Selective-Surface-Ligand-Stripping-Driven Conducting Lead Sulfide Colloidal Quantum Dots Assembly

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The term of colloidal quantum dots (CQDs) is attributed to the solution-processable QDs materials which is attractive for many kind of appilcations such as opto-electronic and energy harvesting devices, owing to their intriguing properties due to the quantum confinement phenomenon. As synthesized, each particle of the QDs is capped by long-organic molecule (e.g. oleic acid) as a ligand to stabilize the QDs in solution. However, from the electronic device's point of view, this long-ligand must be removed in order to enhance the coupling among the QDs within the assembly. The substitution of long-ligand to the short-ligand (e.g. ethanedithiol, mercaptopropionic-acid, iodide, etc.) on the whole surface of the QDs is performed via the well-known ligand-exchange process.[1] Currently, some studies show that removing or stripping the ligand (instead of ligand-exchange) form the specific facet of the QDs surface induces an oriented-assembly with the "epitaxially-connected" among the QDs.[2] Furthermore, the quantum-confinement of this assembly structure is still maintained, leading to the promising way in order to obtain the greatest carrier transport performance through the QDs assembly.[3]

Here we demonstrate the effort on controlling the ligand-stripping process on lead sulfide (PbS) QDs to form an epitaxially-connected of the assembly as well as the measurement and investigation of its electronic properties. The ligand-stripping process was conducted by immersing the deposited PbS QDs into various polar-organic solvent in which the solubility of oleic acid in those kinds of solvent is the key parameter of the stripping. The electronic property of the assembly was evaluated in field-effect-transistor (FET) device. From this experiment we confirm the transition from insulating to conducting PbS QDs assembly after ligand-stripping process while the assembly change from hexagonal (with long space between the QDs) to oriented-square assembly (fig. 1a). The long-time reaction (fig. 1b) or high solubility of oleic acid in the solvent (fig. 1c), however, leading to the suppression of electron transport due to the formation of trap-state generated by over-stripping surface ligand. Therefore, this study will open the new window on how the electronic transport performance in the QDs assembly can be enhanced to satisfy the electronic device performance.

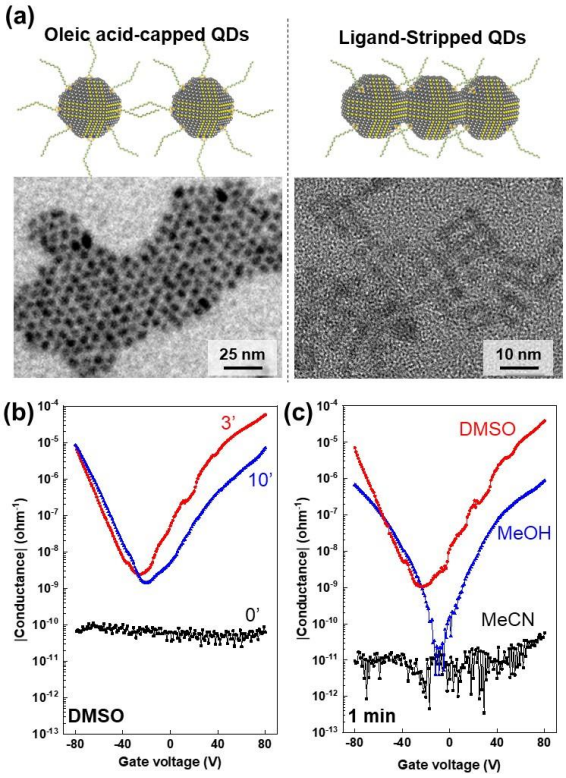

Fig 1. (a) Illustration and TEM image of oleic acid-capped QDs (left) and ligand-stripped QDs assembly (right). I_D-V_G transfer curve of (b) DMSO-treated PbS QDs in various time of immersion and (c) PbS QDs assembly treated by various organic solvent.

Refs.:[1] Septianto, R. D., et al. *NPG Asia Materials* 12.1: 1-14 (2020), [2] Baumgardner, William J., et.al., *Nano letters* 13.7: 3225-3231 (2013), [3] Liu, Liming, et al., *Nanoscale* 11.43: 20467-20474 (2019)