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Synergistic effect of ionic liquid and methylammonium chloride in crystallization of hybrid haloplumbate for perovskite solar cells

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Experimental details

Film preparation and characterization

$FA_{0.85}Cs_{0.15}PbI_3$ and $(FA_{0.98}MA_{0.02})_{0.95}Cs_{0.05}Pb(I_{0.98}Br_{0.02})_3$ films were prepared from stoichiometric precursor solutions of the necessary halide salts from the following list: FAI, FABr, MAI, CsI, $PbBr_2$, and PbI_2 (FA = formamidinium ion, MA = methylammonium ion); in a 4:1 (v/v) mixture of *N*,*N*-dimethylformamide and dimethyl sulfoxide via a single-step antisolvent spin-coating in an inert glove box followed by subsequent annealing for an hour at 125 °C. Additionally 15% excess of methylammonium chloride (MACl) and/or 0.5–5 mol% of ionic liquid 1-(2-hydroxyethyl)-3-methyl-1*H*-imidazol-3-ium cinnamate {[C_2OHmim][Cin]} were admixed to the perovskite precursor solution. All the samples were analyzed by scanning electron microscopy (SEM, Zeiss Supra 40), X-ray diffraction (XRD, Bruker ADVANCE D8) and steady-state photoluminescence spectroscopy (PL, home-built setup based on Thorlabs components with a 405 nm excitation laser).

Perovskite solar cell fabrication and characterization

Perovskite solar cells were assembled in the inverted p–i–n architecture ITO/PTAA/MgF_2/perovskite/C_{60}/BCP/Cu/MgF_2. A layer of poly[bis(4-phenyl)(2,4,6-trimethylphenyl)amine] (PTAA, 2 mg cm^{-3} in toluene) was spin-coated onto a glass substrate with indium tin oxide (ITO) in an inert glovebox, after that 1nm layer of MgF_2 was deposited by thermal vacuum evaporation. Perovskite films were then spin-coated from 1.5 M solution in the DMF–DMSO mixture (4 : 1, v/v) and annealed at 125 °C for 60 min. Layers of C_{60}, bathocuproine (BCP), Cu electrode, and MgF_2 (a protective layer for subsequent encapsulation) were sequentially deposited by thermal vacuum evaporation. The resulting solar cells were eventually encapsulated with a commercially available UV-curable polymer and a cover-glass slide as described previously.[S1]

The *J*–*V* curves of the assembled devices were registered under simulated AM 1.5G sunlight with a power density of 100 mW cm^{-2} in a quasi-steady-state mode (20 s per point) in the reverse scanning direction.

Long-term photothermal stability testing

The long-term photothermal stability test of encapsulated PSCs under ambient air was provided using an unfiltered sulfur plasma lamp (LG PSH 0731B), calibrated with Si reference cells to a 100 ± 10 mW cm^{-2} power density. Additionally, the distance of PSCs from the sulfur plasma lamp was adjusted to achieve similar values of PSCs' current density, obtained under solar simulator. This step was necessary to minimize the effect of different spectra of the sulfur plasma lamp and solar simulator on the PSCs efficiency and stability. The temperature of devices was about 55 °C. Maximum power point tracking (MPPT) was performed using a standard perturb and observe algorithm and the voltage was updated every 5 min with a 10mV step by a homemade electronic board with 16-channel MPPT capability.

References

S1 N. A. Belich, A. A. Petrov, P. A. Ivlev, N. N. Udalova, A. A. Pustovalova, E. A. Goodilin and A. B. Tarasov, *J. Energy Chem.*, 2023, **78**, 246; https://doi.org/10.1016/j.jechem.2022.12.010.