TechXplore

28 August 2025

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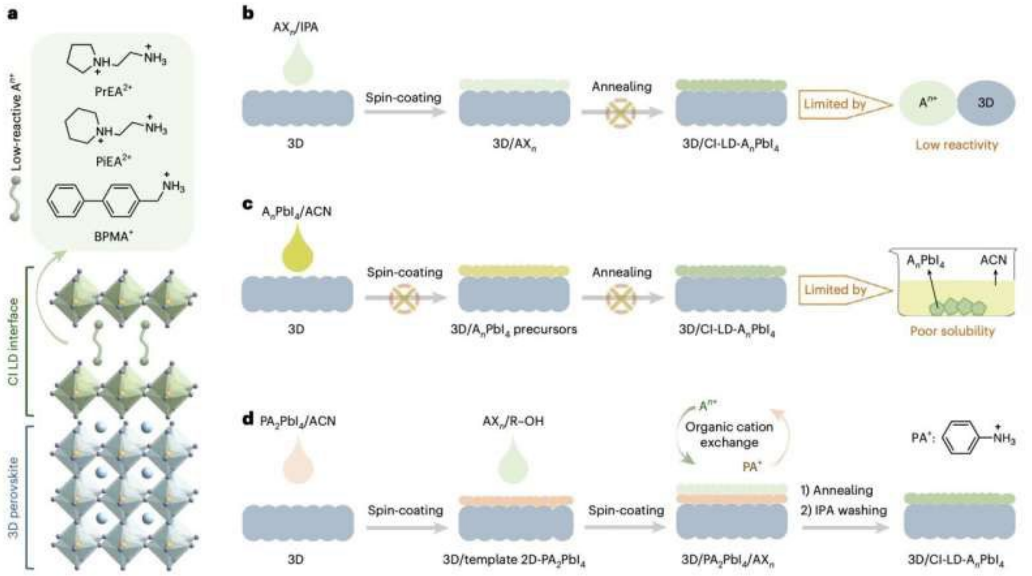
Growth strategy enhances efficiency and stability of perovskite solar cells



Potential solution-processable strategies for the growth of CI LD interfaces on 3D perovskites. Credit: Nature Energy *(2025). DOI: 10.1038/s41560-025-01815-8*

Photovoltaics (PVs), technological systems that can convert sunlight into electricity are among the most promising and widely adopted clean energy solutions worldwide. While existing silicon-based solar cells have already achieved remarkable performances, energy engineers have been working to develop other photovoltaic technologies that could be even more durable, efficient and affordable.

An emerging type of solar cells that could be manufactured at a lower cost, while still retaining good efficiencies, are those based on a class of materials with a characteristic arrangement of atoms, known as perovskites. These cells, known as perovskite solar cells (PSCs), have been found to attain high power conversion efficiencies and are based on materials that could be easier to synthesize when compared to silicon wafers.

Despite their potential, PSCs still face considerable limitations that have so far prevented their widespread deployment and commercialization. Most notably, improving the efficiency of these cells has been found to adversely impact their stability over time, and vice versa.

Researchers at Nanyang Technological University recently introduced a strategy that could help to overcome the trade-off between efficiency and stability influencing the development of PSCs. Their proposed approach, outlined in a paper published in Nature Energy, is aimed at improving the growth of chemically-inert low-dimensional (CI LD) halogenometallate interfaces, boundary layers inside solar cells that are made from metal-halogen compounds and can protect perovskite layers from degradation, enhancing their stability over time.

"CI LD halogenometallate interfaces incorporating low-reactivity bulky cations could address the trade-off between efficiency and stability in perovskite solar cells (PSCs)," Haixia Rao, Senyun Ye and their colleagues wrote in their paper.

"However, their formation is hindered by the low reactivity of their bulky cations and solubility constraints of their precursors in orthogonal solvents compatible with underlying perovskites. We introduce a selective templating growth strategy that leverages conventional metastable LD interfaces as templates to drive the growth of more stable CI LD interfaces through an organic cation exchange process."

CI LD halogenometallate interfaces are essentially layers at an interface between perovskite materials inside solar cells that are chemically-inert, meaning that they resist undesirable chemical reactions that can prompt the degradation of perovskite materials. Rao, Ye and their colleagues devised a new two-step approach to reliably grow these interfaces.

Firstly, they grew a metastable low-dimensional interface, a version of this layer that is easily formed but is not yet as stable as one would like it to be. Subsequently, they improve this initial interface via a process known as organic cation exchange, that replaces initially formed cations with bulkier and more stable ones.

The researchers used their strategy to grow CI LD halogenometallate interfaces in real PSCs and then assessed the resulting cells in a series of tests. The cells were found to attain promising power-conversion efficiencies, while also retaining a good performance after operating for over a month.

"Our prototype PSCs achieve efficiencies of 25.1% over an active area of 1.235 cm2—among the highest reported for 1-cm2 PSCs," wrote the authors.

"The PSCs retain over 93% and 98% of their initial efficiency after 1,000 h of operation and 1,100 h of thermal aging at 85 °C, respectively. The versatility of this strategy unlocks access to CI LD interfaces, paving the way for the development of more efficient and stable PSCs."

The new growth strategy proposed by this research team could soon be further improved and used to fabricate other PSCs. In the future, it might contribute to the realization of low-cost and durable perovskite-based photovoltaics that perform well for longer periods of time.

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