Power to the People

Solar Cells

UNIVERSITY OF BATH

Solar cells convert sunlight into electricity by using the energy of the light to pump electrons around an external circuit. This is the basis for the p*hotovoltaic effect*. The way in which a solar cell works is like a motor that pumps water uphill to a reservoir from where it can flow downhill again, driving machinery as it does so. Only in this case it is electrons that play the role of the water, and the energy for the pump comes from the sun.

The idea of a light-driven pump is not new – Mother Nature has been using it for millennia in *photosynthesis* (Figure 1). The absorption of light by *chlorophyll* molecules in a green leaf drives electrons uphill to an energy reservoir that is linked by an elaborate system of molecular wires to the ‘wheels’ that drive photosynthesis (Figure 2). The electrons finish up converting carbon dioxide to carbohydrates (sugars and starches), effectively running respiration in reverse and keeping us alive.

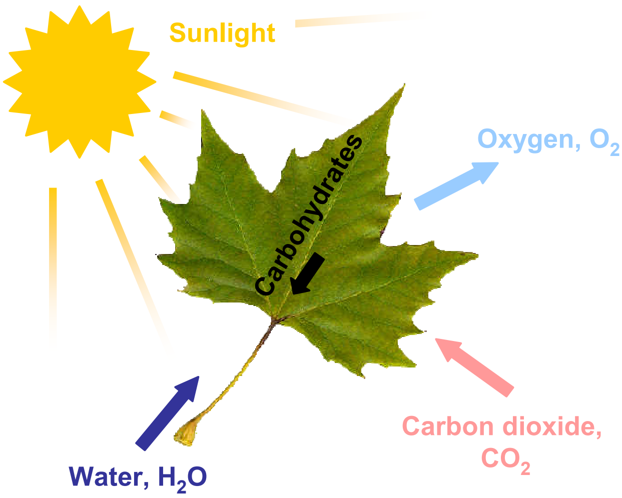

Figure 1: *Nature’s solar cell.*

Of course it would be wonderful if humans could mimic photosynthesis in every detail, but Nature’s intricate molecular architecture is extraordinarily difficult to assemble without the blueprint provided by DNA. Luckily it is not necessary to try to copy Nature exactly. The basic idea is to use light - absorbing molecules to push electrons uphill and from there, via suitable conducting molecules, to the external electrical circuit.

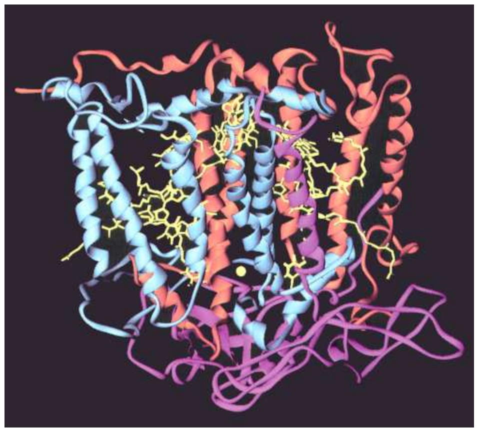

Figure 2: *The intricate molecular architecture of the photosynthetic centre.*

In conventional solar cells (Figure 3), the light absorber is made of silicon, which also acts as the conductor. The problem with silicon cells is that they are expensive to make because the silicon needs to be very pure.

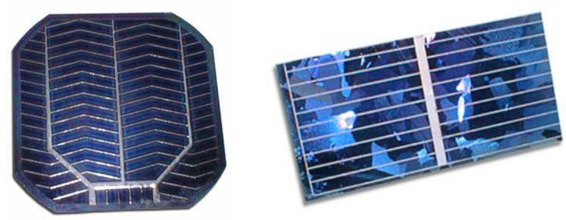

Figure 3: *Conventional, silicon-based solar cells.*

An alternative approach is to use specially designed *dye molecules* to do the job of light absorption and to couple the light absorption process to chemical processes that resemble photosynthesis. This is the basic idea behind the dye-sensitized nanocrystalline solar cell invented by Professor Michael Grätzel of the University of Lausanne in Switzerland (Figure 3). The ‘light harvesting’ dye used originally is an intensely red complex of ruthenium (Figure 4). It is coated onto the high surface area of a very thin porous film consisting of tiny titanium dioxide particles that are around 1/1,000,000 of a centimetre in diameter. The titanium dioxide film can be spread easily onto conducting glass by screen printing.

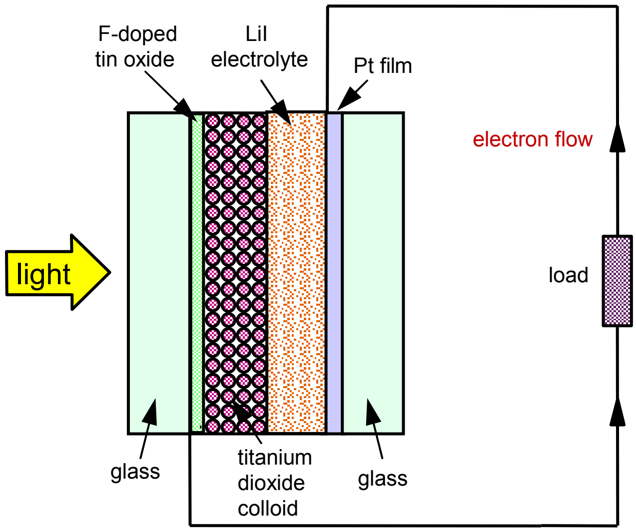

Figure 3: *A dye-sensitised solar cell.*

When the dye absorbs light, it pumps electrons into the titanium dioxide (Figure 5). However, our 'artificial leaf' needs some 'sap' to prevent the dye molecules from bleaching after they have lost their electrons. The 'sap' is provided by a liquid that contains molecules to ferry electrons back to the dye after they have completed their trip through the external circuit. These cells are not yet as efficient as their silicon brothers, but they are cheap to produce and can be made on flexible plastic as well as glass.

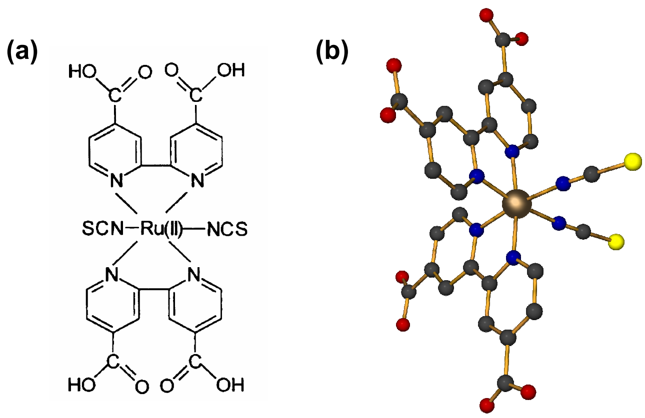

Figure 4: *a) Structural formula, and b) molecular structure of a red ruthenium dye.*

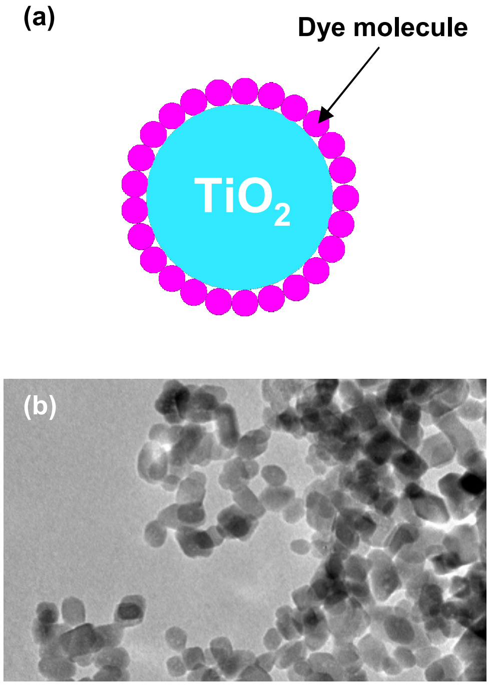

Figure 5: *(a) Dye molecules around a TiO_2 nanoparticle; (b) dye-coated nanoparticles viewed through an electron microscope*

KEY TERMS

Chlorophyll: A molecule that absorbs sunlight and uses its energy to synthesise carbohydrates from CO_2 and water**.**

Photovoltaic effect: The generation of an electric potential (voltage) by light.

Photon: The smallest packet (quantum) of light.

Photosynthesis: The conversion of light energy into chemical energy by living organisms.

'Dye-sensitized' or 'Grätzel' cell: A solar cell based on light absorption by a coloured dye**.**

Molecular wire: A strand of molecules able to conduct electrons.

Nanoparticle: A particle on the order of 1~100 nanometres (1 nm = 10^{-9} m) in size.

Porous: Containing many voids or 'pores'.

FURTHER INFORMATION

- A website dedicated to this exhibit can be found at http://www.bath.ac.uk/powerttp/
- For more details about our research on solar cells visit http://www.bath.ac.uk/chemistry/

the BA festival of science York 9-15 sept 07

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