PEROVSKITE PHOTOVOLTAICS

Surfactants for smoother films

The efficiency of perovskite solar modules is limited by the difficulty in fabricating uniform and high-quality perovskite films. Now, a modified doctor blade method with a surfactant-controlled drying process has been shown to enable high-speed deposition of large-area and uniform perovskite films.

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Perovskite solar cells (PSCs) are a promising low-cost photovoltaic technology to convert sunlight into electricity at high conversion efficiency. The highest certified PSC efficiency reported so far is 22.7%, which is as high as that of other thin-film solar cells[1]. However, most high-efficiency PSCs have been very small, with areas of only ~0.1 cm^2. With an increase in area, the efficiency tends to decrease rapidly. The major challenge lies in the great difficulty of obtaining large-area, high-quality perovskite films with few defects. In laboratories, spin-coating is the most commonly used film-formation method to obtain small devices with high efficiency. However, it is difficult to use it to make large-area perovskite films because of its lack of uniformity. Several potential methods have been reported to solve this issue, such as spray-coating[2], electrochemical deposition[3], soft-cover deposition[4], doctor blading[5] and slot-die coating[6]. A solvent-free, pressure-assisted method has demonstrated a perovskite module[7] with a certified efficiency of 12.1%, but for an aperture area of 36.1 cm^2. Finding appropriate methods that offer the necessary large area and efficiency for commercialization remains challenging.

For thin-film deposition of large devices, doctor blading is widely used (Fig. 1a). In this approach, the precursor solution is dropped onto substrates, which are then swiped linearly by a glass blade at a fixed speed. The substrates are held at elevated temperatures during doctor-blade deposition to evaporate solvents and form smooth perovskite films. However, in the case of deposition of large-area perovskite films, large inhomogeneous islands and ring-like patterns typically occur because of solution flow or convection caused by heat or surface tension during the film-formation process. This then results in low energy-conversion efficiency. Now, writing in *Nature Energy*, Jinsong Huang and colleagues from University of Nebraska–Lincoln and University of North Carolina in the United States report a modified doctor blade deposition method to obtain high-quality, large-area perovskite films with the aid of surfactants in the perovskite precursors[8].

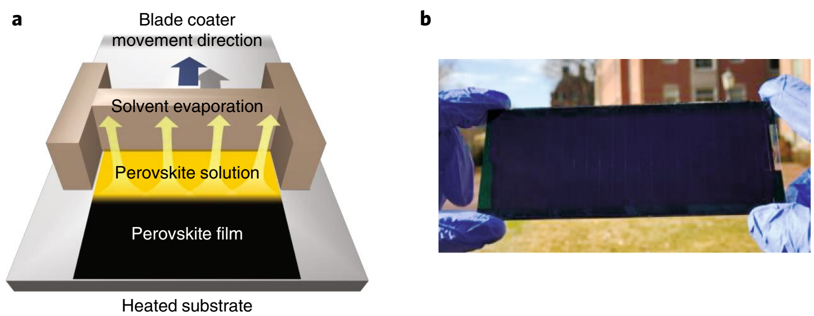

Fig. 1 | Blade-coating of perovskite films. a, Schematic illustration of the doctor blade process. **b**, Photograph of perovskite module fabricated by Huang and colleagues with this modified doctor blade method. Reproduced from ref. [8], Macmillan Publishers Ltd

The researchers' approach is based on the addition of small amounts of surfactants to the perovskite ink solution before deposition. Previously, the authors had shown that the surfactant L-α-phosphatidylcholine can substantially reduce the trap density of the perovskite film[9]. Now, when applying the surfactant in the doctor blading, the researchers find that the direction of flow due to the evaporation of solvents is opposite to the direction due to the Marangoni flow (caused by concentration gradients of the surfactants), so that the solution flow is balanced. The suppressed solution flow means any big islands disappear, enabling full coverage of the blade-coated perovskite films on the device substrate. In addition, the researchers find that the wetting property of the perovskite solution is largely improved. The method allowed Huang and colleagues to reach a coating speed of 180 m h^{-1}, which allowed for the fast production of 50 cm^2 perovskite solar cells. The researchers then used these cells to fabricate high-performance and large-area perovskite modules (Fig. 1b) with efficiencies of 15.3% and 14.6% for aperture areas of 33 cm^2 and 57.2 cm^2, respectively. Preliminary stability tests showed no obvious degradation in device performance after 20 days of storage in inert atmosphere.

Cost analysis has shown that a module efficiency higher than 12% with stability longer than 12 years and an aperture area of 1 m^2 are necessary conditions to achieve electricity generation costs below traditional sources, which are around 6 US cents kWh^{-1} (ref. [10]). In addition to the ~50 cm^2 perovskite modules fabricated by Huang and colleagues, modules with aperture areas of 16 cm^2 and efficiency of 16.29% have also been reported[1]. Nonetheless, the problem that efficiencies of perovskite modules decrease as the area increases remains. Perovskite solar cells with an area of 1 m^2 are thus still far from achieving high efficiency, as is required for commercialization. The development of new deposition methods or the modification of existing ones is urgently required for further advancement. A second challenge lies in the stability of perovskites under light soaking, heat stress and humidity tests. This is related to fabrication of highly crystallized perovskite films, the development of ideal charge transporting materials with high carrier mobility and the inhibition of ionic or molecular diffusion in devices. Efficient fabrication methods, such as the one shown by Huang and colleagues, can help make progress in these challenges and are thus important for the realization of low-cost perovskite solar modules. ❐

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