# COURSE 146C

## Laboratory Experiment #2

# Making a Solar Cell with $TiO_2$ nanoparticles

Please read the lab procedure and finish the attached prelab questions before your experiment!


References:

1. Hagfeldt, A. and Gratzel, M. “Molecular Photovoltaics” *Acc. Chem. Res.* **33**, 269-277 (2000)

2. Law *et al.* “Nanowire dye-sensitized solar cells”. *Nature Materials* **4**, 455-459 (2005)

3. Cherepy, N. J.; Smestad, G. P.; Gratzel, M. and Zhang, J. Z. “ Ultrafast electron injection: Implications for a photoelectrochemical cell utilizing an anthocyanin dye-sensitized $TiO_2$Na nocrystalline electrode”. *J. Phys. Chem. B* **101**, 9342-9351 (1997)

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## Introduction

Energy and environment are currently the most challenging issues for human being. We have been looking for renewable energy, which is clean and constantly replenished for many years. Most renewable energy comes directly or indirectly from the sun. To convert solar energy efficiently to other form of energy, for example electricity that can be easily used is the focal point of research. Solar cell is a semiconductor device that converts photons from sunlight into electricity. Significant progress has been accomplished in developing solar cells, including inorganic, organic, hybrid organic-inorganic and dye sensitized solar cells. Dye sensitized cells is currently one of the most efficient, stable and low cost solar cell with a typical efficiency of 10%.

In this laboratory experiment, you will learn the basic principle of dye sensitized solar cells. More important, you have a chance to make a solar cell using simple device fabrication techniques. Finally, you will carried out electrical measurements for your dye sensitized solar cells and see how it performs at various light illuminations.

## Design and Operation Principle of Dye Sensitized Solar Cell

Dye sensitized cell was invented by Prof. Michael Gratzel in 1991, so it is also called *Gratzel cell*.[1] The original Gratzel cell design composes of four major components, including dye molecules, semiconductor nanoparticles, electrolyte and transparent electrodes, as shown in Figure 1. A thick semiconductor nanoparticle film provides a large surface area for anchoring dye molecules (usually Ru-based molecules), which are used as chromopore to absorb sunlight in the visible region. Upon illumination, photons absorbed by dye molecules create electron and hole pairs, which will split at the nanoparticle surface. Electrons will be injected into semiconductor (usually $TiO_2$) nanoparticles, transport through the $TiO_2$ layer and collected by the conductive layer on the glass. The remained holes in dye molecules will be scavenged by redox species such as iodide ($I^-$ / $I_3^-$ redox couple) in electrolyte, the resulting iodine or triiodide obtains an electron at the counter electrode as current flows through the electrical load.

The design of dye sensitized cell has been modified for increase the photo-conversion efficiency. Nanoparticle dye sensitized cell rely on trap-limited diffusion for electron transport, which is a slow mechanism that limits the device efficiency. A new version of the dye sensitized cell has been developed recently by replacing nanoparticles with semiconductor ZnO nanowires.[2] Although the total surface area of nanowire is smaller than that of nanoparticles, the direct electrical pathways provided by nanowires can improve the electron transfer efficiency. This experiment is modified from the original papers for $TiO_2$-based dye sensitized cell.[3]

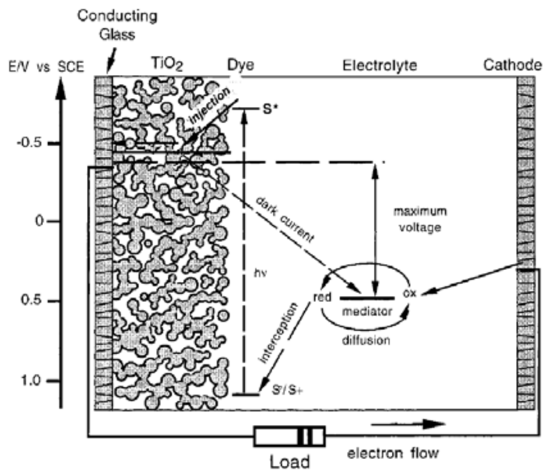


Figure 1. Schematic representation of the principle of the nanocrystalline injection cell to indicate the energy level in the different phases. The iodide/triiodide redox couple used to mediate charge transfer between the electrodes. [Ref. 1]

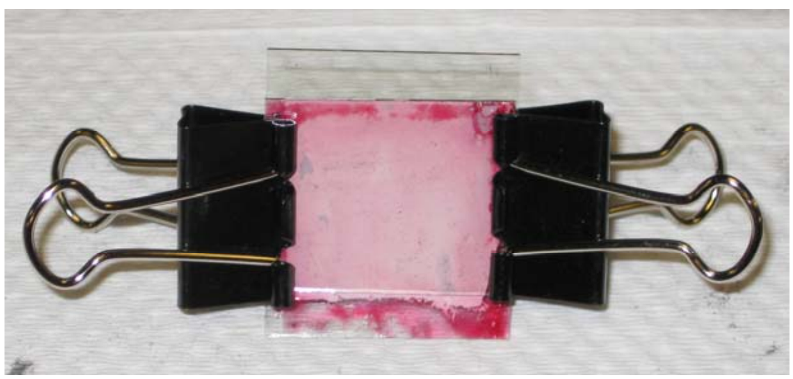

Figure 2. The $TiO_2$ coated substrate and the graphite coated substrates are contacted using two binder clips.

# Procedure

## Fabrication of $TiO_2$ Nanoparticle Dye Sensitized Cell

1. Weight 1g of $TiO_2$ powder and transfer it into a beaker.
2. Add 1ml of distilled water and 1 drop of dishwashing liquid.
3. Measure 1.5ml of vinegar into a measuring cylinder.
4. Slowly add vinegar to the $TiO_2$ powder and mix thoroughly until the paste is formed.
5. Slowly pour the water and dishwashing liquid mixture into the $TiO_2$ paste and mix thoroughly. Let the mixture stand for 15 minutes.
6. Prepare the blackberry juice: 5 berries used, add 2 ml of deionized water to the blender. Run the blender until the mixture is mostly liquid. Filter the mixture with Buchner funnel to get the solution. Pour the solution into a petri dish.
7. Clean an ITO substrate and identify the conducting side. Protect the sides of the substrate with scotch tape.
8. Take a small amount of $TiO_2$ paste and spread it uniformly over the ITO substrate with glass rod. The smoother the film the better the result.
9. Put the $TiO_2$ coated substrate into an oven and baked at 450 °C for 30 minutes.
10. Once the substrate is cooled down, stain the $TiO_2$ by blackberry juice for 10 minutes until the substrate show a deep purple color.
11. Coating the conducting side of another ITO substrate with graphite pencil. Do not heavily scratch the substrate surface.
12. Wash the stained substrate with distilled water and then with ethanol gently. Gently blot the substrate with Kim Wipes.
13. Once the substrate is dried. Place the graphite coated substrate on top of the $TiO_2$ coated substrate. Use two binder clips to attach the glass slides, as shown in Figure 2.
14. Add iodide electrolyte solution into the cell at the point where two slides meet.
15. Attaching the alligator clips to the slides with coating.
16. Performing measurements on the cell.

## Measurements

1. Connect the dye sensitized cell to a multimeter.
2. Measure the potential under 1) dark; 2) ambient room lighting; 3) under light bulbs 50W and 100W; and 4) under illumination of blue, green and red light.
3. Measure the potential as a function of distance from 100W light source to substrate
4. Compare your results to other group members.

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# Pre-Lab Questions

To be completed and handed in as you ***enter*** the lab.

1. What's the function of blackberry juice?

2. What is the purpose to coat the ITO substrate with graphite pencil?

3. What's the function of $I^-$ / $I_3^-$ redox couple in electrolyte? Write the redox reactions occur in electrolyte.

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# Lab Report

To be completed and handed in within ***one week***

1. Draw a schematic of your dye sensitized cell. Label all the major components.

2. List all the voltage recorded under different conditions. What's the maximum voltage you can get with your cell? What's the maximum voltage produced in the class?

3. Explain the changes of the voltage when the solar cell is measured under dark, ambient light and 100W light bulb.

4. Explain the changes of the voltage when the solar cell is measured under illumination of blue, green and red light.

5. Explain why the solar cell voltage changes as a function of distance between light source and the cell.

6. What factors affect the voltage produced by your cell? How to increase the voltage/current of your cell?