

TOWARD THE STRUCTURAL UNDERSTANDING AND IMPROVED
PERFORMANCE OF QUANTUM DOT SOLAR CELLS

ABSTRACT

by

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Of the candidates for meeting our world's increasing demand for clean energy, solar energy outshines the others, presenting the potential for orders of magnitude more power than is currently demanded. In order for solar energy use to be economically feasible, however, efficient yet inexpensive solar cells need to be developed. Third generation photovoltaics utilizing nano-scale materials have the potential to fill that need. In this dissertation, three aspects of quantum dot solar cells are addressed with the objective of understanding the nature of the nano-materials utilized and improving efficiencies of the devices based on those nano-materials.

Firstly, growth of ZnO nanowires (commonly employed as high-surface area, directional substrates in nano-structured solar cells) is examined. Reaction species are identified and quantified via *in-situ*, time-resolved x-ray absorption spectroscopy. Contrary to explanations presented in the literature, ZnO nanowire growth is shown to

proceed via direct deposition from precursors without the formation of an intermediate species. Better understanding of the growth mechanisms of will lead to finer control of properties of the deposited nanowires.

Next, a nano-scale semiconductor active layer is considered. Spectroscopic, microscopic, and photovoltaic characterization of CdSe deposited on meso-porous TiO₂ nanoparticle films via Successive Ionic Layer Adsorption and Reaction (SILAR) is described. Using x-ray absorption fine structure (XAFS), the identity of deposited species is shown to depend on the order in which the Cd and Se are deposited, and the interface is only affected during the first few cycles of deposition. Photocurrent and power conversion efficiencies of similarly-constructed quantum dot solar cells also indicate that the order of deposition has a small but noticeable effect on photovoltaic performance. CdSe films deposited via Se-initiated SILAR cycles are shown to increase photocurrent by as much as 16%, and a mechanism for this enhanced performance is described.

Finally, a polymer hole-conductor is employed as the counter-electrode interface for a solid-state solar cell. PEDOT:PSS is shown to efficiently quench the emission of CdSe quantum dots, and analysis of the degree of quenching indicates strong association of the two species. The quantum yield of CdSe is increased by up to 40% in the presence of PEDOT:PSS under steady-state illumination, providing evidence of hole transfer from excited CdSe to PEDOT:PSS. Solid-state solar cells with a TiO₂ / CdSe active layer and a PEDOT:PSS hole-conducting layer show a >80 times increase in power conversion efficiency when compared to a solid-state device prepared without a PEDOT:PSS layer.