Solution-processed inorganic photovoltaics from semiconductor nanocrystals

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Colloidal semiconductor nanocrystals (NCs) are attractive building blocks for solar photovoltaics (PV) for at least two reasons. First, some NCs offer the potential for ultra-high power conversion efficiency by, for example, the process of multiple exciton generation (the production of several electron-hole pairs per absorbed photon) in PbS or PbSe NCs. Multi-exciton generation may result in larger currents and higher efficiencies than traditional PV. Second, NCs are amenable to low-cost, roll-to-roll processing from NC inks, which ideally contain only nontoxic, earth-abundant materials. The ability to print PV like newspaper may offer excellent manufacturing scalability at very low cost compared to conventional single-crystal and thin-film approaches. This talk highlights projects that target both approaches. I describe NC solar cells based on thin films of electronically-coupled PbS or PbSe NCs in Schottky and *p-n* heterojunction configurations. Variable-temperature electron and hole field-effect mobility measurements of alkanedithiol-treated PbSe NC films as a function of NC size, ligand length, and illumination are used to probe the mechanism of charge transport in these materials and to test strategies for boosting carrier diffusion lengths. These results establish a baseline for mobility trends in PbSe NC solids and have implications for fabricating high-mobility NC-based optoelectronic devices. I show that oxidation and photothermal degradation of NC films can be prevented by using low-temperature atomic layer deposition (ALD) to fill the pores of these films with various inorganic matrices to produce inorganic nanocomposites in which the NCs are locked in place and protected against oxidative and photothermal damage. ALD-infilling of PbSe NC field-effect transistors and solar cells yields devices that operate with enhanced and stable performance for at least months in air. I also discuss an effort at UCI to make efficient PV from NC films of earth-abundant iron pyrite (FeS_2). Phase-pure, stable pyrite NC inks have been synthesized and used to make polycrystalline pyrite thin films. The optical and electronic properties of these films are described, along with strategies for fixing the historically low photovoltage of pyrite PV.

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