Multi-cation thiocyanate-based pseudohalide perovskite solar cells with MASCN additive

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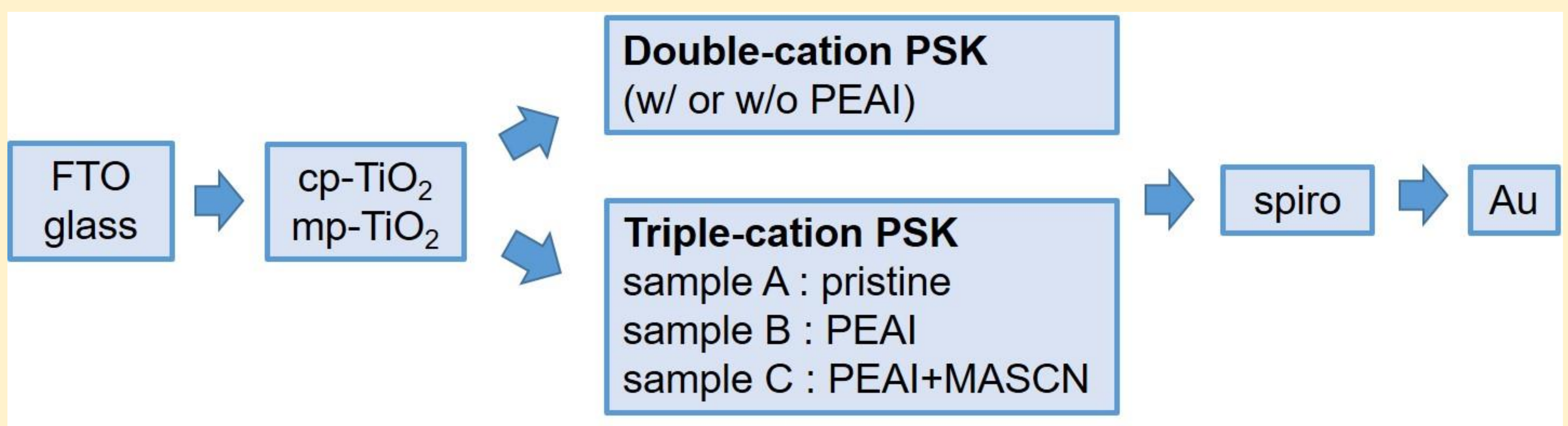
Abstract

Currently, the organic-inorganic hybrid perovskite solar cells (PSCs) have achieved high efficiency; however, their stability remind a concern under ambient condition for real application. The purpose of this study is to enhance the perovskite stability in virtue of composition engineering by doping large-sized cation and pseudohalide SCN^- into perovskite. Mixed cations and halides (or pseudohalide) in perovskite have been demonstrated to stabilize the perovskite lattice structure. For example, addition of $Pb(SCN)_2$ in thermal unstable and moisture sensitive methylammonium lead triiodide ($MAPbI_3$) perovskite enhances the $MAPbI_3$ grain size, reduces defects state and improves the film stability. In addition to the composition engineering, introduction of two-dimensional (2D) perovskite into three-dimensional (3D) perovskite could significantly enhance the stability of perovskite active layer and the perovskite solar cells. Thus, we incorporated a large-sized aromatic cation phenethylammonium (PEA^+) into double-cation perovskite $(FAPbI_3)_{0.85}(MAPbBr_3)_{0.15}$ and triple-cation perovskite $FA_{0.85}MA_{0.1}Cs_{0.05}Pb(Br_{0.15}I_{0.85})_3$. We further add MASCN into PEAI-doped triple-cation perovskite to enhance the stability of the perovskite solar cells.

Process flow diagram



Stability of double-cation perovskite

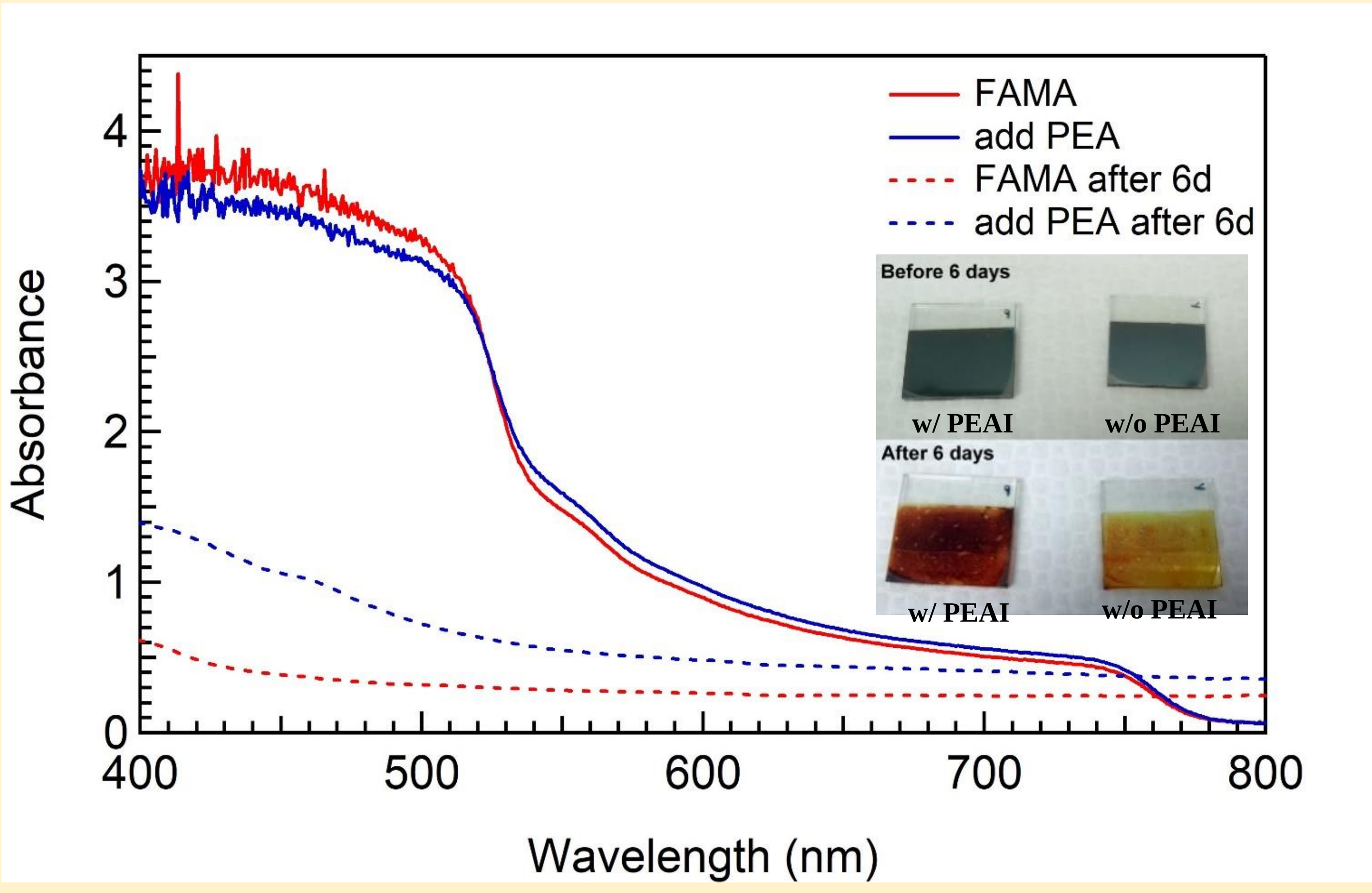


Fig.1 UV-vis spectra of double-cation perovskite with (red) and without (blue) PEAI dopant and that of perovskite film storage with a relative humidity of 60 ± 5% after 6 days. Corresponding photographs are shown for comparison.

Material characteristic

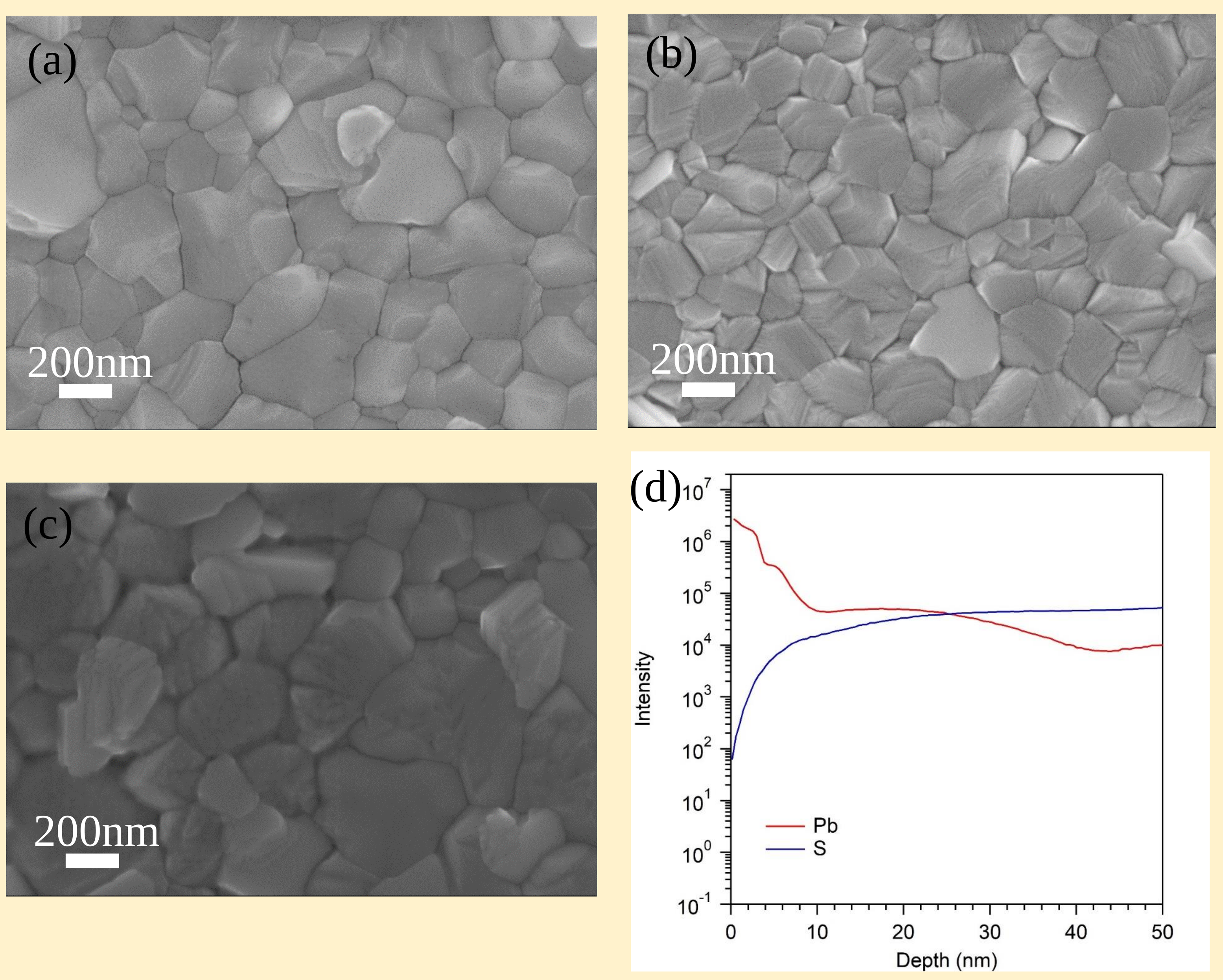


Fig.2 SEM images of (a) triple-cation perovskite film, (b) PEAI-doped, and (c) PEAI+MASCN doped triple-cation perovskite film. (d) The SIMS depth profile for PEAI+MASCN doped triple-cation perovskite film.

Photovoltaic performance

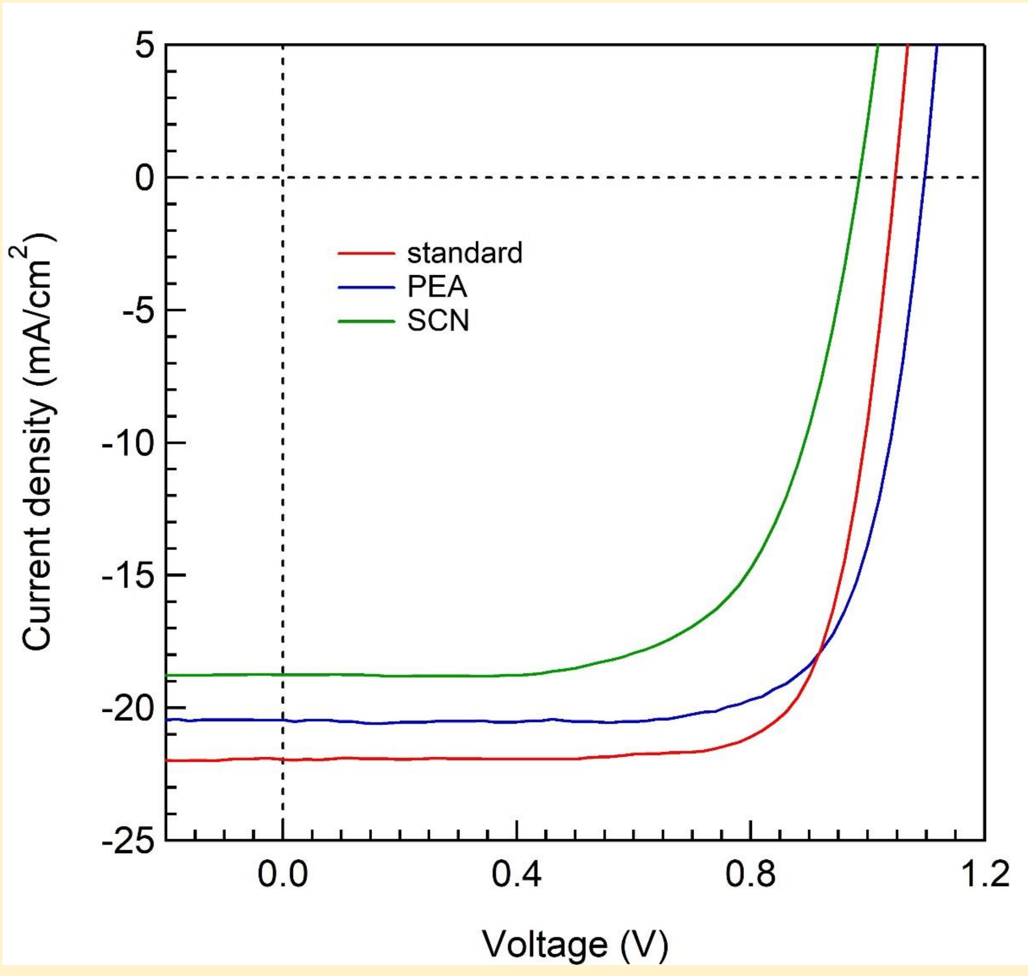


Table.1 The photovoltaic parameters of as-fabricated perovskite solar cells.

Devices	Voc (V)	Jsc (mA/cm^2)	FF (%)	PCE (%)
standard	1.04	21.94	75.44	17.33
PEA	1.09	20.45	73.78	16.61
SCN	0.98	18.75	65.22	12.05

Fig.3 J-V curves of perovskite solar cells based on triple-cation perovskite (standard), PEAI-doped (PEA), and PEAI+MASCN doped (SCN) triple-cation perovskite.

Stability of triple-cation perovskite solar cells

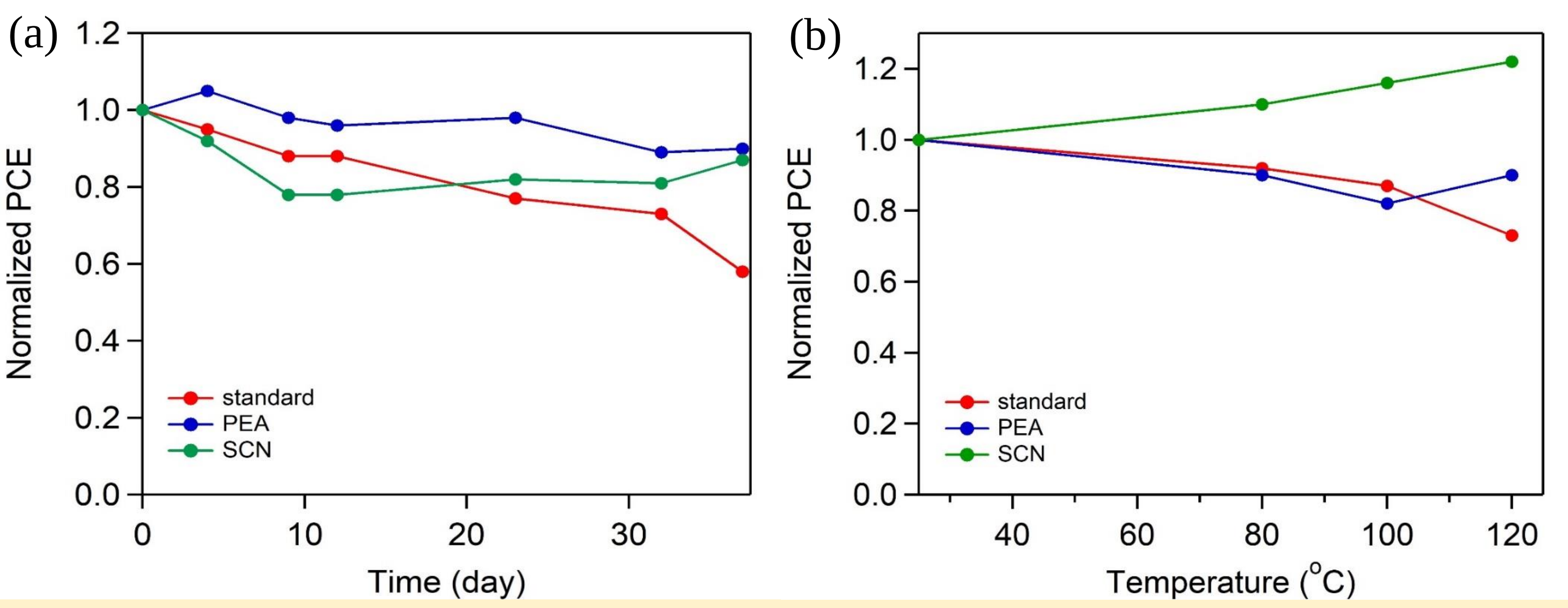


Fig.4 (a) Efficiency tracking for devices (without encapsulation) under a relative humidity of 40-50% for a period of 37 days. (b) Thermal stability test for devices placing on the hot plate for 30 min. Relative humidity is controlled within 15-20%.

Conclusions

- The PEAI-doped perovskite film shows superior water resistance than the pristine triple-cation perovskite which is presumably attributed to the formation of 2D layered perovskite as passivation against moisture. Further doping of MASCN in the PEAI-doped triple-cation perovskite significantly enhances the perovskite grain size.
- The optimized pseudohalide-doped perovskite solar cell achieves a PCE of 12% with good stability when the devices are soaked under high relative humidity and heating.

ACKNOWLEDGMENTS

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