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Matrix engineering, state filling, and charge transport in PbSe quantum dot solids

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Colloidal semiconductor quantum dots (QDs) are attractive building blocks for solar photovoltaics (PV). In this talk, I will highlight our recent progress in designing PbX (X = S, Se, Te) QD thin film absorbers for next-generation PV. Basic requirements for QD absorber layers include efficient light absorption, charge separation, charge transport, and long-term stability. I begin by discussing QD film fabrication, charge transport physics, insights from theory, and evidence that the carrier diffusion length is short and limited by electronic states in the QD band gap. Studies of carrier mobility as a function of basic film parameters such as inter-QD spacing, QD size, and QD size distribution have led to a better understanding of charge transport within highly disordered QD films. Efforts to improve carrier mobility by enhancing inter-dot electronic coupling, passivating surface states, and implementing surface doping will be highlighted. Engineering the inter-QD matrix to produce QD/inorganic or QD/organic nanocomposites is presented as a powerful way to optimize coupling, remove surface states, eliminate hysteretic charge trapping and ion motion, and achieve long-term environmental stability for high-performance, robust QD films that feature good carrier multiplication efficiency. New results on the use of atomic layer deposition infilling of QD films to yield all-inorganic QD transistors free of the bias-stress effect will be presented, and the likely role of ion transport in QD optoelectronics discussed. The use of infrared transmission spectroscopy to understand state filling and study charge transport in QD thin film transistors will be presented.