

Background

- Photoelectrochemical solar cells are devices consisting of a photoelectrode, a redox electrolyte, and a counter electrode.ⁱ
- Semiconducting materials such as single-crystal and polycrystal n- and p-Si, n- and p-GaAs, n- and p-InP, and n-CdS have been used as the photoelectrodes in these devices yielding a solar light-to-current conversion efficiency of about 10%ⁱⁱ
- Under irradiation in electrolyte solution, the photoelectrodes tend to corrode yielding poor stabilityⁱⁱⁱ
- Oxide semiconductors (TiO₂, ZnO, SnO₂) are much more stable under irradiation in solution, but suffer from poor absorption of visible light due to their large bandgaps.^{iv}
- Large bandgap oxide semiconductors with photosensitizers, such as organic pigments, are adsorbed onto the semiconductor surface absorb visible light and excited electrons are injected into the conduction band of the semiconductor electrodes.^v
- In early research, single-crystal and polycrystal oxide semiconductors were used. These had limited surface area and could not adsorb sufficient quantity of pigment in order to achieve competitive light harvesting efficiency. Also, the organic pigments used had a narrow absorption range in visible light.^{vi}
- Engineering Opportunity → Two avenues for improvement:
 - Increased surface areas of oxide semiconductor photoelectrodes
 - We will explore nanoporous TiO₂ thin film electrodes → Nanoporous provides significantly greater surface area for adsorption compared to single-crystal
 - Pigments with broader absorption of light
 - Ru bipyridyl complex photosensitizers → Absorb wide visible and near-IR region from 400~900nm, has carboxyl groups to serve as anchors for adsorption.^{vii}
- 7-10% efficiency has been observed
- Transparent conducting oxide-coated glass substrate (Indium-Tin Oxide or Fluorine-Doped Tin Oxide has low sheet resistance and high transparency) . Colloidal solution of TiO₂ is spread and sintered at 450°C -500°C.
- Nanoparticles 10-30nm with roughness factors exceeding 1000
- Pigment assumed adsorbed onto surface in a monolayer
- Film typically has 250-300nm particles
- The anchoring carboxyl groups cause significant electronic interaction between the ligand and the conduction band of TiO₂ allowing for electron injection from the Ru complex into the TiO₂.^{viii}
- “The porous titanium dioxide layer facilitates the transport of the electron to the conductive layer on the glass where it is collected. Meanwhile, positive charge is transferred from the dye to a mediator that is an electron donor present in the liquid with which the solar cell is filled. The oxidized mediator brings the positive charge from the dye to the opposite side of the cell which is called the counter electrode. After traveling through the electrical load (for example, a motor or light) the electron collected at the titanium dioxide side of the cell reacts at the counterelectrode and the mediator is returned to its original reduced form. The circuit is thus closed and electricity is produced.” ix

Goals

- What parameters can we examine?
 - Sintering?
 - Material?
- What methods can we use to characterize the differences?

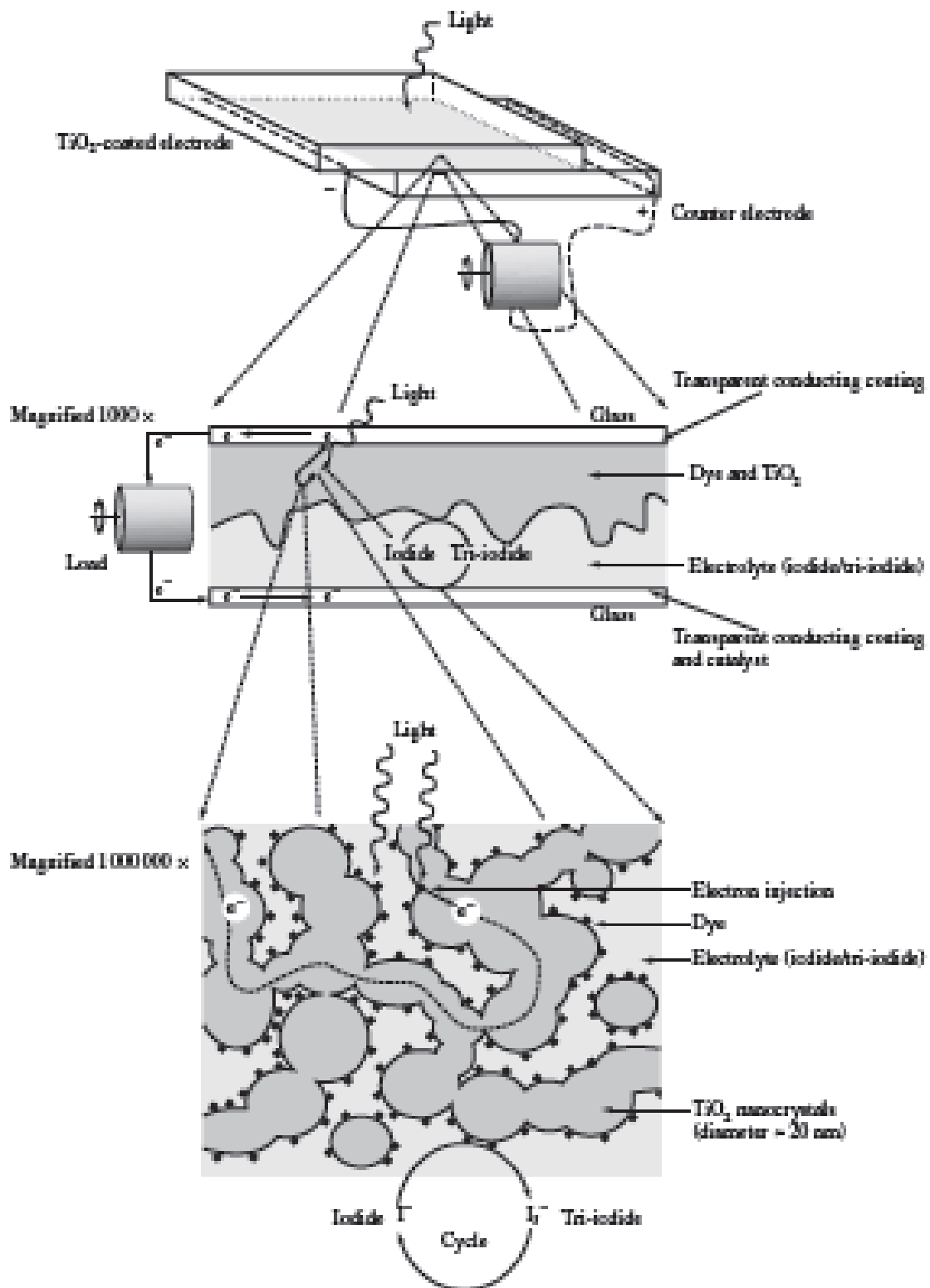


Figure 01 – Device Schematic for DSSC^x

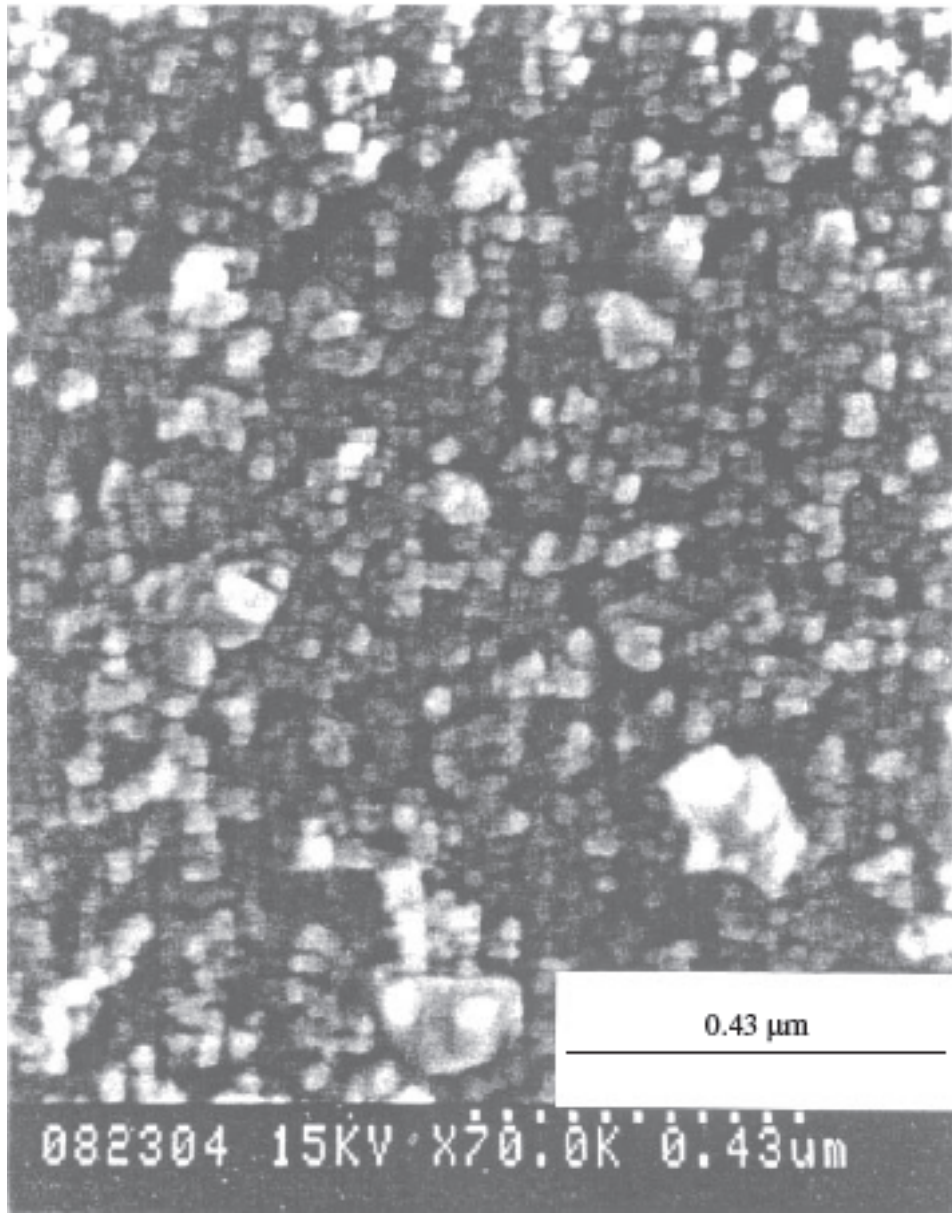
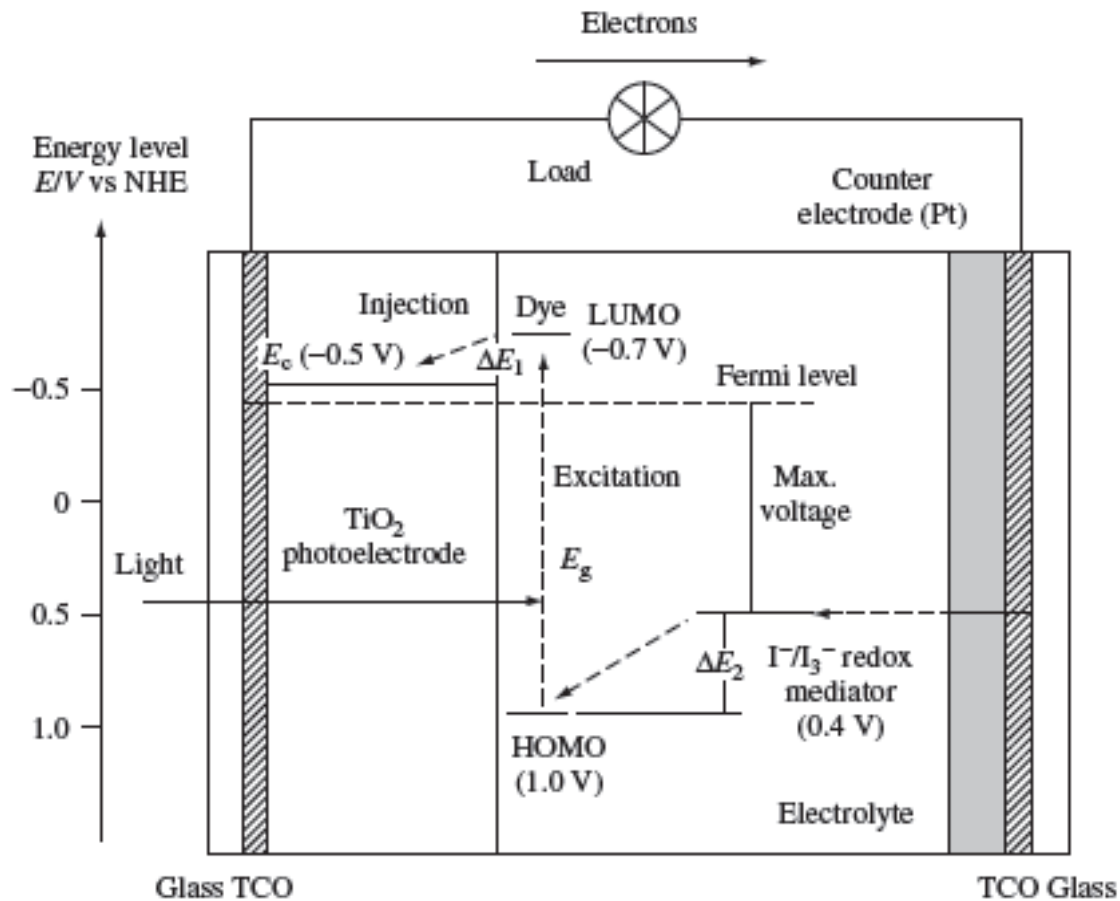
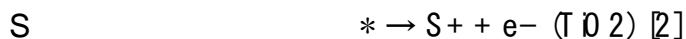
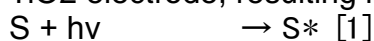


Figure 02 – Surface image of DSSC^{xi}



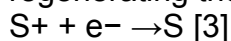
(1. Ru complex photosensitizers adsorbed on the TiO₂ surface absorb incident photon flux.

2. The photosensitizers are excited from the ground state (S) to the excited state (S*) owing to the MLCT transition. The excited electrons are injected into the conduction band of the TiO₂ electrode, resulting in the oxidation of the photosensitizer.

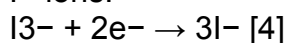


3. Injected electrons in the conduction band of TiO₂ are transported between TiO₂ nanoparticles with diffusion toward the back contact (TCO) and consequently reach the counter electrode through the external load and wiring.

4. The oxidized photosensitizer (S⁺) accepts electrons from the I⁻ ion redox mediator, regenerating the ground state (S), and I⁻ is oxidized to the oxidized state, I₃⁻.



5. The oxidized redox mediator, I₃⁻, diffuses toward the counter electrode and is rereduced to I⁻ ions.



Overall, electric power is generated without permanent chemical transformation.)^{xii}

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- i Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 663.
 - ii Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 663.
 - iii Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 663.
 - iv Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 663.
 - v Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 663.
 - vi Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 663.
 - vii Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 664.
 - viii Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 667.
 - ix GP Smestad, Solar Energy Materials and Solar Cells 55 (1998) 157-178
 - x GP Smestad, Solar Energy Materials and Solar Cells 55 (1998) 157-178.
 - xi Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 667.
 - xii Handbook of PV Science and Engineering, John Wiley & Sons Inc., Hoboken, NJ, USA, page 670.