Printable Semiconductor Nanocrystal "Inks" for Solar Energy Conversion

If economically harvested, the Sun could provide a carbon neutral source of renewable energy to meet the world's current consumption. Widespread utilization of solar power will depend on the development of efficient light-to-electricity conversion technologies suitable for massive scale-up. The current leading technology in commercial photovoltaics – crystalline silicon – is prohibitively expensive for many solar energy applications due to low-throughput, energy-intensive processing. As an alternative, micro- and nanoscale semiconductors can be used as the building blocks for inexpensive and efficient photovoltaics. Solution-based engineering of nanomaterials has seen tremendous developments in the past decade, with synthetic strategies developed for a variety of technologically important semiconductors. Nanostructured semiconductors offer exciting pathways for inexpensive next-generation photovoltaic technologies – nanomaterial surfaces can be coordinated with molecular species, nanostructures can easily form stable colloidal solutions, convenient for materials processing and roll-to-roll fabrication of large-area photovoltaic modules.

I will describe the implementation of small (~ few nanometer) semiconductor crystallites (quantum dots or QDs) as the light-absorbing layer in solar cells. The advantages of using QDs in solar cells include (i) band gap tunability by changing their size, (ii) potential for generating multiple electron-hole pairs per photon, and (iii) the ability to produce large (kilogram) quantities of material using mild conditions, which can then be deposited using inexpensive high-throughput coating processes to form photovoltaic devices. These aspects make solar cells based on QDs promising for "third-generation" photovoltaic technologies. I will discuss two different strategies to using colloidal nanocrystals for photovoltaics. The first route uses room-temperature spray deposition of nanocrystals to construct a nanocrystalline semiconductor light-absorbing layer. The second approach uses low-temperature (~350°C) sintering of CdTe QDs to form large (> 100 nm) sized grains. This talk will cover the synthesis of the nanomaterial precursors, approaches to manipulating electronic and optoelectronic properties of the semiconducting films, and their assembly into solar cells. Finally, I will discuss how manipulation of the nanocrystal surface chemistry can lead to improved transport, giving potential for further improvements in power conversion efficiency.