Dopant and Interfacial Engineering giving Tin-Lead (SnPb) Perovskite Solar Cells with High Efficiency and Thermal Stability

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In this research, the improvement in the performance and stabilities of the tin-lead (SnPb) PSCs was studied via two approaches; (1) addition of a dopant material which is capable of reducing the oxidized components in SnPb perovskite, (2) interfacial engineering. Doping technique has been used widely in order to improve the performance of the PSCs because doping materials are able to rectify defects and passivate the perovskite surface to produce high efficiency PSCs. Meanwhile, various research has demonstrated positive impact on the performance of the PSCs via interfacial engineering due to the reduced interfacial recombination and also good energy alignment for effective carrier extractions. The interlayer between the stacks of the inverted p-i-n single junction SnPb PSCs was modified by adopting the use of self-assembled monolayer (SAM) and modified-electron transport layer (m-ETL). These strategies have brought the improvement in terms of air, heat and light stabilities which have been demonstrated in various studies involving lead (Pb) based PSCs. However, there is a knowledge gap for SnPb based perovskite solar cells, more research is required in order to produce SnPb PSCs with similar stabilized performance to their Pb PSCs counterpart. This adverse performance gap occurred mostly due to the presence of the vulnerable tin (Sn) component in the SnPb PSCs. Sn component in the SnPb based perovskite films makes the perovskite films easily oxidized, especially in high humidity and high ambient temperature. The chemical and the physical structure of the perovskite films will be altered upon oxidation which in turn compromising the PSCs performance. In this study, we introduced metallic reducing dopant material (RDM) in the SnPb perovskite for the performance and stability enhancement. The thermal stability of the PSCs was investigated by analyzing their performance using solar simulator by subjecting the PSCs to the temperature of 85 °C for over 700 hours in nitrogen atmosphere. From series of experiments, we managed to achieve SnPb based PSCs with the highest efficiency of more than 21% and demonstrated high photo and thermal stability when RDM and m-ETL were incorporated. The SnPb PSCs which was stored in the nitrogen filled air are able to retain more than 99% of their efficiencies after 1 month of storage. In term of thermal stability, the PSCs are able to retain 100% of their initial efficiencies after subjected to the temperature of 85 °C for over 700 hours in nitrogen atmosphere. We will elucidate the successful treatment of the doping and interlayer engineering by studying the morphological, structural and elemental of the SnPb thin films before and after exposure to thermal heating via SEM, XRD and XPS. We will also demonstrate the effects of doping and interlayer engineering via impedance spectroscopy technique by extracting electronic parameters in the SnPb PSCs such as the series and recombination resistances, and also the capacitance of the investigated devices. We conclude this research by proving the performance of the SnPb based PSCs could be enhanced by incorporation of RDM and m-ETL; rendering them more stable thermally and beneficial for long term application.

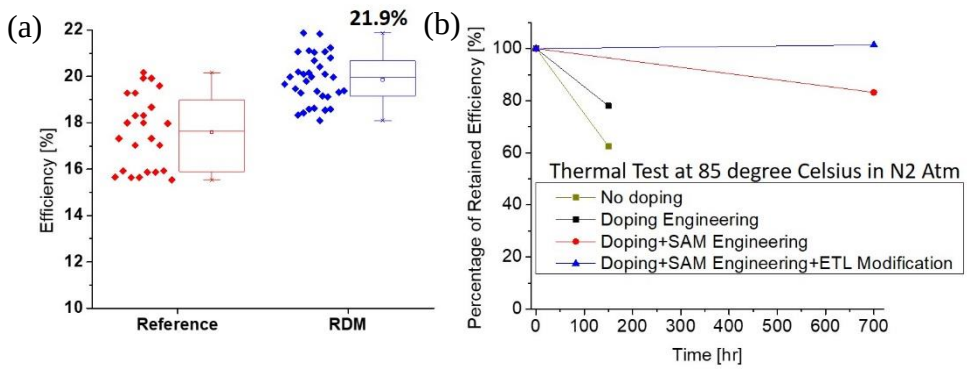

Figure 1: (a) Efficiencies of fresh SnPb devices without doping and with RDM. (b) The plot showing relationship between normalized efficiency and thermal heating duration.