High Mobility and High Carrier Density in PbS Colloidal Quantum Dot FETs

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Colloidal quantum dot superlattices (CQDS) emerge as new type of hybrid solid thin-films allowing solution-processable fabrication of optoelectronic devices that exploits the quantum confinement properties of the individual QD. PbS CQD displays peculiar characteristics prospective for photovoltaic and photodetector applications. Nevertheless, the charge carrier transport properties of this are not well understood and yet to be investigated. One of the difficulties is the large amount of carrier traps due to the fabrication process. Only in an ultraclean condition, PbS CQD FET can be realized.[1,2] Efforts have been made to quantify the number of traps for holes and electrons in the CQD ambipolar FETs.[3]

Here we discuss the investigation of the properties of PbS CQDs using electric double layer transistor (EDLT) of ionic liquid. The high carrier density accumulated by EDLT allow us to fill the carrier traps, to improve the device performance, and to evaluate the intrinsic nature of the QD assembly.[1,4] We demonstrate ambipolar FET of PbS CQDs with electron mobility as high as 14 $cm^2/V.s$ owing to the usage of the ionic liquid gating in addition to the improved ordering in the QD superlattice within the FET channel. Through the usage of ionic liquids with larger electrochemical window as well as higher capacitance, the ambipolar FET can be used to access the discrete energy subbands of the QDs. This opens way for a further exploitation of the quantum size effect for new devices beyond FETs, e.g. laser, thermoelectric, multistate FETs, etc., where access to the QD energy subbands is crucial.

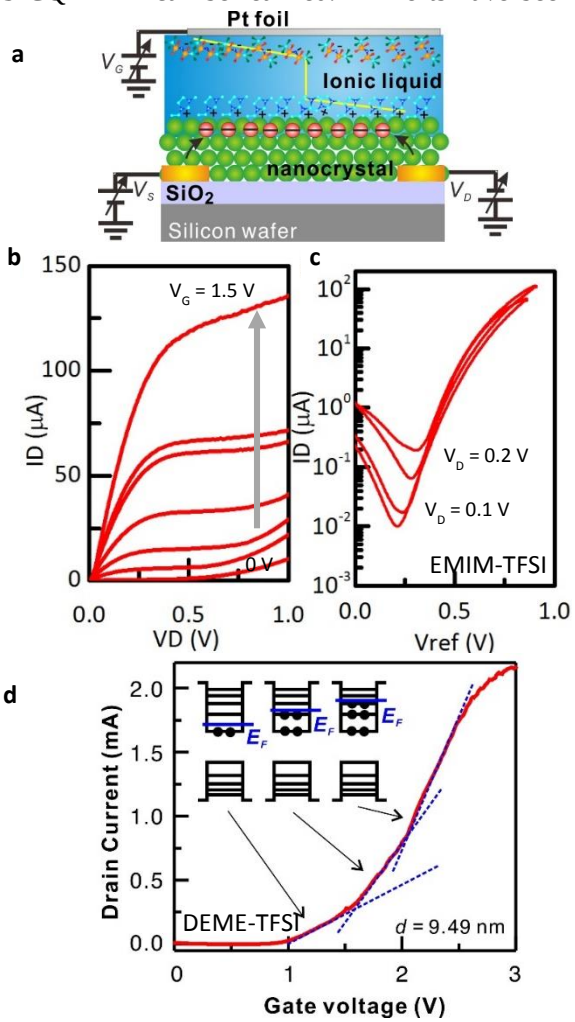

Figure 1 (a) Schematic of field-effect transistors of colloidal quantum dots gated using ionic liquid. **(b)** n-channel I_D-V_D output and **(c)** I_D-V_G transfer characteristics of ambipolar FET of PbS QDs gated using EMIM-TFSI ionic liquid. **(d)** Probing the energy subbands of 9.49 nm diameter PbS QD using the ambipolar FET gated using large electrochemical window of DEME-TFSI ionic liquid. Reprinted and adapted with permission from ref. 4. Copyright Wiley-VCH 2014.

Refs:[1] S. Z. Bisri, et al. *Adv. Mater.* **25**, 4309 (2013); [2] D. M. Balazs, S. Z. Bisri, et al. *Appl. Phys. Lett.* **104**, 112104 (2014); [3] M. I. Nugraha, S. Z. Bisri, et al. *Adv. Mater.* **27**, 2107 (2015); [4] S. Z. Bisri, et al. *Adv. Mater.* **26**, 5639 (2014).