Supporting Information

Recent Progress and Challenges in $A_3Sb_2X_9$ Based Perovskite Solar Cells

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Construction of PSCs

Different device architectures of PSCs have been reported so far which also plays crucial role in controlling the performance of the PSCs.[S1] In general, PSCs consists of five different components which are: (i) conductive transparent glass substrate, (ii) electron transport layer, (iii) light absorber, (iv) hole transport layer and (v) metal contact. The fabrication of some PSCs device architectures associated with Sb are discussed in this section.

Planar architecture

In 2016, Hebig *et al*.[S2] proposed $MA_3Sb_2I_9$ as energy material and developed the planar hetero-junction solar cell device. Here, the authors have used solvent engineering approach to prepare the $MA_3Sb_2I_9$ energy material. The surface of the Indium doped tin oxide (ITO) glass substrate was modified with PEDOT:PSS followed by the deposition of $MA_3Sb_2I_9$. Further $PC_{61}BM$ layer was prepared on the $MA_3Sb_2I_9$ followed by the deposition of ZnO as interlayer. Finally, aluminium (Al) contact was also deposited using evaporation approach.

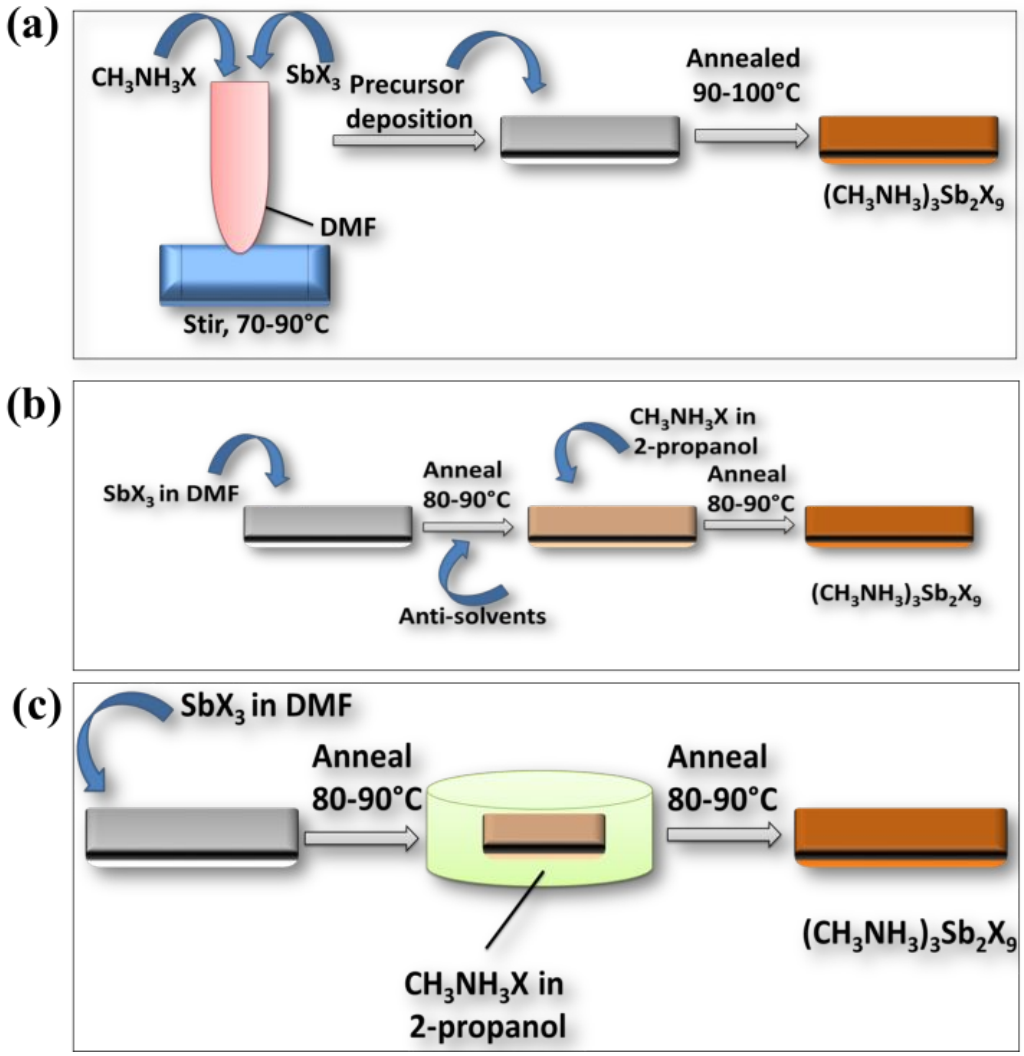
Mesoscopic architecture

For mesoscopic PSCs, Fluorine-doped Tin Oxide (FTO) glass substrate (transparent conductive electrode substrate) to be cleaned and patterned with the help of HCl and zinc powder. Further compact and electron transport layers of transition metal oxides to be deposited using spin coat method. Energy materials such as $MA_3Sb_2I_9$ also deposited on the electron transport layer followed by the deposition of hole transport material and metal contact. Ahmad *et al*.[S3] developed the PSCs with mesoscopic architecture using TiO_2 as electron transport layer.

Inverted planar architecture

In typical, PEDOT:PSS was spin coated on to the ITO glass substrate and annealed at 160 °C for 15 min. Further light absorber thin films was grown on the PEDOT:PSS/ITO glass substrate. The

electron transport layer was deposited on to the above prepared electrode. The device stack was completed by the deposition of silver using thermal evaporation approach.



Scheme S1. Schematic illustration of the various synthesis approaches for the construction of perovskite films for PSCs (a) $(CH_3NH_3)_3Sb_2X_9$ perovskite by one-step, (b) two-step and (c) sequential deposition method.

References

(S1) Ahmad, K.; Mobin, S.M. Graphene Oxide based Planar Heterojunction Perovskite Solar Cell under Ambient Condition. *New J. Chem*. **2017**, *41*, 14253-14258.

(S2) Hebig, J.C.; Kühn, I.; Flohre, J.; Kirchartz, T. Optoelectronic Properties of $(CH_3NH_3)_3Sb_2I_9$Thin Films for Photovoltaic Applications. *ACS Energy Lett*. **2016**, *1*, 309-314.

(S3) Ahmad, K.; Kumar, P.; Mobin, S.M. A Two-Step Modified Sequential Deposition Method-based Pb-Free $(CH_3NH_3)_3Sb_2I_9$ Perovskite with Improved Open Circuit Voltage and Performance. ChemElectroChem **2020**, *7*, 946-950.

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