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Contents

1.0 Introduction

1.1 Making Your Own Grätzel Cell

This manual will take you through step by step on how to prepare Grätzel cells and use them to power a small electronic calculator. The steps are sectioned into four parts. A brief outline of these sections is described on page 4.

Below gives an overview of what Grätzel Cells are, what they look like, the making of them and how they work?

1.2 The Grätzel Cell

Grätzel cells are dye sensitised solar cells that use a dye for directly converting sunlight energy into electrical energy. They were first invented in 1991 by Michael Grätzel and his researchers at the Swiss Federal Institute.

Using the *Man Solar Educational Kits* you can experience making your own Grätzel cell using a range of organic dyes. These dyes can be extracted from simple foods, such as blackcurrants, cranberries, hibiscus tea, tinned summer fruits, blackberries and many more.

The cells are prepared from two transparent glass plates that have been pre-treated on one side with a transparent thin layer of a conducting material. Onto the conducting sides, one plate is coated with graphite and the other plate is coated with titanium dioxide (TiO_2). A dye is then adsorbed onto the TiO_2 layer by immersing the plate into a dye solution for approximately 10 minutes. The plates are then carefully sandwiched together and secured using a paperclip. To complete the cell a drop of iodide electrolyte is added between the plates. Figure 1 shows a Grätzel cell prepared from hibiscus tea. The upper plate is the TiO_2 plate, dyed with hibiscus tea (1) and the lower plate is coated with graphite (2).

Figure 1. A Prepared Grätzel Cell

Like batteries, Grätzel cells also have negative (-ve) and positive (+ve) terminals. The dyed TiO_2 plate is negative and the graphite plate is positive.

1.3 How Does The Grätzel Cell Work

Figure 2 illustrates the four steps for creating an electric current from sunlight energy.

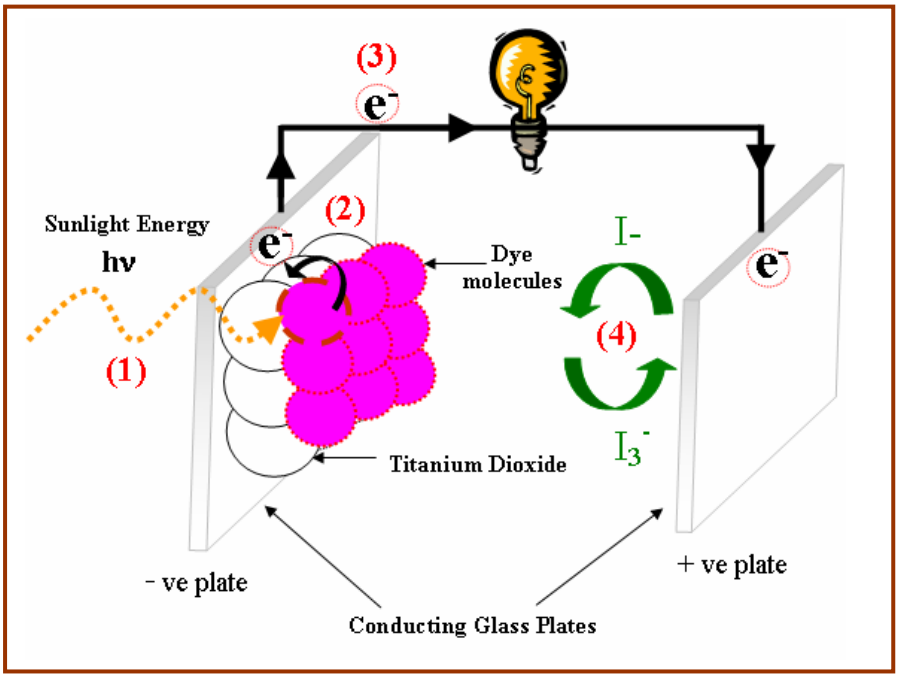

Figure 2. Basic Principle of Grätzel Cells

1) Sunlight energy (photon of light) passes through the titanium dioxide layer and strikes electrons within the adsorbed dye molecules. Electrons gain this energy and become excited because they have the extra energy.

2) The excited electrons escape the dye molecules and become free electrons. These free electrons move through the titanium dioxide and accumulate at the -ve plate (dyed TiO_2 plate).

3) The free electrons then start to flow through the external circuit to produce an electric current. This electric current powers the light bulb.

4) To complete the circuit, the dye is regenerated. The dye regains its lost electrons from the iodide electrolyte. Iodide (I^-) ions are oxidised (loss of electron) to tri-iodide (I_3^-). The free electrons at the graphite plate then reduce the tri-iodide molecules back to their iodide state. The dye molecules are then ready for the next ***excitation/oxidation/reduction*** cycle.

The Grätzel cells can generate sufficient electrical energy to power a small electronic calculator. Figure 3 shows five Grätzel cells connected in series to power a small electronic calculator.

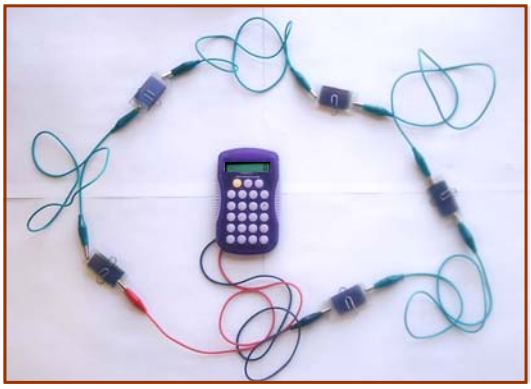

Figure 3. Five Grätzel cells connected in series to power a calculator

1.4 A Brief Outline of Sections

Section 2.0 Preparation of Graphite and Titanium Dioxide (TiO_2) plates

The graphite and TiO_2 coated plates are prepared from transparent glass plates that are conducting on one side. It is important that the graphite and TiO_2 coatings are applied onto these sides.

The graphite plate is prepared by simply colouring the glass surface with a pencil.

The TiO_2 plate is prepared by applying a very thin layer of TiO_2 paste, which consists of TiO_2 powder (20-30nm particles) and solvent. The TiO_2 coating is then sintered over a bunsen burner for 2 minutes.

Some kits will have supplied you with pre-made titanium dioxide coated plates, in which case you can go straight onto adsorbing a dye onto the TiO_2 layer.

Section 3.0 Adsorption of Dye onto Titanium Dioxide layer

The TiO_2 plate is soaked in a dye solution for 10 minutes. This allows dye molecules to adsorb onto the titanium dioxide particles.
Various natural dyes can be used, some include hibiscus tea, turmeric powder, ribena, onion skin, cranberries, strawberries, raspberries and many more. The kits are supplied with hibiscus tea.

Section 4.0 Assembly of Grätzel Cell

A Grätzel cell can now be assembled by sandwiching a graphite plate and dyed titanium dioxide plate together. A paper clip is turned into a clamp and used to secure the two plates together. To complete the cell, a drop of iodide electrolyte is placed between the two plates.

Section 5.0 Grätzel Cell Powered Calculator

Five Grätzel cells are needed to power a small electronic calculator. The cells are connected in series and a total voltage of 1.2 V is required to power the calculator satisfactorily. Using the instructions in this manuals, hibiscus tea and blackberries provide the most power.

Various other small electronic devices can be used to test the Grätzel cells, such as melody modules (supplied in some kits) and low powered fans.

2.0 Preparation of Graphite and Titanium Dioxide (TiO_2) Plates

2.1 Determining the Conducting Side

A simple test is carried out to determine the conducting sides of the uncoated transparent glass plates. This is done by measuring the resistance along the length of the plates. You will require the following items:

- Multimeter
- Uncoated transparent glass plates

1. Set up a multimeter to measure the resistance in ohms (Ω).
2. Take the two ends of the multimeter leads and measure the resistance along the entire length of the glass plate, Figure 4. Do this for both sides.

Figure 4. A multimeter being used to determine the conducting side of a transparent glass plate

3. The conducting side will have a resistance of ~ 30 ohms. The non conducting side will show infinite resistance (this may be displayed as '1').

Having determined the conducting sides you are now ready to prepare your graphite and TiO_2 plates.

2.1 Preparation of Graphite plate

For this step you will require the following items:

- Uncoated transparent glass plate
- Pencil

1. Carefully clean both sides of the plate with water or ethanol. Take care to remember the conducting side of the plate.
2. Take a pencil and evenly coat the conducting surface with a layer of graphite. Leave roughly 1/5 of the surface uncoated for crocodile clip connection, Figure 5.

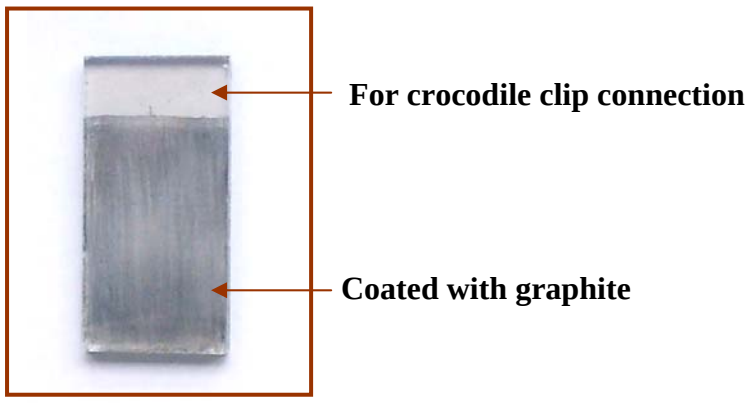

Figure 5. Transparent conducting plate coated with graphite

Your graphite plate is now prepared. The next step is to prepare your TiO_2 coated plate. If you have been supplied with a plate that is pre-coated with TiO_2 you can go straight to Section 3.0.

2.2 Preparation of Titanium Dioxide (TiO_2) plate

You will require the following items:

- Uncoated transparent glass plate
- TiO_2 paste
- Cello-tape
- Glass side

- Bunsen burner

1. Take the uncoated glass plate and place it on the bench with the conducting side facing up.
2. Cello-tape the two long sides and one short side of the glass plate onto the bench, Figure 6.

Figure 6. Transparent glass plate set up for coating with TiO_2

3. Carefully place a few drops of the TiO_2 mixture at the end of the glass plate. Then using a glass slide gently spread the paste evenly over the exposed surface, Figure 7. **DO NOT PRESS TOO HARD AS THIS MAY SNAP THE GLASS SLIDE.**

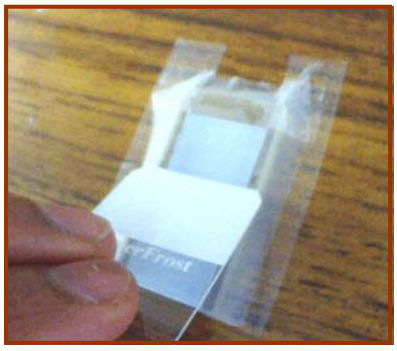

Figure 7. Coating the transparent glass plate with TiO_2 paste

4. Leave to dry in air.
5. You are now ready to sinter the coated TiO_2.

2.2.1 Sintering Titanium Dioxide

Sintering is a method used for adhering particles together, so that the TiO_2 particles are touching one another, this is called necking. This is done using heat, Figure 8.

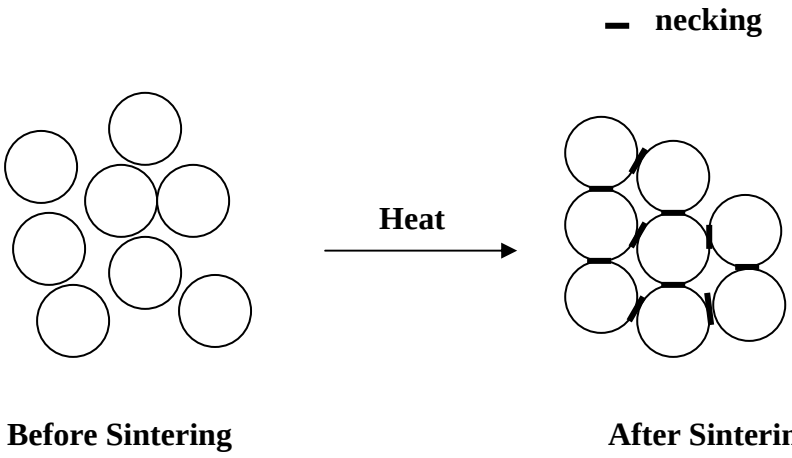

Figure 8. Illustrates the behaviour of TiO_2 particles after sintering

1. Turn on a bunsen burner and set the flame to blue.
2. Using tongs securely grip the TiO_2 plate around the sides, making sure the TiO_2 side is facing upwards.
3. Direct the TiO_2 plate roughly 10cm above the blue flame. The white TiO_2 coating will start to colour brown after approximately 1 minute and then gradually turn white again. At this point, the sintering process is complete. The sintering process should not take more than 3 minutes to complete.
4. Allow your sintered TiO_2 plate to cool down.

You are now ready to dye the TiO_2 layer.

3.0 Adsorption of Dye onto Titanium Dioxide

3.1 Preparation of dye solution

You now need to decide on the dye you want to use in your Grätzel cell. Table 1 gives a list of dyes, along with their section for preparing the dye solution.

Table 1. A list of various dyes that can be used, along with their section for preparing the dye solution

Dye	Section
Hibiscus Tea	3.1.1
Turmeric Powder	3.1.2
Ribena	3.1.3
Onion Skin	3.1.4
Cranberries	3.1.5
Strawberries	3.1.6
Raspberries	3.1.7
Tea Bag	3.1.8

You will require the following items:

- 100ml Beaker
- Tap water
- Dye
- Measuring balance
- Measuring cylinder
- Pestle and Mortar

3.1.1 Hibiscus Tea

1.Weigh out 1g of hibiscus tea leaves and add them to 50ml of water in a 100ml beaker.

2. Using a hot plate, allow the solution to boil for a couple of minutes. The solution

will become an intense purple colour.

3.1.2 Turmeric Powder

1. Weigh out 0.3g of turmeric powder and add it to 50ml of water in a 100ml beaker.
2. Using a hot plate, allow the solution to boil for a couple of minutes. The solution will become an intense yellow colour.

3.1.3 Ribena

1. In a 100ml beaker, add 10ml of Ribena and 50ml of water.
2. Using a hot plate, allow the solution to boil for a couple of minutes. The solution will become a purple colour.

3.1.4 Onion Skin

1. In a 100ml beaker, add 5 pieces of onion skin and 50ml of water.
2. Using a hot plate, allow the solution to boil for a couple of minutes. The solution will become an intense yellow/orange colour.

3.1.5 Cranberries

1. Carefully crush 2-4 cranberries using a pestle and mortar.
2. Transfer the crushed cranberries to a 100ml beaker and add 10ml of water.
3. Using a hot plate, allow the solution to boil for a couple of minutes. The solution will become an intense red colour.

3.1.6 Strawberries

1. Carefully crush 2-4 strawberries using a pestle and mortar
2. Transfer the crushed strawberries to a 100ml beaker and add 10ml of water.

3. Using a hot plate, allow the solution to boil for a couple of minutes. The solution will turn a red colour.

3.1.7 Raspberries

1. Carefully crush 2-4 raspberries using a pestle and mortar.
2. Transfer the crushed raspberries to a 100ml beaker and add 10ml of water.
3. Using a hot plate, allow the solution to boil for a couple of minutes. The solution will turn a red colour.

3.1.8 Tea Bag

1. Place a black tea bag into beaker with 50ml of boiling water.
2. Using a hot plate, allow the tea bag to boil in water for a couple of minutes. The solution will turn a brown colour.

3.2 Soaking the Titanium Dioxide Plate

Once your dye solution is prepared you are now ready to dye the TiO_2 plate. You will require the following items:

- TiO_2 coated plate
- Prepared dye solution
- Petri dish
- dryer (optional- oven/hairdryer)

1. Place the coated TiO_2 plate into a petri dish so that the TiO_2 layer is facing up.
2. Pour the boiled dye solution into the dish, ensuring that the TiO_2 layer is entirely immersed in the solution for optimum dye adsorption, Figure 9.

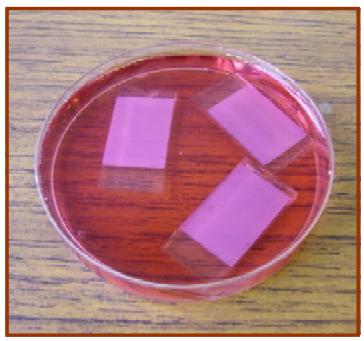

Figure 9. TiO_2 coated plates soaked in dye solution (hibiscus tea)

3. Leave to soak for 10 minutes.

4. Carefully rinse the dyed TiO_2 plate with water to remove excess dye. Leave to dry in air. Alternatively an oven or hairdryer can be used to speed up drying.

Figure 10 shows a dyed TiO_2 plate.

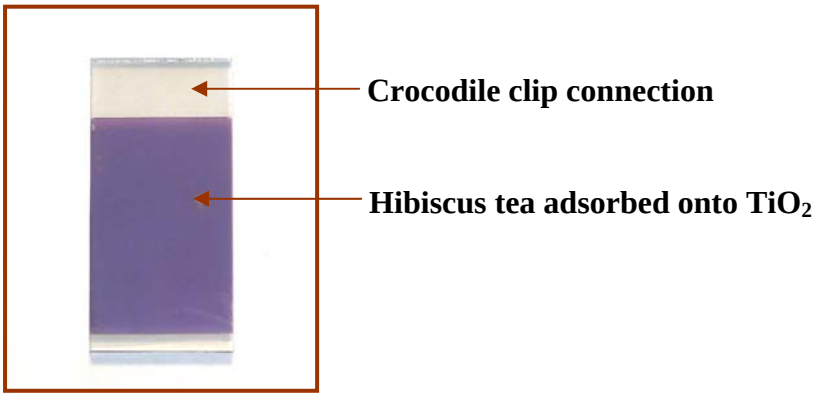

Figure 10. A TiO_2 coated plate adsorbed with hibiscus tea

4.0 Assembly of Grätzel Cell

You are now ready to assemble your Grätzel cell. You will need the following items;

- Prepared graphite plate
- Prepared dyed TiO_2 plate
- Paperclip
- Iodide Electrolyte

Safety Note - Iodide Electrolyte: Iodide is an irritant. Avoid skin and eye contact. Must wear gloves and goggles when handling the chemical.

1. Before assembling the Grätzel cell, a paperclip needs to made into a clamp. To do this, pull the shorter end of the paperclip outwards and then bend it forward to form a arch, Figure 11.

Figure 11. Steps to preparing a paperclip clamp

2. Carefully place the dyed TiO_2 plate on top of the graphite plate. The coated sides of both plates should be touching. Make sure that they are placed slightly offset, Figure 12. The ends are required for crocodile clip connection.

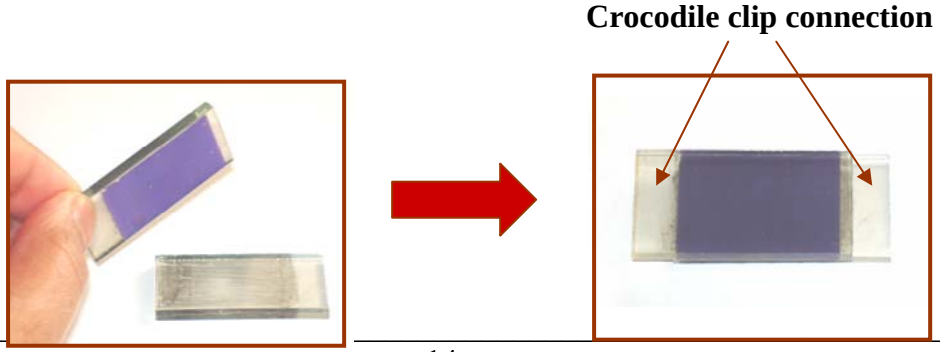

Figure 12. Illustrates the assembly of a Grätzel Cell

3. Secure the plates in position using the paperclip clamp.
4. Finally, add a drop of iodide electrolyte between the two plates, Figure 13. The iodide electrolyte will flow through to the other end of the cell. If it does not, add another drop on the other side. Carefully wipe any excess iodide electrolyte at the ends of the Grätzel Cell using a tissue.

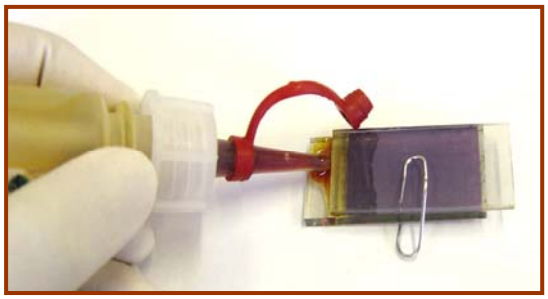

Figure 13. To complete the Grätzel cell a drop of iodide electrolyte is placed between the plates

You can now use your Grätzel cell to power a calculator.

5.0 Grätzel Cell Powered Calculator

Five Grätzel Cells should produce a voltage high enough to power a calculator.

You will need the following items;

- 5 Grätzel Cells
- 6 Crocodile clips
- Multimeter
- Calculator
- Screw driver
- Desk Lamp

1. You firstly need to measure the voltage of each of the prepared Grätzel cells. Take a multimeter and connect one lead to each end of the Grätzel cell. Place the Grätzel cell under a lamp and set the multimeter to measure the voltage (V). If a voltage between 0.2 - 0.3 V is produced for each of the Grätzel cells, then this will be sufficient for powering the calculator.
2. Place all five Grätzel cells in a line, making sure that the dyed TiO_2 plates of each of the cells are facing up.
3. Now connect the Grätzel cells in series using crocodile clips. It is important that the graphite plate (+ve) of one Grätzel cell is connected to the dyed TiO_2 plate (-ve) of another Grätzel cell, Figure 14. This is repeated until all Grätzel cells are connected in series. The positive and negative plates at the end of the line of Grätzel cells will be used to connect to a calculator.

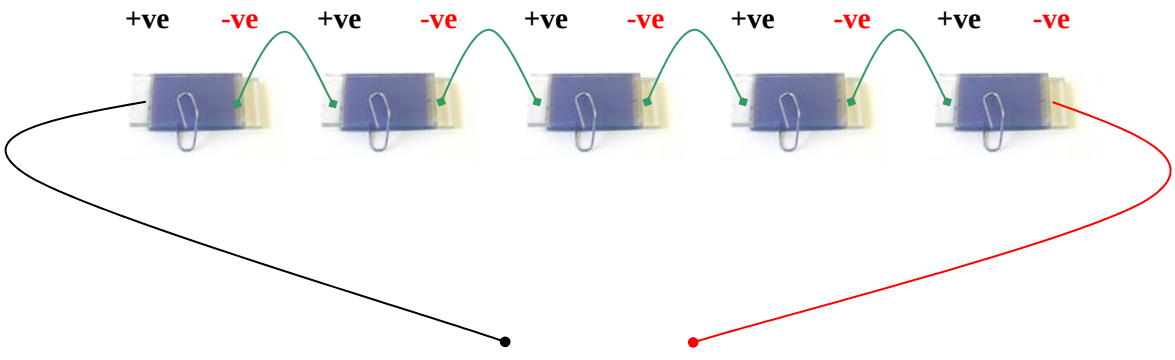

Figure 14. Illustrates the crocodile clip connection of Grätzel cells

4. Remove the battery out the backside of the calculator using a screwdriver.
5. Connect the negative pole of the series connection to the spring and the positive pole to the flat metal part opposite of the spring.
6. Lastly, illuminate the Grätzel cells using a desk lamp and switch on the calculator. If there is sufficient light in the room you may not need to use a desk lamp. Alternatively, if the sun is shining you could take it outside.

You could also try replacing the calculator with a melody module (supplied in some kits) or a low powered fan. You may need to use more Grätzel cells.