

コロイド量子ドット薄膜における高い正孔移動度

High hole mobility in PbS Colloidal Quantum Dot Assemblies○Liming Liu^{1,2}, Satria Zulkarnaen Bisri¹, Yasuhiro Ishida¹, Yoshihiro Iwasa^{1,2} and Takuzo Aida^{1,2}

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Doping in Colloidal Quantum Dot (QD) assemblies is very important for many of their applications, such as solar cells [1], light emitting diode (LED), thermoelectrics, and so on. For QDs that have inherently ambipolar characteristics in their bulk, such as in lead chalcogenides, appropriate doping strategy will determine the type of majority charge carrier in the device. Several efforts to effectively dope lead chalcogenide QDs have been reported. Controlling the usage of ligands, which determine the distance between the QDs and could crosslink them [2], would provide route to modify the trap states and dope the QDs. While controlling n-type QD films have been successfully obtained by capping them with ligands such as hydrazine and halide ions (I⁻, Br⁻, Cl⁻), it is not the case for performing p-type doping. P-type PbX QD films have so far mostly been obtained via either intentional or unintentional oxidation of the films in ambient conditions, which is much harder to control and only capable to provide low mobility values ($<10^{-3} \text{ cm}^2 \cdot \text{V}^{-1} \cdot \text{s}^{-1}$). [3] This limits the performance of many QD-based devices, in particular QD-based solar cells. Therefore, to find a new type of ligands that can provide better hole transport in QD films is very crucial to improve carrier extraction.

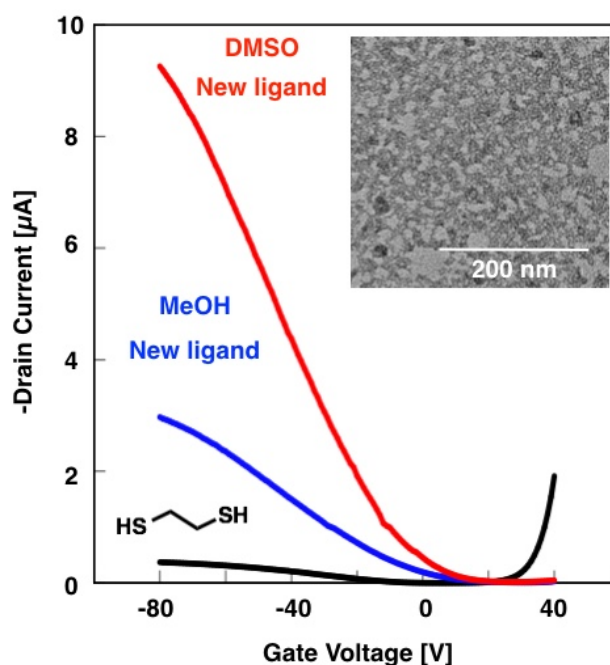


Figure1. I_D - V_G transfer characteristics measured in new ligand-treated QDs FETs demonstrate p-type characteristics. The usage of DMSO solvent for ligand exchange gives 10x higher mobility than that of MeOH. (inset) TEM of QD assembly after ligand exchange.

Here we demonstrate the utilization of a new kinds of bidentate molecular ligand based on thiophene core that able to significantly enhance hole transport in lead sulfide (PbS) QDs. We realized a p-type field-effect transistor with hole mobility as high as $0.018 \text{ cm}^2 \cdot \text{V}^{-1} \cdot \text{s}^{-1}$. This value is a record highest ever reported for PbS QDs. This hole mobility enhancement is achieved without compromising the current modulation on/off ratio that commonly occurs in p-type doping via deliberate oxidation. Our devices consistently demonstrate on/off ratio around 10^3 , which rarely achieved in any p-type transistors of colloidal QD assemblies. Detailed study reveals that the solvent used for the ligand exchange/film formation process is also a crucial factor for the assembly quality of QDs and their hole transport characteristics (Fig.1). The transmission electron microscopy (TEM) of QDs film fabricated with aid of dimethyl sulfoxide (DMSO) for the ligand exchange were found to be more closely packed than that fabricated with the aid of methanol. This also justified by the enhanced hole mobilities in the more compact films. The present new ligand, giving QD films with high hole mobility, will be vital for constructing high-performance QD-based photovoltaics, especially those of p-n junction type.

Reference

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