Multi-junction Solar Cells of Lead (II) Selenide Quantum Dots and Zinc Oxide Nanowires

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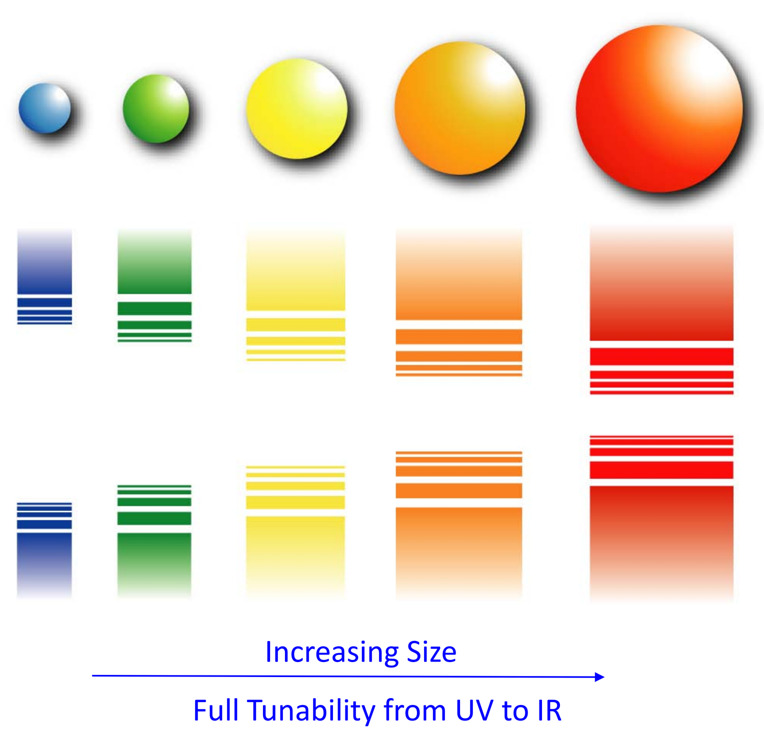
Quantum Dots and Nanowires



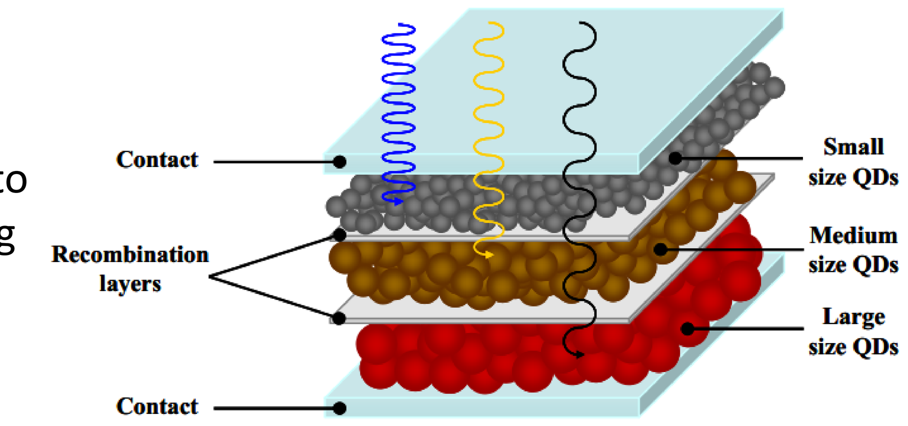
Klimov, *Los Alamos Science* **28**, 214 (2003)

Quantum Dots (QDs) are single crystals of semiconducting material that are only a few nanometers wide. Unlike their bulkier counterparts, the band gaps of these QDs can be controlled by the size of the crystal. This allows quantum dots to be tuned to absorb wavelengths of light, increasing absorption efficiency. In this project, lead (II) selenide (PbSe) is used as the semiconducting layer.

Nanowires (NWs) are crystalline rods with diameters on the order of a nanometer. Incorporating such structures into the photosensitive layer increases carrier transport efficiency. Zinc oxide (ZnO) is used in this experiment due to its favorable band gap alignment for electron extraction.

Solar Cells

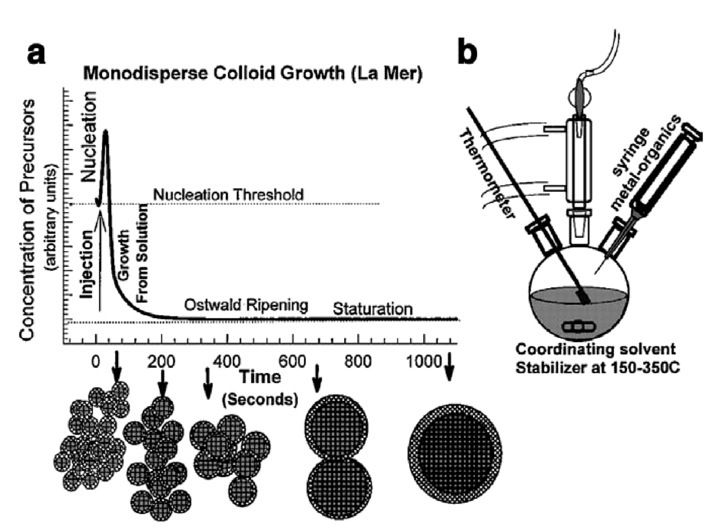
Solar cells are devices able to convert light into electrical power. A semiconducting layer absorbs light and releases charge carriers, which are transported to carrier acceptors and the contacts to carry current. Often, the cell will also have blocking layers that only allow one direction of carrier flow. In this project, indium doped tin oxide (ITO) and gold (Au) are used for contacts, while ZnO and α-NPD (N,N′-bis(naphthalene-1-yl)-_N,N′-bis(phenyl)-benzidine) are used as blocking layers.



Leschkies, "Assembly and Characterization of Quantum-Dot Solar Cells." *Diss. University of Minnesota*, (2009)

Multi-junction solar cells have multiple photoactive layers, each able to absorb a different wavelength of light. This reduces power loss due to inability of one material to absorb various wavelengths.

Synthesis of PbSe Quantum Dots

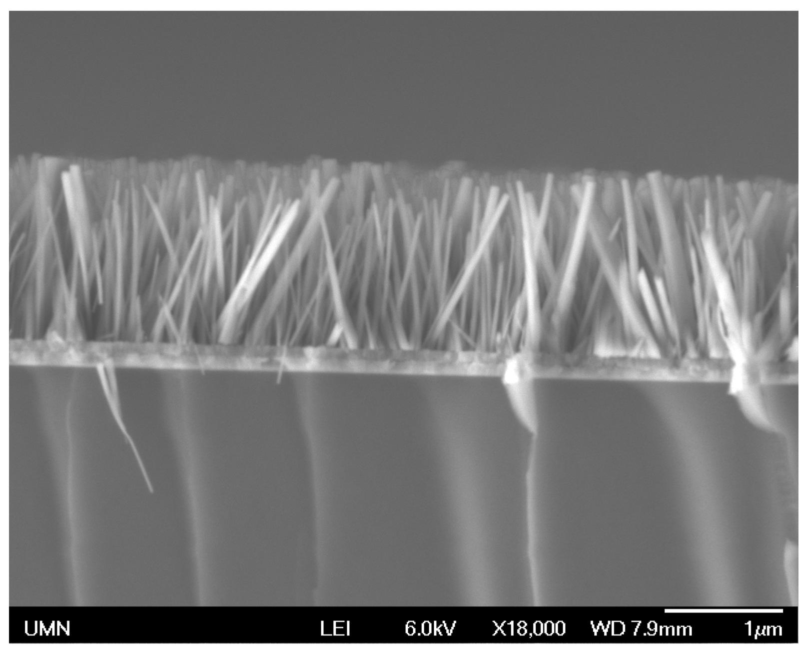


a. Murray *et al.*, *Annu. Rev. Mater. Sci.* **30**, 545 (2000).
b. LaMer & Dinegar, *JACS* **72**, 4847 (1950).

A bottom-up method was used for synthesizing QDs. This method uses high temperature injection and allows precise control over the reaction and yields crystals of higher quality.

The chemical synthesis of QDs has two main stages: First, nucleation occurs, where tiny particles similar to little seeds of the crystal precipitate out of the chemical solution. Then, growth of the crystals occurs until the experiment is stopped by quenching the system.

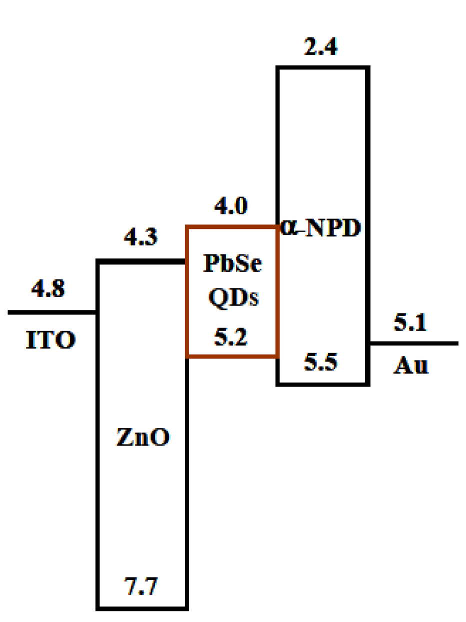
Growth of ZnO Nanowires

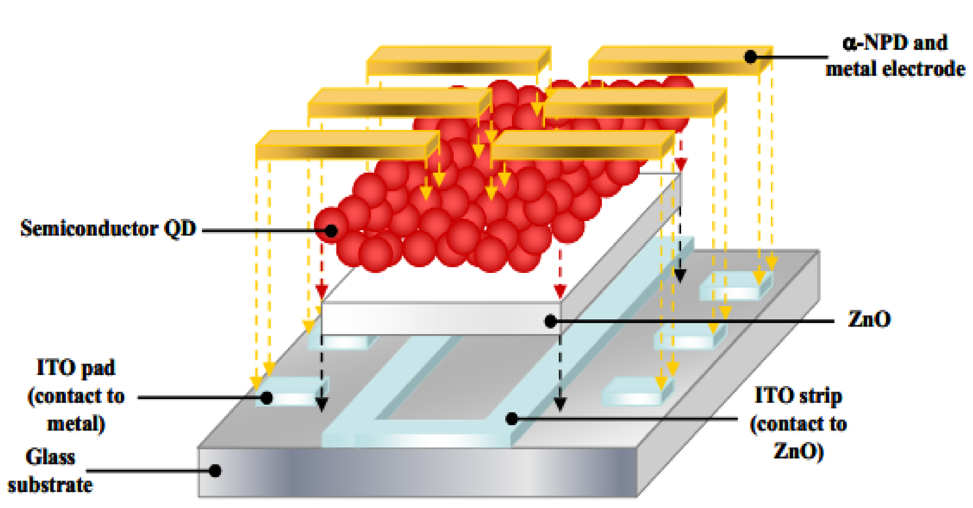


Zinc oxide nanowires were grown by immersing previously sputtered zinc oxide thin films in a reagent solution. This allows homogenous growth of the nanowires. Heating the set up initiates the reaction, which continues until the substrate is removed from the solution and cooled.

The length of the nanowires is linearly related to the growth time. Further, the presence of the ITO layer seems to affect the density and orientation of NWs.

Fabrication and Performance of Planar PbSe – ZnO Cells





Leschkies, "Assembly and Characterization of Quantum-Dot Solar Cells." *Diss. University of Minnesota*, (2009)

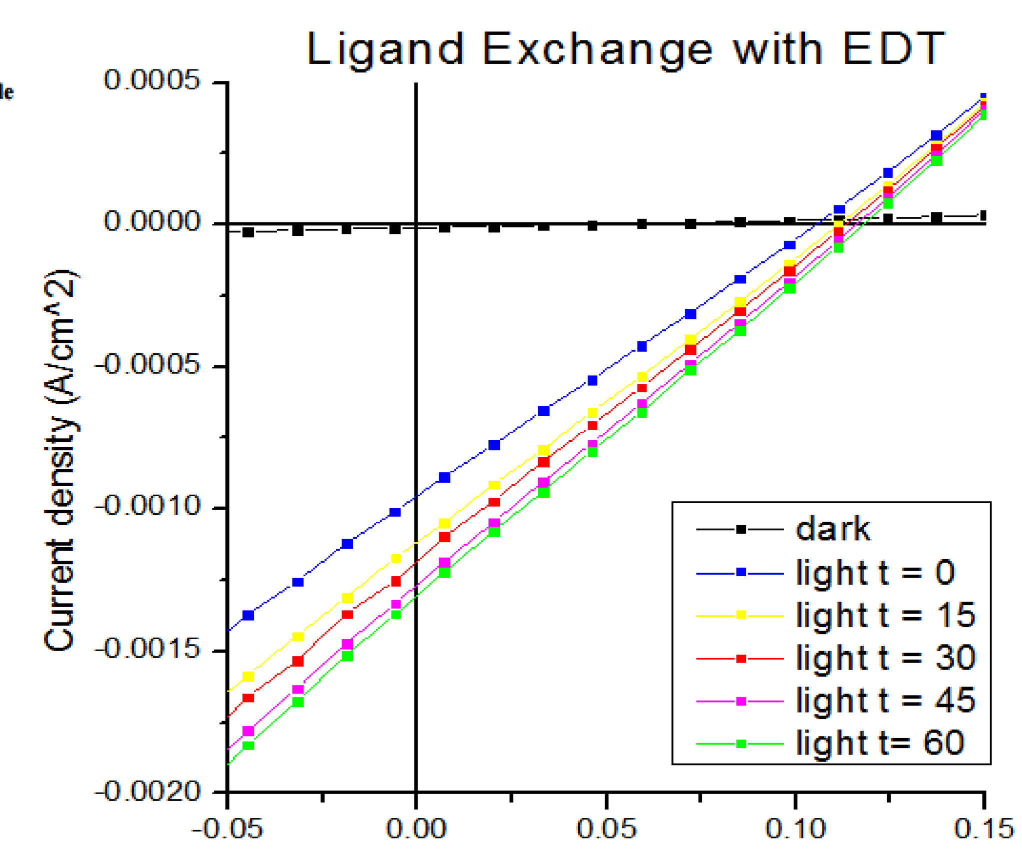
$$PCE = \frac{P_{max}}{P_s} = \frac{J_{sc} \bullet V_{oc} \bullet FF}{P_s}$$

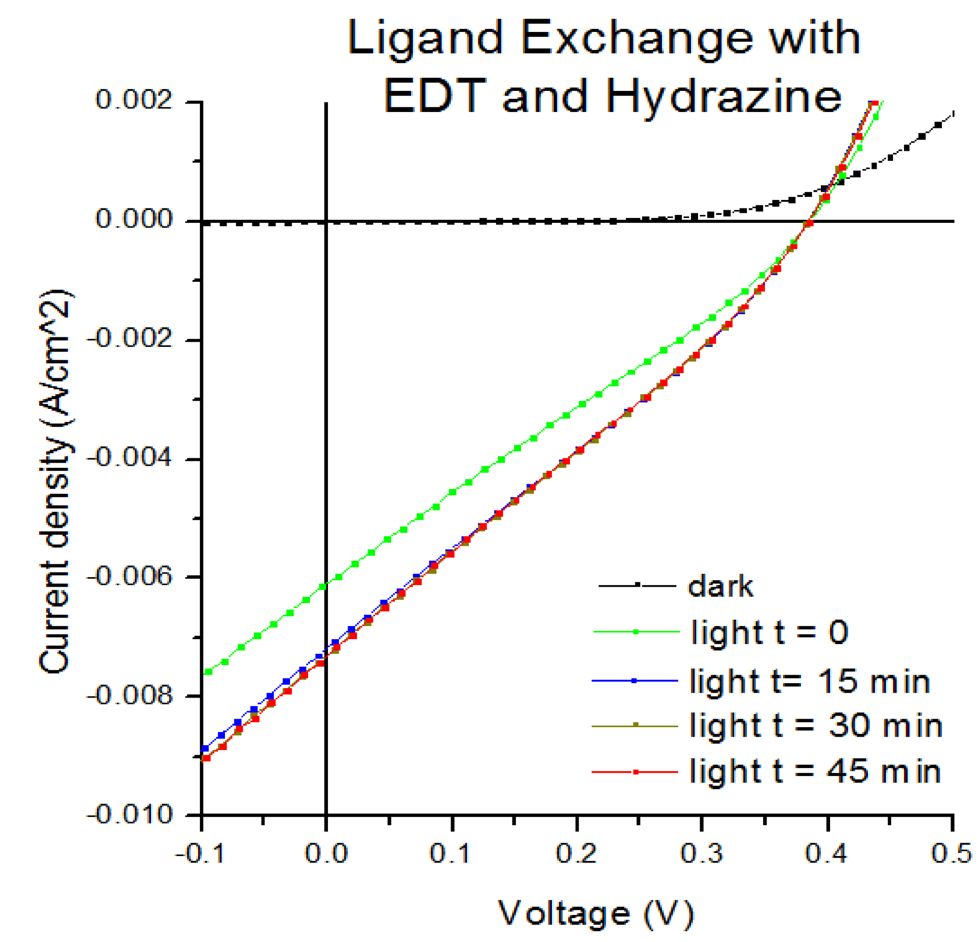
In preparation for solar cell fabrication, long organic ligands used to stabilize the QDs during synthesis are exchanged with shorter ligands. This is done by dipping the substrate into the exchange ligand solution. With shorter ligands, the QDs are closer together and the film conductivity increases. 1,2-ethanedithiol (EDT) and hydrazine were used as ligands.

Ligand Exchange	J_{sc} (A/cm^2)	V_{oc} (V)	Fill Factor	PCE (%)
EDT only	0.00131	0.118	0.252	0.388
EDT + Hydrazine	0.00733	0.386	0.275	0.777

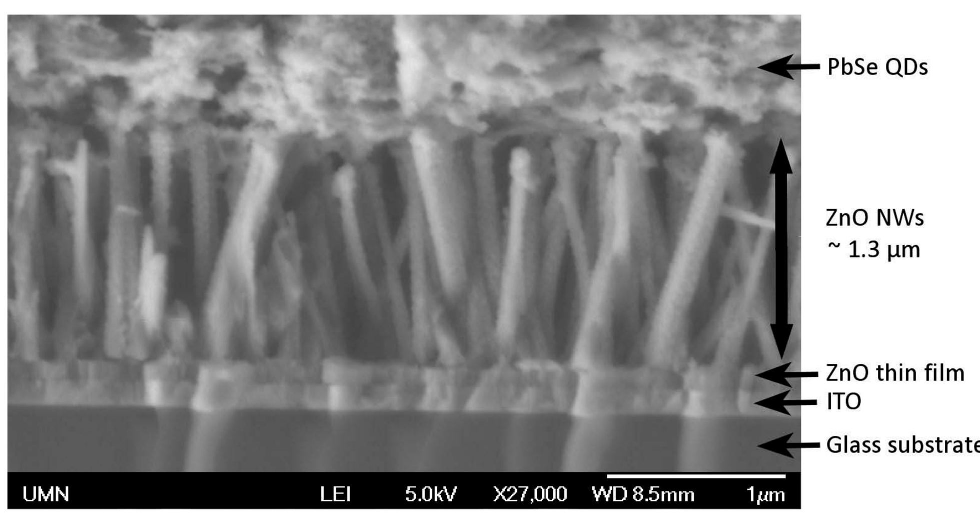
Exchanging organic ligands on the QDs with hydrazine in addition to EDT showed a dramatic increase in the solar cell efficiency compared to exchanging only with EDT.

Furthermore, the power conversion efficiency (PCE) increases with increased exposure to light.

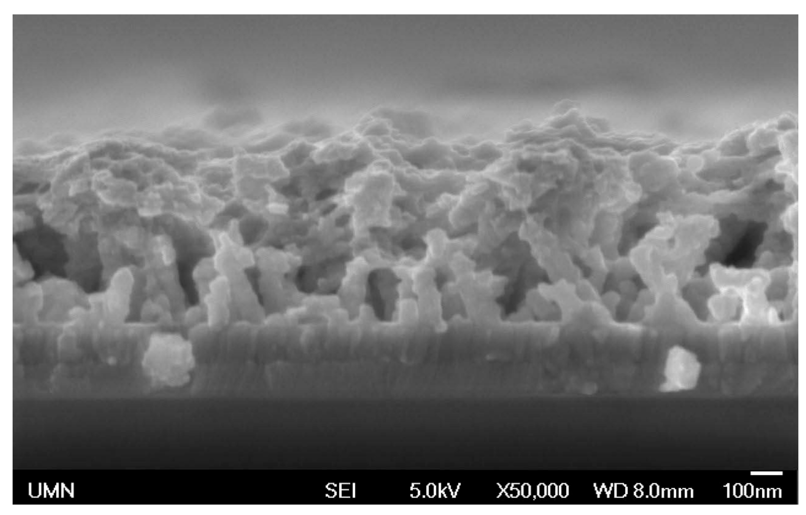




QD-NW junction

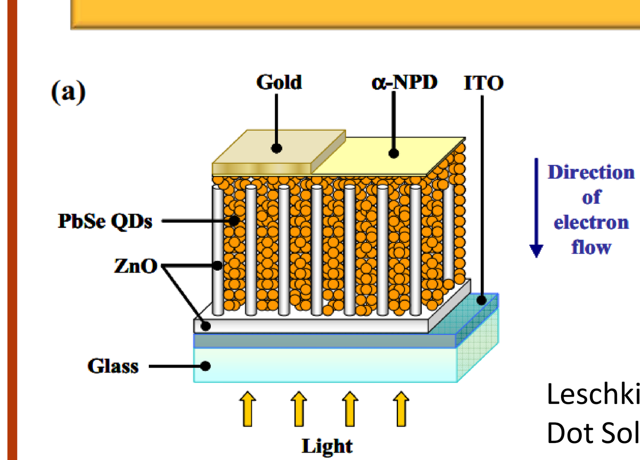


PbSe QDs were dip coated onto the substrate; however, we were unable to penetrate the ZnO NW layer with QDs.



Lowering the concentration of the QD dispersion allowed more penetration into the NW layer.

Future Works



- Fabricate solar cells with ZnO NWs
- Fabricate solar cells with multilayers of different sized QDs and ZnO NWs

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