

PASSIVATING LEAD SELENIDE QUANTUM DOT THIN FILM SOLAR CELLS WITH INORGANIC PEROVSKITE NANOPARTICLES

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Colloidal quantum dots (QDs) are prominent candidates for high performance photovoltaic (PV) devices due to their low cost, tunable band gap energy by size modification, ease of device fabrication and the solution based process which is suitable for large scale manufacture such as printing. Lead selenide (PbSe) QDs in particular are attractive to PV applications owing to their efficient multiple exciton generation (MEG) effect which may potentially lead to devices with power conversion efficiencies (PCE) exceeding the Shockley-Queisser limit.¹ Recently we reported the most efficient PbSe QD solar cell (to date) with a PCE of 7.2%.² In this conference we will report further progresses on the development of PbSe QD solar cells within our group, namely using inorganic perovskite nanoparticles (NPs) to for passivating PbSe QD thin films via halide migration.

PbSe QDs and perovskite NPs (CsPbBr₃ used for this report) were chemically synthesized using hot injection method according to our previous report.² Transmission electron microscopy (TEM) images of the materials are as shown in Figure 1a and b, confirming the good dispersity. The PbSe QDs were then used to fabricate heterojunction solar cells, with a structure of FTO/TiO₂/i-PbSe/p-PbSe/Au. The carrier type of PbSe thin film were controlled by using lead iodide (i) and 3-mercaptopropionic acid (p) for ligand exchange during the film fabrication processes. Prior to the deposition of Au contacts, we intentionally soak the PbSe film into the CsPbBr₃ NP dispersion for 5 s and 20 s, followed by rinsing with pure hexane to remove the residue NPs.

The current density – voltage (J-V) curves of the PbSe QD solar cells are shown in Figure 1c. The PV performance parameters are summarized in Table 1. The device without the passivation treatment has a PCE of 4.8%. After being treated with CsPbBr₃ NPs, the PCE gradually improved to 7.2% and then 8.4% for 5 and 20 s treatment times, respectively. All of the PV performance parameters were improved after the treatment; however the increases in open-circuit voltage (V_{OC}) and fill factor (FF) were the most prominent. We proposed that by soaking the PbSe thin film into CsPbBr₃ NP dispersion, the surface defects on the PbSe QDs can be effectively passivated. By further investigation we discovered that the underneath mechanism for the passivation was halide (Br⁻) ion migration from the CsPbBr₃ NPs to PbSe QDs. More results on this study will be presented during the conference.

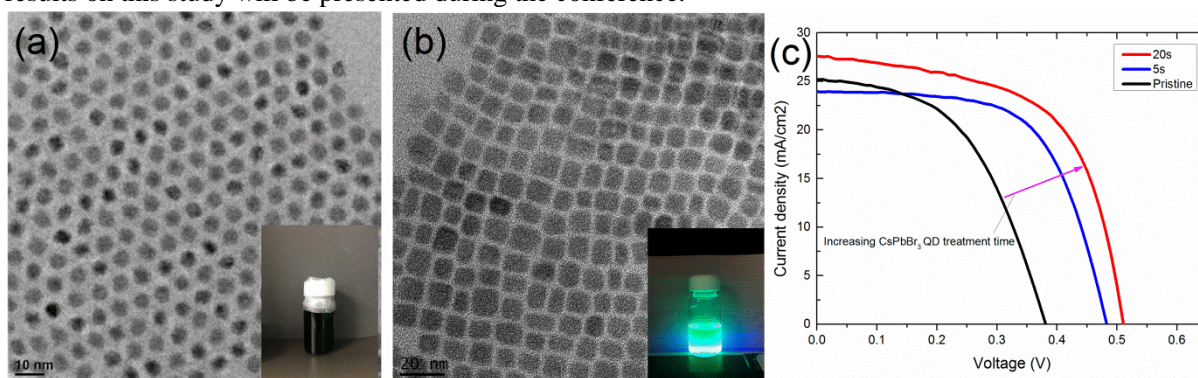


Figure 1. TEM images of (a) PbSe QDs and (b) CsPbBr₃ NPs. Inset: photos of the QD and NP dispersion in hexane (CsPbBr₃ under UV illumination). (c) J-V curves of the devices.

Table 1. Performance parameters of the devices with difference treatment times.

Passivation	Voc (mV)	Jsc (mA/cm ²)	FF (%)	Efficiency (%)
Pristine	390	25.2	50.0	4.8
5 s	482	24.0	62.4	7.2
20 s	509	27.6	59.5	8.4

References:

1. W. Shockley, H. J. Queisser, J. Appl. Phys. 1961, 32, 510.
2. Z. Zhang et.al., Adv. Energy Mater. 7, 1601773 (2017).