The Birnie Group solar class and website were created with much-appreciated support from the NSF CRCD Program under grants 0203504 and 0509886. Continuing Support from the McLaren Endowment is also greatly appreciated!

Dye Sensitized Solar Cells

Slides from Graduate Student Presentation by JD Sorge in 2004 - mainly Summarizing the groundbreaking work of Michael Graetzel of EPFL.

Slides on these *other topics* might also be of interest (most collected during teaching years 2004 and 2005):

http://www.rci.rutgers.edu/~dbirnie/solarclass/BandGapandDopingLecture.pdf	Band Gap Engineering of Semiconductor Properties
http://www.rci.rutgers.edu/~dbirnie/solarclass/MultijunctionLecture.pdf	Multi-Junction Solar Device Design
http://www.rci.rutgers.edu/~dbirnie/solarclass/MBEgrowth.pdf	Molecular Beam Epitaxy
http://www.rci.rutgers.edu/~dbirnie/solarclass/amorphousSi.pdf	Amorphous Silicon Solar Cells
http://www.rci.rutgers.edu/~dbirnie/solarclass/TransparentConductors.pdf	Transparent Conductors for Solar
http://www.rci.rutgers.edu/~dbirnie/solarclass/ARCoatings.pdf	Anti-Reflection Coatings for Solar
http://www.rci.rutgers.edu/~dbirnie/solarclass/OrganicPV.pdf	Organic PV
http://www.rci.rutgers.edu/~dbirnie/solarclass/MotorPrimerGaTech.pdf	Working with Simple DC Motors for Student Solar Projects
http://www.rci.rutgers.edu/~dbirnie/solarclass/2005ProjectResultsindex.htm	Examples of Previous Years' Student Solar Projects

Note: in some cases it may be possible to design custom courses that expand on the above materials (send me email!)

Journal Publications of Some Recent Research: (best viewed through department home index: http://mse.rutgers.edu/dunbar_p_birnie_iii)

Other Birnie Group Research:

Sol-Gel Coating Quality and Defects Analysis (mostly Spin Coating):	http://www.coatings.rutgers.edu
Solar Research at Rutgers: Broader Overview	http://www.solar.rutgers.edu
Solar and Electric Vehicles System Projects (early stage emphasis)	http://www.rave.rutgers.edu

RUTGERS UNIVERSITY

Professor Dunbar P. Birnie, III (dunbar.birnie@rutgers.edu)
Department of Materials Science and Engineering
http://mse.rutgers.edu/faculty/dunbar_p_birnie

Dye Sensitized Solar Cells (DSSC)

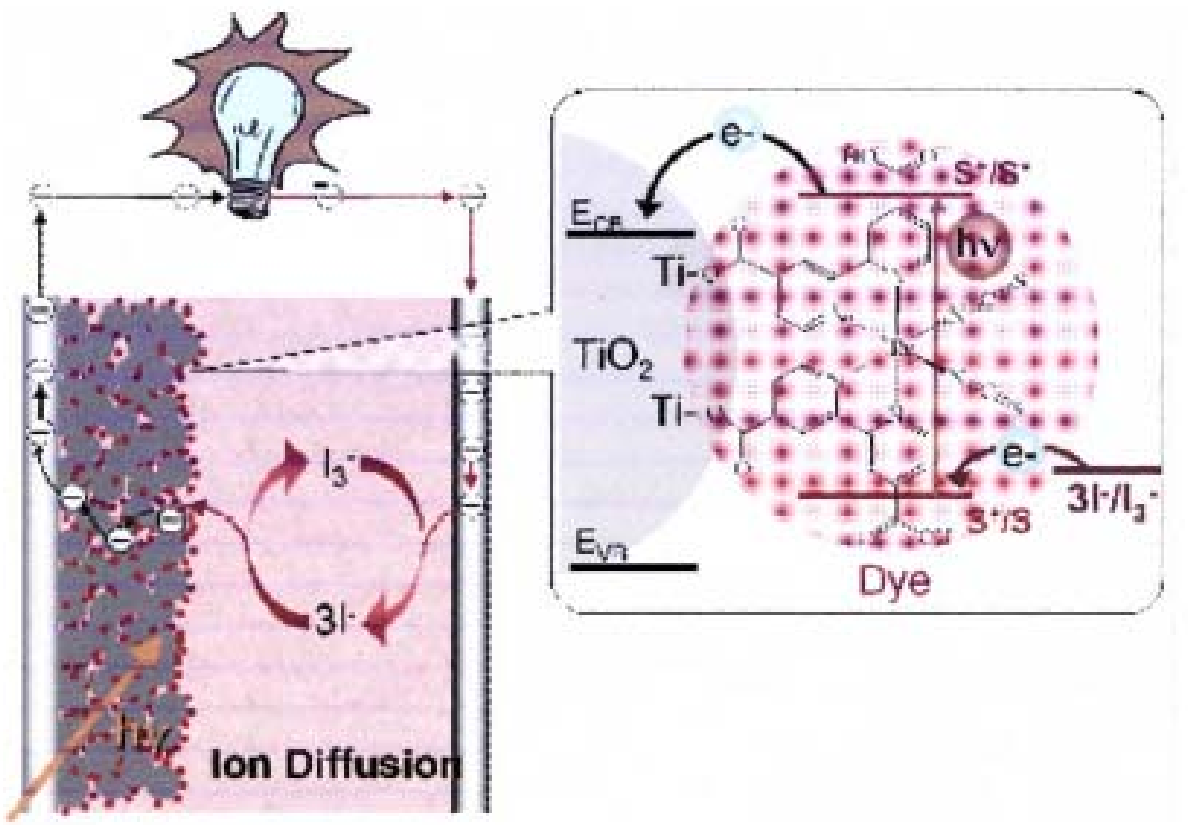
JD Sorge

November 22, 2004

Outline

- Structure of the dye sensitized solar cell
- Method of electronic conduction
- History of the solar cell: photogalvanic to dye sensitized
- Why DSSC
- Processing Example
- Current Research

Structure of DSSC



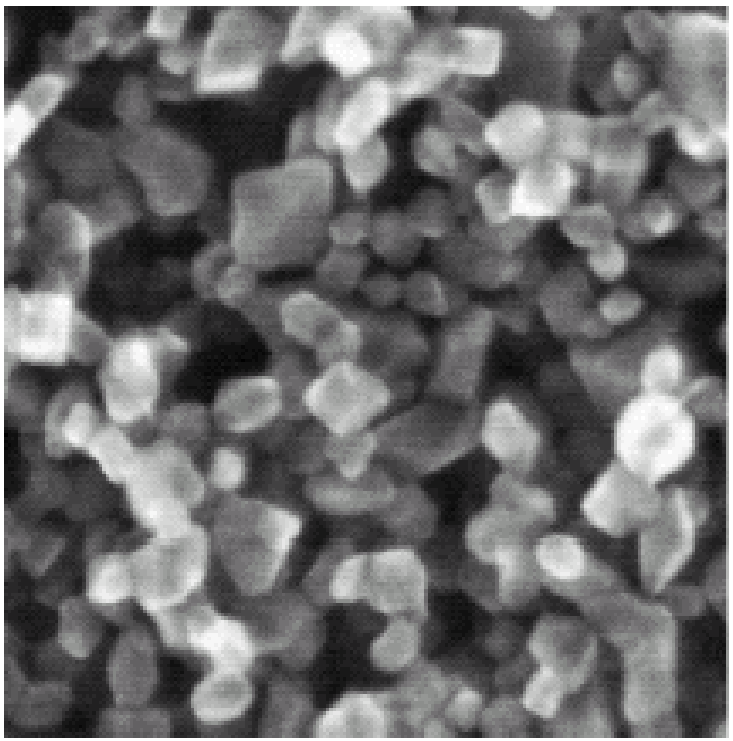
Gratzel, M. J. Photochem. And Photobio. A 164 (2004) 3-14.

Structural Properties

- Electrode: glass with conductive oxide

  usually SnO_2 or SnO_2:F
  - Substrate
  - Transparent
  - Electrically conductive
  - Connections to load
- Counter Electrode
  - Platinum

Wide Band Gap Semiconductor



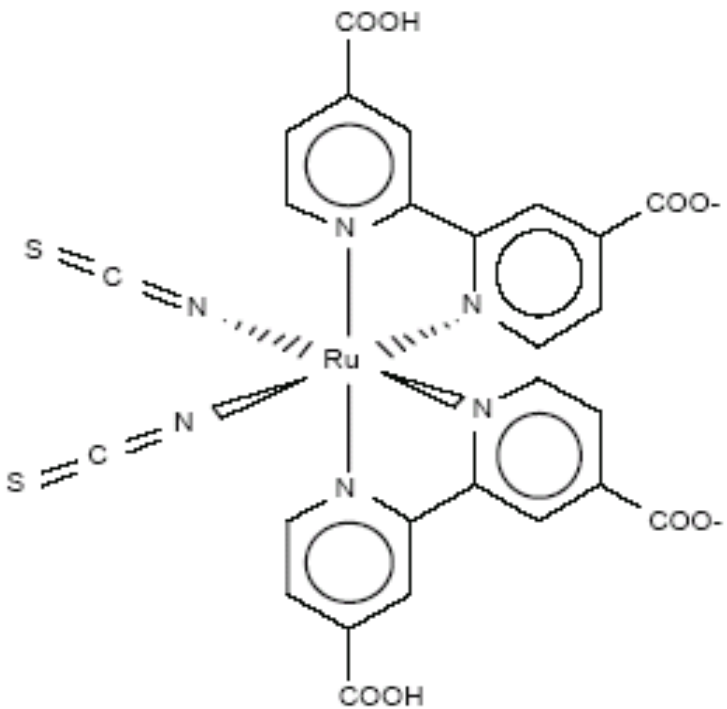
- TiO_2: must be mesoporous for greater surface area to attach dye
  - Porosity >50%
  - Nanoparticles: ~20nm diameter
  - Can use other semiconductor materials
  - TiO_2 – easy to synthesize, abundant, inexpensive

Gratzel, M. J. Photochem. And Photobio. A 164 (2004) 3-14.

Electrolyte – Hole Carrier

- Electrolyte: redox couple to reduce dye
  - Usually iodide/tri-iodide couple
  - Reduces dye after electron injection to TiO_2
  - Oxidized by contact with second electrode
- New research: gel electrolyte
  - Easier to seal cells
  - Researching whether conduction is as good in gel as in liquid

Ruthenium Based Dye

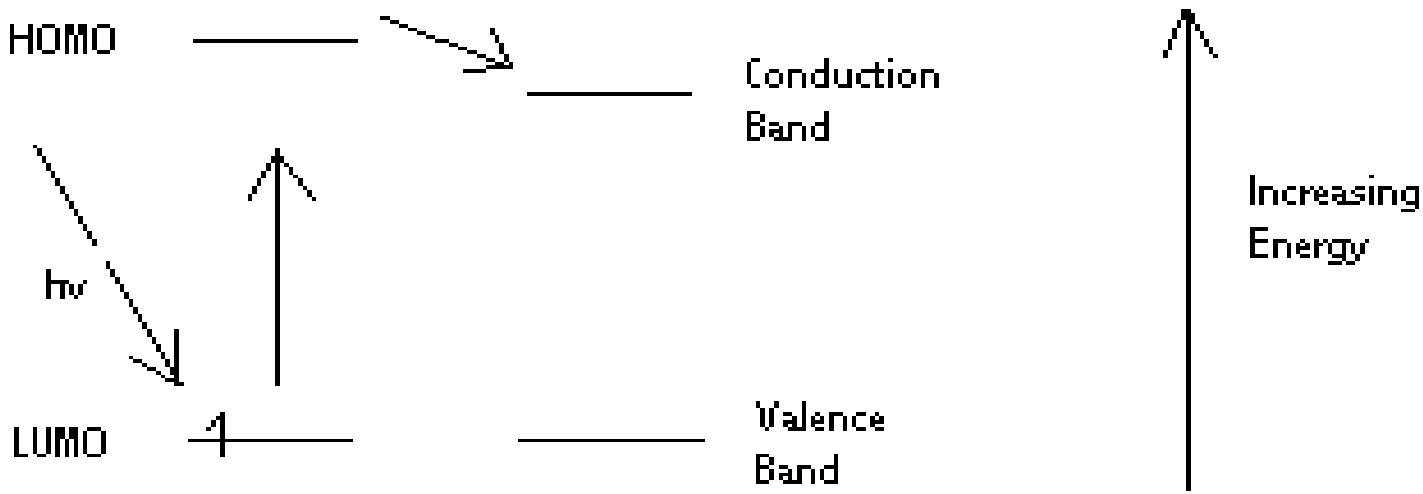


- Dye: usually Ruthenium based, must have carboxylate or phosphonate groups
  - Ligands chemisorb to semiconductor surface

Gratzel, M., J. Photochem. and Photobio. C 4 (2003) 145.

Electronic Processes in DSSC

- How light excites dye and charge transfer occurs



Photogalvanic to DSSC

- Electrolyte Solution:
  - photoredox dye: thionine
  - reversible redox couple: iron salt
- Electrodes:
  - SnO_2 thin film
  - Platinum thin film

- Electrolyte Solution
  - photosensitizing dye: Ru(II) complex
  - reversible redox couple: iodide/tri-iodide
- Electrodes:
  - SnO_2 thin film and Pt
- Semiconductor particles

Modern DSSC

- Michael Graetzel:
  - Swiss Federal Institute of Technology, Lausanne, Switzerland
  - Patents: ***4,927,721,*** **May 22, 1990**
    5,728,487, **March 17, 1998**
    6,245,988 **June 12, 2001**

Why DSSC

- Current Solar Cells: Silicon (p-n junction)
  - expensive
  - difficult to produce
  - framing/substrate – heavy, fragile
- DSSC
  - cost effective – much less expensive
  - can produce using layered coatings on glass
  - may be able to produce on flexible substrates

Simple Processing Example

- 2 conductive oxide coated glass plates
- Plate 1:
  - spread TiO_2 dispersed solution – TiO_2 in acetic acid
  - heat treat ~450°C for 30 min.
  - immerse in dye solution
- Plate 2:
  - coat with graphite for catalyst

Processing, Cont'd

- Set electrode with catalyst onto dye covered electrode at an offset
- Clip solar cell together
- Place two drops of iodine on edge of cell – allow capillary action to coat inside of cell with electrolyte

Current Research - Coating

- Solution – Gelation Method of TiO_2 Preparation
  - prepare monolayer coating by depositing a solution that gels upon heat treatment
  - characterization
    - optical microscopy
    - ellipsometry – thickness, surface roughness

Solution – Gelation (Sol-gel)

- Low temperature process
- Solution chemistry
- Solution → dries to form gel → heat treat to form solid coating

Spin Coating

- Produces thin film coating by fluid dynamics
  - Pipette coating onto rotating wafer
  - Spinning process thins fluid
  - Evaporation processes lead to gelation
  - Heat treatment for sol-gel

Current Research - flexibility

- Use roll coater to deposit titanium dioxide solution onto conductive flexible film
  - types of polymer that can be used?
  - will coating adhere well?

Conclusion

- Although less efficient conversion of power, DSSC's should be more cost efficient than current solar cells
- Conduction by electron injection from dye to semiconductor and redox reaction to reduce dye.
- Future research: monolayer TiO_2 coating, flexible substrate