Thermoelectric Properties of Colloidal Quantum Dot Solids

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Colloidal quantum dot solids (QDS) are solution-processable thin-films that exploit the quantum confinement properties of the constituent nanocrystals. The quantum confinement effect occurred in this materials generates distinct features than their bulk counterparts that are energy bandgap variations by size and the quasi-atom-like discrete energy levels. These two important properties of the QDs, in addition to the solution-processability, are intriguing for applications in developing novel energy harvesting devices. While the tunable absorption spectrum and the possibility to have multiple exciton generation in these systems are attractive for highly efficient solar cells,[1] the discrete energy levels with sharp peaks of their density of states, are prospective for developing new thermoelectric material systems. Moreover, the QD diameters are smaller than phonon mean-free-path, thus predicted to have low thermal conductivity. Nevertheless, the low electronic conductivity of the QDS still hamper this possible applications.

Here we demonstrate the field-induced doping control in monolayers of PbS QDS by the use of ionic liquid gating. This technique accumulate a very high carrier density that fill the available carrier traps,[2] so that carrier mobility value and the electronic conductance can greatly increase.[3] Furthermore, it allow us to access the preserved discrete energy levels of the QDs.[4] Through this capability, we establish a way to characterize the thermoelectric properties of monolayers of QDS, from which a high value of Seebeck coefficient more than 1 mV/K is demonstrated. The achieved field-induced doping is beneficial to modulate the Seebeck coefficient of these materials, proving their prospects for developing ubiquitous near-room-temperature thermoelectric devices.

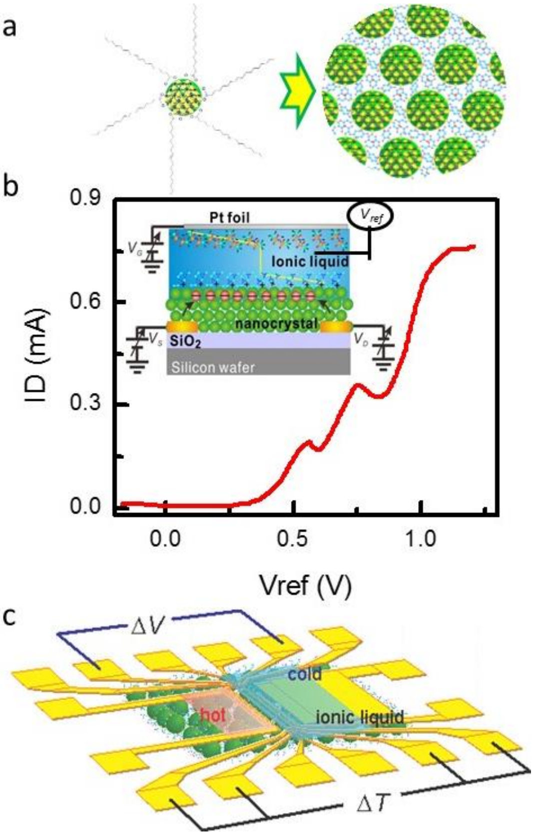

Figure 1 **(a)** Schematic of crosslinking PbS colloidal quantum dot solids (QDS) with shorter ligands to form a well-ordered superlattice. **(b)** I_D-V_{ref} transfer characteristics of field-effect transistors of PbS QD solids gated using ionic liquid. The steps and negative transconductance features reflect the discrete energy levels of the QDs. **(c)** Schematic of the thermoelectric microdevice of the QDS from which high Seebeck coefficient was obtained.

Refs: [1] C. Piliego, S.Z. Bisri, et al. *Energy & Env. Sci.* 6, 3054 (2013); [2] M.I. Nugraha, S.Z. Bisri, et al. *Adv. Mater.* **27**, 2107 (2015); [3] S.Z. Bisri, et al. *Adv. Mater.* **25**, 4309 (2013); [4] S.Z. Bisri, et al. *Adv. Mater.* **26**, 5639 (2014).