Carrier Dynamics in Semiconductor Quantum Dots and Potential Applications to High Efficiency Solar Photon Conversion (Research Award Lecture)

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Recent analyses of future global energy needs indicate that from 10-20 TW- yr (1 TW = 1E12 watts) of carbon-free energy will be required by 2050 to stabilize the atmospheric carbon dioxide concentration at levels not exceeding 2 to 3 times the pre-industrial values (550 and 750 ppm, respectively). This is an exceeding daunting goal considering that the current total global consumption of energy of all forms is about 12 TW- yr. Solar energy is the major renewable resource that has the potential to supply such levels of carbon-free power; about 600 TW of solar power arrives on earth on land in favorable sites. In order to utilize solar power for the production of electricity and fuel on a massive scale, it will be necessary to develop photon conversion systems that are either highly efficient or extremely inexpensive. One potential approach to high efficiency is to utilize quantum dots to produce either enhanced photocurrent through impact ionization or enhanced photopotential through hot electron transport and transfer processes. To achieve these desirable effects it is necessary to understand and control the relaxation dynamics of the photogenerated carriers with fs time resolution. We report on such studies in semiconductor quantum dots and discuss potential configurations of quantum dot solar cells that could yield high conversion efficiency or low cost.