

Air stable PbSe quantum dot heterojunction solar cell: ligand dependent exciton dissociation, recombination, photovoltaic property and stability

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Introduction

PbSe quantum dot (QDs) have attracted attention due to their small bulk bandgap, high dielectric constant, and large exciton Bohr radius. However, the performance of PbSe based quantum dot solar cells (QDSCs) tend to quickly degrade after the solar cells expose to air. Here, we investigated the ligand dependent air stability, energy level shift and charge transfer of ligand-treated PbSe QDs. In addition, the exciton dissociation, recombination processes and carrier lifetimes in PbSe QDSCs were also revealed through transient absorption (TA) spectra, and open-circuit transient voltage decay measurements.

Experimental Method

PbSe QDs were synthesized following a literature method.¹ To fabricate PbSe QDSCs, PbSe octane solution was dropped onto FTO/TiO₂ substrate and spun-cast at 2500 rpm for 15 s. Then, the ligand solution (EDT, MPA, CTAB and TBAI) was dropped onto the substrate and spun dry after a 30 s wait. The substrate was then rinsed three times with methanol. Finally, Au top electrode was deposited onto the PbSe layer by thermal evaporation.

Results and Discussion

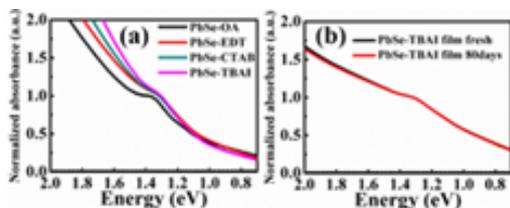


Fig. 1 The absorbance of PbSe QDs thin film with different ligand.

As shown in Fig. 1a, the absorption peak of PbSe film were redshift when long chains ligand OA was exchanged by short ligand (EDT, CTAB and TBAI), it meant that the distance between PbSe QDs were narrowed which benefit for charge transport between QDs. Fig. 1b shows that PbSe-TBAI QDs film was still

very stable after store in air for 80 days.

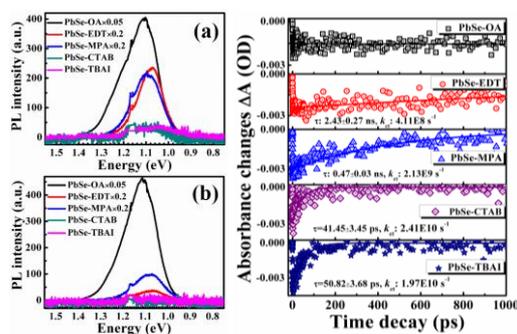


Fig.2 Steady state PL spectra measured at 77K (a) and 298K (b) for PbSe QDs films treated with ligands (left), and TA decays of PbSe QD films with different ligands (right).

From PL and TA spectra (Fig.2) we found that short ligand can enhance the QD-QD coupling, which leads to faster charge transfer rate between QD-QD. And the charge transfer rate for PbSe-CTAB and PbSe-TBAI sample are 2.4×10^{-1} and 2.0×10^{-1} s⁻¹, respectively.

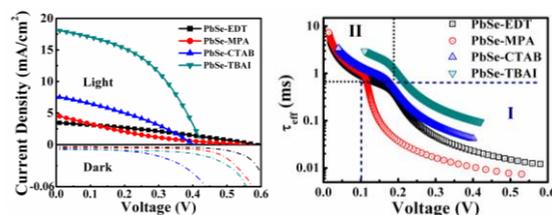


Fig. 3. *J-V* curves of PbSe QDSCs using different ligands (left) and the effective carrier lifetime of these QDSCs (right).

In Fig. 3, the PbSe-TBAI QDSCs got the highest efficiency. The reason is that TBAI formed PbI₂ layer on the QDs surface which was more stable and resistant to oxidation.² What's more, TBAI treatment significantly reduced the intrinsic hole trapping-assisted recombination in PbSe and improved the carrier lifetime in the PbSe QDSCs.

References

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2. Z. L. Zhang, J. F. Yang, X. M. Wen, et al. *J. Phys. Chem. C*, 2015, 119, 24149-24155.