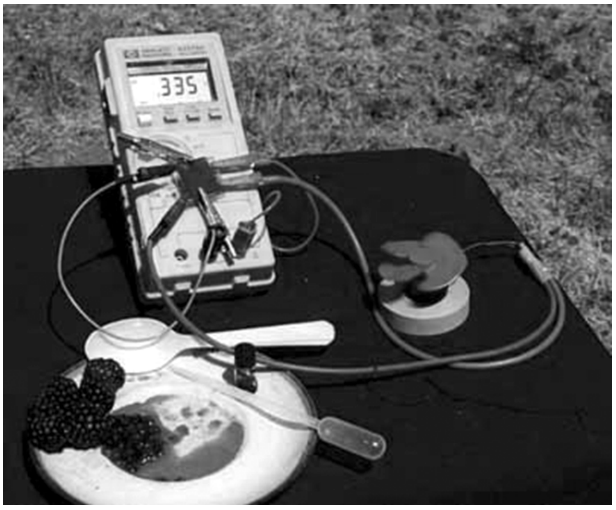


Figure 11-10 *The cell driving a small motor.* Image courtesy Greg P. Smestad.

Figure 11-11 *A closeup of the photochemical cell in action.* Image courtesy Greg P. Smestad.

Figure 11-11 shows a close-up of the cell working in action!

### Online resources

The materials required for this project are available from the Institute of Chemical Education from the following link or the address in the Supplier's Index: ice.chem.wisc.edu/catalogitems/ScienceKits.htm#SolarCell

## Where does it all go from here?

This technology has a lot of promise for the future. There is a growing trend for manufacturers to integrate renewable energy systems into building elements—this allows us to feed two birds with one crumb, rather than shelling out for roof tiles and solar cells, why not buy a solar roof tile! The exciting thing about photochemical solar cells is that unlike photovoltaic cells, they don't necessarily have to be opaque. This opens up exciting possibilities—shaded windows and skylights which simultaneously produce electricity. How cool would that be!

When you consider all of the glazing that adorns the skyscrapers in our cities, you begin to realize that this technology has interesting applications for energy generation. It also allows us to make good use of daylight with our south-facing building areas, while generating energy at the same time.

There are also implications for consumer electronics, the watch giant Swatch has already built a prototype watch with a photochemical cover glass. This allows the glass which covers the watch to generate electricity all the time the watch is exposed to light. When you think that people wear watches on their wrists where they are permanently exposed to daylight, this becomes quite a sound idea! Of course, you also need some means of storing the electricity to enable the watch to run at night! It would be no good to wake up, put on your watch, only to find the time is set to the evening before.

## Are there any limitations to this technology?

One of the problems with this particular type of cell is that the cell contains liquid which is essential for its function. Unfortunately, liquid is hard to seal and keep in—preventing the liquid from leaking is a real technical issue that needs to be solved. After all, you wouldn't want leaky windows! If you have ever seen a poorly fitted double glazing panel with condensation inside, you realize how hard it is to seal building fixtures and fittings against the ingress or egress of fluid.

However, there is hope on the horizon, Grätzel together with the Hoescht Research & Technology in Frankfurt, Germany, and the Max Planck Institute for Polymer Research in Mainz, Germany, have announced that they have developed a version of the cell with a solid electrolyte; however, efficiencies are low.

## Photobiological solar cells?

Truth can sometimes be stranger than fiction. Realizing that conventional solar cells require expensive industrial processes, researchers at Arizona State University have initiated a project codenamed Project Ingenhousz which is looking at photosynthesis and how organisms can be used to harness solar energy to produce fuels that will wean us away from our carbon-based fossil fuels. Could your car one day run from hydrogen that has been produced by algae from solar energy?