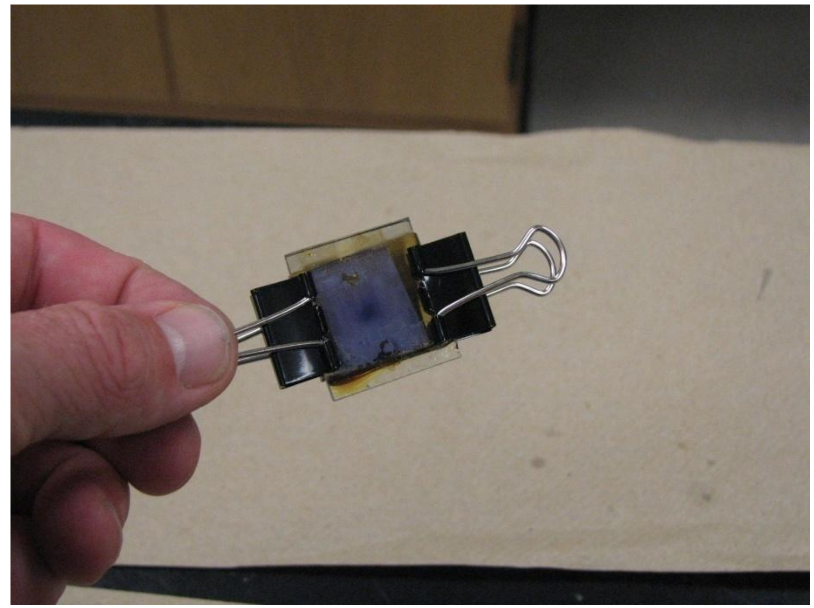
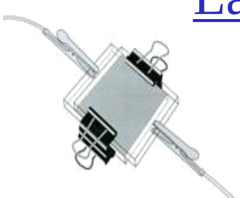
Building the Grätzel Solar Cell

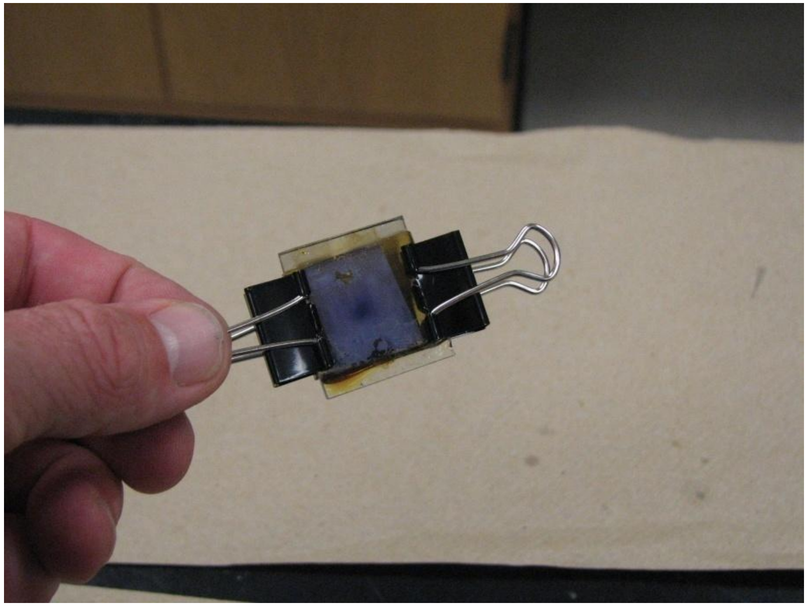
- CEBC Summer Workshop, June and July 2008



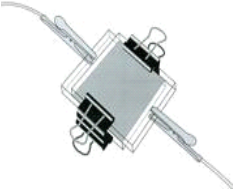
Alan Gleue, physics teacher,
Lawrence High School
LHS Science Department
Lawrence Public Schools



What is a Grätzel solar cell? (dye-sensitized solar cell, DSSC)

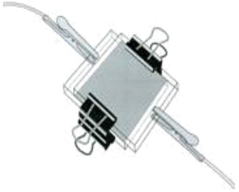


- A type of a photovoltaic cell
- Created by Michael Grätzel and Brian O'Regan in 1991
- Promising as an alternative to silicon-based photovoltaics



What is a photovoltaic cell?

- A device that can convert sunlight directly in electricity.
- First used in spacecraft and satellites.
- Traditional types are based on two types of silicon sandwiched together (n-type and p-type).
- Based on using photons to separate charges: electron-hole pairs
- Many new types are in research/production stage.



The Grätzel Solar Cell Project, Summer 2008

- How does a traditional silicon-based solar cell work?

http://www.uctv.tv/search-details.asp?showID=12114

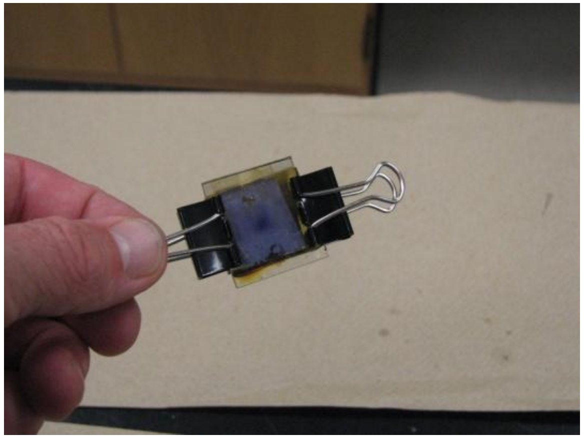
http://www.youtube.com/watch?v=u0hckM8TKY0

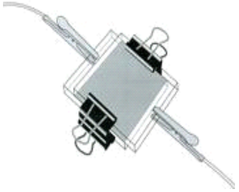
University of California TV

22 minute video

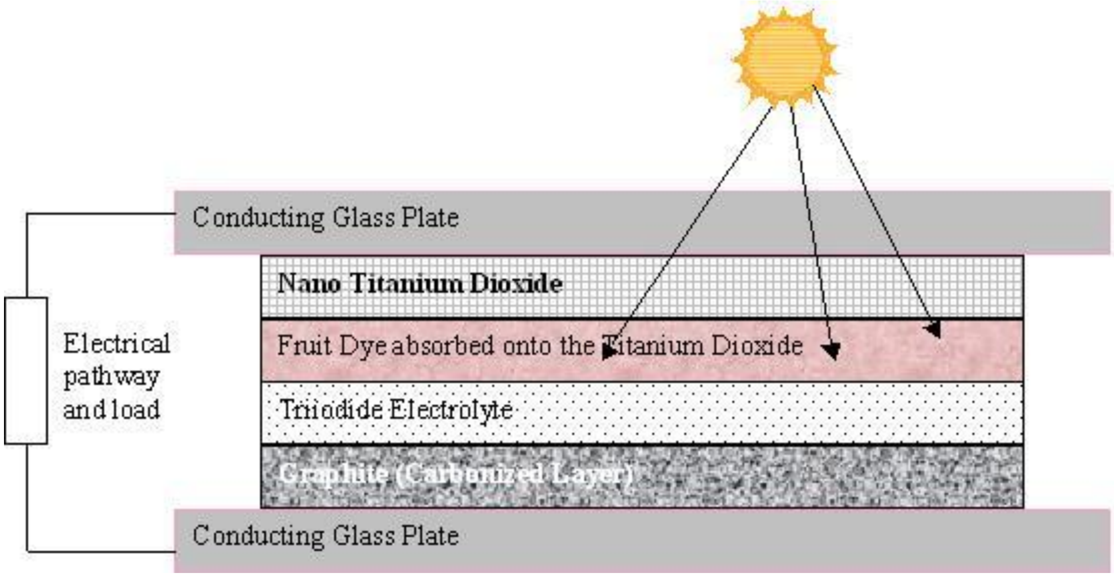
See my website

Basic mechanism of action of a DSSC





The Grätzel Solar Cell Project, Summer 2008



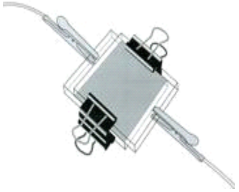
Comparison / Contrast between DSSC and traditional silicon-based solar cell

Advantages

- Low cost materials
- No elaborate apparatus
- Works in low light conditions
- High price/performance ratio

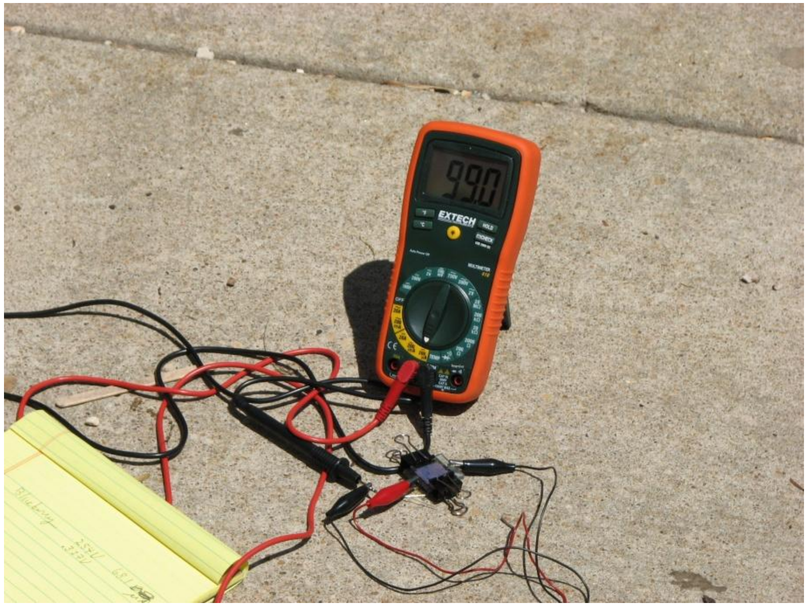
Disadvantages

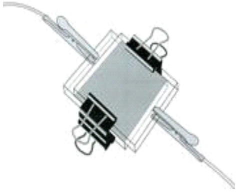
- Slightly lower efficiencies
- Breakdown of the dye
- Bandgap slightly larger than silicon (fewer solar photons able to produce a current)
- Liquid electrolyte can leak



Secondary Science Project?

- Concepts from physics, chemistry, astronomy, and biology
- Nanotechnology
- Environmental science and alternative energy





The Grätzel Solar Cell Project, Summer 2008

A kit exists!

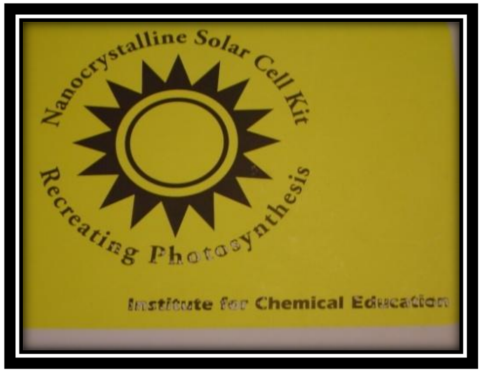
[Institute of Chemical Education](#)

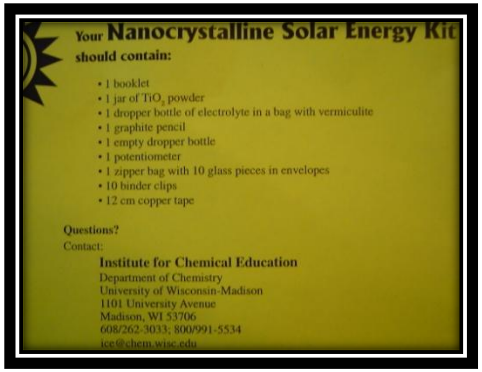
Everything needed to make 5 DSSCs

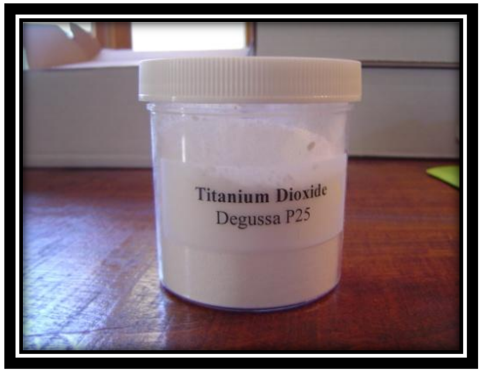
Need to provide some basic lab apparatus, several basic chemicals, and the fruit dyes (see [pdf file](#) for complete list of what the kit does and doesn't contain)

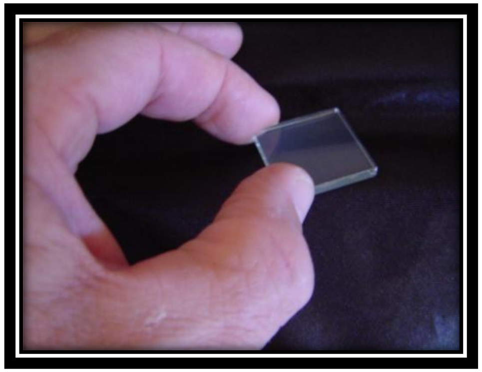
A nice lab spiral-bound lab manual with directions, information, and activities.

[See my website](#) for more information.

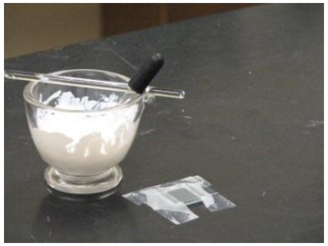
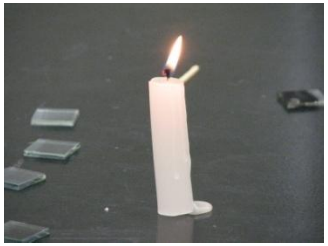


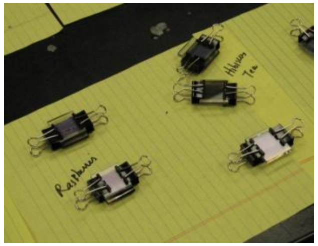




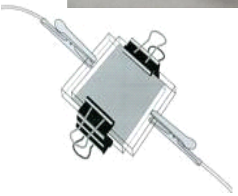


Building the Grätzel Solar Cell step-by step

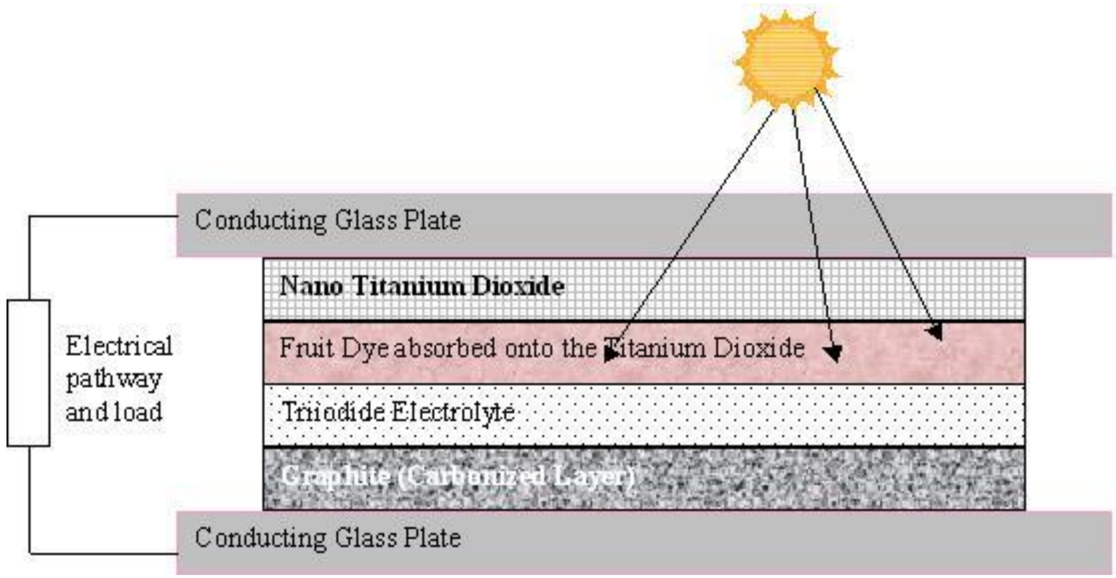



- Basic Steps
  - Mix, coat slides with nano-TiO_2, and sinister.
  - Carbonize other slides.
  - Apply dye to TiO_2.
  - Sandwich cells together with binder clips.
  - Add electrolyte to sandwich cell
  - Hope for a sunny day!

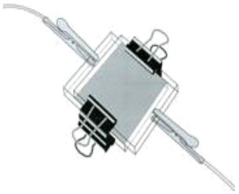


[See my website](#)
for more info, pics, and video.



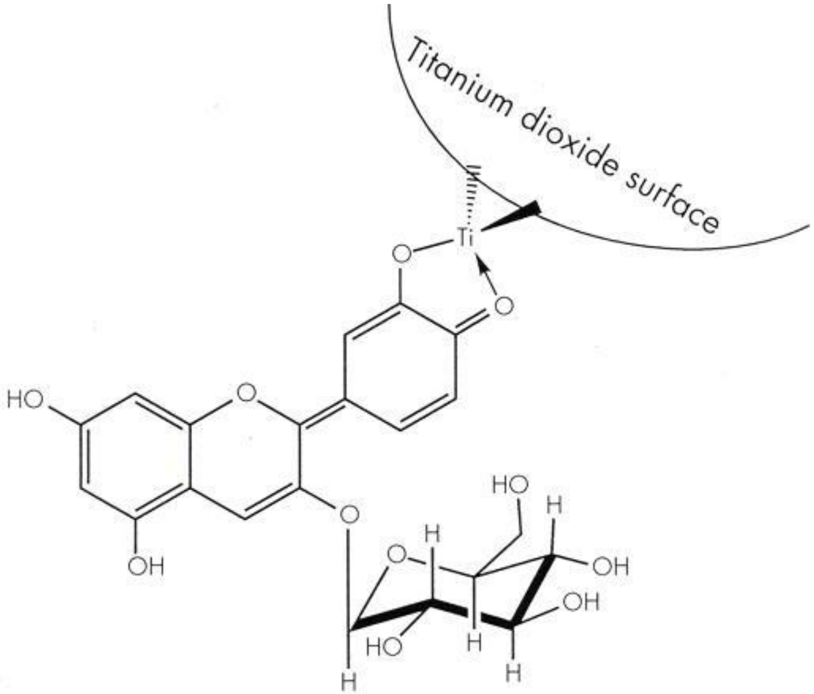
How does it work?

Photons strike the cell and their energy is absorbed by the fruit dye. Depending upon the dye used, different energy levels of photons are absorbed. The goal is to maximize absorption over the visible solar spectrum to produce the maximum energized electrons.

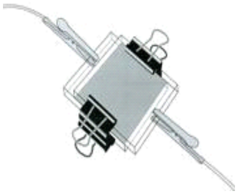


The recommended fruit dyes contain anthocyanin pigments of which there are many. Anthocyanins molecules absorb photons around the 520-550 nm range. These are the pigments that produce the red, blue, violet, and orange colors we see in fruits and flowers.

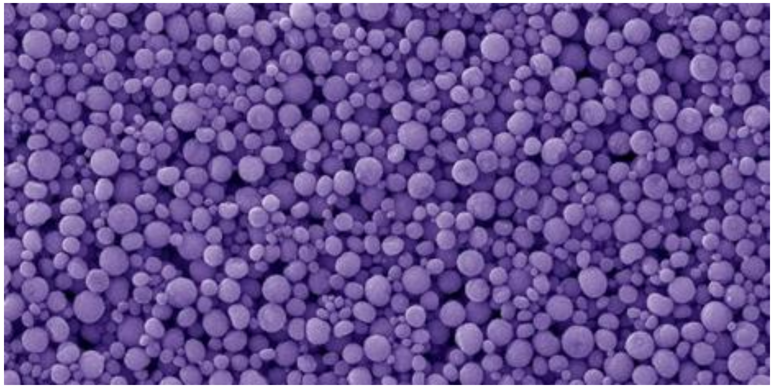
How does it work?

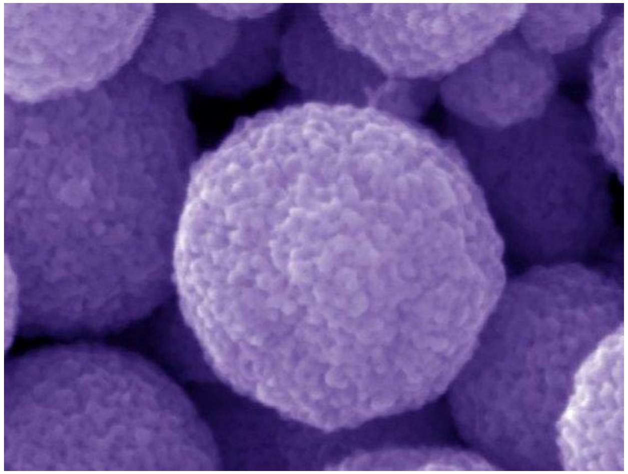


The dye has several important properties. It must be complexed or chelated (attached) to the titanium dioxide and it must be able to absorb the photons' energy, exciting and freeing some of its electrons.



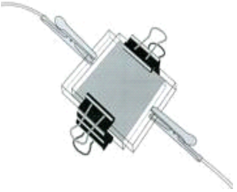
The nanoparticle titanium oxide acts as a scaffold to hold the dye molecules into its 3 dimensional array.



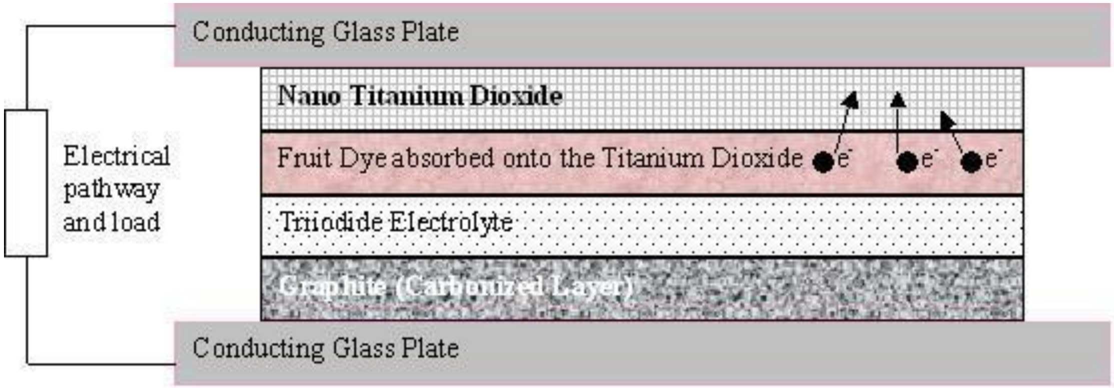


Pictures courtesy of the University of Washington

How does it work?

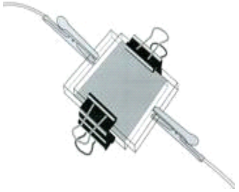


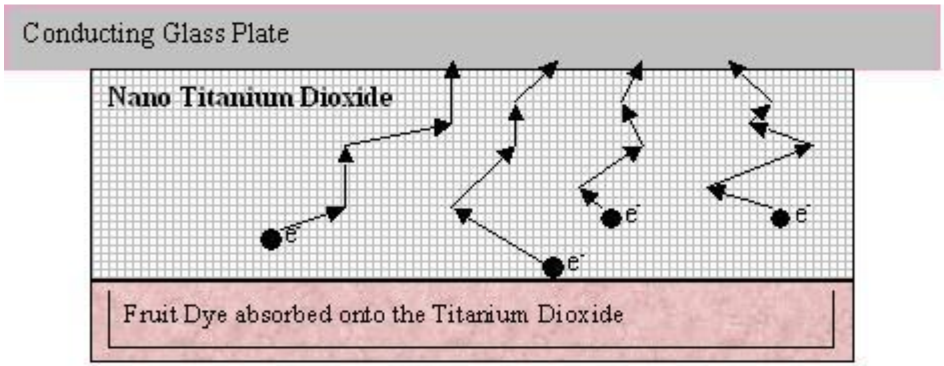
Because of the small size of the titanium dioxide nanoparticles (10-300 nanometers), many dye molecules are attached after staining providing many photoelectrons produced. The nanoparticles increase this available surface area 100-1000 times (relative to the area of the glass squares) enhancing dye attachment, porosity, and consquently, photoelectron production.   Non-nanoparticle titanium dioxide isn't very effective as a substrate.



How does it work?

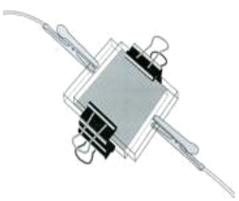
These excited electrons from the dye are transferred or injected into the conduction band nanoparticle titanium dioxide. The titanium dioxide acts as a n-type semiconductor (like n-type silicon).

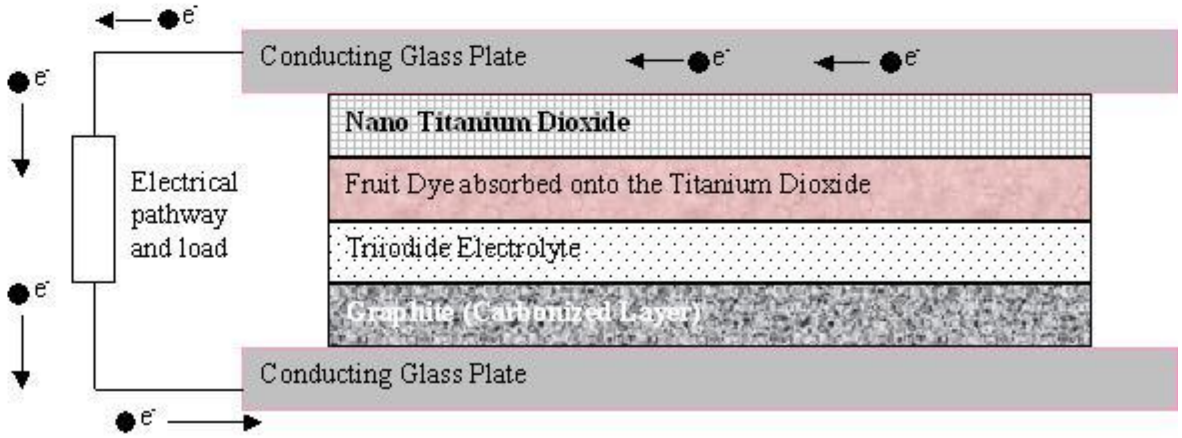




How does it work?

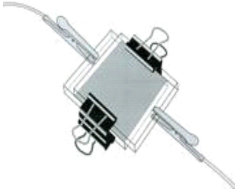
The injected photoelectrons move along the nanoparticles towards the top conducting plate (anode). With the thin layer of titanium dioxide (on the order of microns) , the excited electrons do not need to travel far to reach the anode.



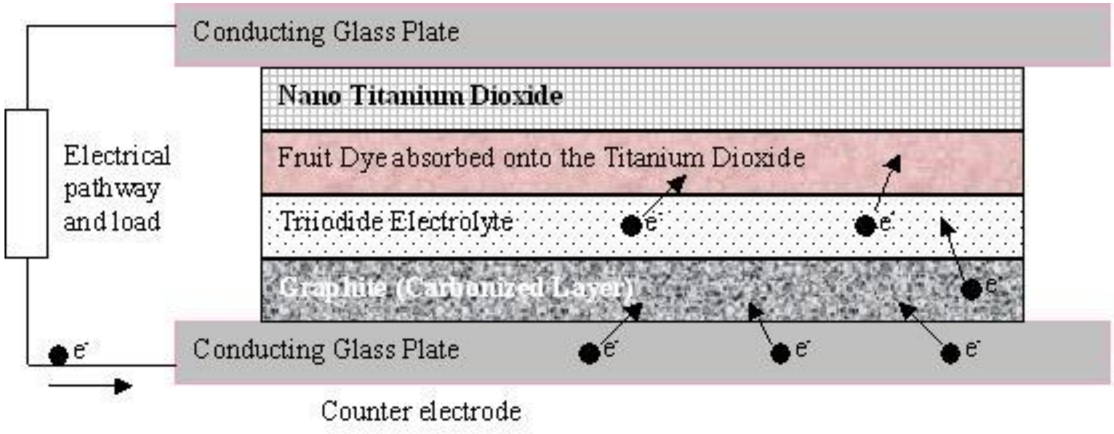


How does it work?

Once the photoelectrons reach the anode, the photoelectrons migrate through the electrical pathway and the extra energy is converted to electrical energy by devices in the circuit (loads).



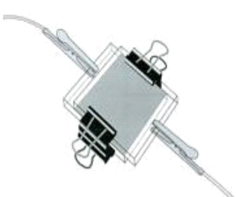
The amount of electrons per second flowing through the load is the current and the available energy per electron is the voltage or electrical potential.



How does it work?

The triiodine electrolyte supplies electrons to replenish the electron deficient dye molecules back to their original states.

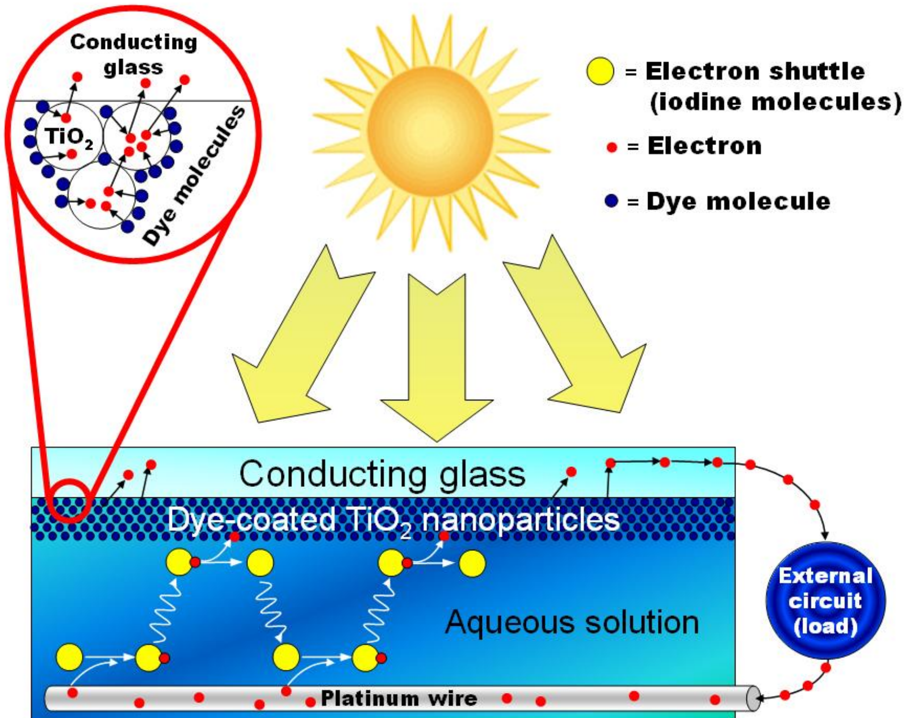
The triiodide electrolyte recovers its missing electrons by migrating toward the cathode (conducting glass plate at the bottom of the cell also called the counter electrode).



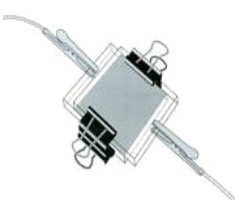
Electrons migrating through the circuit reach the counter electrode and recombine with the oxidized triiodide electrolyte. The triiodide electolyte liquid acts as a true catalyst as it is not consumed in the reactions taking place.

Click on pic for animation

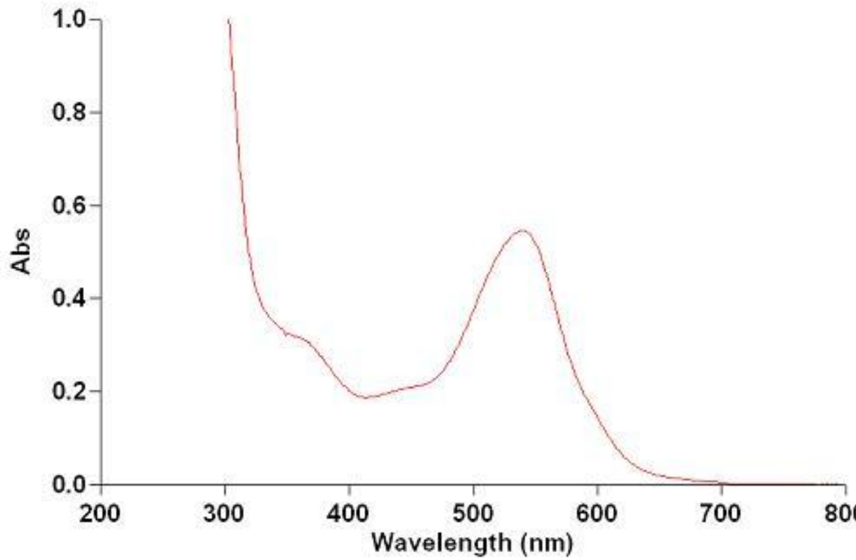
http://www.bath.ac.uk/powerttp/solar_cells.shtml

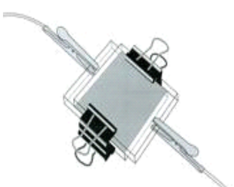


http://www.nsf.gov/news/mmg/media/images/pr04095solarcell_h.jpg



Complete data, results, and UV-Vis spectroscopy of the dyes I used can be found on my website.





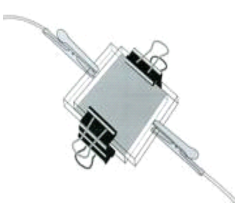
The Dye-Sensitized Solar Cell and Photosynthesis

There has been discussion about the similarities between the mechanism of action of the Grätzel solar cell and photosynthesis in green plants. In aerobic photosynthesis, photons, carbon dioxide, and water combine to produce carbohydrates (glucose) and oxygen.

In the case of photosynthesis, pigments such as chlorophyll a, chlorophyll b, xanthophylls, and carotenoids absorb energy from photons. This absorbed energy excite electrons; these electrons are moved around inside the chloroplasts found in plant cells and through many reactions, ATP and NADPH molecules are formed. Through additional reactions glucose and carbohydrates are produced.

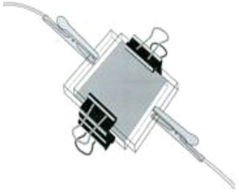
Here is a particularly good animation of photosynthesis and the many reactions that take place. Several more are here.

Subsystem	Gratzel Solar Cell	Photosynthesis
Electron Acceptor:	Nanoparticle TiO_2	Carbon Dioxide
Electron Donor:	Triiodide Electrolyte	Water
Photon Absorber	Fruit Dye	Chlorophyll



Activities with the Grätzel Solar Cell

- Current and Voltage obtained with different fruit dyes;
- Parallel and Series Circuits with a number of solar cells;
- Running a small motor with a solar cell;
- Current-Voltage Graphs using different resistive loads;
- Electrical power obtained when using different dyes;
- Comparision of a silicon solar cell with a Grätzel Solar Cell;
- Effects of different light bulbs (halogen, colored, etc.) on the cell;
- Grätzel Solar Cell powered calculator;
- Intensity of light vs current / voltage obtained;
- compare /contrast photosynthesis and the mechanism of action of the Grätzel solar cell and
- Nano vs non-nano titanium dioxide



- Discussion and future research
- Resources and links
- My DSSC webpage

- I was guided in my project by Professor Javier Guzman, Professor of Chemical and Petroleum Engineering at the University of Kansas. I also received guidance from Professor Darius Kuciauskas, at Rowan University. I would also like to thank Wei Ren, a graduate student at the CEBC and Jack Randall at Vernier Software and Technology for assistance with the UV-VIS spectrometer and in taking absorption spectra.

- Also, I want to especially thank Claudia J. Bode, Ph.D., Education, Outreach and Diversity Programs Coordinator, Center for Environmentally Beneficial Catalysis for her assistance throughout the summer.