Third Generation Solar Photon Conversion to Electricity and Fuel: *Multiple Exciton Generation in Quantum Dots; Quantum Dot Arrays and Solar Cells*

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Abstract:

In order to utilize solar power for the production of electricity and fuel on a massive scale, it will be necessary to develop solar photon conversion systems that have an appropriate combination of high efficiency (delivered watts/m^2) and low capital cost ($/$m^2$); our long-term goal is make solar power (in the form of electricity and fuel) competitive with the cost of coal. One potential, long-term approach is to utilize the unique properties of quantum dot (QD) nanostructures and unique molecular chromophores to control the relaxation pathways of excited states to produce enhanced solar conversion efficiency through efficient multiple exciton generation (MEG) in QDs and singlet fission in molecules. We have observed very efficient multiple exciton generation (MEG) in PbSe, PbS, PbTe, and Si QDs at threshold photon energies of 2-3 times the HOMO-LUMO transition. We have studied MEG in close-packed QD arrays where the QDs are electronically coupled in the films and thus exhibit good carrier mobility. We have developed a simple, all-inorganic metal/QD/metal sandwich solar cell that produces a large short-circuit photocurrent (~25-35 mA/cm^2 - equivalent to crystalline Si) via a Schottky junction at the negative electrode, without the need for QD sintering, superlattice order or separate phases for electron and hole transport. We have demonstrated that the MEG efficiency in conductive PbSe QD films after certain chemical treatments is comparable to isolated QDs in colloids, but it varies greatly depending upon the specific chemical treatment. We have also demonstrated multiple triplet formation in unique molecules designed to undergo single fission—a process that is the molecular analog of MEG. Selected aspects of this work will be summarized and recent advances will be discussed.