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SOLAR CELLS

Reproducible, high-performance perovskite solar cells

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Halide perovskite solar cells (PSCs) have reached efficiencies comparable with those of more established inorganic technologies. Moreover, the solution processability of perovskites offers possibilities for the scalable fabrication of solar cells at low cost. Commercialization of PSCs, however, is impeded by their poor reproducibility, in part due to the instability of the precursor solutions. Now, writing in *Science Advances*, Jinsong Huang and colleagues report a simple approach to stabilizing perovskite precursor solutions containing organic iodide salts, enabling them to reproducibly fabricate high-performance PSCs.

"The poor reproducibility of high-performance devices is a general problem in the PSC community," says Huang. "PSCs fabricated using fresh precursor solutions exhibit good power conversion efficiencies, but after storage for a few days, the precursor solutions no longer produce high-efficiency devices." Organic halide salts, such as methylammonium iodide (MAI) and formamidinium iodide (FAI), are commonly used to prepare perovskite precursor solutions, but the I^- ions get oxidized to I_2, which is detrimental to device performance.

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Seeking to address this stability issue, the team explored whether a low-cost reductant — benzylhydrazine hydrochloride (BHC) — can reduce I_2 to I^- and, thus, restore degraded precursor solutions. The researchers started by preparing a solution of MAI and FAI in 2-methoxyethanol, which changed from colourless to light yellow over 2 days when stored in air, with an absorption band at 365 nm indicating the formation of I_3^- (the I_2 adduct of I^-). However, addition of BHC reversed the solution to colourless and the I_3^- absorption disappeared, consistent with reduction of the oxidized species to I^-.

To examine the effects on perovskite films, the team blade-coated different $MA_{0.7}FA_{0.3}PbI_3$ precursor solutions onto glass substrates, namely a freshly prepared solution, a solution stored for 2 months in a N_2-filled glovebox and the same 'aged' solution regenerated by adding BHC. Storing the precursor solution decreases the crystallinity and photoluminescence (PL) intensity of the resulting film. However, adding BHC to the aged solution increases the crystallinity and PL intensity of the corresponding film, with the PL intensity even exceeding that of the film prepared from the fresh solution.

With perovskite films in hand, Huang and colleagues fabricated PSCs with a planar p–i–n heterojunction configuration. The device fabricated from the aged precursor solution with BHC exhibited a high power conversion efficiency (PCE) of 23.2%, outperforming the other two devices. Probing the origins of this superior efficiency revealed that the reduction of I_2 in the precursor solution decreases the number of unfavourable I_3^- trap states in the resulting film. The high performance also proved more reproducible than that of the other device types: out of 244 devices fabricated using aged precursor solution with BHC, >80% achieved a PCE of >22%. Additionally, a PSC prepared from the aged solution with BHC showed enhanced operational stability. "Excess BHC in the perovskite films serves as a safety guard to scavenge any I_2 generated during device operation under sunlight, increasing operational stability," explains Huang. Demonstrating scalability, mini-modules fabricated from a precursor solution with added BHC reached PCEs of 18.2% — one of the highest values for such devices to date.

Given its simplicity, the team are hoping that their method will help the PSC community to improve device reproducibility and promote commercialization. "With their excellent stabilization effects and low cost, hydrazines are very promising for the scalable manufacturing of perovskite modules," says Huang. "We hope that this approach helps industry solve one of the issues encountered in upscaling perovskite modules."

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ORIGINAL ARTICLE Chen, S. et al. Iodine reduction for reproducible and high-performance perovskite solar cells and modules. *Sci. Adv.* **7**, eabe8130 (2021)