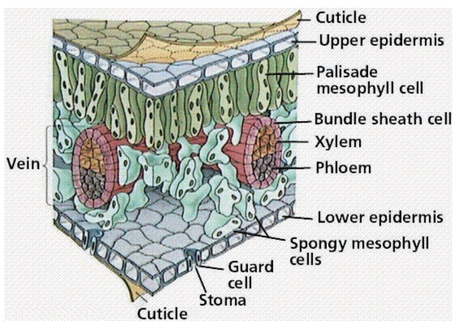
Dye-sensitised Solar Cell (Artificial photosynthesis)

L LE ROUX, C ARENDSE, S HIETKAMP
CSIR Materials Science and Manufacturing, PO Box 395, Pretoria 0001, South Africa
Email: lleroux@csir.co.za

ABSTRACT

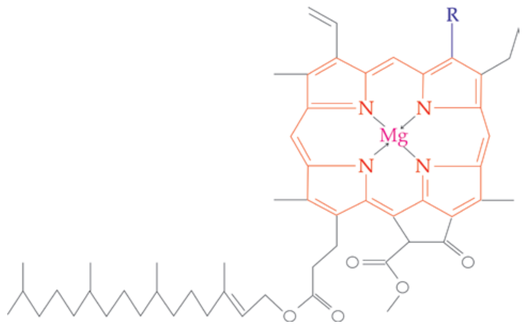
As our fuel sources become depleted, we will increasingly turn to alternative sources of energy. Of particular interest, especially in southern Africa, is solar energy, since it is clean and abundant. A novel system that harnesses solar energy is the nano-crystalline TiO2 dye-sensitised solar cell (DSC), in conjunction with several new concepts, such as nanotechnology and molecular devices. An efficient and low-cost cell can be produced by using simple materials. The production process generates very small quantities of residue, resulting in environmentally friendly devices with low-energy-demanding production techniques. Furthermore, recent developments in the area of sensitizers for these devices have led to the production of dyes that absorb across the visible spectrum, leading to higher efficiencies that hold great potential.

PHOTOSYNTHESIS

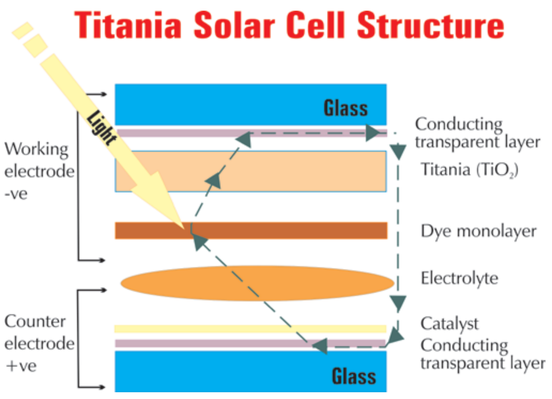


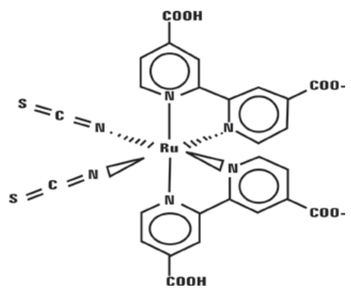
Sunlight and Chlorophyll

$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$



Chlorophyll a, R=CH_3
Chlorophyll b, R=CHO
The porphyrin ring is shown in Red





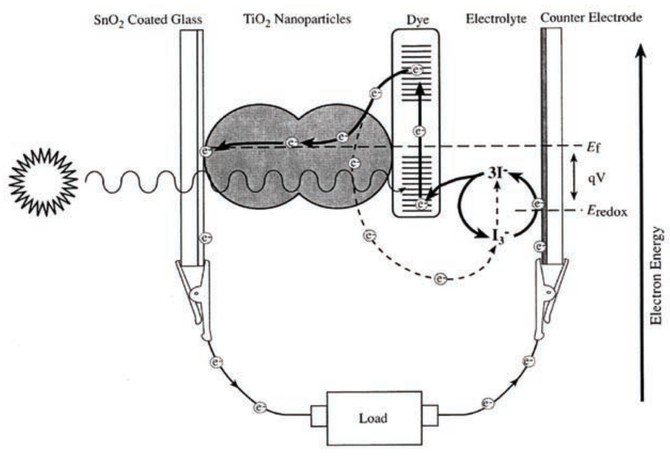
Ru(II) $\xrightarrow{h\nu}$ Ru(II)* Photo excitation of the Ruthenium complex

TiO_2 +Ru(II)* $\longrightarrow$ TiO_2(e) + Ru(III) electron injection

$3I^-$ $\xrightarrow{2Ru(III)}$ 2Ru(II) regeneration of Ru(II) by iodide at TiO_2 film

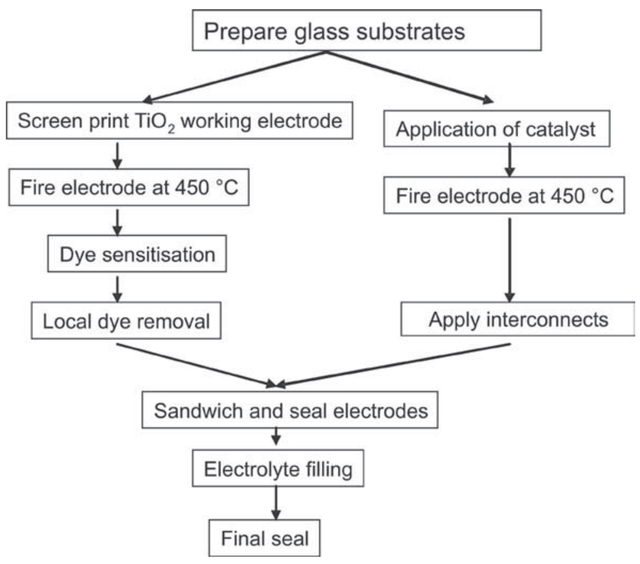
$I_3^- + 2e^- \longrightarrow 3I^-$ regeneration of iodide from triiodide at Pt electrode

MECHANISM



When light enters the cell through the glass substrate, the electrons in the Ru-dye get excited. The active components in these cells are nano-particles of titanium oxide – a semiconductor with a large band gap of 3-3.2 eV. Incident light excites the organic dye molecules on the titanium sites in the nanoporous film. This causes electrons to be released into the semiconductor layer to generate an electrical current. The band gap is too large for the electrons to fall back, which makes the process very stable. The electrolyte is regenerated in the presence of a platinum catalyst which is on the counter electrode.

CELL CONSTRUCTION



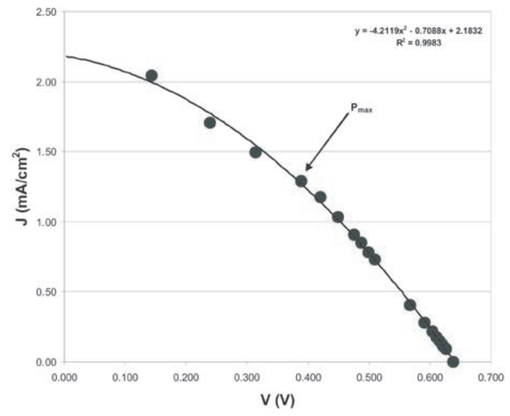
Glass substrates with a conductive layer (Indium-Tin oxide) are used for the cell construction.

Working electrode

A layer of nano-TiO_2 is deposited on the glass and treated at 450 °C. The dye is introduced onto the TiO_2 layer.

Counter electrode

The platinum catalyst (3 monolayers) is deposited onto the glass and treated at 450 °C.
The two substrates are sealed together and the electrolyte is introduced via holes in the counter electrode. The holes are sealed and the cell is ready for use.



CELL CHARACTERISATION

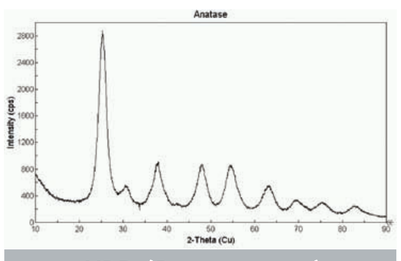
Measured in sun (P_{input} = 100 mW/cm²) and cell area = 70 cm²

P_{max} = 0.503 mW/cm²; J_{max} = 1.29 mA/cm² and V_{max} = 0.389 V

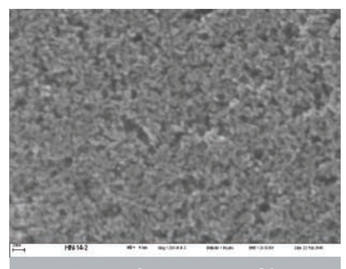
J_{sc} = 2.18 mA/cm² and V_{oc} = 0.638 V

Fill factor = 36% and n (efficiency) = 0.5%

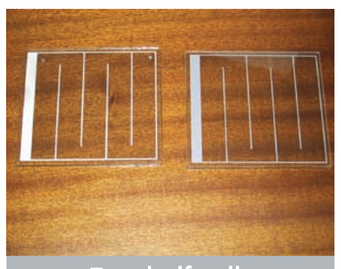
RESULTS



XRD (Pure anatase)



SEM of anatase film



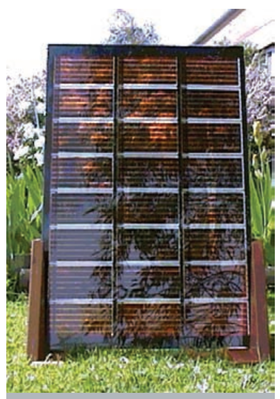
Two half cells

Complete cell

Demonstration

DSC APPLICATIONS

Façade



Module

Niche applications

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