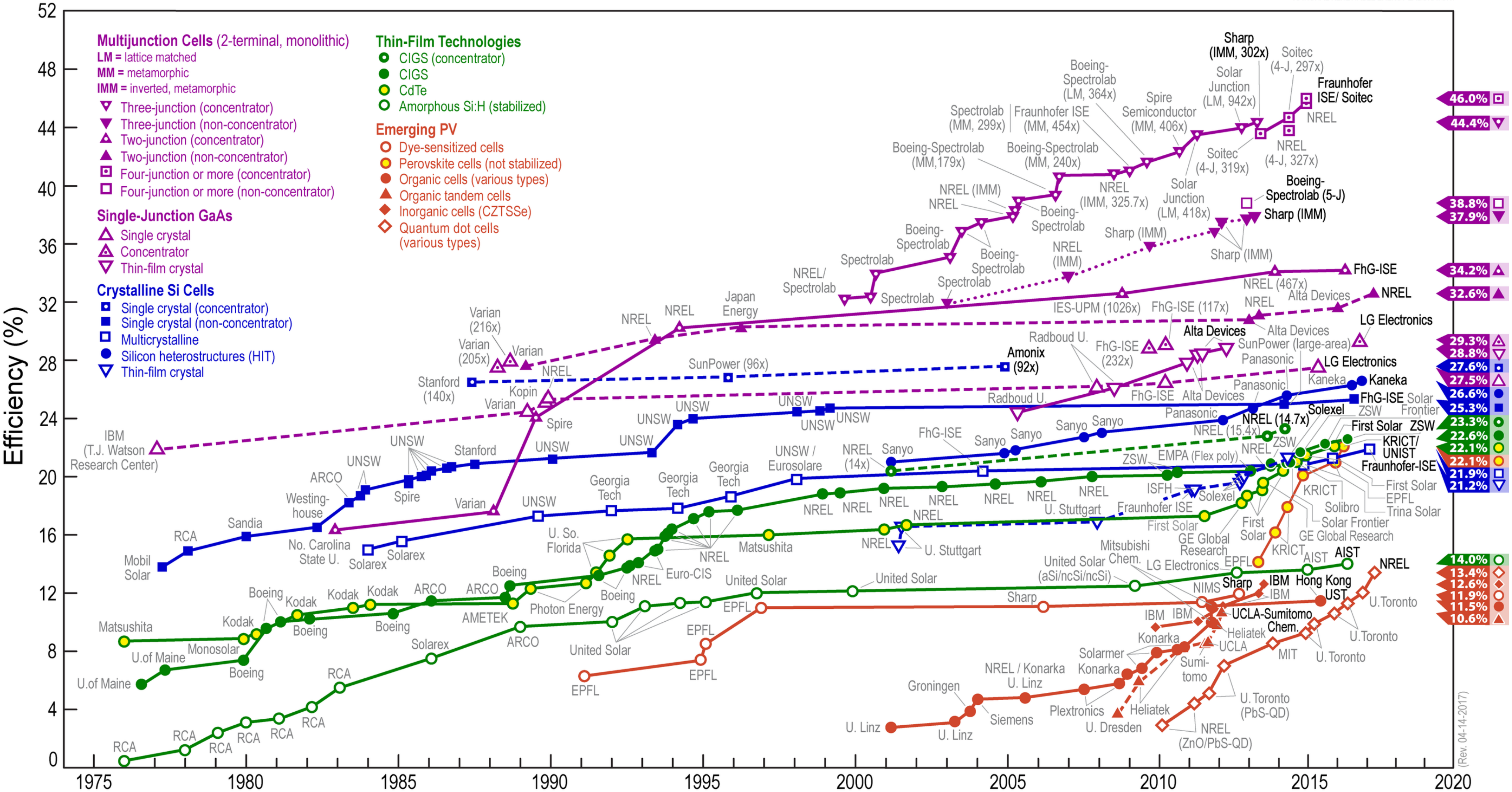
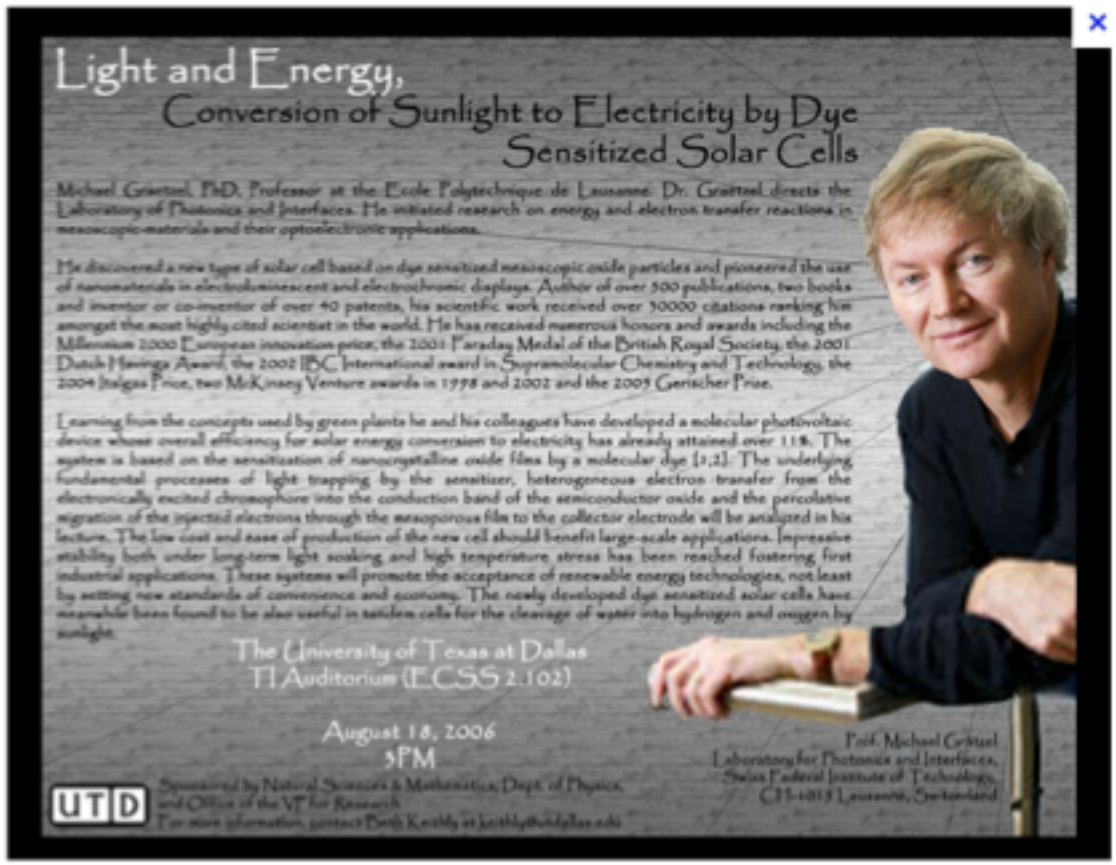
Best Research-Cell Efficiencies



[Michael Grätzel. YouTube EPFL]

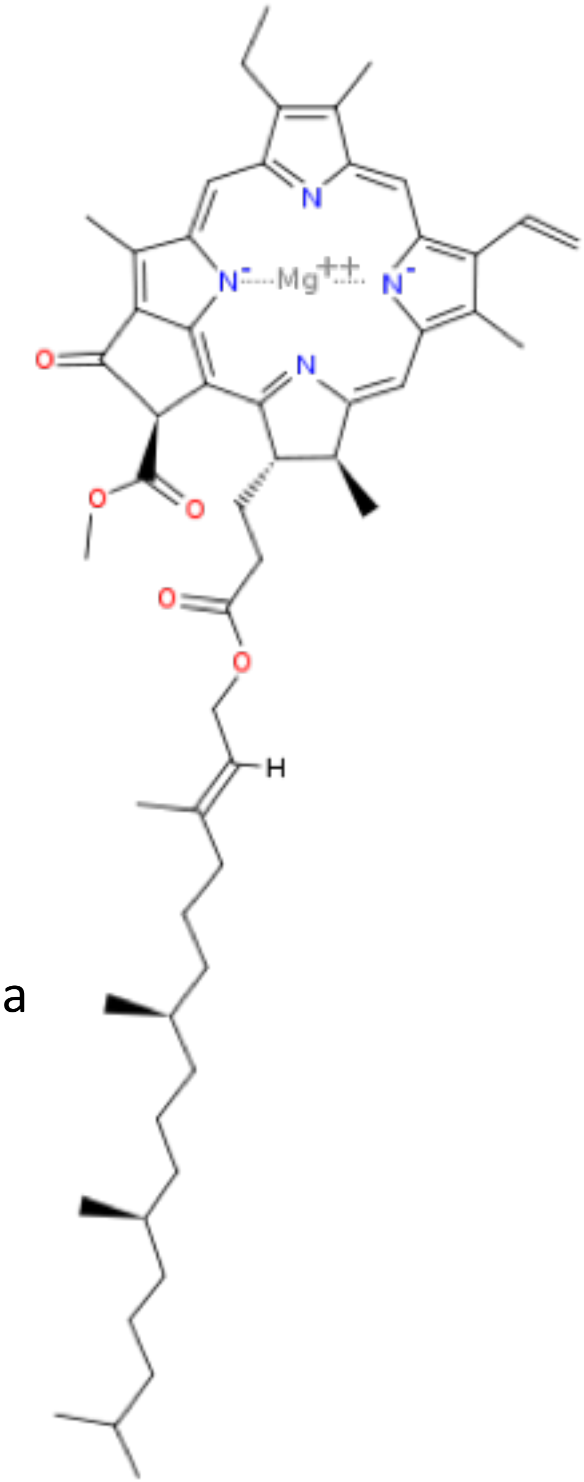
[How the cell is made]

[G24i]



Why not make an artificial leaf?

Porphyrin Ring



Chlorophyll a

(Why Green
And not Black?)

Why not make an artificial leaf?

Incident light excites electrons in porphyrin ring.

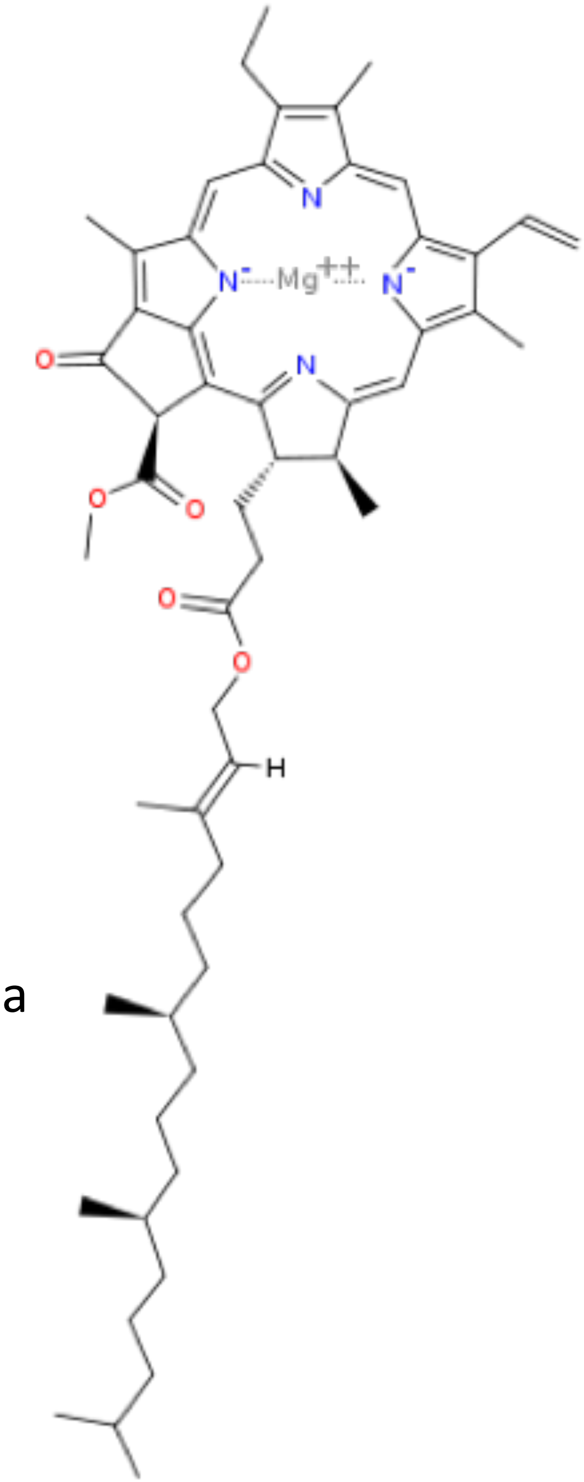
Chlorophyll is in a protein complex that separates charge.

Charged chlorophyll is reduced by oxidation of water. 2 Waters are oxidized releasing O_2 and protons, $4H^+$.

The released electrons power the transport of protons further interact with ATP for cell energy eventually reducing CO_2 to sugars.

Light

Porphyrin Ring



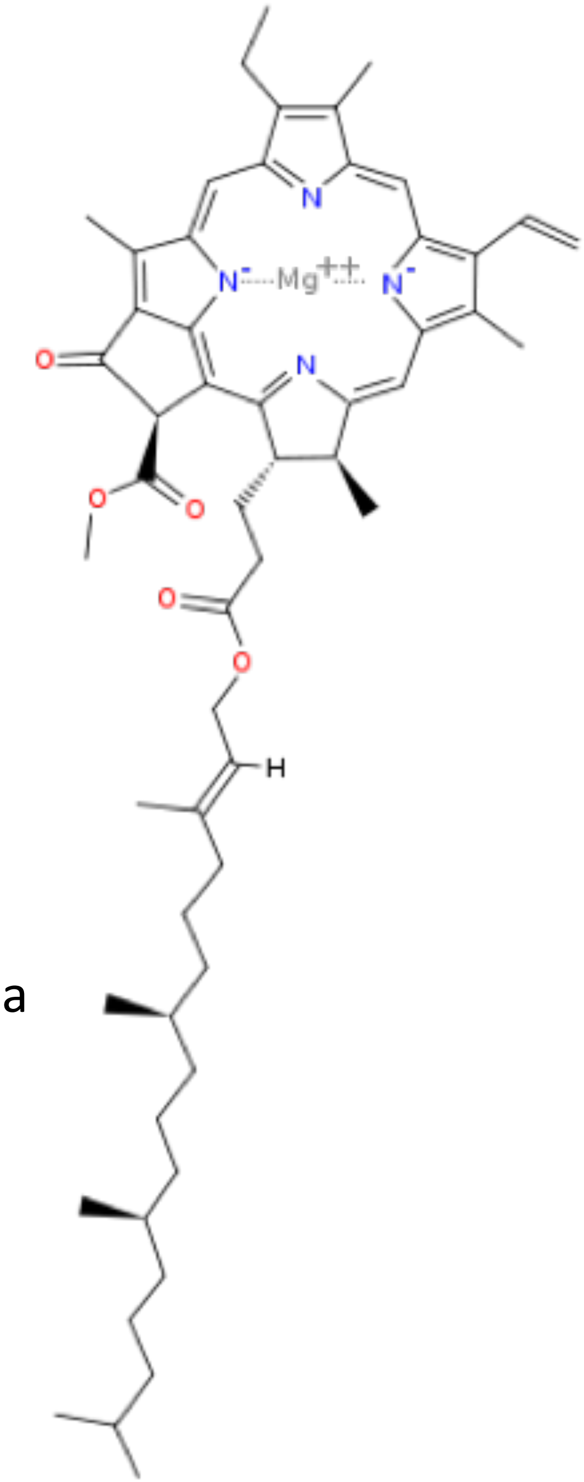
Chlorophyll a

Why not make an artificial leaf?

1970 Helmut Tributsch
and Melvin Calvin wanted to study the electrochemical properties of chlorophyll in an extra cellular environment (away from the protein).

Light

Porphyrin Ring



Chlorophyll a

They found they could achieve charge separation using large band gap semiconductors
ZnO or CdS in contact with an electrolyte.

Chlorphyll injects electrons from excited levels into the conduction band giving an anodic photocurrent.

Charge separation is irreversible.

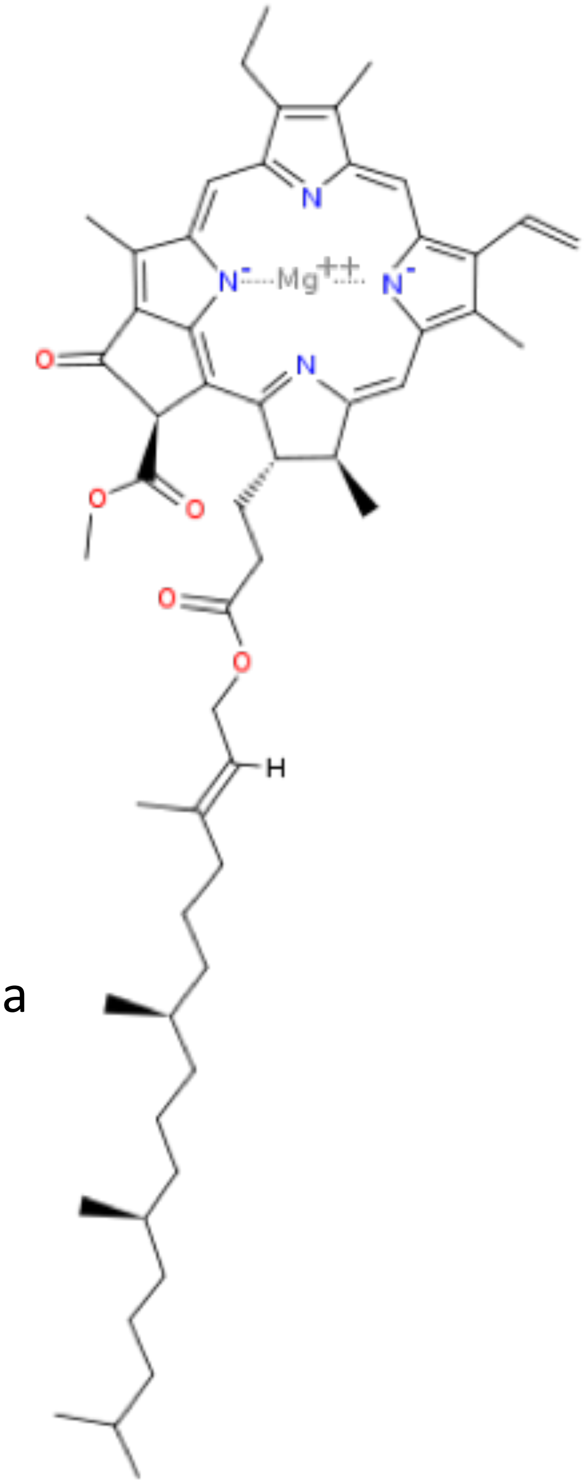
The electrolyte is oxidized at the chlorophyll molecule and is reduced at the cathode to complete the circuit.

Why not make an artificial leaf?

1970 Helmut Tributsch
and Melvin Calvin used this
process to measure the absorption
Spectrum of various chlorophylls
And other natural organic dyes.

Light

Porphyrin Ring



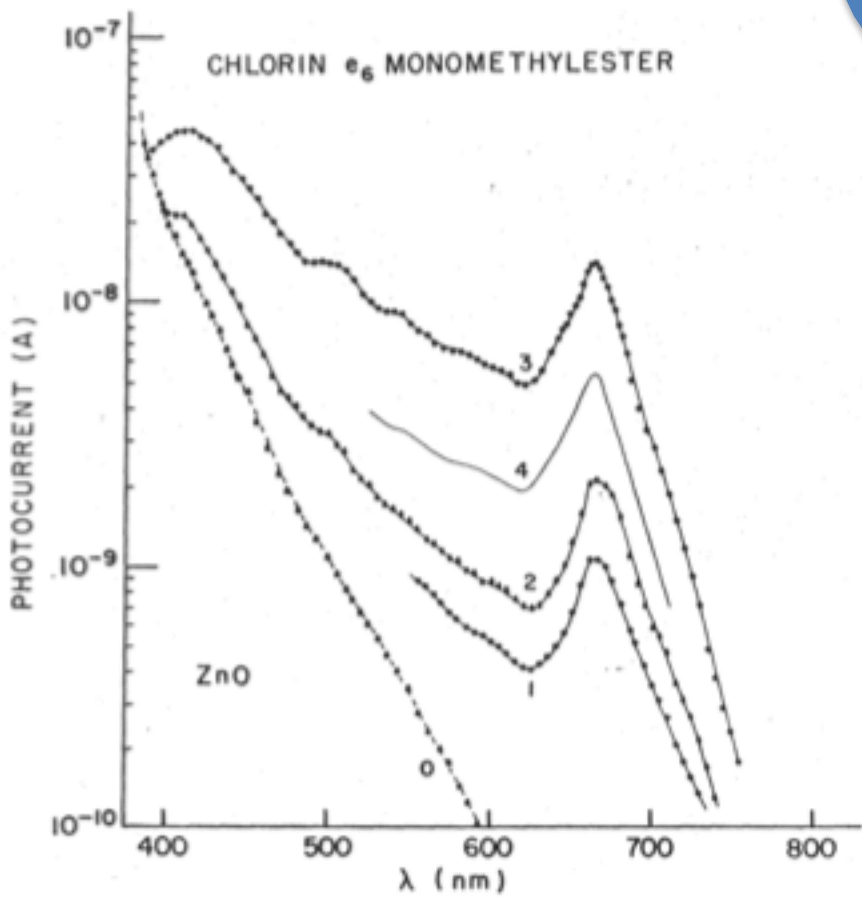
Chlorophyll a

In the absence of an energy gap
the charged chlorophyll molecule is
quenched since both holes and electrons
can be conducted in metals.

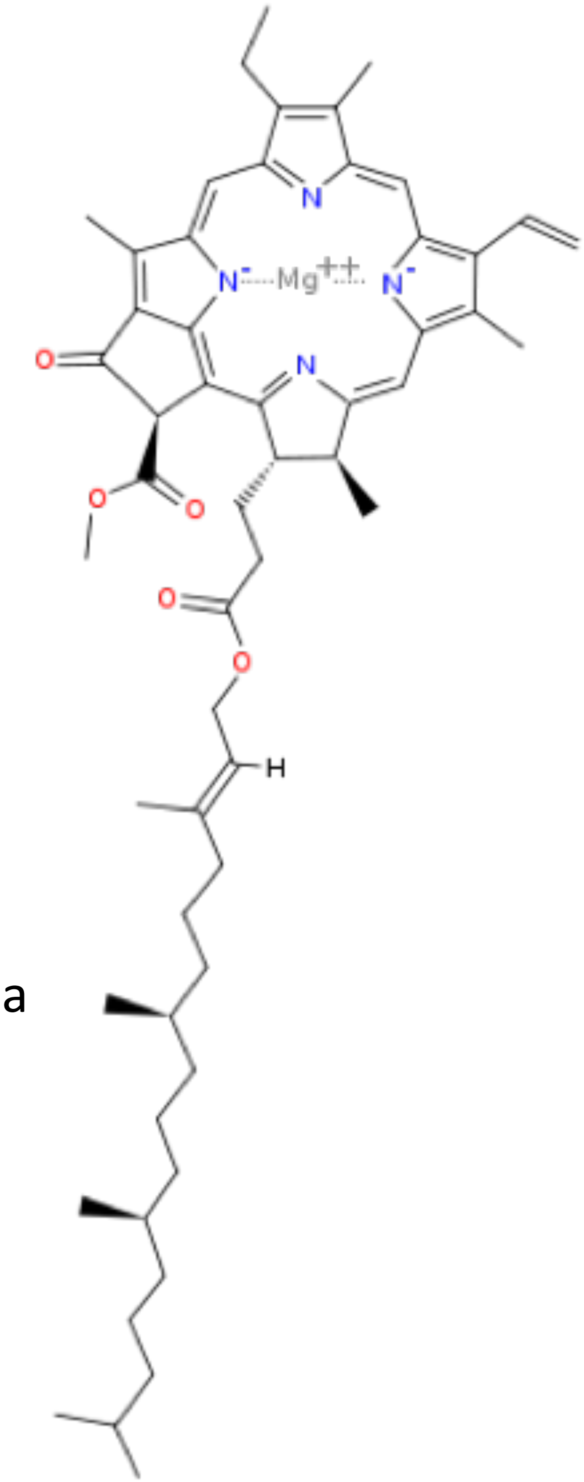
They used ZnO semiconductor anode
Platinum cathode in KCl electrolyte solution.

Why not make an artificial leaf?

Photocurrent measured



Porphyrin Ring



Chlorophyll a

Electrochimica Acta, 1968, Vol. 13, pp. 1509 to 1515. Pergamon Press. Printed in Northern Ireland

SENSITIZATION OF CHARGE INJECTION INTO SEMICONDUCTORS WITH LARGE BAND GAP*

H. GERISCHER, M. E. MICHEL-BEYERLE,
F. REBENTROST and H. TRIBUTSCH
Institut für Physikalische Chemie der Technischen Hochschule, München, Bundesrepublik Deutschland

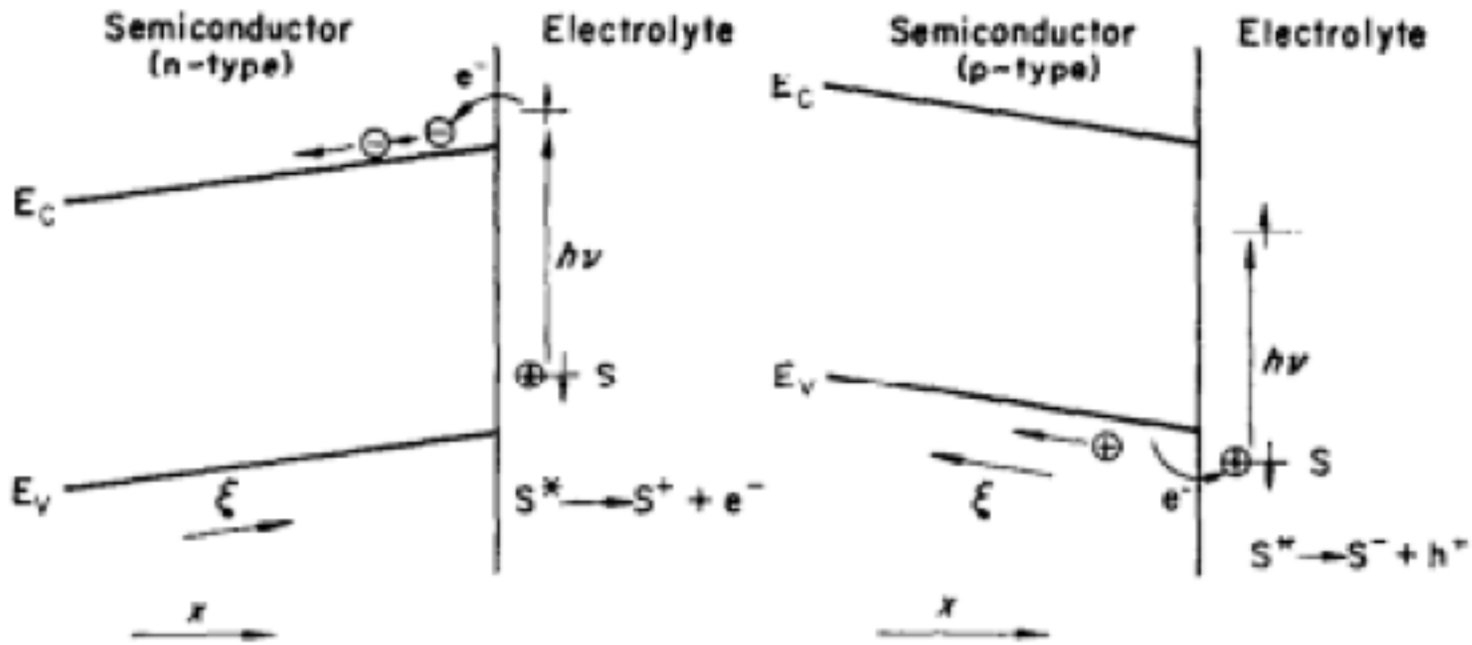


FIG. 8. Sensitized charge transfer at semiconductor electrodes.

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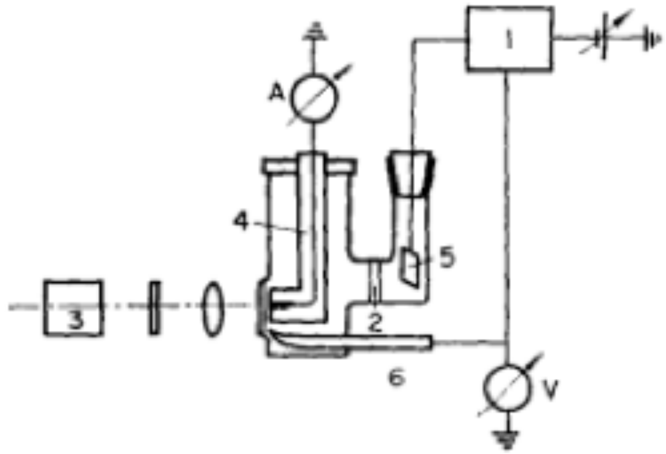

Fig. 1. Circuit for steady-state measurements with zn 0 single-crystal electrode. 1, potentiostat; 2, diaphragm; 3, light source; 4, specimen holder; 5, inert electrode; 6, luggin capillary.

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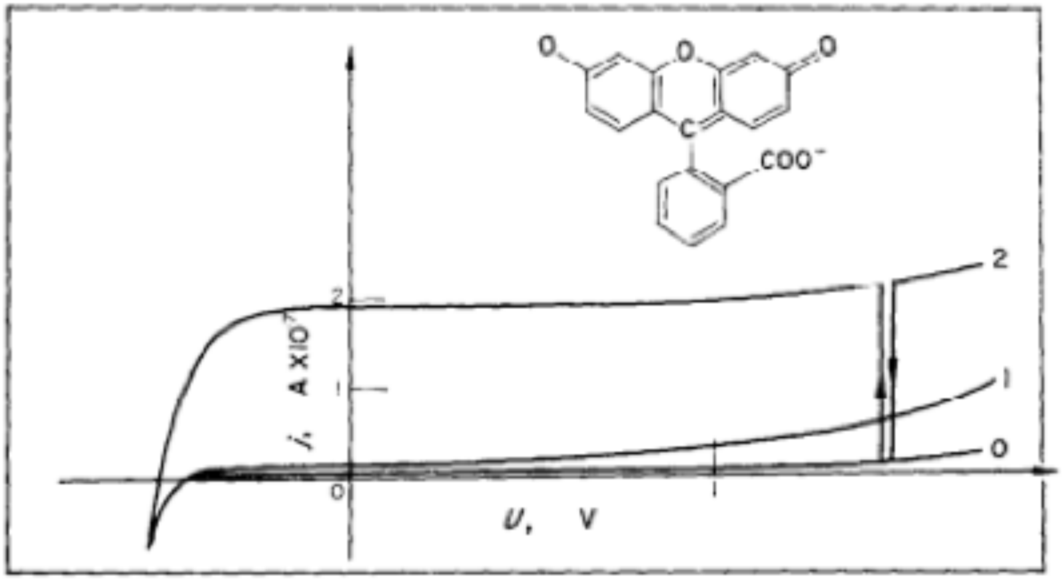

FIG. 2. Current/voltage characteristic for zinc-oxide single-crystal electrode-
0, without illumination and without dye; 1, with illumination and without dye;
2, with illumination and with dye.
Effect of switching off the light is indicated by the arrows.

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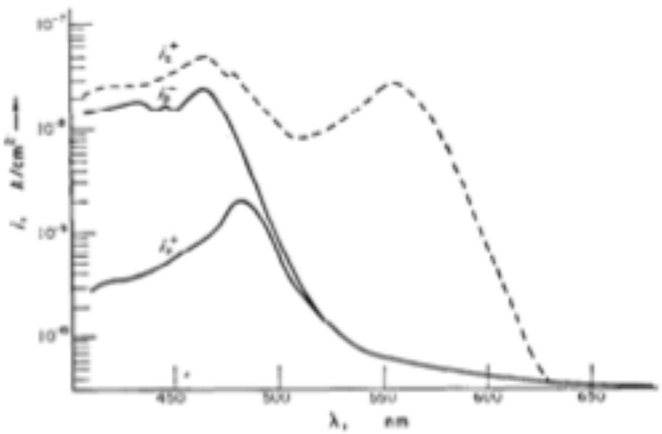

FIG. 6. Spectral dependence of the photocurrent i_p and the photosensitized current i_s at perylene single-crystal electrodes.
i^- refers to currents with electrode A (see Fig. 5) negative, i^+ to currents with electrode A positive. The subscript p indicates the photocurrent due to absorption of light by the perylene crystal; the subscript s means the limiting current due to absorption of light by the dye adsorbed at the perylene/solution interface; the first peak corresponds to the absorption edge of the crystal, the second to the absorption maximum of the dye. The dye was rhodamine B (*ca* 10^{-5} M).

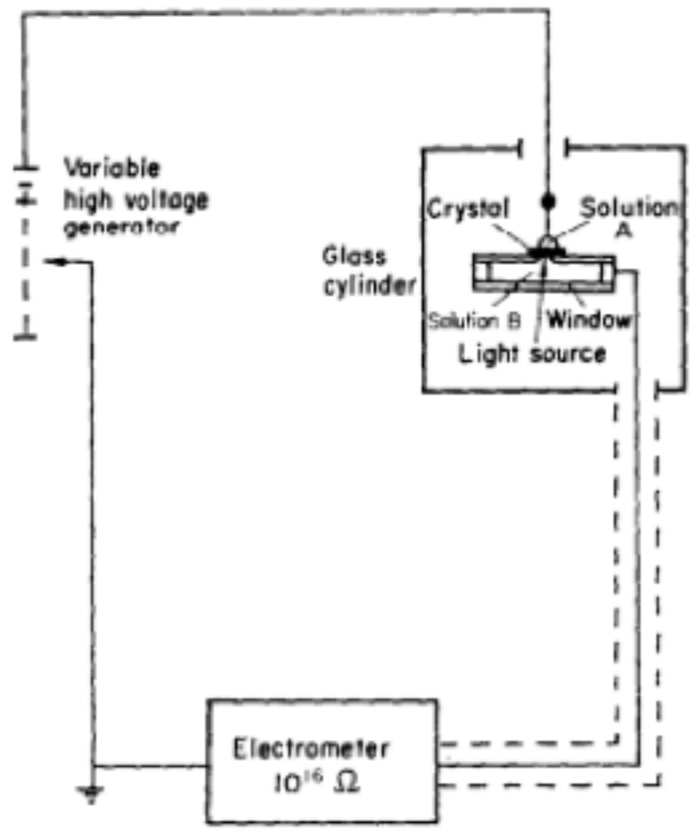

FIG. 5. Circuit for steady-state measurements of dye sensitized photocurrents.

Ind. Eng. Chem. Prod. Res. Dev. **1980**, *19*, 415–421

Dye Sensitization and Surface Structures of Semiconductor Electrodes

Michio Matsumura, Shigeyuki Matsudaira, and Hiroshi Tsubomura*

Department of Chemistry, Faculty of Engineering Science, Osaka University, Toyonaka, Osaka, 560, Japan

Masasuke Takata and Hiroaki Yanagida

Department of Chemistry, Faculty of Engineering, University of Tokyo, Tokyo, 113, Japan

The dye-sensitization effects on the ZnO, CdS, and TiO_2 electrodes in electrochemical photocells were investigated for anionic, cationic, and zwitterionic dyes. The most efficient dye-sensitized photocell was achieved by using an aluminum-doped porous ZnO sinter electrode dyed with rose bengal (an anionic dye), the energy conversion efficiency being 2.5% for incident light of 562 nm. The effect of aluminum doping was attributed to the increase of the porosity (or surface area) of the sinter and the decrease of the electrical resistance. The effect of pH and the added salts in the solution as well as the effect of crystal face were extensively investigated. It turned out that these effects mainly influence the adsorptivity of the electrode surfaces for the sensitizing dyes, not the intrinsic current quantum efficiency. From these results, the structures of the dyes on the semiconductor surfaces were discussed in relation with the mechanism of photoinjection of electrons. The merits of dye-sensitized photoelectrodes as a photoenergy converter were discussed.

Ind. Eng. Chem. Prod. Res. Dev. **1980**, *19*, 415–421

Use a Porous electrode to improve efficiency
Lifetime still a problem

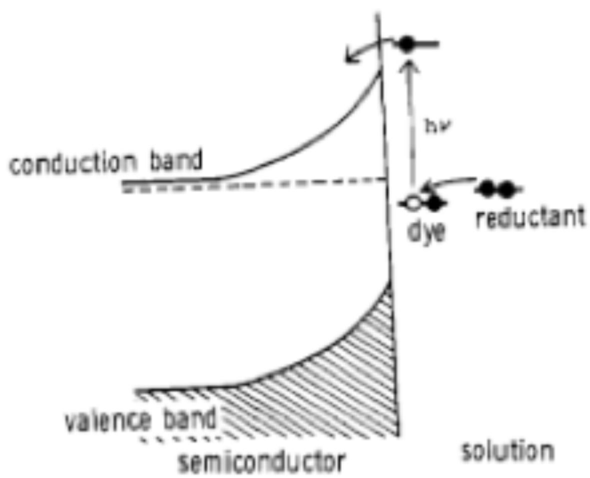

Figure 1. A model for the electron injection from an excited dye into an n-type semiconductor.

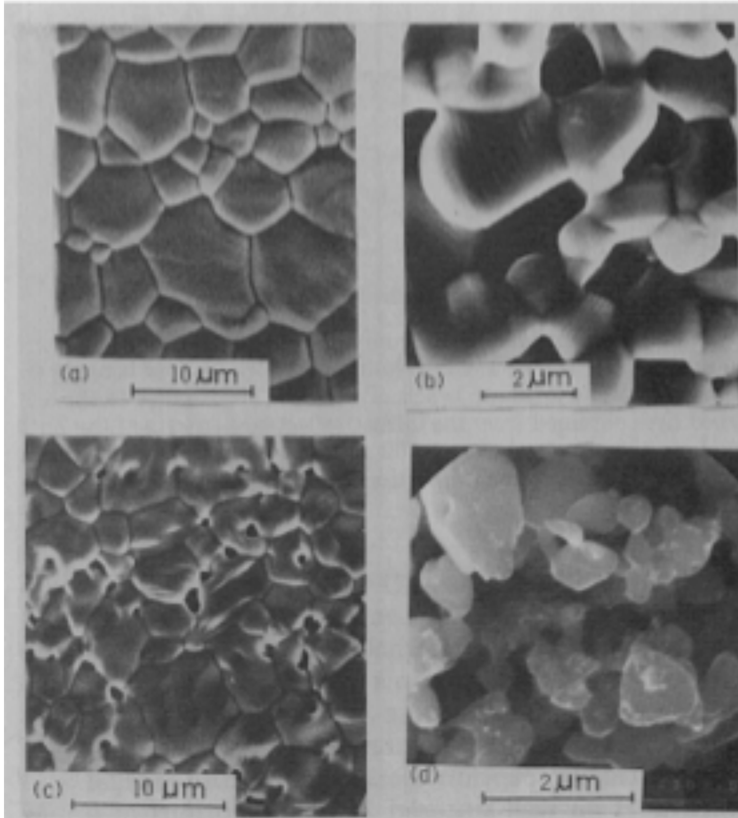

Figure 2. Scanning electron micrographs of the ZnO sinter obtained by sintering various ZnO powder materials at 1300 °C for 1 h: (a) pure ZnO; (b) ZnO powder washed with 2 M (= mol dm^{-3}) HCl for ca. 1 min; (c) ZnO powder containing $ZnCO_3$ (25% by weight); (d) ZnO powder doped with 0.5 mol % Al_2O_3.

Optimum porous electrode is pyrolytic titania made in a spray flame as a Pigment in white paint, paper etc.

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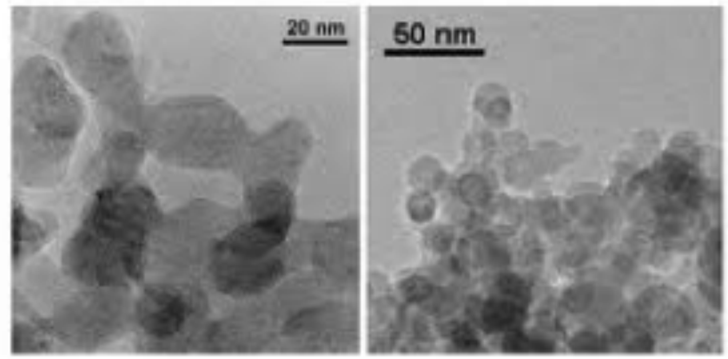
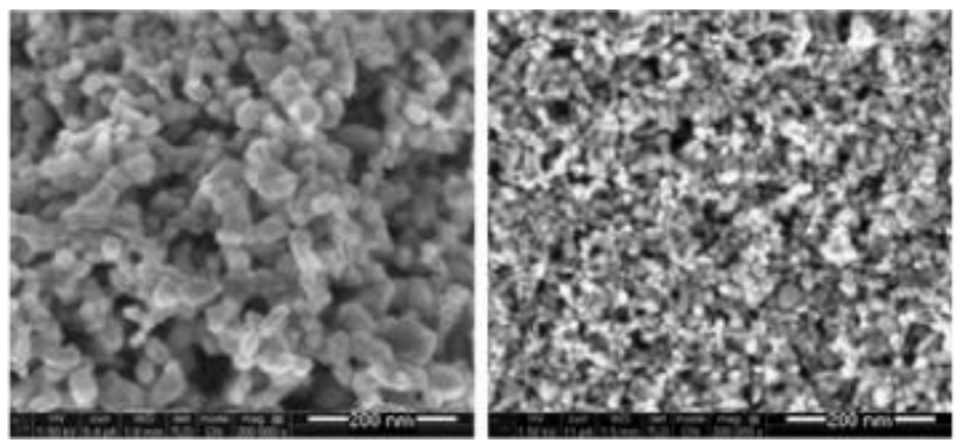


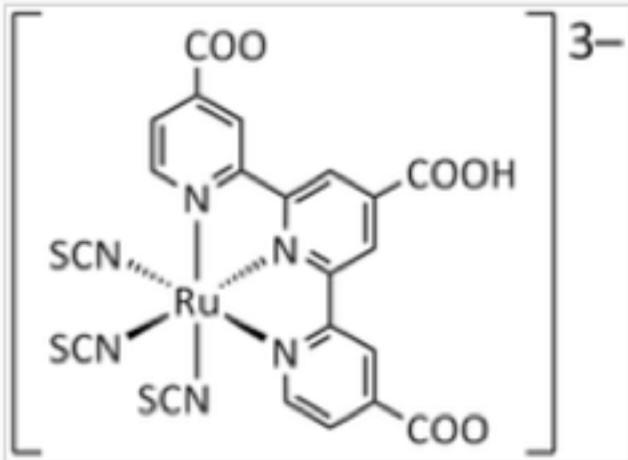
Fig. 1: Transmission electron micrograph of flame-made amorphous calcium carbonate (left) and calcium phosphate (right) nanoparticles. The morphology resembles the structure of fumed silica.



Compared to a silicon solar cell the Grätzel cell separates duties that are done by the pn-junction.

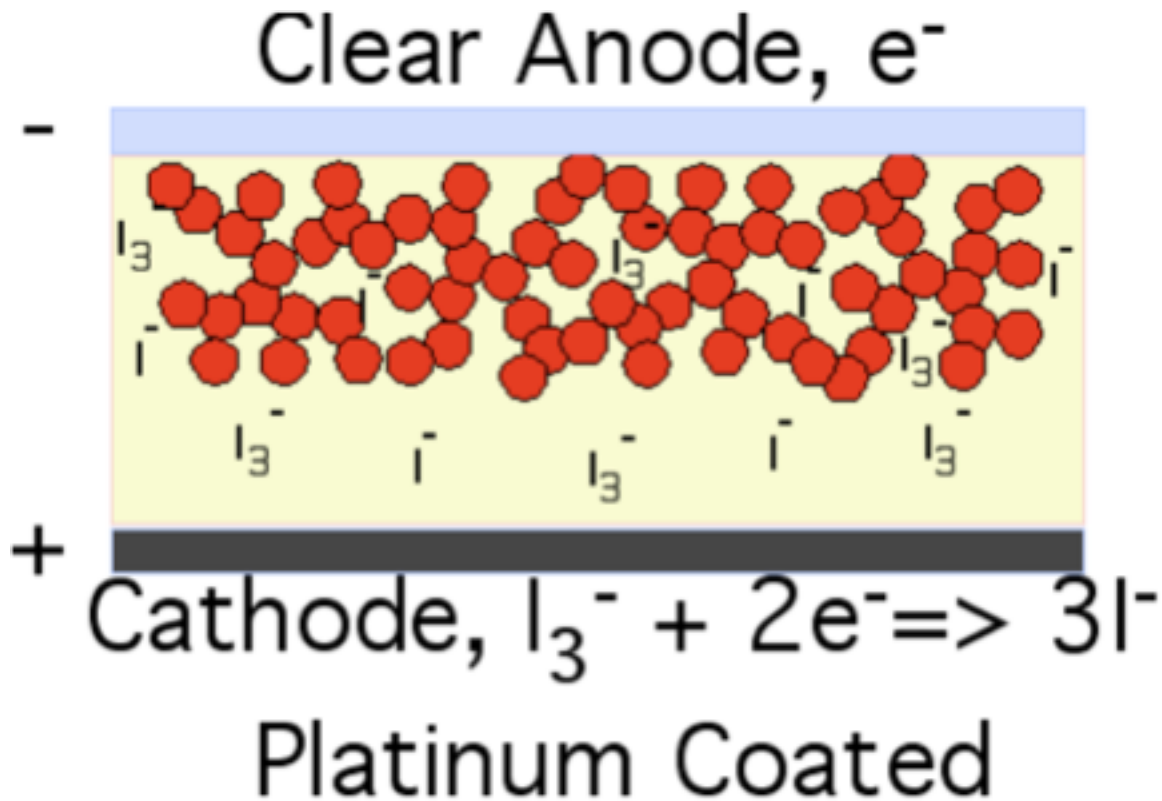
Electron-hole pair are generated in the dye molecule (depletion zone in Si). Charge separation occurs at the dye/semiconductor interface due to the band gap in the semiconductor an ionization energy level difference between the dye and semiconductor conduction band (for electrons) or valence band (for holes). This is done also by the pn junction in silicon.

Charge transport is done by the semiconductor and the anode. At the cathode the elecrolyte is reduced and an electron is carried to the dye molecule to compete the circuit. This is all done by the silicon in a pn-junction cell.



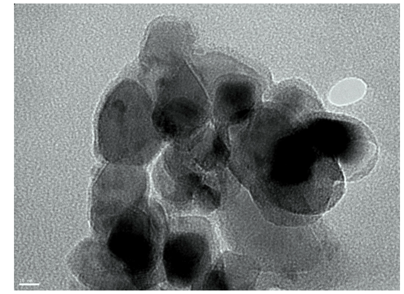
"Black Dye", an anionic Ru-terpyridine complex

One type of simple photovoltaic device that could be produced in Africa



Schematic of a Graetzel Cell. Red circles are titania aggregates coated with a dye. Pink background is an iodide electrolyte gel. Platinum coated cathode is at the bottom and a clear plastic sheet coated with fluorine doped tin oxide anode is at the top.

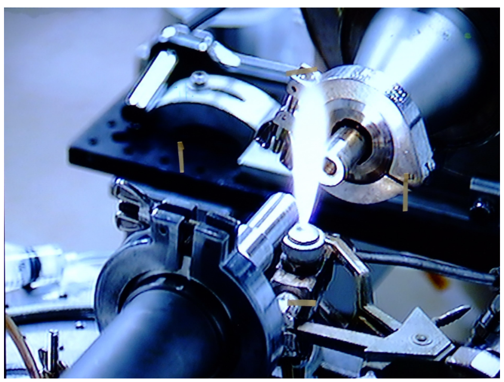
Grätzel Cell Production by Spray Flame

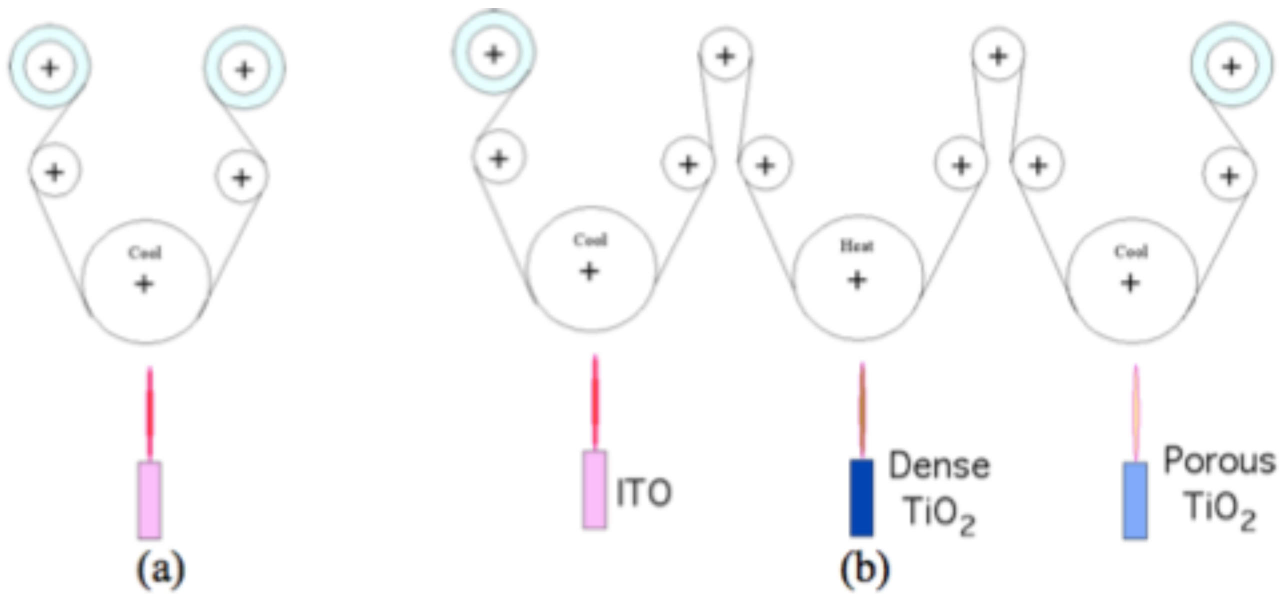


-Dye/titania development for inexpensive single step synthesis

-Use carbon coated titania to enhance interaction
-Use in situ synthesized CdS nano particles supported on titania

-A single reel-to-reel, flame-based process for coating of plastic substrates in a continuous process for flexible solar cell sheets.





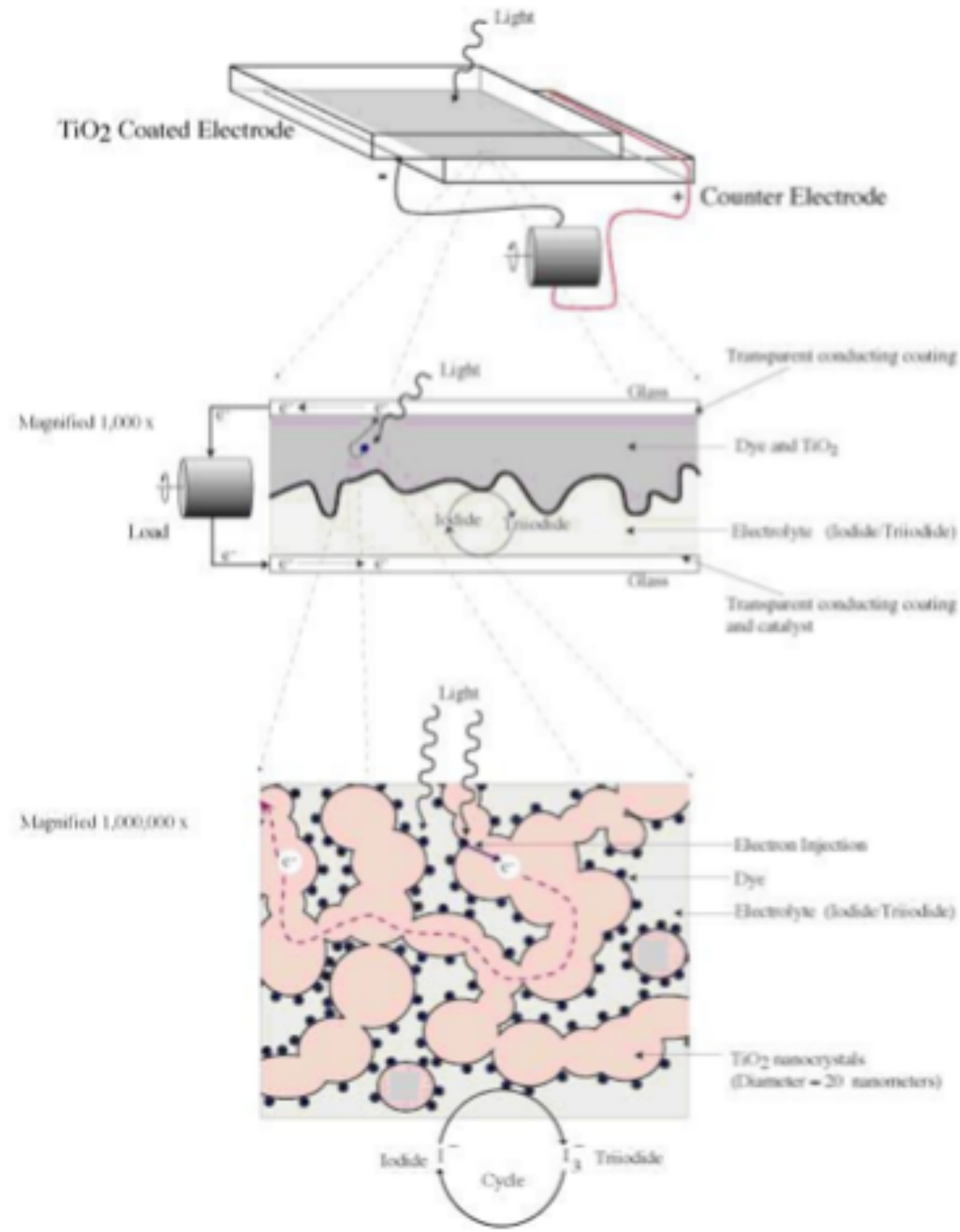
Grätzel Cell or Dye Sensitized Solar Cell

Web link to Grätzel Cell Fabrication

College/High School Lab to Make a DSSC

Grätzel Cell or Dye Sensitized Solar Cell

Lab UTexas



http://www.solideas.com/solrcell/howworks.html

Grätzel Cell or Dye Sensitized Solar Cell

Lab UTexas

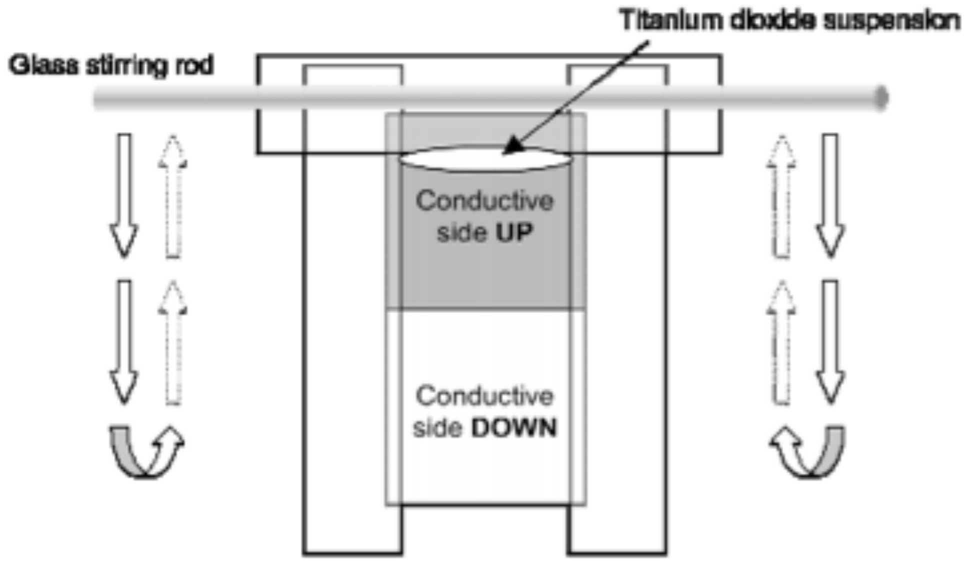


Figure 2 Diagram of how to make a thin layer of TiO_2 on the glass slide.

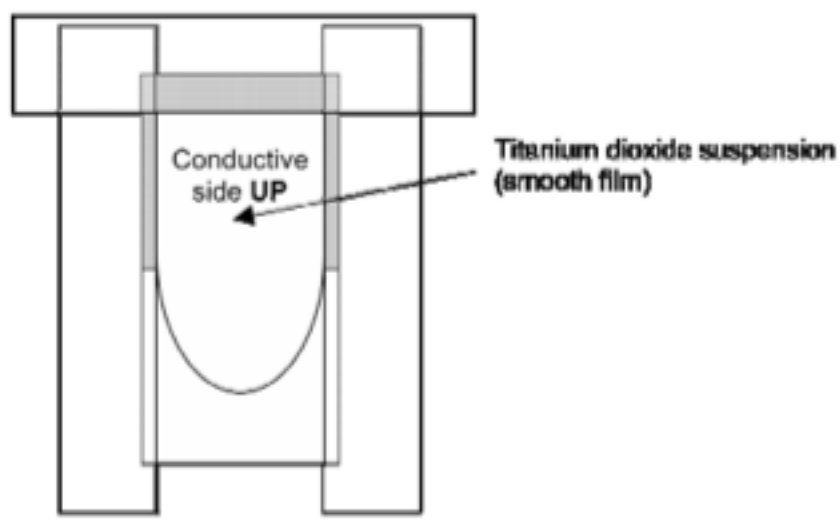
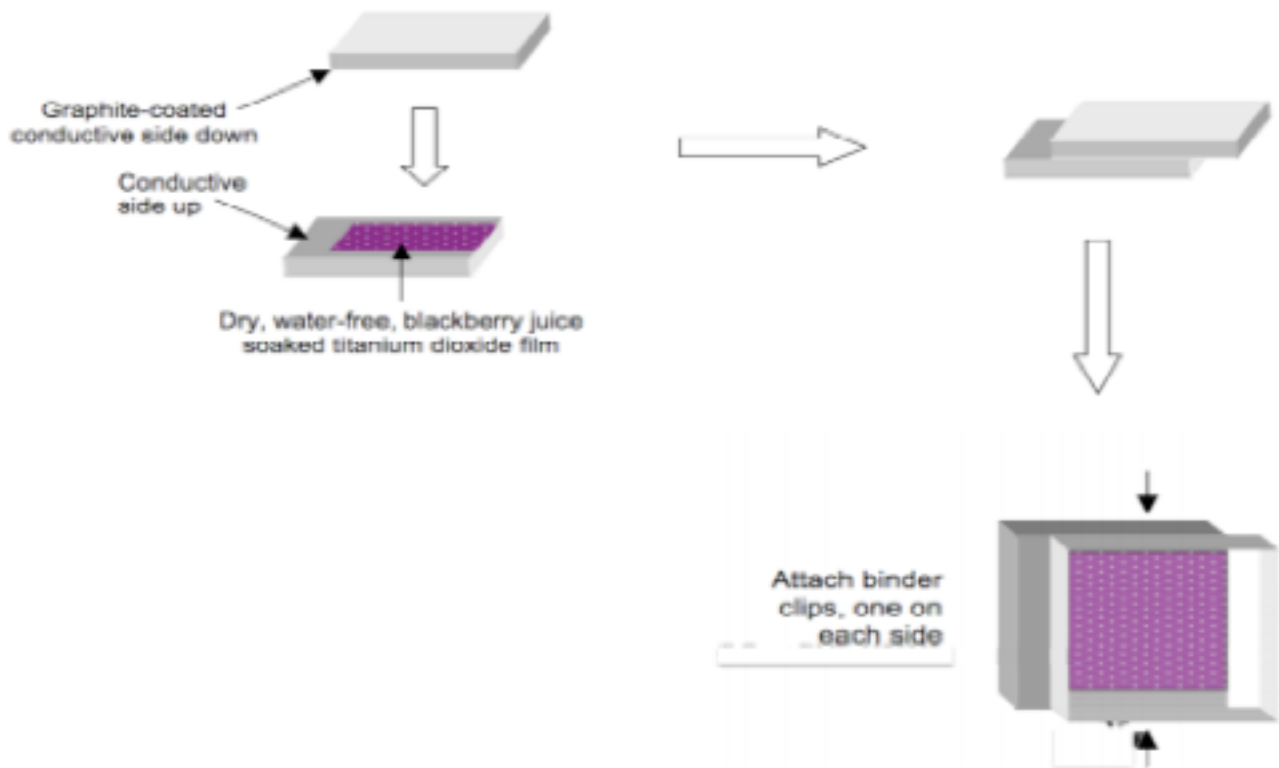


Figure 3 The TiO_2 will cover all of the slide with the conductive side up.

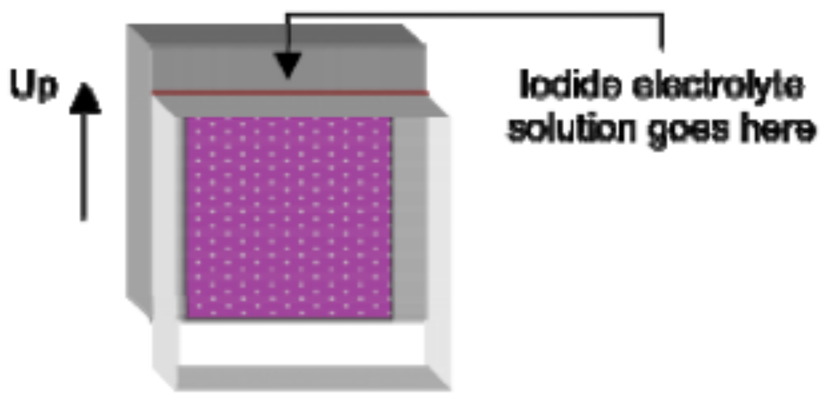
Grätzel Cell or Dye Sensitized Solar Cell

Lab UTexas

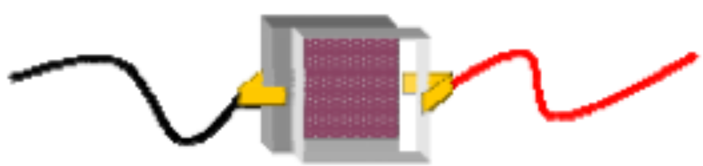


Grätzel Cell or Dye Sensitized Solar Cell

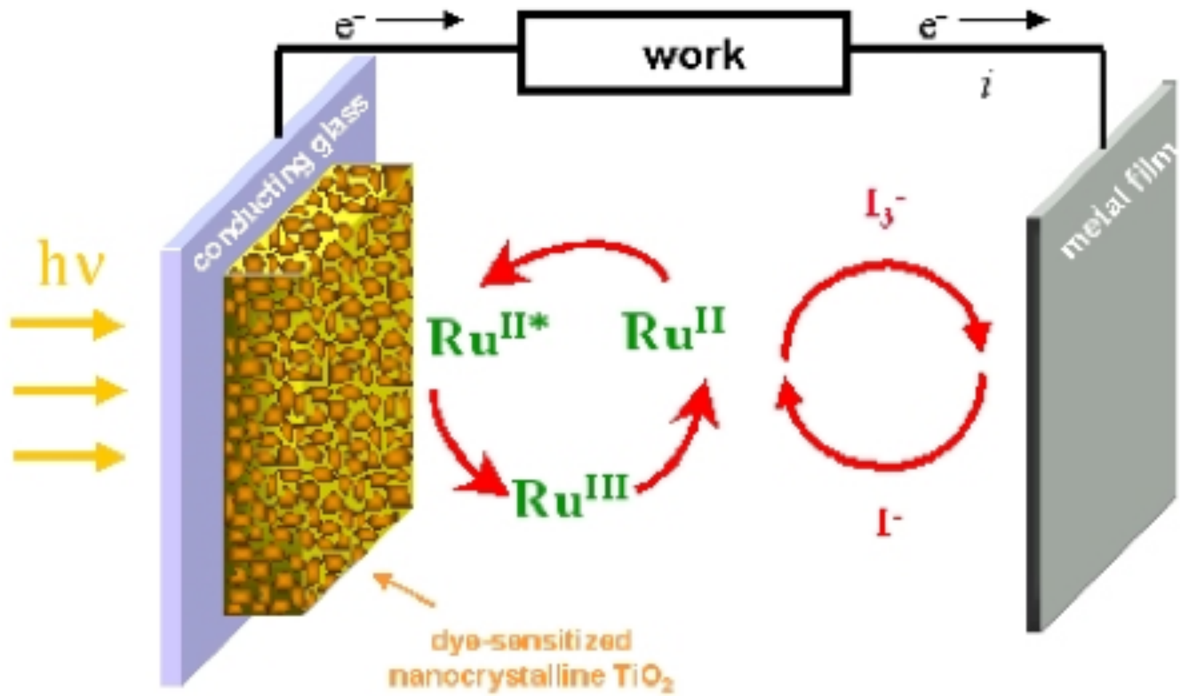
Lab UTexas



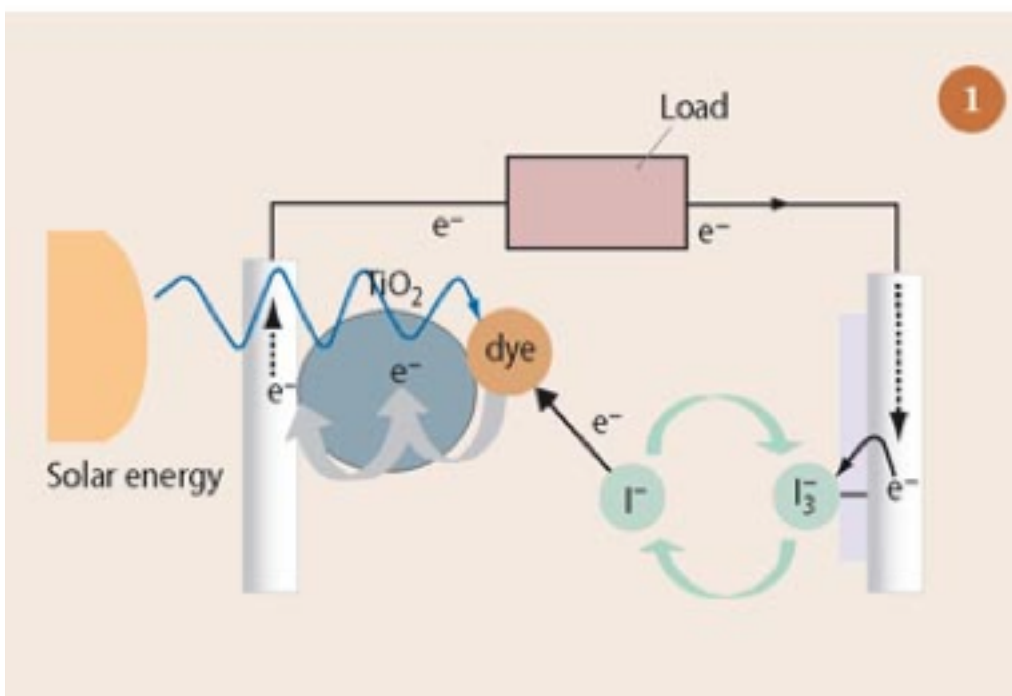
15. Your solar cell is complete! Now, get a multimeter and use the alligator clip leads to attach your cell to the multimeter, in the positions shown below (make sure neither alligator clip touches both slides). Measure both the voltage and the current output of your cell in light and in darkness, and examine its behavior (ask an instructor to assist in this step).



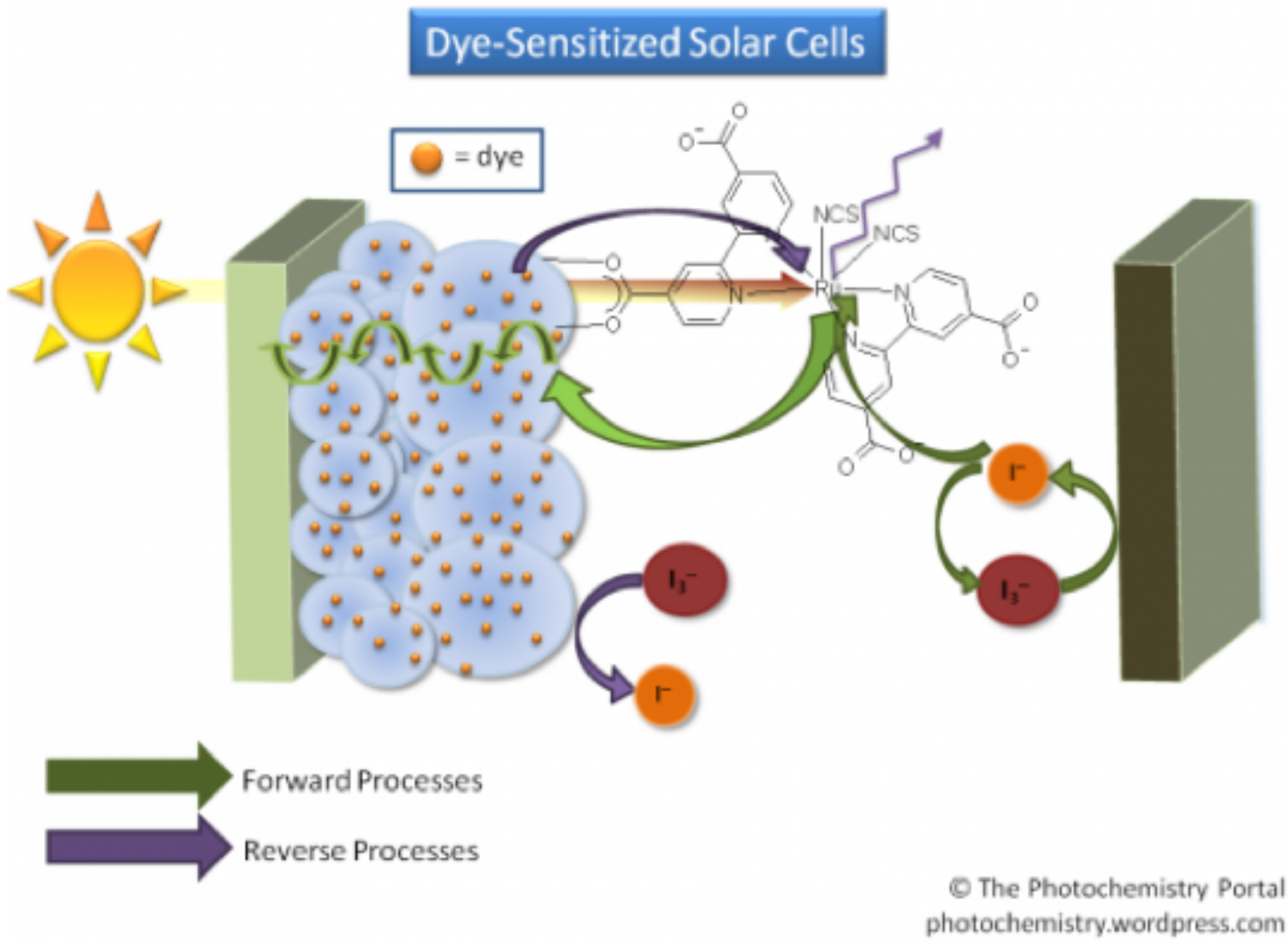
Grätzel Cell or Dye Sensitized Solar Cell



Grätzel Cell or Dye Sensitized Solar Cell

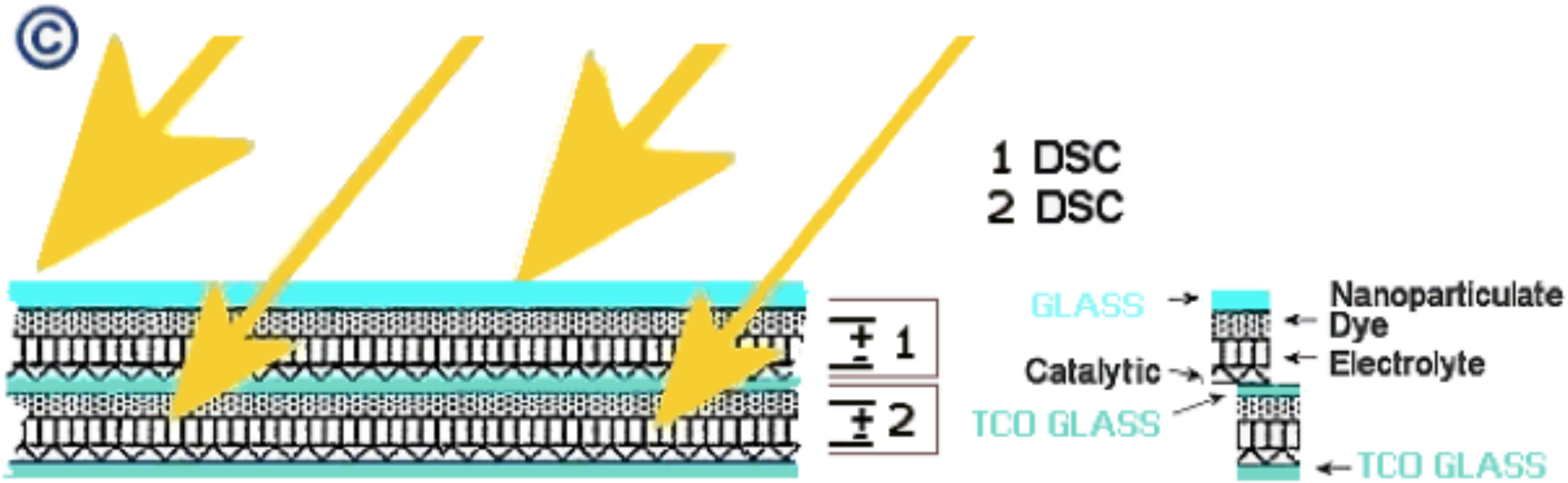


Grätzel Cell or Dye Sensitized Solar Cell

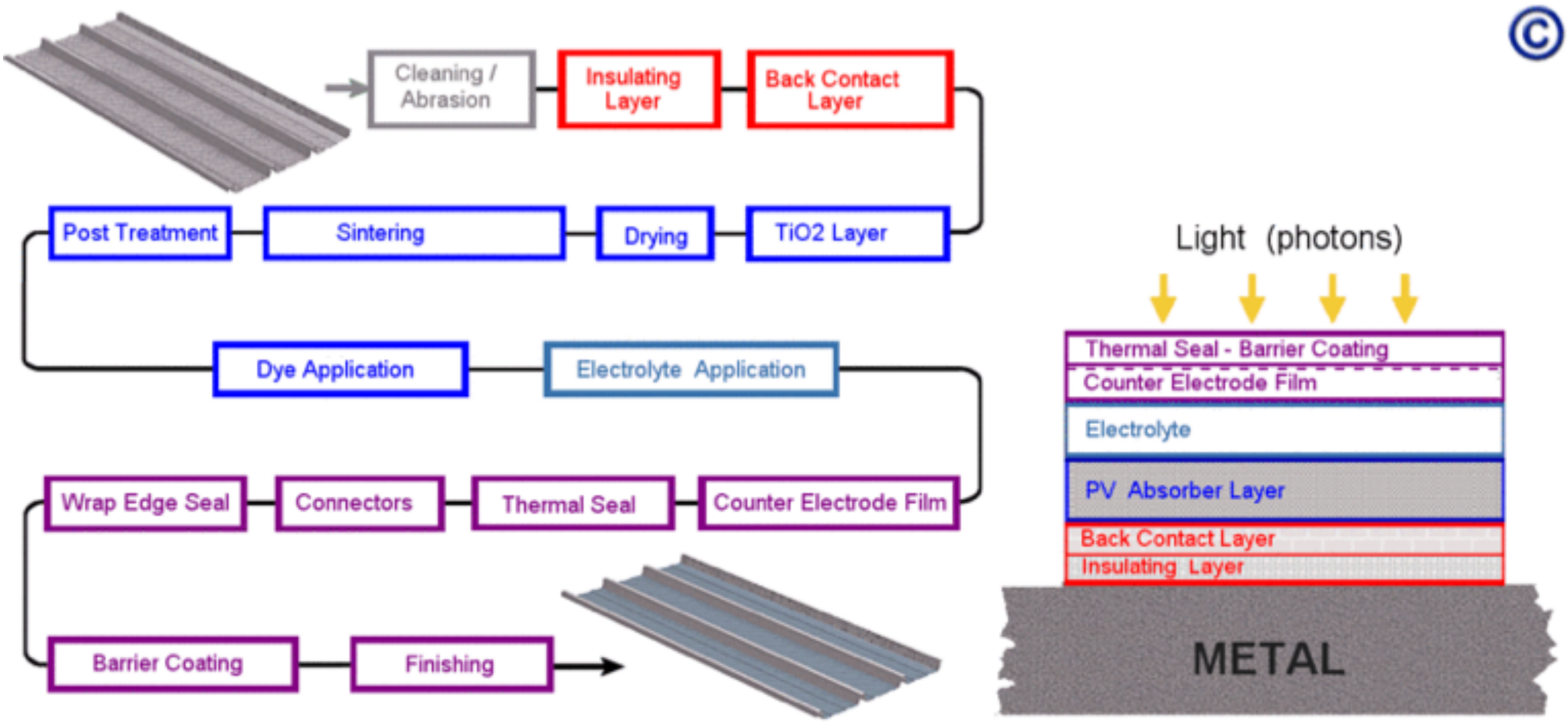


Grätzel Cell or Dye Sensitized Solar Cell

Dyesol, Queanbevan, New South Wales



[Dyesol, Queanbeyan, New South Wales]



How to Make a Perovskite Cell

Solaronix Switzerland

Purchase DS Solar Cells

DSSC Chemicals for Sale

Solaronix Switzerland

Sony DSSCs

Gcell (Video in bottom left)

G24innovations Australia

Fujikura

Perovskite Solar Cell

Perovskite Improvements Park

TED Talk on Perovskite