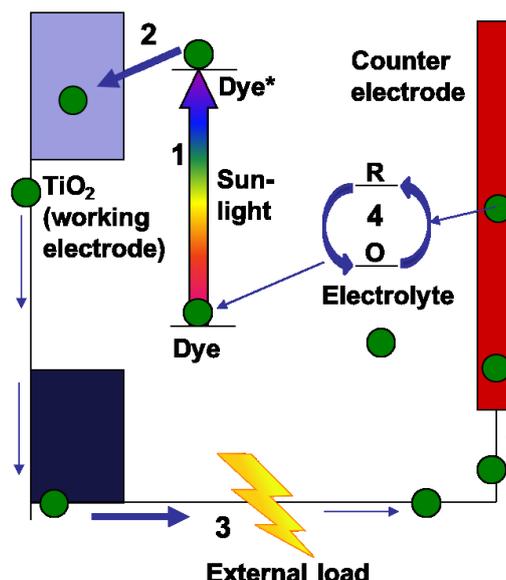


Making a Grätzel Cell Teachers' Notes

The 'Making a Grätzel Cell' experiment is a great way of allowing students to make their own solar cells out of cheap and readily accessible materials in their own school lab. The mechanism behind this solar cell is that of a Dye-Sensitised Solar Cell (DSSC).

Mechanism of a dye-sensitised solar cell

1. The process starts at the working electrode when the sensitising dye (i.e. the raspberry juice bound to the TiO_2 layer) absorbs sunlight. The energy from the light allows the raspberry dye to excite an electron to a higher energy level.
2. From the excited state, the electron is injected into the TiO_2 semiconductor.
3. The electron travels around the circuit to the counter electrode, powering an external load
4. Sustained conversion of light energy is facilitated by regeneration of the reduced sensitising dye by the reversible redox couple (O/R) I_3^-/I^- (electrolyte).



During the experimental

Step 1: Checking which side of the glass is conducting

The working and counter electrodes are prepared using special glass. The glass is coated on one side with fluorine-doped tin oxide (FTO), a material which conducts electricity. Therefore, only one side of the glass conducts electricity.

Step 2: 'Doctor blading' the titania paste onto the working electrode

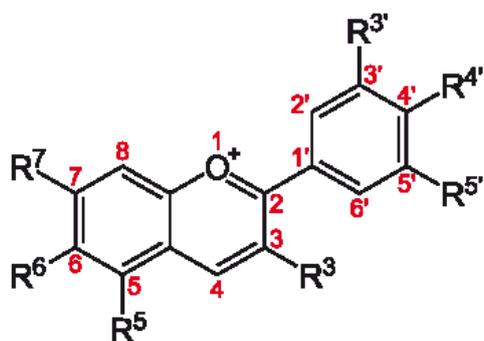
The titania (TiO_2) paste is a semiconductor. It is naturally occurring, inexpensive, non-toxic, chemically stable and readily available, so is of great interest in low-cost solar cells. It is used in everyday materials such as paint, sun cream, toothpaste and food colouring.

Step 4: Preparing the counter electrode

We need to make a complete electric circuit for the solar cell to work. The graphite in a pencil conducts electricity so can be put onto the counter electrode to complete the circuit.

The dye bath

Since TiO_2 is white, it reflects light and so is unsuitable for use in its standard form. We can use a molecular dye, such as that found in raspberries, to 'sensitise' the semiconductor to visible light.



The raspberry dye molecules belong to a group called **anthocyanin** molecules which have the basic structure shown here. The R groups are typically hydrogens, alcohol groups or ester groups. These last two help the dye bind to a semiconductor. The aromatic rings in the structure are responsible for the strong colour of the dye.

Step 5: Dying the titania paste

If time allows, leave the working electrode in the dye bath for 15 minutes. Our Magic Dye experiment can be done in this time and is good for exploring further the chemistry of molecular dyes, covering functional groups and the concepts of different types bonds.

5 minutes will be enough to produce a working cell, but the longer the titania paste is dyed for, the more efficient the cell will be.

Questions

Here are some questions which could be used as either an introduction or follow-up to this experiment.

Why are we interested in solar cells/energy?

- Probe for advantages of renewables vs fossil fuels (e.g. clean, unlimited etc)
- Enough sunlight hits the earth in 1 hour to power the world for 1 year!
- Can get paid for electricity you generate but don't use (feed-in tariffs)

Why do we use a pencil to make the counter electrode?

- Graphite (form of carbon) is very good at conducting electricity

Why do we need to dye the titanium dioxide?

- White things reflect light (think about white clothing vs black clothing on hot day)
- Ideally, the dye would be black (the darker the better) BUT it is difficult to find a light-absorbing dye which will also bind to the semiconductor

Why do we add iodine solution to the cell?

- Electrolyte solution completes the circuit, conducts electricity

How could we connect two solar cells together to increase a) the voltage and b) the current?

- a) in series
- b) in parallel
- Try connecting several together to power a small battery-powered appliance e.g. calculator

Variations

Doctor blading the working electrode

This step can be quite fiddly and difficult to do well. If the titania layer is too thick, it will simply flake off once dried and the cell will not work. The pupils need to get as thin and uniform a layer as possible. This may be easier with a paintbrush if available.

Heating the titania paste

If you don't have access to a hotplate, this step can be done using a Bunsen burner and tripod. Place the working electrode in a crystallising dish/watch glass and heat over a Bunsen burner with a **small flame** for 3-5 minutes. The coating will turn yellow or brown almost immediately and then slowly start going back to white (almost white) as the organic component of the paste (acetic acid) is decomposed and burned off

Extensions

Several projects and investigations could be devised from this experiment. Some ideas are listed below:

- **Change the dye bath**
 - Many types of fruits and vegetables contain suitable dye molecules (anthocyanins). Some good ones to try are blackberries, beetroot, and spinach. Note, however, that some of these do not bind well to the titania (which itself could be an investigation!)
- **Vary the light intensity of the cell**
 - Investigate the differences in electrical output with different intensities of light
- **Vary the surface area of the counter electrode/working electrode**
 - This can easily be done by using Scotch tape to increase/decrease the surface area of the working electrode, and changing how much of the counter electrode is covered in graphite
- **Investigate other suitable electrolyte compounds**

Sourcing equipment

- Conducting glass - These are available from ManSolar or you might be able to get some free conducting glass from a company such as Pilkington Glass, who can be willing to give away cut-offs or non-research grade glass
- Titanium dioxide powder - Titanium (IV) dioxide nanoparticles P25 ~21nm particle size is available from Sigma-Aldrich or elsewhere online
- Iodine solution – 'Iodine tincture,' for antiseptic use, is a ready-made solution of iodine/potassium iodide in ethanol/water and is available from some pharmacies (Lloyds) and online.