Perovskite photovoltaics

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Colloidal chemistry in tin perovskite

Antonio Abate

Recent advancements in perovskite colloid engineering have shown promise in overcoming the complex processing challenges of tin-based formulations compared to lead-based ones.

Tin is essential for maximizing the power conversion efficiency in single-junction and multi-junction solar cells made from perovskite materials. The practical application of tin-based perovskite formulations encounters considerable challenges that must be addressed for successful implementation. These challenges primarily arise from the intricate processing requirements essential for effectively preparing thin films of tin perovskite. Achieving the desired film quality demands precise control over several parameters, including atmosphere, temperature and composition of the precursor ink[1]. In a recent article published in *Nature Nanotechnology*, He et al. have demonstrated advancements in solution processing by engineering the colloidal chemistry of perovskite ink. The fabricated tin-based perovskite solar cell achieved a remarkable power conversion efficiency of over 17%, marking a milestone in the field[2].

Extensive literature on lead-based perovskite solar cells emphasizes that forming monolithic perovskite films featuring crystalline grains that extend throughout the entire film thickness is critical for achieving high efficiency and stability. This finding is not entirely surprising, as chemical defects and charge trapping sites, which hinder efficient charge extraction, are primarily located at the surfaces of perovskite grains. Increasing the number of grains amplifies the overall surface area, raising the defect formation. This scenario is especially pronounced in tin perovskites, where the oxidation of tin and resultant defect formation predominantly occur at the grain surfaces. Striving for larger crystalline domains that are uniformly distributed within a monolithic film of perovskite is vital for minimizing the surface-to-bulk ratio and, consequently, the overall defect density. Therefore, enlarging the crystalline domains while maintaining a compact and uniform perovskite film results in higher power conversion efficiency.

He et al. revealed the crucial role in engineering the film formation for highly efficient tin-based perovskites. By choosing cations with varying dimensional characteristics, that is FA^+, PEA^+ and Cs^+, they were able to influence the electrical double-layer composition of the colloidal nanoparticles in the precursor solutions used to create perovskite films as schematically depicted in Fig. 1a. By fine-tuning the dimensions of colloids in these precursor solutions, it is possible to optimize the density of crystallization nuclei, promoting the formation of larger crystalline domains within a well-structured perovskite film.

He et al. harnessed a newfound understanding of the colloidal nature of tin perovskite precursors, allowing them to navigate the complexities of tin perovskite crystallization dynamics effectively. Their approach combines the benefits of using large organic cations, which have proven effective in protecting tin-based perovskite surfaces and inducing passivation effects, with smaller cations that fit within the perovskite crystal structure, resulting in larger crystalline domains. The outcome is a carefully orchestrated blend of two-dimensional and three-dimensional perovskite phases, which are uniformly distributed throughout the perovskite film. This distribution facilitates efficient charge extraction and provides essential protection for the materials at the interfaces with other layers within the device. A scanning electron microscopy image of the device's cross-section reveals a tin perovskite film characterized by a monolithic block structure, which has been challenging to achieve. This film boasts a thickness of approximately half a micron, as shown in Fig. 1b, a feat that has been challenging to attain without compromising the film's uniformity. Such advancements in

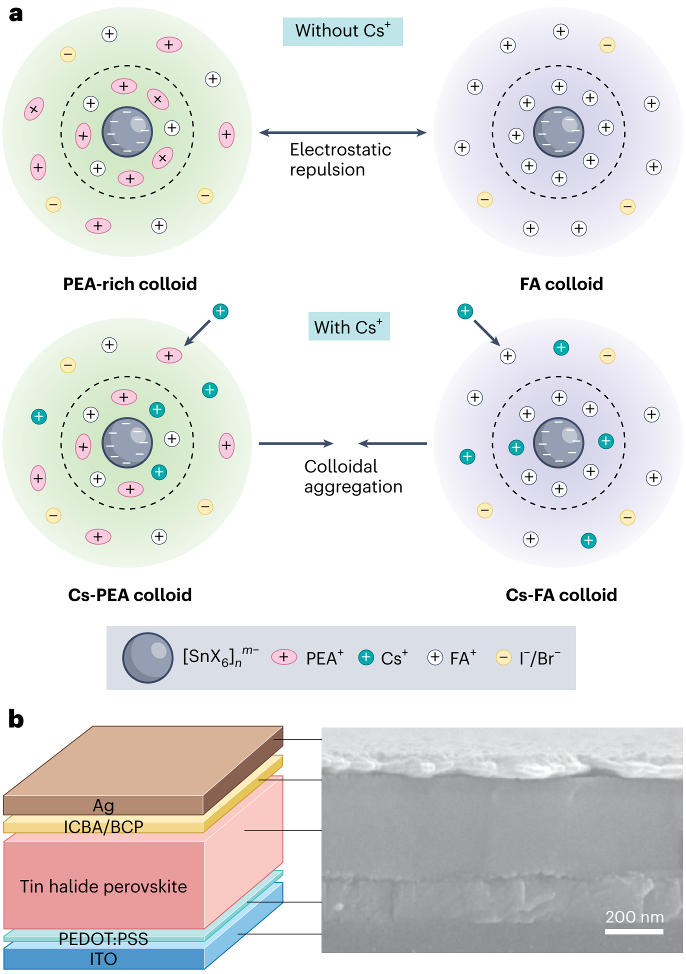

Fig. 1 | From the colloidal chemistry of tin perovskite ink to the perovskite film microstructure. a, Schematic of the colloidal manipulation engineering via perovskite ink composition. **b**, Cross-section of a compact, thick perovskite film that enables over 17% power conversion efficiency for tin-based perovskite solar cells. Adapted from ref. 2 under a Creative Commons licence CC BY-NC-ND 4.0.

thickness and homogeneity are crucial for enhancing device performance and extending its longevity in various applications.

Recent data indicate accelerating improvements in the power conversion efficiency of tin perovskite solar cells. As we look ahead, a transformative shift in perovskite formulations will likely occur within the next few years, favouring tin over lead. This transition is driven by the pressing need for safer alternatives and the realization that tin offers a more dependable and promising solution for the future of perovskite solar cells and their broader applications as semiconductors.

The research conducted by He et al. has undoubtedly contributed to the field of tin perovskites. However, it also underscores the persistent challenge of achieving long-term stability in these materials. Notably, a performance degradation of approximately 20% over 2,000 hours under continuous illumination falls short of the rigorous requirements expected in the market. Previous studies suggest that incorporating dimethyl sulfoxide in the formulation of perovskite ink may be a key factor contributing to these rapid performance declines[3]. In contrast, alternative solvents[4] have shown promise in preserving tin in its desired oxidation state, thereby enhancing the longevity and efficiency of the perovskite. This area of research warrants further exploration to develop more stable tin perovskite formulations that can meet the demands of real-world applications.

Antonio Abate
Helmholtz-Zentrum Berlin, Berlin, Germany.
e-mail: antonio.abate@helmholtz-berlin.de

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Competing interests

The author declares no competing interests.