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Multiple Exciton Generation for Highly Efficient Solar Cells[1]

ARTHUR NOZIK, National Renewable Energy Laboratory

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 and low capital cost ($\$/m^2$). One new potential approach to high solar cell efficiency is to utilize the unique properties of semiconductor quantum dot nanostructures to control the relaxation dynamics of photogenerated carriers to produce either enhanced photocurrent through efficient multiple exciton generation (MEG) or enhanced photopotential through hot electron transport and transfer processes. To achieve these desirable effects it is necessary to understand and control the dynamics of electron relaxation, cooling, multiple exciton generation , transport, and interfacial electron transfer of the photogenerated carriers with fs to ns time resolution. We have been studying these fundamental dynamics in bulk and nanoscale semiconductors (quantum dots, quantum wires, and quantum wells) using femtosecond transient absorption, photoluminescence, and THz spectroscopy. This work will be summarized and recent advances in creating multiple excitons from a single photon will be discussed, including a unique model to explain efficient MEG based on the coherent superposition of multiple excitonic states. Various possible configurations for quantum dot solar cells that could produce ultra-high conversion efficiencies for the production of electricity, as well as for producing solar fuels (for example, hydrogen from water splitting), will be discussed, along with associated thermodynamic calculations that show the increase in the maximum theoretical gain in solar photon conversion efficiency for both electricity and fuel production.

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