Dye Sensitized Solar Cell (DSSC) Lecture for ENG 230

May be 50 minutes of 3 hr lab.- would follow 30 minutes of cell assembly

INTRODUCTION

Economics

Solar cells absorb some of the photons from sunlight and convert it to a useable amount of direct current electricity. The costs of solar power have been declining steadily and eventually will be competitive with traditional dirty sources of power which are currently contributing to climate change. The solar power falling on about one square mile is around 3 gigawatts, so a 30% efficient cell would produce 1 gigawatt per sq mile, the same as a nuclear plant.

The cost of solar is not just in the cells but in the structure to hold the cells in all weathers, and in some cases to orient the cells to the sun.

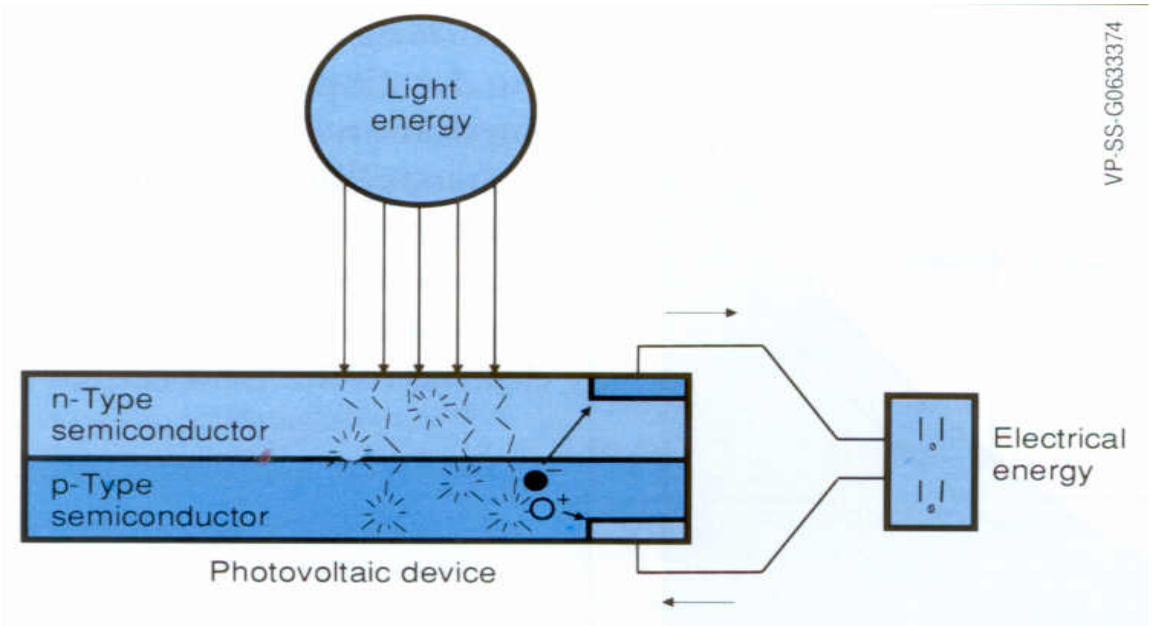
However, the cell cost is significant, and the DSSC combines the natural photovoltaic effect of pigments with nanotechnology to make it competitive with the silicon cells which are in production.

The Photovoltaic Effect

The **photovoltaic effect** is the creation of voltage in a material upon exposure to light. Though the photovoltaic effect is directly related to the photoelectric effect, they are different processes. In the photoelectric effect, electrons are ejected from a material's surface upon exposure to radiation. The photovoltaic effect differs in that electrons are transferred between different bands (i.e., from the valence to conduction bands) within the material, resulting in the buildup of voltage between two electrodes.

Illuminating the material creates an electric current as excited electrons and the remaining holes are swept in different directions by the built-in electric field of the depletion region.

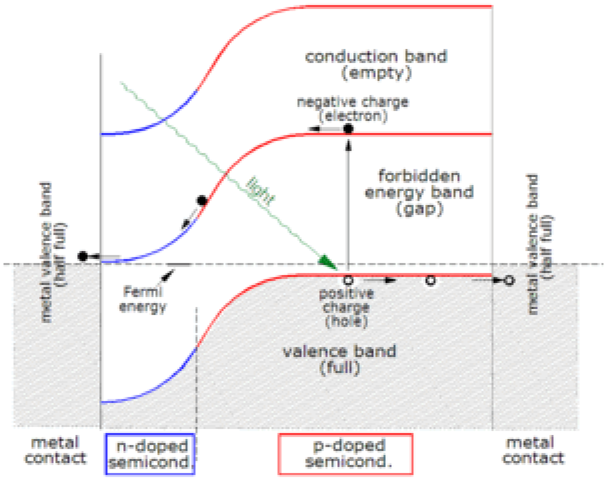
The photovoltaic effect is the basic physical process through which a PV cell converts sunlight into electricity Sunlight is composed of photons--packets of solar energy. These photons contain different amounts of energy that correspond to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through. The absorbed photons generate electricity.



The energy of a photon is transferred to an electron in an atom of the semiconductor device. With its newfound energy, the electron is able to escape from its normal position associated with a single atom in the semiconductor to become part of the current in an electrical circuit. Special electrical properties of the PV cell a built-in electric field provide the voltage needed to drive the current through an external load.

SILICON CELLS

The silicon cell is basically a pn junction diode, optimized to allow sunlight to excite electrons into the conducting band, which generates an electron-hole pair.



The electrons and holes move to the electrodes due to drift and the electrostatic field created by the junction. Some of these carriers will recombine before reaching the electrodes and the energy will be lost to heat.

Ohmic metal-semiconductor contacts are made to both the n-type and p-type sides of the solar cell, and the electrodes connected to an external load. Electrons that are created on the n-type side, or have been "collected" by the junction and swept onto the n-type side, may travel through the wire, power the load, and continue through the wire until they reach the p-type semiconductor-metal contact. Here, they recombine with a hole that was either created as an electron-hole pair on the p-type side of the solar cell, or a hole that was swept across the junction from the n-type side after being created there.

The voltage measured is equal to the difference in the quasi Fermi levels of the minority carriers, i.e. electrons in the p-type portion and holes in the n-type portion.

Operating principle of the dye-sensitized solar cell (ref 1)

At its simplest configuration (Figure 7), the dye-sensitized solar cell (abbreviated hereafter as the DSSC or the dye cell) is comprised of a transparent conducting glass electrode coated with porous nanocrystalline TiO_2 (nc-TiO_2), dye molecules attached to the surface of the nc-TiO_2, an electrolyte containing a reduction-oxidation couple
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such as I^-/I_3^- and a catalyst coated counter-electrode. At the illumination the cell produces voltage over and current through an external load connected to the electrodes.

The absorption of light in the DSSC occurs by dye molecules and the charge separation by electron injection from the dye to the TiO_2 at the semiconductor electrolyte interface. A single layer of dye molecules however, can absorb only less than one percent of the incoming light (O'Regan & Grätzel 1991). While stacking dye molecules simply on top of each other to obtain a thick dye layer increases the optical thickness of the layer, only the dye molecules in direct contact to the semiconductor electrode surface can separate charges and contribute to the current generation. A solution to this problem, developed by the Grätzel group, was to use a porous nanocrystalline TiO_2 electrode structure in order to increase the internal surface area of the electrode to allow large enough amount of dye to be contacted at the same time by the TiO_2 electrode and the electrolyte (Figure 7).

Having this construction, a TiO_2 electrode typically 10 µm thick, with an average particle (as well as pore) size typically in the order of 20 nm, has an internal surface area thousands of times greater than the geometrical (flat plate) area of the electrode, (O'Regan & Grätzel 1991). Essential to the optical operation of this porous electrode structure is the fact that TiO_2, as a large band gap semiconductor, absorbs only below about 400 nm letting the major part of the solar spectrum available for the dye molecules.

The regenerative working cycle of the dye-sensitized solar cell is depicted in Figure 8, showing schematically the relative energy levels of a working DSSC. The incoming photon is absorbed by the dye molecule adsorbed on the surface on the nanocrystalline TiO_2 particle and an electron from a molecular ground state S_0 is exited to a higher lying excited state S^* (1). The exited electron is injected to the conduction band of the TiO_2 particle leaving the dye molecule to an oxidized state S^+ (2). The injected electron percolates through the porous nanocrystalline structure to the transparent conducting oxide layer of the glass substrate (negative electrode, anode) and finally through an external load to the counter-electrode (positive electrode, cathode) (3). At the counter-electrode the electron is transferred to triiodide in the electrolyte to yield iodine (4), and the cycle is closed by reduction of the oxidized dye by the iodine in the electrolyte (5).

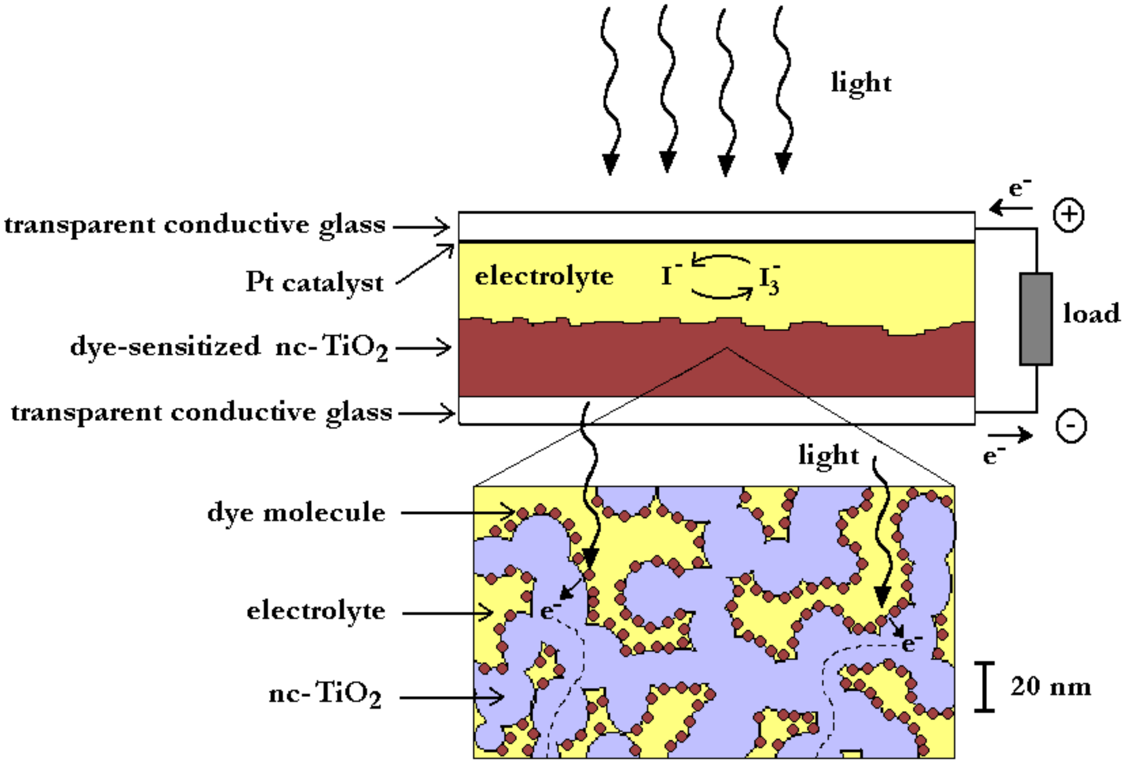

Figure 7. A schematic representation of the structure and components of the dye-sensitized solar cell

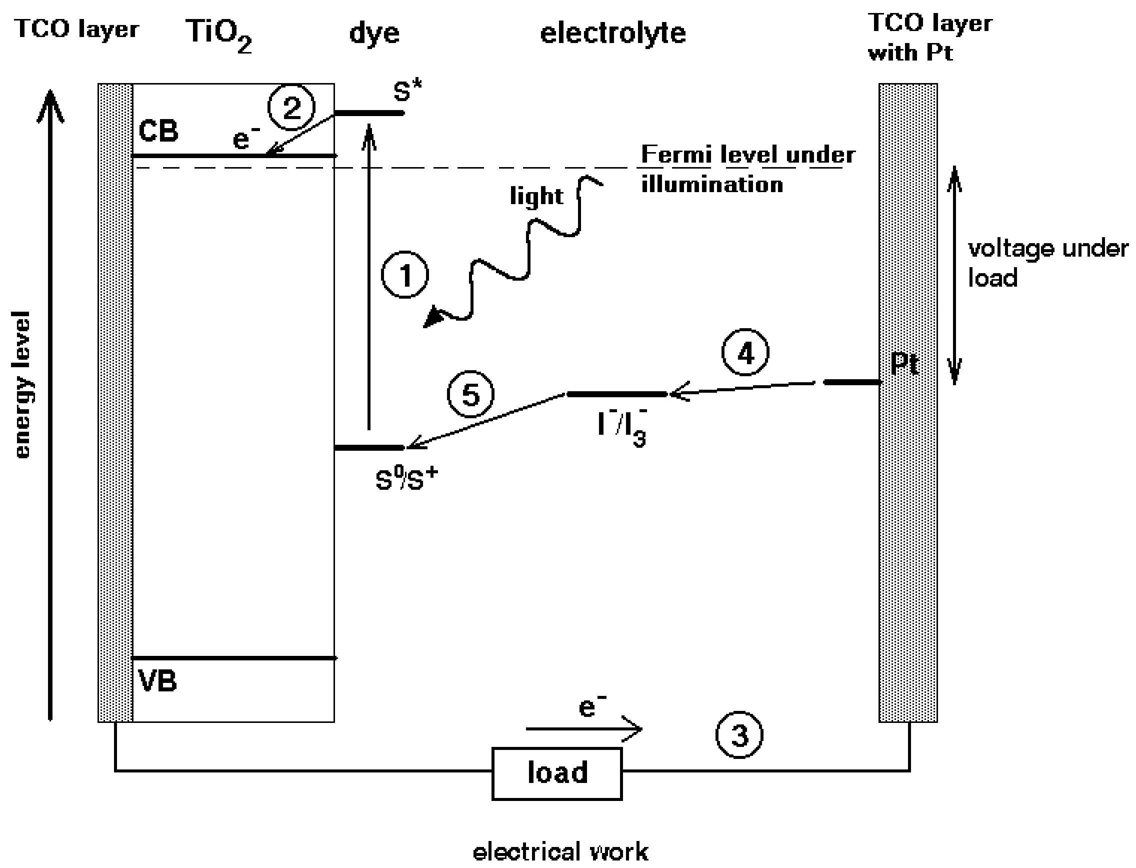

Figure 8. The working principle of the dye-sensitized nanostructured solar cell. See text for the explanation of the basic processes in the cell.

Ref 1: Janne Halme

Dye-sensitized nanostructured and organic photovoltaic cells: technical review and preliminary tests

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http://203.199.213.48/1914/1/halme.pdf

Notes form Wiki ---Typically a ruthenium metalorganic dye (Ru-centered) is used as a monolayer of light-absorbing material. The dye-sensitized solar cell depends on a mesoporous layer of nanoparticulate titanium dioxide to greatly amplify the surface area (200–300 m^2/g TiO_2, as compared to approximately 10 m^2/g of flat single crystal). The photogenerated electrons from the *light absorbing dye* are passed on to the *n-type* TiO_2, and the holes are absorbed by an electrolyte on the other side of the dye. The circuit is completed by a redox couple in the electrolyte, which can be liquid or solid. This type of cell allows a more flexible use of materials, and is typically manufactured by screen printing and/or use of Ultrasonic Nozzles, with the potential for lower processing costs than those used for *bulk* solar cells. However, the dyes in these cells also suffer from degradation under heat and UV light, and the cell casing is difficult to seal due to the solvents used in assembly. In spite of the above, this is a popular emerging technology with some commercial impact forecast within this decade. The first commercial shipment of DSSC solar modules occurred in July 2009 from G24i Innovations.[32]