CALIFORNIA STATE SCIENCE FAIR
2013 PROJECT SUMMARY

Name(s)

Alexander S. Powers

Project Number

S0696

Project Title

Effects of Nanocrystal Shape on Efficiency of Quantum Dot Sensitized Solar Cells

Abstract

Objectives/Goals

Nanocrystal (NC) research mainly focuses on the effects of NC size. NC shape has been relatively unexplored in its application to photovoltaics. I hypothesize that elongated NC shapes will impact optical and electrical properties and consequently alter the efficiency of a NC solar cell compared to spherical NCs.

Methods/Materials

Colloidal CdSe quantum dots were synthesized by an organometallic route. CdO, myristic acid, and hexadecylamine in octadecene were heated under nitrogen to 220C. Then Trioctylphosphine-Se was injected and samples were withdrawn at various reaction times and purified. Growth of anisotropic NCs was achieved with a recently developed gold nanoparticle seeding method. The gold surfaces provide a low energy path for CdSe nucleation and result in different growth rates on different crystal faces. Gold nanoparticles in toluene were synthesized via the Brust-Schiffrin method.

To measure photochemical characteristics, NC solar cells were designed based on dye cells. NCs were adsorbed onto mesoporous TiO2 thin films on conductive FTO glass. The counter electrodes were carbon coated and the cell filled with iodide electrolyte. Anthocyanin dyes and bare TiO2 were used as positive and negative controls respectively. The second cell design improved performance with a sealed cell and mercaptopropanoic acid as a bifunctional linker molecule to improve NC adsorption.

Results

NC morphology and optical properties were characterized. HRTEM revealed a unique homogenous tripod nanocrystal with arm lengths of 17.8+/-7.2nm and arm diameters of 3.4+/-0.7nm. Photoluminescence and absorbance spectroscopy demonstrated typical quantum confinement properties; longer growth times (larger particles) were red shifted due to smaller band gaps. Calculations revealed that tripod behavior was determined by arm diameter rather than length and had a band gap of 1.96eV.

Conclusions/Discussion

Despite low quality materials, efficiencies of nearly 0.1% were obtained for tripod-sensitized cells, 45% greater than the efficiency of dot-sensitized cells. These results support the hypothesis. The improved photochemical characteristics of the tripod over dots may be the result of an elongated shape, producing a dipole that improves charge injection into the TiO2. This is the first time tripod NCs have been tested in solar cells. The tripod shape is promising for biomedical diagnostics, quantum computing, and photovoltaics.

Summary Statement

This project demonstrates that a new shape for semiconductor nanocrystals - tripods, rather than simple spheres - increases efficiency of nanocrystal sensitized solar cells.

Help Received

TEM imaging performed by local company (Charles Evans Analytical). Some materials obtained from Stanford and Santa Clara Universities