

学 位 論 文 の 要 旨

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学位論文題目	Development of Large-area High-performance Inverted Perovskite Solar Modules (大面積高性能逆構造型ペロブスカイト太陽電池モジュールの開発)		
学位論文要旨			
<p>A considerable efficiency gap exists between large-area perovskite solar modules (PSMs) and small-area perovskite solar cells (PSCs). The control of forming uniform and large-area film with perovskite crystallization is still the main obstacle restricting the efficiency of PSMs. In this work, a solid-liquid two-step film formation technique has been developed, which involved the evaporation of a lead iodide film and blade-coating of an organic ammonium halide solution to prepare relatively large-area perovskite films. This method possesses the advantages of integrating vapor deposition and solution methods, which could apply to the substrates with different roughness but avoid using toxic solvents to achieve a more uniform, large-area perovskite film.</p> <p>Firstly, the perovskite film was prepared by a solid-liquid two-step method, which showed good homogeneity. We investigated the effects of evaporation rate and blade coating speed on the formation and performance of perovskite films and modules. The results showed that the films with different evaporation rates exhibited relatively complete PbI_2 conversion with good crystallinity, indicating that evaporation rate effect is minor with better crystallinity and reproducibility. Besides, the optimal evaporation speed of Formamidinium iodide (FAI) solution of 15 mm/s resulted in more complete PbI_2 conversion and good crystallinity, leading to a better power conversion efficiency (PCE) of 17.23%.</p> <p>Secondly, the CsPbBr_3 seed layer was introduced onto the NiO_x hole transport layer (HTL) via vacuum evaporation prior to perovskite film deposition using a vapor-blade coating method. Synchrotron-based <i>in-situ</i> grazing incidence wide-angle X-ray scattering (GIWAXS) analysis confirmed that the CsPbBr_3 seed layer provided nucleation sites that facilitated the formation of a more spatially oriented α-FAPbI_3 film with enhanced crystallinity. This enhanced the final perovskite film quality by prolonging the crystallization time to enhance the conductivity and carrier transport ability of NiO_x. As a result, the efficiency of perovskite solar module (PSM, active area: 61.56 cm^2) incorporating a CsPbBr_3 seed layer increased from 17.62% to 20.02%, and simultaneously the encapsulated PSMs demonstrated more excellent ambient stability compared the pristine one. This strategy, demonstrated utilizing vacuum evaporation for the formation of CsPbBr_3 seed layer, shows great prospects for industrial applications, enabling the fabrication of highly efficient and stable large-area PSMs.</p> <p>Lastly, the modification of the NiO_x/perovskite buried interface and the introduction of Urea additives</p>			

in ammonium salts solution were utilized to reduce the interface recombination and regulate perovskite crystallization. As a result, a large-area perovskite film possessing larger grains, fewer pinholes, and reduced defects was achieved. The inverted PSM with an active area of 61.56 cm² (10×10 cm² substrate) achieved a champion PCE of 20.56% with significantly improved stability.

All in all, an innovative approach indicated above has been developed for the resolving of the uniformity issue associated with large-area film fabrication, which provides an attractive way for the application of perovskite solar cells in the future.