
Presented by
The ARC Centre of Excellence in Exciton Science
SOLAR CELLS
The sun is a large ball of burning gas at the centre of our solar system. The sun's nuclear reactions send energy in the form of light to Earth.
The light that reaches the Earth's surface exists in a range of wavelengths (λ) and energies. Each packet of light is known as a photon.
short λ
long λ
The range of wavelengths of photons that arrive at the Earth's surface is known as the Solar Spectrum.
λ
During the day, this sunlight lands on the face of solar panels such that the materials from which the cells are constructed are Energised. This is achieved by...
An incoming photon of light being absorbed by the electron of an atom. This photon elevates the electron to a higher energy level and leaves behind a positive hole
Electron
Atom
Guess what this we call electron-hole pair?
AN EXCITON!!
And in a solar panel we try to separate electron and hole.
Once several electrons have been energised, they are funnelled along conductive wires to form an electric current.
This electricity can then be used to power our schools, workplaces and other devices.
The current solar panels commonly found on the roofs of houses are composed mainly of silicon.
14
Si
Silicon
Si
Silicon is a metalloid element with 14 electrons that often bonds in a covalent network
However, commercial Silicon solar panels in their current form are limited in that they
• can only produce electricity when it's sunny
• Are expensive to produce
• And only use 18-22% of the available solar spectrum
So, it's important to keep investigating new materials and devices for solar energy conversion.
Are you Ready to get involved?


YOUR MISSION
SHOULD YOU CHOOSE TO ACCEPT IT...
...is to create a simplified version of a Dye sensitised solar cell* (DSSC) which is a cheap, thin film solar cell. Commercially they aim to be semi-transparent and flexible.
*Also known as a Grätzel cell.
The process that occurs in a DSSC is similar to photosynthesis in that light energy is essential in allowing the reaction.
$CO_2$
$H_2O$
$O_2$
$C_6H_{12}O_6$ Glucose
In plant cells, the chloroplasts contain a green pigment called chloropyll which absorbs light in the blue and red regions of the solar spectrum.
Chloroplast
In DSSCs, we will use a dye to decide which colours and wavelengths of light are absorbed by the solar cell.
To construct your DSSC, you will firstly need to determine which side of your ITO glass is conductive.
conductive side up
tape neatly on edges
Then, using masking tape, secure it to a lab safe surface.
Now here is the trickiest part!
You need to turn the $TiO_2$ powder into a paste and replicate a technique called Doctor blading to create a thin and uniform layer of white on the face of the glass.
Then, its up to you... You need to find a safe and natural dye with which to to stain the white $TiO_2$ coated glass. There are so many options! You may even choose to do some research...
Once the dye has been applied, it is time to prepare the other ITO glass sample.
conductive side down
Using a tealight candle, a film of carbon needs to be deposited on the conductive side of the glass.
conductive sides are facing each other
The two slides of ITO glass can then be placed together and become the alternate 'electrodes' of the cell. This is kind of like the positive and negative ends of a battery.
+
-
The solar cell can then be connected up to a multimeter in preparation to initiate the reaction.
One aligator clip needs to carefully be connected to each slide of the off-set solar cell.
Once the $I/I_3^-$ electrolyte has been applied and light is shone onto the solar cell a reaction should be initiated and a voltage observed.
VOLTS!
It's not easy to complete this challenge, and you will need to experiment and adjust the method. However the number one rule will always be
SAFETY FIRST
Ensure you listen and follow the instructions of your teacher at all times!

SOLAR CELL CHALLENGE

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# Method and Materials

**Dye-Sensitized Solar Cell**

**Materials:**

**Provided by your school:**

- 1 x Multimeter (with µA sensitivity)
- 2 x Alligator clips
- 1 x plastic chopping board/lab-safe surface
- Masking tape
- Scales
- 1 x small spatula
- Mortar and pestle
- 0.035M Acetic acid (pH 3-4)
- 0.5M Potassium Triiodide, $KI_3$ ($I/I_3^-$) electrolyte
- Measuring cylinder (≥10mL)
- 3 x Plastic pipettes
- Glass stirring rod
- Forceps
- Hot plate
- Small beaker
- Deionised water
- Detergent
- Ethanol
- Matches
- Tea candle
- Q-tip
- 2 x small bull dog paper clips

**Provided by Exciton Science:**

- Titanium dioxide ($TiO_2$) powder
- ITO conductive glass (x6 slides)

**Provided by you:**

- Materials of your choice to create a dye

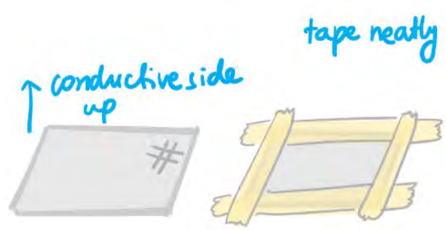
**Method:**

**Notes before you get started**

- This method is NOT perfect and will require you to make slight adjustments. Look out for the steps that are in GREEN. These are the ones where you may need to adjust amounts slightly, repeat the step with a 'trial and error' approach or make your own decision around which materials you choose to use.
- This method creates **one** Dye Sensitized solar cell. However, you have been provided with enough materials to do this experiment at least three times total. This will allow you to try slightly different approaches to your experiment each time if you wish.

**Preparing the electrodes (ITO glass)**

1. Using a small amount of ethanol, rinse the ITO glass to clean. Allow to air dry.
2. Using a multimeter on the resistance (Ω) setting, use alligator clips and press against each face of each square of ITO glass to test which side is conductive. A reading (usually at about 0.0 Ω) will occur when the conductive side is connected.
3. Tape 2 opposite edges of a single piece of ITO glass (conductive side facing upward) to a lab-safe surface or plastic board.




**Preparing $TiO_2$ paste**

*Note- This part of the method will use up should produce excess amounts of $TiO_2$ paste, however it should not be disposed of until after the entire experiment is complete. To keep it fresh, transfer it to a very small beaker and seal using Parafilm.*

1. Using a spatula, transfer approximately 0.50 g of $TiO_2$ powder into a mortar.
2. Dropwise, add 1-2 mL of 0.035 M acetic acid until a colloidal, soupy consistency is formed. Use the pestle to stir.
3. Add 1 small drop of colorless detergent and carefully mix uniformly through paste but avoid agitating to form bubbles.

*** You may need to make slight adjustments to these quantities to get a smooth consistency of paste.*

**Doctor blading paste to the electrode (ITO glass)**

*Note- It is recommended that this technique is practiced on a microscope slide prior to ITO glass.*

1. Using a plastic pipette, take a small drop of $TiO_2$ paste and carefully drop it on one edge of the ITO glass that is taped down.
2. Using a glass stirring rod, held at each end, carefully spread the paste along the surface of the glass. You want to ensure a thin layer of paste covers the entire exposed surface of the glass. Try not to roll, but instead scrape the rod along the surface.
3. If it does not work the first time, wipe the layer off using a piece of tissue and start again.
4. Allow to dry.

***The thinner the layer, the better, however it should not have any holes and should be a consistent thickness. Ensure that you don't scratch or disturb this layer for the rest of the experiment.*

**Setting the $TiO_2$ paste**

1. Turn the hot-plate onto high and wait a for a few minutes.
2. Carefully remove the tape from the sides of the glass without disturbing the paste.
3. Carefully transfer the slide to the hot-plate (conductive face up) with the help of forceps.
4. Allow to heat for at least 10-15 minutes. The white paste should turn yellow, then brown and return to white. If it does not, increase the hot-plate heat or length of heating.
5. After heating is complete, use the forceps to lift the glass off the hot plate. It should be held in the air (just a few cm above the bench) for at least 2 minutes to cool before it is placed on another surface. Allow to cool at least a further 10 minutes.

*Note- the glass can be carefully packed away at this point and placed in a sealed container to continue the experiment later if required.*

*Note- If a hot-plate is not available, a Bunsen burner with a tripod, gauze mat and small crystalline dish or watch glass can be used on a low-level flame as an alternative, however, be careful to not deposit carbon onto the glass.*

*You can use water and ethanol to wipe clean $TiO_2$ that is too thick from glass. However, be sure to not scratch the glass and if so, it can be reused.*

***In some versions of this experiment, the heating is for much longer. You need to be sure the paste has set and the colour change described above is usually a good indication that this has occurred.*

### Preparing the dye bath

A dye is a natural or synthetic compound that causes a colour change in another material.

An example method has been included below for a student who want to use raspberries to colour their solar cell, however, you can choose what you would like to dye your cell.   Not all dyes will require prior-preparation to form a solution.

1. *Place 3 raspberries in a small beaker.*
2. *Crush the berries with a stirring rod and by adding a few mL of water until a deeply coloured solution is formed.*

*Note- Some substances will need to be dissolved in ethanol, in which case they should be rinsed in ethanol solution in the next step. Others will need to be dissolve in water, in which case the slide should be rinsed with water after sensitizing.   Talk to your teacher to help workout how your dye material needs to be treated.*

***Yes, this whole step is up to you!*

### Sensitizing the electrode (ITO glass)

1. Using forceps, carefully transfer the cooled ITO glass into a bath of dye sample.
2. Allow it to sit in the bath for at least 15 minutes until it appears completely dyed.
3. Using forceps, remove the glass and carefully rinse any excess dye using a small amount of water, then ethanol, over a sink, then allow to air dry.  This should be done gently as to not disturb the dyed titanium dioxide.

*Note- if the Titanium dioxide is still white, the dye has not caused a colour change and an alternative dye will need to be used.*

### Preparation of counter electrode

1. Light a tea candle.
2. Using forceps, move the conductive side (facing down) of a second piece of ITO glass in and out of the flame so as to coat this side with a thin and uniform layer of carbon.
3. Once cool, using a Q-tip, remove 2-3mm of carbon from two opposite edges of the glass.
4. Turn the hot-plate onto high and wait a for a few minutes.
5. Carefully transfer the slide to the hot-plate (conductive face up) with the help of forceps.
6. Allow to heat for at least 10-15 minutes.
7. After heating is complete, use the forceps to lift the glass off the hot plate.  It should be held in the air (just a few cm above the bench) for at least 2 minutes to cool before it is placed on another surface.  Allow to cool at least a further 10 minutes.

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**Assembling the solar cell**

1. Place the sensitized glass, dye-face up on the lab bench.
2. Carefully place the carbon-coated glass (conductive and carbon side face down) on top, offset such that all the Titanium dioxide is covered, but the side-strip of each electrode over-hang. Ensure that overhanging sides are free of carbon and the $TiO_2$. Ensure to not scratch either surface when placing the two electrodes together.
3. Clip the 2 electrodes together using 2 x bull dog clips on their flush edges.
4. In a fume hood with a pipette, add 2-3 drops of the iodide/iodine ($I_3^-/I$ electrolyte) solution to the exposed edge of the glass plates.
5. Open and close the clips carefully, in turn, to distribute the electrolyte solution between the two plates of glass. The entire Titanium dioxide surface should be wet.
6. Wipe off any excess electrolyte carefully.

**Testing the solar cell**

1. Connect an alligator clip to each over-hanging side of the conductive glass.
2. Then connect the other ends of the alligator clips to a multimeter at the μA setting
3. With the dye-side up, shine a strong LED light onto the solar cell and observe the change in the current on the multimeter.

***Sometimes a current is so small that it is difficult to detect. You can also switch your multimeter to the smallest volt unit, and you may be able to observe a voltage reading.*

***It can be hard to detect a current and voltage under sunlight on your first solar cell, so other sources of light might help you observe the generation of electricity better. Try out light sources that you have available.*