Abstract of Master's Thesis, 2015

Solar cell fabrication based on surface modified PbS colloidal quantum dots

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[Introduction] Photovoltaic (PV) cell is expected to be the dominant renewable energy source. However, current commercial PV cells are expensive and not efficient enough. Solution processed quantum dots (QDs) PV cells are the focus of our research because it offers a path to more cost-efficient devices. In particular, the use of quantum confinement to tune the bandgap to efficiently absorb the broad solar spectrum. In addition, QDs exciton dynamics allow the multiple exciton generation (MEG) by absorption of a single photon. These two very interesting features can reduce thermalization and transmission losses, which are the main issues limiting the efficiency of current PV cells. Despite its great potential and the expectations for QDs PV cells to become the third generation of solar cell, its energy conversion efficiency remains low; although, the solutions remain unclear, often the issues driving the efficiency low are known: electrical conductivity on the QDs film and low open-circuit voltage (Voc). The origin of the lack of conductivity in PbS QDs films resides on its capping agent, oleic acid (OA), which has a long organic ligand tail affecting the particle inter-spacing. I approach this problem by exchanging the OA, through a solid state surface treatment, to potassium thiocyanate (KSCN). This research expects KSCN to shorten the participles inter-spacing, thus improving conductivity in PbS QDs film1), as shown in Figure 1. Furthermore, as the second aim of this research, PbS QDs were synthesized regarding size the distribution (SD). Devices with broad SD QDs have both compromised: Voc and conductivity.

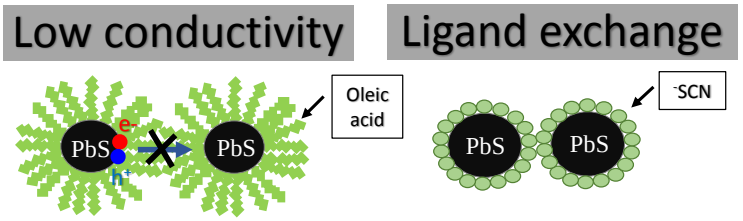

Fig. 1. Surface modification of PbS QDs.

[Experimental] Synthesis of PbS QDs: PbS QDs were synthesized in the same method as by Murray and co-workers2). In the attempt to get narrow SD of PbS QDs, the growth time after the injection of hexamethydisilathiane (TMS) was controlled. Four samples of the PbS QDs solution were collected from the same reaction bottle after njection: 30 s, 2 min, 5 min and 10 min. The SD was estimated from absorption and photolum inescence spectra.

PbS QDs PV cell with surface treatment: as shown in Figure 2, the heterojunction PV cell was fabricated using FTO as the cathode, TiO2 as the electron transporter layer, the PbS QDs as the active layer, molybdenum oxide as the hole injection layer and gold as the anode.

PbS QDs surface treatment: surface treated PbS QDs layers were soaked into 100 mM KSCN/MeOH solution for 60 s and then rinsed by methanol and octane. The same procedure was repeated for the 15 layers. The PbS QDs PV cell was evaluated by electric characterization and its power conversion efficiency was measured under simulated sunlight of AM 1.5. The PL spectra and the decay curves were measured by using a fluorescence microspectroscopy technique.

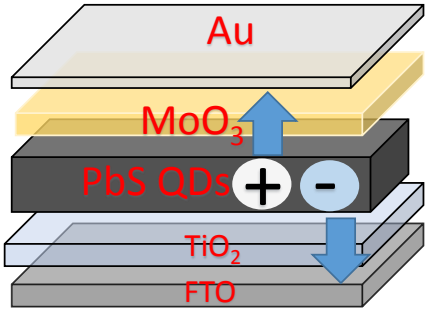

Fig. 2. Structure of fabricated PbS QDs PV cell.

[Results and discussion] The narrow SD of PbS QDs could be

achieved by limiting the reaction time as shown in Figure 3. The best result regarding SD and PL intensity was by stopping the reaction after 30 s. As shown in Figure 4, longer growth time results in broader SD. For the optical characterization, the results indicated that KSCN was efficient in reducing the particle inter-spacing. The PL decay curve in Figure 5, the KSCN treated film shows a faster decay compared to PbS QDs capped with oleic acid film. The absorption spectra in Figure 6 confirmed redshift in the bandgap of PbS QDs film treated with KSCN. However, in Figure 7, the electrical characterization results show, for this research, KSCN could not improve conductivity for PbS QDs PV cells, and the PCE result was as small as 0.41%. The difference in quality from the optical characterization to the electrical characterization might be consequence of PbS QDs film homogeneity. Transmission microscope images in Figure 8 show QDs aggregation areas in different parts of the film.

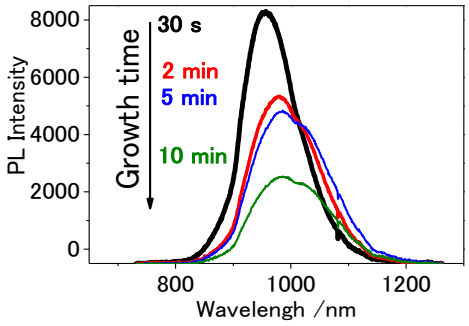

Fig. 3. PL spectra of synthesized PbS QDs with change of size distribution by change of growth time.

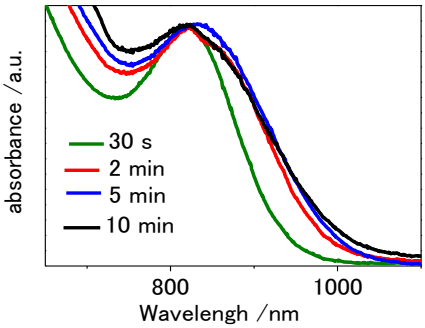

Fig. 4. Absorption spectrum of samples with different growth time: 30 s, 2 min, 5 min and 10 min. The 30 s growth sample has a more narrow size distribution

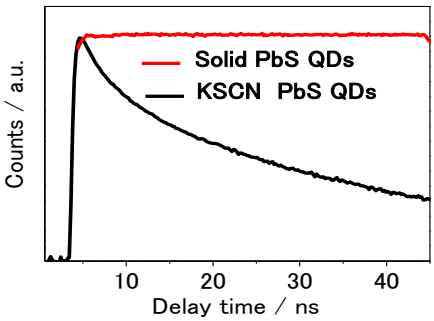

Fig. 5. The decay curves of PbS QDs film drop coated (dark red) and of PbS QDs film tread with KSCN (dark).

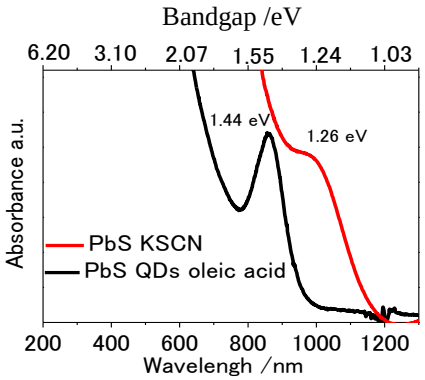

Fig. 6. The KSCN surface treatment caused red shit in the PbS QDs film absorption spectrum.

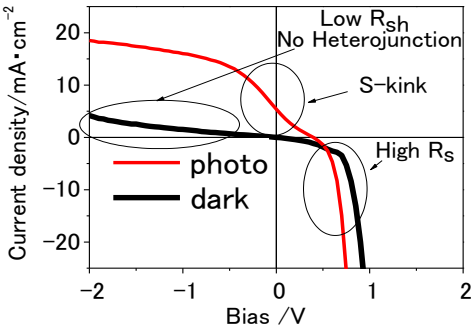

Fig. 7. The J-V curve for the champion device which were fabricated. The curve in black is the dark current, while the curve in red is the photocurrent. The dark curve shows a low Rsh for the device, likely meaning current leak. The S-kink in the photocurrent curve is result of an unbalanced mobility for carriers. The voltage drop is result of a high Rs.

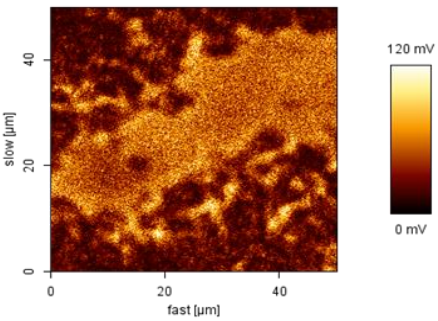

Fig. 8. The fluorescence microscope image of PbS QDs film with KSCN surface treatment under excitation at 465 nm. The PbS QDs film treated with KSCN shows many QDs aggregation areas.

1) M. Ono, T. Nishihara, T. Ihara, M. Kikuchi, A. Tanaka, M. Suzuki and Y. Kanemitsu, Chem. Sci, 5, 2701, 2014.

2) C. B. Murray, C. R. Kagan, M.G. Bawendi, Mater. Sci, 30, 610, 2000.