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Material Engineering toward High Performance Perovskite Solar Cells and Modules

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Organometal halide perovskites have captured wide interest as a promising material for light-weight and high-efficiency solar cells. Through recent studies of the organometal halide perovskite solar cells (PSCs), the composition of organometal halide perovskites is recognised as one of the key factors in the improvement of the PCE. In this study, we investigated mixed cation perovskite absorber. The results revealed that incorporating a small amount of K^+ into the double organic cation perovskite absorber ($FA_{0.85}MA_{0.15}Pb(I_{0.85}Br_{0.15})_3$) improved the photovoltaic performance of PSCs significantly, and K^+ incorporation diminished I-V hysteresis. Consequently, the 0.187 cm^2 PSC of 22% power conversion efficiency (PCE) without I-V hysteresis were constructed. The crystal lattice of the organometal halide perovskite was expanded with increasing of the K^+ ratio, where both absorption and photoluminescence spectra shifted to the longer wavelength, suggesting that the optical band gap decreased. It is concluded that stagnation-less carrier transportation could minimise the I-V hysteresis of PSCs. Additionally, we successfully constructed 2.76 cm^2 monolithic PSC mini-module of 20.5% PCE without I-V hysteresis. In the case of MA-free PSCs, the 24.9% PCE (0.187 cm^2) and 21.6% PCE (2.76 cm^2 monolithic PSC mini-module) were obtained, respectively.
On the other hand, the micro-structural aspects within the organometal halide perovskite are still unknown, even though it belongs to a crystal system. In this study, direct observation of the microstructure of the thin film organometal halide perovskite using transmission electron microscopy was investigated. Unlike previous reports, it is identified that the tetragonal and cubic phases coexist at room temperature, and it is confirmed that superlattices composed of a mixture of tetragonal and cubic phases are selforganized without a compositional change. The organometal halide perovskite self-adjusts the configuration of phases and automatically organizes a buffer layer at boundaries by introducing a superlattice. These results shows the fundamental crystallographic information for the organometal halide perovskite and demonstrates new possibilities toward high performance perovskite solar cells.

Keywords: organometal halide perovskite, perovskite solar cell, tetragonal, cubic, superlattice

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