Lead Chalcogenide Nanocrystals for Solar Cell Applications

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Abstract

Lead sulfide (PbS) and lead selenide (PbSe) nanocrystals were investigated for their potential photovoltaic applications, including their emergence in solar cells. They can create more efficient and cheaper solar cells that can be used to power large scale systems. The best samples were determined by changing the size of the nanocrystals and performing several different ligand exchanges. It was found that thiocyanate (SCN) ligands provide the best electron mobility but also can make the material too conductive for photovoltaic use. The larger nanocrystals also exhibited more semiconducting qualities.

Methods

Lead Chalcogenide Synthesis

- Lead oxide, octadecene and oleic acid were dried under vacuum for 2 hours and stirred.
- The solution was heated to a desired temperature.
- Depending on the nanocrystals being synthesized, a precursor was injected once the solution reached the desired temperature.
  - TOP-Se for PbSe
  - TMS for PbS
- The solution was quenched in an ice (PbSe) or water (PbS) bath after the desired growth time.

Solid Ligand Exchange

- Three drops of nanocrystal solution deposited on an MPTS-treated glass substrate then immediately spun (800 rpm, 30 sec)
- Film coated with ligand solution (1 min); sample then spun (800 rpm, 30 sec)
- Film rinsed three times with the same solvent in ligand solution; sample spun between each coat (800 rpm, 30 sec)

Results

It was observed that for both types of nanocrystals, the higher the temperature of injection, the larger the nanocrystals. For PbS, the more oleic acid, the larger the nanocrystals. For PbSe, the longer the growth time was the larger the nanocrystals.

Motivation for Lead Chalcogenides

PbS and PbSe nanocrystals are of interest in solar cell applications because of their tunable bandgap which gives them the ability to absorb a large range of wavelengths, including infrared. The material is also known for:

- High carrier mobilities
- Low thermal conductivity
- Ability to be processed in solution
- Relatively inexpensive synthesis

Application

Existing solar cells are not ready to supply the high energy consumption our society requires. Currently, crystalline silicon solar cells are very expensive to produce and cheaper organic solar cells are not nearly as efficient. Lead chalcogenides could be the alternative in solar cell applications.

By maximizing the material’s light absorption and charge carrier collection, the introduction of lead chalcogenides in solar cells promise efficiencies well above what conventional solar cells produce today.

Measurements

- **Thickness** using Atomic Force Microscope
  - Uses a cantilever to raster across the surface. A laser beam is set up to detect any deflection due to the surface of the sample.
  - Films were measured to be between 100-200 nm.
- **Ligand exchange verification** using Fourier Transform Infrared Spectrometer
  - Detects double bonds in organic ligands before exchange.
  - Shows if the exchange worked with absence of double bonds.
- **Electron mobility, resistance, and carrier type** using Hall Measurement
  - Sends current through sample with and without an applied magnetic field.
  - Deflection due to the magnetic field is measured and mobility, resistance and carrier types are determined.
- **Seebeck coefficient** using Seebeck Measurement
  - Heat is applied to one end of a sample and the temperature gradient becomes the Seebeck voltage.
  - The seebeck coefficient is measured as Seebeck voltage per unit temperature.

Conclusions

Nanocrystals on the larger size show more promise for solar cell applications. Although SCN improved the electron mobility it also made the material more conductive, which is not ideal solar cells. Hall measurements are still being tested. Different size nanocrystals will continue being tested.