Combining surface passivation and Br anion addition to achieve efficiency more than 22% in tin-lead perovskite solar cells

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Introduction

Tin-lead (Sn-Pb) perovskite solar cells (PSCs) are now getting great attention due to the rapid increase in photoconversion efficiency (PCE) more than 20%, which brings them near to their Pb counterparts [1]. They possess the bandgap of 1.2-1.3 eV, which is according to Shockley-Queisser (SQ) limit can give higher PCE than Pb-PSCs where bandgap lies in between 1.45-1.55 eV. Also, according to SQ limit the Voc of 0.9-1 eV is possible for the solar absorbing materials with a bandgap of 1.2-1.3 eV [2]. In our previous work, we have reported a PCE of 20.4% using $Cs_{0.025}FA_{0.475}MA_{0.5}Sn_{0.5}Pb_{0.5}I_3$ (1.27 eV) perovskite as the absorber layer in PSCs with a Voc of 0.81 V [3]. In the work, we revealed that lattice strain relaxation is one of the important properties to look for cation mixing at A position of ABX_3 (where, A is monovalent cation, B is bivalent cation and X is halide anion) perovskite. Therefore, following the same strategy, in the present research, we added a small fraction of Br anion with I anion at X position that led to further decrease in lattice strain and reduction of urbach energy that resulted into increase in Voc. In addition to this, we used Lewis base surface passivation that solved the two major problems of Sn-Pb perovskite, first is the reduction in formation of amount of Sn^{4+} and second is neutralization of positive surface of perovskite due to I anion vacancy.

Results and discussion

The perovskite used in the study is $Cs_{0.025}FA_{0.475}MA_{0.5}Sn_{0.5}Pb_{0.5}I_{3-x}Br_x$ (where x=0, 0.025, 0.05, 0.1). Four devices with different concentration of Br anion are prepared such as ① Br 0%, ② Br 2.5%, ③ Br 5% and ④ Br 10%. Device ② showed a best PCE of 21.10% with a FF of 0.81, Voc of 0.84V and Jsc of 31.22 mA/cm^2. The change PCEs with Br concentration is well supported by UV, PL, SEM, XRD, XPS analysis of perovskite films. Finally, PSC with 22.64% (highest so far in Sn-Pb) after optimization will be reported.

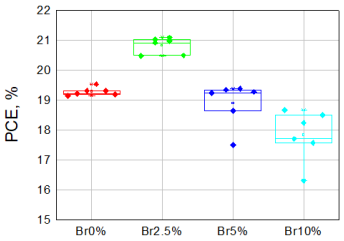

Fig1. Box chart showing the change in PCE with different concentration of Br anion

References

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