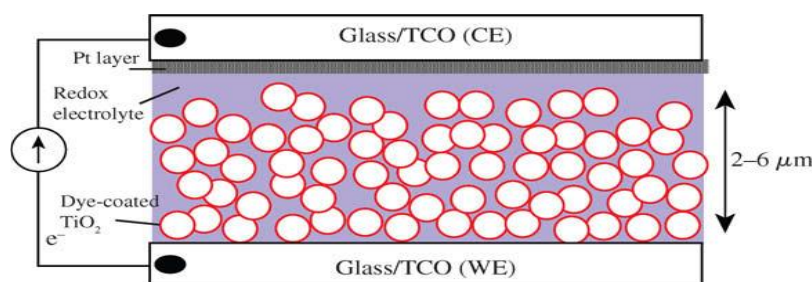


## Dye-sensitized solar cells

A DSC is basically a thin-layer solar cell formed by sandwich arrangements of two transparent conducting oxides electrodes (ITO coated glass).



- The main electrode has a few-micron-thick mesoporous TiO<sub>2</sub> layer coated with a photosensitizer.
- The counter-electrode is composed of islands of finely divided Pt deposited onto another ITO coated glass substrate.
- The inter-layer space is filled with an organic electrolyte containing a redox mediator, usually a mixture of iodine and iodide in a low viscosity organic solvent such as acetonitrile.
- Best solar conversion efficiency obtained for this type of DSC is in the range of 11-12 % for laboratory scale cells (area < 1 cm<sup>2</sup>) and around 8.5 % for large-area modules (100 cm<sup>2</sup>).

### Materials used:

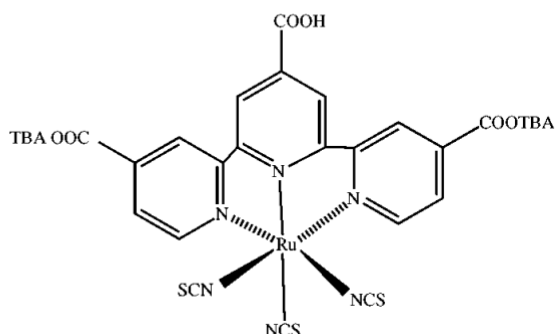
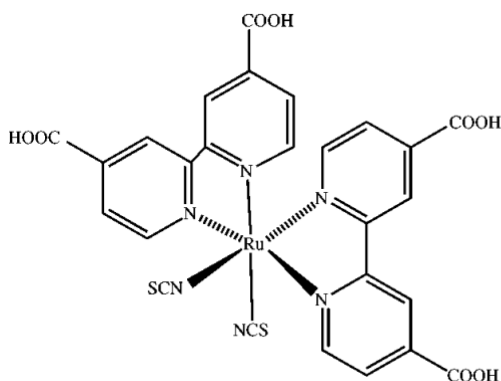
#### Photoelectrode:

- Many wide-bandgap oxide semiconductors (TiO<sub>2</sub>, ZnO, SnO<sub>2</sub>, ...) have been examined as potential electron acceptors for DSCs. TiO<sub>2</sub> turned out to be the most versatile, delivering the highest solar-conversion efficiency.
- TiO<sub>2</sub> is chemically stable, nontoxic and readily available in vast quantities.
- In the standard version of DSCs, typical film thickness is 2-15 μm, and the films are deposited using nanosized particles of 10-30 nm TiO<sub>2</sub> using colloidal particles prepared by sol-gel technique. The dye sensitizer is deposited on the TiO<sub>2</sub> by immersion in a solution of the dye.

#### Dye sensitizer:

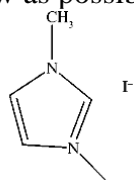
Desirable properties for a photosensitizer:

- strong light absorption in the visible and near-IR region (for efficient light harvesting)
- good solubility in organic solvents (for facile deposition from stock solutions in few hours or less)
- presence of suitable peripheral anchoring ligands such as -COOH (to promote the effective interaction of the dye with the oxide surface and thus the coupling of donor and acceptor levels)
- suitable disposition of the HOMO and LUMO of the dye molecule (to permit quantitative injection of charges from their electronically excited states to the TiO<sub>2</sub>)
- good thermal stability and good chemical stability (to retain the chemical identity over repetitive oxido-reduction cycles).
- Examples of dyes that function well in DSCs are coordination complexes of Ru and Os



### Electrolytes for the DSC:

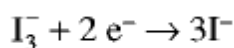
- The electrolyte plays a very important role in the DSC by facilitating the transport of charge between the working and counter electrodes (WE and CE).
- Among the many redox mediators examined, the iodide/triiodide couple has been found to be the best. Under optimized conditions, the iodide has a concentration of a few millimolar (and iodine ten times greater), dissolved in acetonitrile.
- The ionic liquid methylpropylimidazolium iodide is used as the iodide source. Since the  $I/I_3^-$  mixture also absorbs in the visible-light region, their concentrations have to be kept as low as possible.



Alkylimidazolium iodide

### The counter electrode:

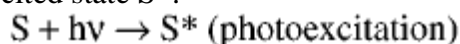
- To balance the charge and regenerate the key components, the oxidized form of the mediator needs to be reduced by the electrons flowing through the external circuit passing through the counter electrode.
- To reduce losses, the counter-electrode material should show good electrocatalytic properties. The material of choice has been platinum. Very low quantities of platinum is deposited onto ITO coated glass (a few  $\mu\text{g}/\text{cm}^2$ ) as finely divided particles. As an electrode material, Pt shows excellent chemical stability.



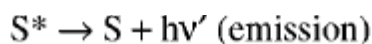
### WORKING PRINCIPLE

Exposure of the DSC assembly to visible light leads to a sequence of reactions .

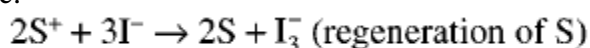
- At the anode, where the absorption of the light by the dye S leads to formation of its electronically excited state  $S^*$ :



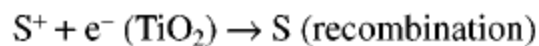
- The molecule in the excited state can decay back to the ground state or undergo oxidative quenching, injecting electrons into the conduction band of  $\text{TiO}_2$ .



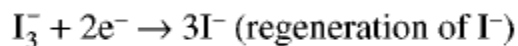
- The injected electrons travel through the mesoporous network of  $\text{TiO}_2$  particles to reach the back-collector electrode to pass through the external circuit.
- The oxidized dye is reduced rapidly to the ground state by the donor (iodide) present in the electrolyte:



**Note:** In the absence of a redox mediator to intercept and rapidly reduce the oxidized dye ( $S^+$ ), recombination with the electrons of the titania layer takes place, without any measurable photocurrent:



- The electrons reaching the counter-electrode through the external circuit in turn reduce the oxidized iodide ( $I^-$ ) so that the entire sequence of electron transfer reactions involving the dye and the redox mediator is rendered cyclic:



The sequence of reactions is shown schematically in the following diagram

