Incorporation of Semiconductor Quantum Dots and Perovskite for High Efficiency Perovskite Solar Cells

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Abstract

Photovoltaic (PV) technology is in the forefront of the renewable energy research, while the most promising PV protocol is based on perovskites with efficiencies exceeding 25%. However, perovskite solar cells (PSCs) suffer from chemical, thermal and humidity instability, preventing them from commercialization. In this context, the utilization of quantum dots (QDs) has been proposed as an innovative strategy to tackle with stability issues. The present study focuses on exploring the effect of PbS and CdS QDs incorporation to CsFAMAPbI3-xBrx PSCs using successive ionic adsorption and reaction (SILAR) on the cell's performance. The solar cell structure is: FTO/TiO2(CL)/TiO2(ML)/QDs/Perovskite/Spiro-MeOTAD/Ag. In this work, was studied the effect of the addition of $TiCl_4$ or SnO_2 to the electron transport layer on the photovoltaic characteristics and the performance of the perovskite cells.

Solar Cell Fabrication

Formation of the CdS and PbS quantum dots layer

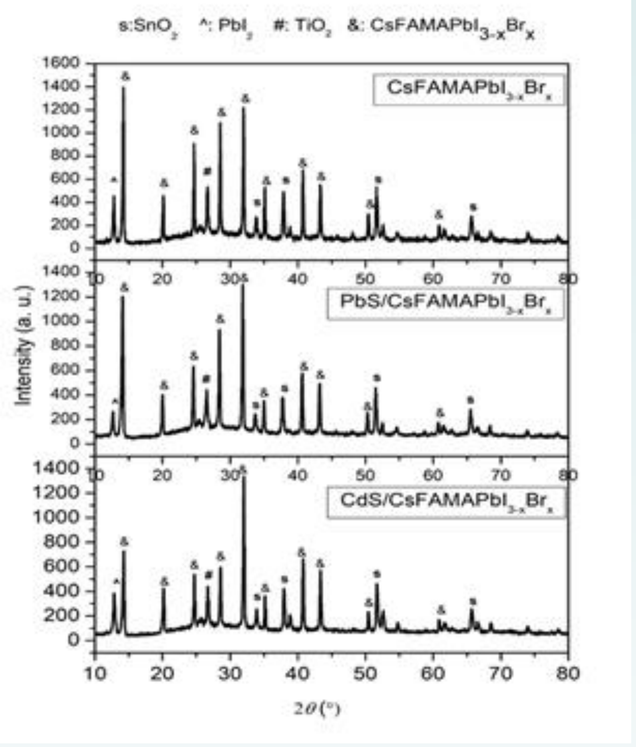
The CdS and PbS QDs were deposited on the TiO_2 film by the successive ionic layer adsorption and reaction (SILAR) method.

Formation of the CsFAMAPbI3-xBrx perovskite layer

The completely dissolved solution was spin-coated on the quantum dot layer at 1000 rpm for 10 sec and 6000 rpm for 20sec. 0.15 ml of chlorobenzene was slowly dripped on the rotating substrate as anti-solvent

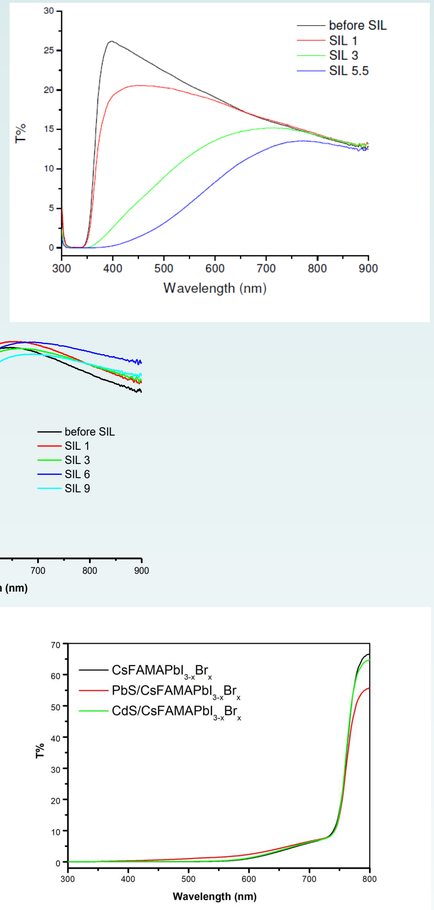
Results

XRPD Analysis



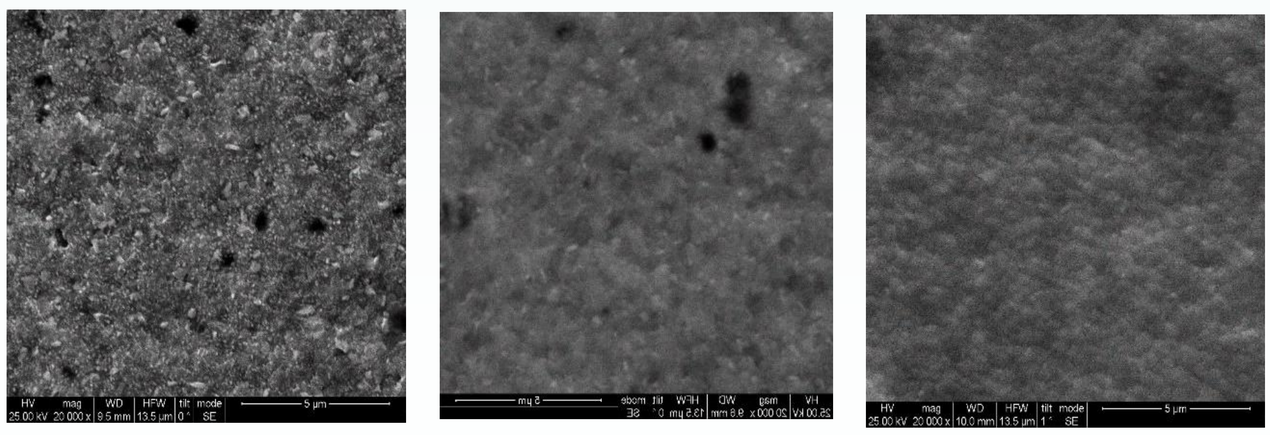
The XRPD analysis (fig. 1) confirmed the presence of the main reflections from the 3D- $CsFAMAPbI_{3-x}Br_x$ perovskite (at 2θ = 14°, 20°). The perovskite and the co-sensitized perovskite-QDs curves are similar because the peaks of perovskite overlap those of quantum dots.

UV-Vis Analysis



UV- Vis T% spectra of QDs , perovskite and co-sensitized perovskite-QDs films. The perovskite and the co-sensitized perovskite-QDs curves are similar, although PbS/CsFAMAPbI3-xBrx seem to have the best absorbance

SEM Analysis

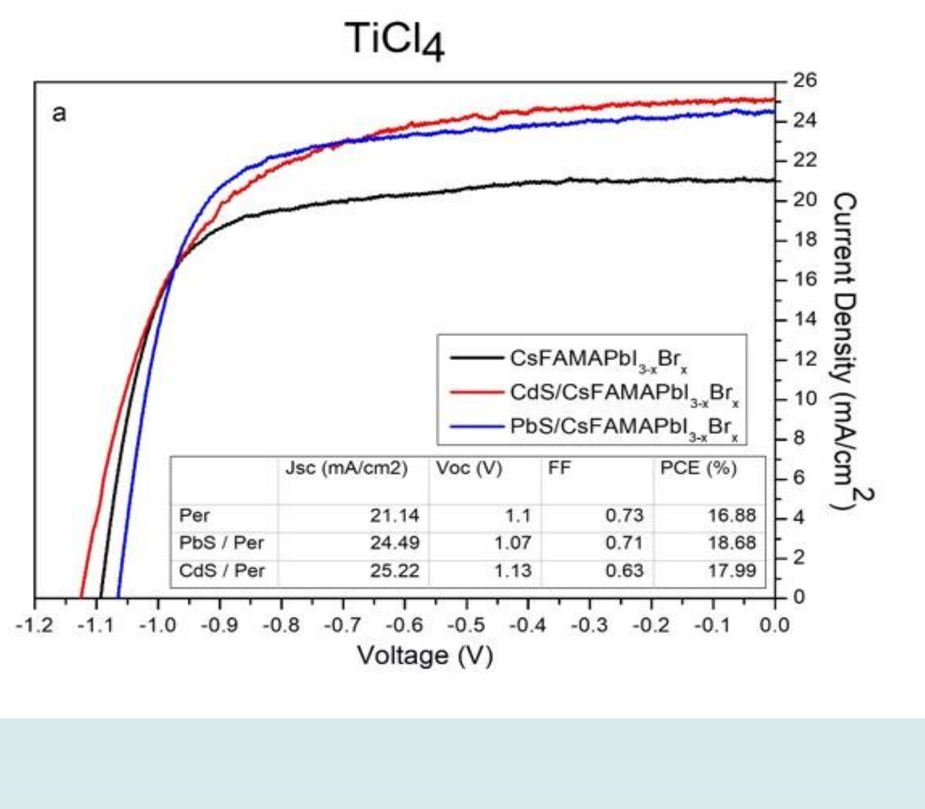


SEM images of $CsCH_3NH_3PbI_xBr_{3-x}$ perovskite and co-sensitized perovskite-QDs $PbS/CsCH_3NH_3PbI_xBr_{3-x}$, $CdS/CsCH_3NH_3PbI_xBr_{3-x}$ films.

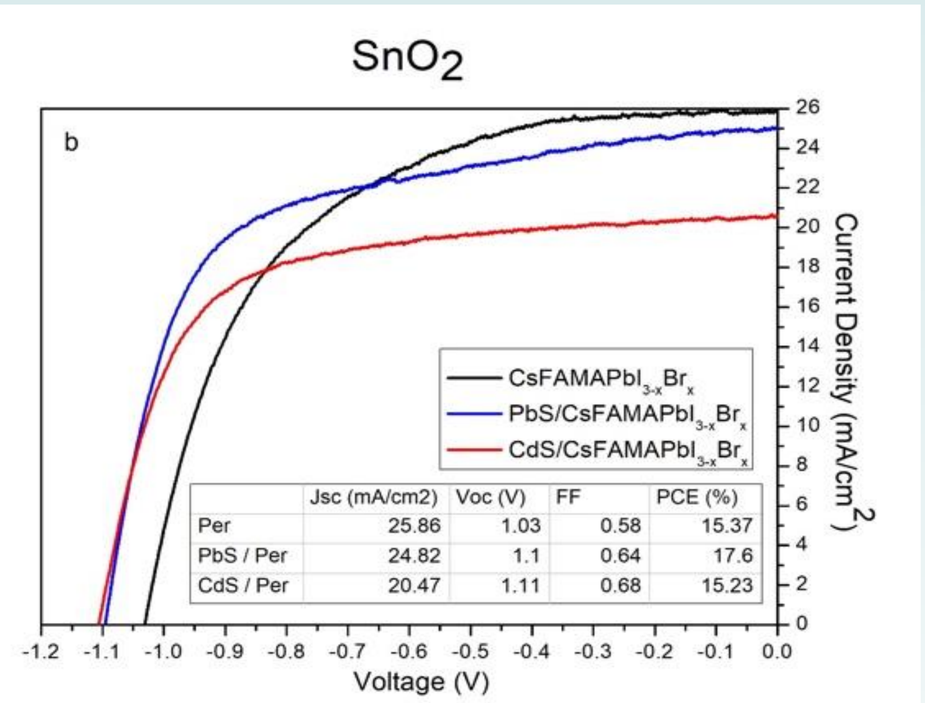
Results

Electrochemical characterization

In order to examine the contribution of the QDs in the solar cell's performance, co-sensitized solar cells with the addition of $TiCl_4$ or SnO_2 to the electron transport layer, were tested and the photovoltaic performance was calculated. All measurements were taken under 1 Sun illumination using a PGSTAT302N potentiostat and the photovoltaic characteristics are presented below



	Jsc (mA/cm2)	Voc (V)	FF	PCE (%)
Per	21.14	1.1	0.73	16.88
PbS / Per	24.49	1.07	0.71	18.68
CdS / Per	25.22	1.13	0.63	17.99



	Jsc (mA/cm2)	Voc (V)	FF	PCE (%)
Per	25.86	1.03	0.58	15.37
PbS / Per	24.82	1.1	0.64	17.6
CdS / Per	20.47	1.11	0.68	15.23

Conclusions

- Successful incorporation of PbS and CdS semiconductor QDs with SILAR method in perovskite solar cells.
- In case of the $TiCl_4$ modification, all the solar cells present higher values of the photovoltaic characteristics and enhanced performance in comparison with the SnO_2 modification.
- The highest efficiency (18.68%) was achieved with the solar cell incorporating PbS QDs and $CsFAMAPbI_{3-x}Br_x$ perovskite with the$TiCl_4$ addition to the electron transport layer.

References

1. Elsenety, M.M.; **Antoniadou, M.; Balis, N.; Kaltzoglou, A.; Sygellou, L.; Stergiou, A.; Tagmatarchis**, N.; Falaras, P. Stability Improvement and Performance Reproducibility Enhancement of Perovskite Solar Cells Following (FA/MA/Cs)$PbI_{3-x}Br_x$/$(CH_3)_3SPbI_3$ Dimensionality Engineering. *ACS Appl. Energy Mater*. 2020**,** *3*, 2465−2477.

2. Givalou, L.; **Antoniadou, M.; Kaltzoglou, A.;** Falaras, P. High performance solid state solar cells incorporating CdS quantum dots and $CH_3NH_3PbI_3$ perovskite. *Materials Today: Proceedings* 2019, *19,* 79–85.

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