2010 Fall Physics Colloquium Series

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Hot Electrons and a Path Towards the Ultimate Solar Cell

This lecture will address a fundamental question related to the use of nanomaterials in solar energy -- namely, whether semiconductor nanocrystals can help surpass the efficiency limits in conventional solar cells. As is known as the so-called "Shockley-Queisser" limit, the maximum theoretical efficiency of a single-junction solar cell, such as the silicon solar cell in use today, is ~31%. This is because absorption of photons with energies above the semiconductor bandgap generates hot charge carriers that quickly cool to the band edges before they can be utilized to do work. If instead, all of the energy of the hot carriers could be captured, solar-to-electric power conversion efficiencies could be increased, theoretically, to as high as 66% in the so-called hot carrier solar cell. Semiconductor nanocrystals have been touted as promising materials for photovoltaics because discretization of their electronic energy levels may slow down hot carrier cooling and, thus, enable the harvesting of hot carriers. However, such hot carrier transfer to electron or hole conductors has not been demonstrated experimentally. Using time-resolved optical second harmonic generation, we show that hot electron transfer from semiconductor nanocrystals (PbSe) to a widely-used electron acceptor (TiO2) is indeed possible and, with appropriate chemical treatment of the nanocrystal surface, occurs on a much faster timescale than previously expected (within 50 fs). Moreover, we discovered that the transient electric field resulting from ultrafast charge separation across the PbSe-TiO_2 interface impulsively excites coherent vibrations of the TiO_2 surface atoms, whose motions can be followed in real time. These results are expected to be of general significance to other semiconductor nanocrystals. Moreover, if hot electron (hole) transfer can be controlled to occur in very narrow energy windows to also minimize loss in the electron (hole) conductor, the highly efficient hot carrier solar cell may be realized. The lecture will end with a discussion on future challenges in designing and building the ultimate solar cell.

Wednesday, November 3, 2010

4:00 p.m.

Room E.125, Baylor Sciences Building

Reception at 3:40 p.m. in BSB D.311

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