cwcp2022.05c00ac

Design and Fabrication of Lead Free Sb-based Perovskites for Photovoltaic Application

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Abstract

The photovoltaic devices using lead halide perovskites as light absorber have pulled the attention of researchers due to their outstanding performance. However, the lead halide perovskite based photovoltaic devices suffering from the toxicity of lead (Pb) and lower stability in air. Recently, enormous efforts have been made to develop the efficient, lead (Pb) free and stable perovskite solar cells (PSCs). In this regards, various strategies were applied and the optoelectronic properties of various Pb free perovskites such as $(CH_3NH_3)_3Bi_2I_9$, $Cs_3Sb_2I_9$, $Cs_3Bi_2I_9$, $CH_3NH_3SnI_3$ and $CH_3NH_3GeI_3$ etc has been investigated. However, the photovoltaic performance of the developed PSCs was still low and shows poor stability against moisture and heat. Herein, we have investigated the optoelectronic properties of Pb free perovskite by utilizing $(NH_4)_3Sb_2I_9$ as light absorber material. Moreover, we have employed modified two step procedure for the preparation of $(NH_4)_3Sb_2I_9$. The developed Pb free PSCs device (FTO/CL-TiO2/m-TiO2/$(NH_4)_3Sb_2I_9$/HTM/Au) exhibited enhanced power conversion efficiency (PCE) of 0.42% with open circuit voltage (Voc) of 945 mV.

Methodology

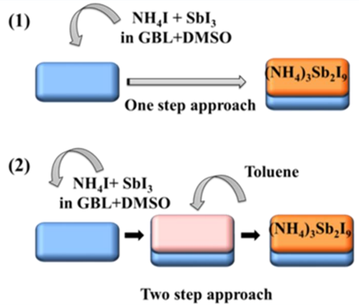

Fig. Schematic representation of the fabrication of $(NH_4)_3Sb_2I_9$ films using one step (1) and two-step (2) deposition approaches.

Characterisation

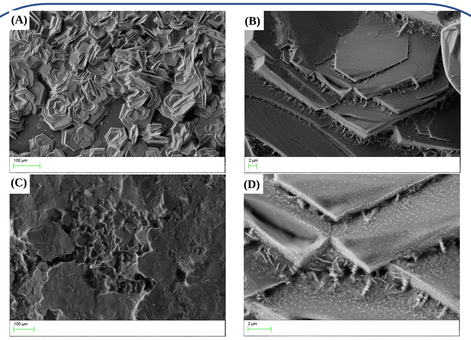

Fig. SEM images of the $(NH_4)_3Sb_2I_9$ prepared by one step (A,B) and two step (C,D) methods.

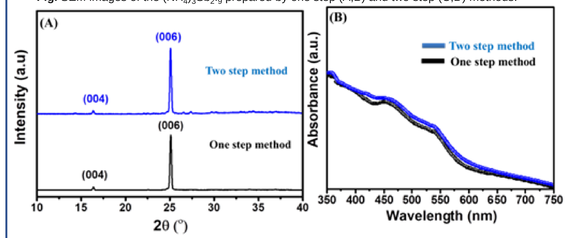

Fig. (A) PXRD and (B) UV-vis spectra of the $(NH_4)_3Sb_2I_9$ films prepared by one step (black) and two step (blue) method.

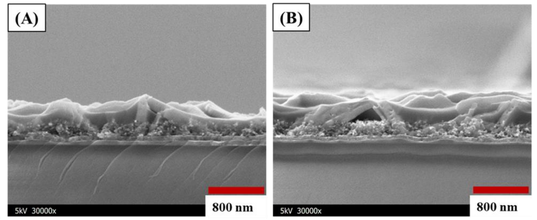

Fig. Cross-sectional SEM images of the PSC-1 (A) and PSC-2 (B).

Result and Discussion

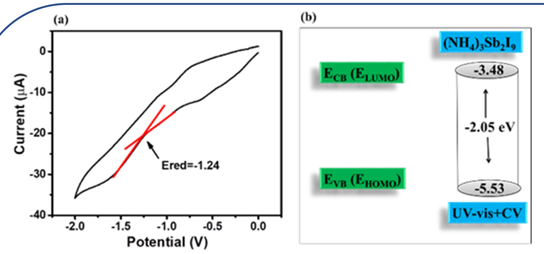

Fig. CV (a) and energy level values (b) of $(NH_4)_3Sb_2I_9$

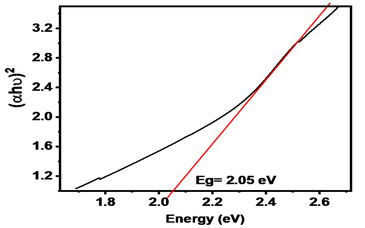

Fig. Tauc plot of $(NH_4)_3Sb_2I_9$

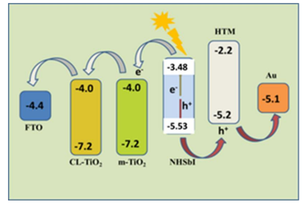

Fig. Showed the energy level diagram of PSCs contains $(NH_4)_3Sb_2I_9$ as perovskite material

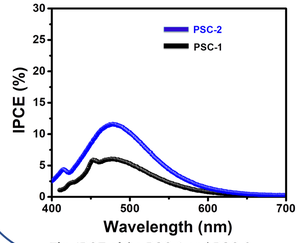

Fig. IPCE of the PSC-1 and PSC-2

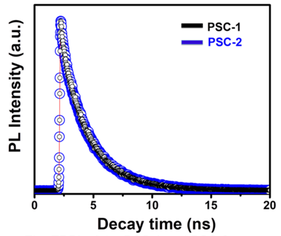

Fig. TRPL of the PSC-1 and PSC-2

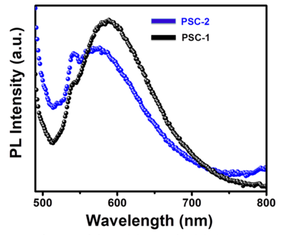

Fig. PL of the PSC-1 and PSC-2

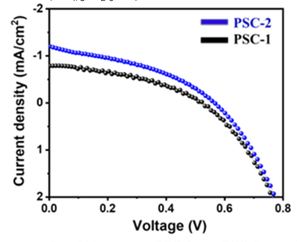

Fig. J-V curves of PSC-1 and PSC-2

Conclusion

We believe that Antimony and Bismuth based organic- inorganic hybrid perovskites are the most promising alternatives to the Pb based perovskite solar cells because of their low toxicity and higher stability in air.

- We have demonstrated the fabrication of $(NH_4)_3Sb_2I_9$ thin films using one step and two step deposition approaches which showed good stability and optoelectronic properties which suggested their potential in photovoltaic applications.
- The $(NH_4)_3Sb_2I_9$ based PSCs devices exhibited good open circuit voltage and decent photocurrent density. This performance further can be improved by insertion or doping of $(NH_4)_3Sb_2I_9$ structures with less toxic metals would also be helpful to enhance the optical properties of the $(NH_4)_3Sb_2I_9$.

Acknowledgement

- DST-Inspire fellowship and RGNFD for fellowship, SIC IIT Indore, CSIR (Project No. 01(2935)/18/EMR-11), SERB-DST (Project No. CRG/2020/001769), New Delhi, and BRNS (Project No. 58/14/17/2020-BRNS), India.

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