On-Demand Electrical Properties of Building-Block Quantum Dots Solid by Assembly Control

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Colloidal quantum dots (QD) materials have become a great attention among researchers since they show the unique properties beyond their bulk form. Their unique properties are attributed to the quantum confinement effect since the size of materials reduced to their excitonic Bohr radius, thus exhibiting the size-dependent band-gap and discrete energy level. Therefore, they are suitable for many application such as photovoltaic cells, displays, lightings, thermoelectric, etc.[1] Even more, the solution-processable synthesis technique of colloidal QD is already able to precisely control the size which has a great impact in obtaining the on-demand properties. Furthermore, to perform the colloidal QD for such kind of applications, the post-surface treatment is required since the original QDs are capped by insulating molecular ligand which can limit the devices performance. For this reason, the post-treatment, so-called ligand-exchange, is performed to replace the insulating ligand and increase the coupling (interaction) among the individual QDs.[2] However, the mesoscopic defects on the large scale assemblies caused by the ligand-exchange processes itself remains as a big challenge. Here we demonstrate the efforts to control the film formation of PbS colloidal QDs as well as the investigation on the influence of the assembly structures to their electrical properties by means of electrolyte-gated field effect transistor (FET).[3] Through this technique, the high carrier accumulation can be produced to virtually fill the charge trap states, thus the comprehensive comparison of the assemblies could be obtained. In brief, three different assembly morphologies of QDs were obtained by three different deposition methods, exhibiting strong influence to their electrical properties, with respect to the high electron mobility (in superlattice) and the high density of the accumulated charge carrier (in porous structure) that can be achieved. These findings demonstrate that each deposition technique of QD assemblies can be specified and tailor-made to satisfy requirements for different applications of this emerging materials.

Refs.:[1] C. R. Kagan, C. B. Murray. *Nat. nanotech.* 10.12: 1013-1026 (2015) [2] Liu et al. *ACS Appl. Nano Mater.* 1.9 (2018): 5217-5225, [3] Bisri et al. *Adv. Mater.* 25.31 (2013): 4309-4314.

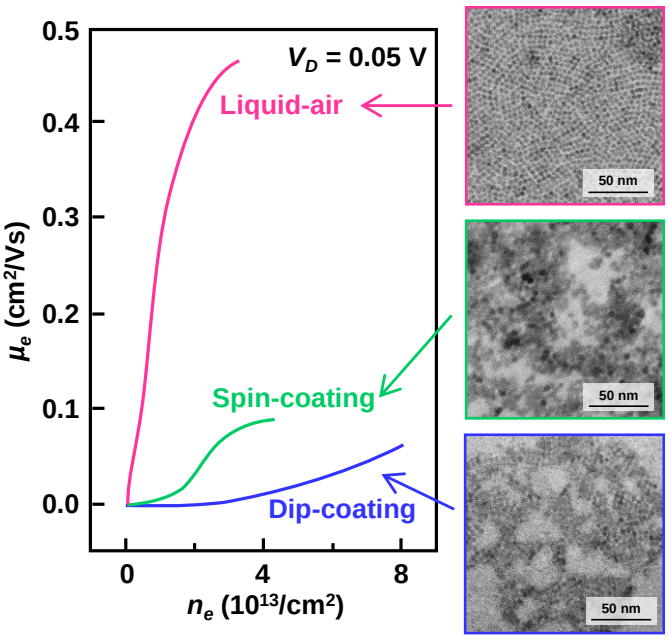

Figure 1. Electron mobility vs. carrier density curve of electrolyte (ionic liquid)-gated FET. Carrier accumulation density was determined by displacement current measurement (DCM). TEM images of PbS QD assembly show highly-ordered assembly, amorphous-like, and porous structure which derived from liquid-air interfacial assembly, spin-coating, and dip-coating method, respectively.