Efficient Organic-inorganic Hybrid Perovskite Solar Cells Fabricated under High Humidity Condition

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A recent rapid emergence of a newcomer in the PV field is the hybrid organic-inorganic halide perovskite solar cell, the conversion efficiency of which have advanced from 3.8% reported in 2009 to a confirmed extremely high efficiency of 20.1% in the late 2014.[1,2] Critical to the solution process is the morphology of the perovskite active layer, since the perovskite crystal formation largely depends on the interfacial energy, solution concentration, precursor composition, solvent choice, and deposition temperature [3-5]. When the fabrication is processed in the ambient condition with high humidity, controlling the film morphology becomes dominant because the water in the air will dissolve or attack the resulting perovskite film during the processing, resulting in a more porous and rough surface film, which will largely degrade the device peroformance, as shown in Figure 1. In the paper, we provide a variety of controllable perovskite morphologies by employing different fabrication approaches conducted in the ambient atmosphere. We correlate the morphology to the solar cell performance. A bilayer structure, which has a combination of the strengths of the mesoscopic and planar structures, is identified to be essential for realizing high-performance perovskite solar cells with high reproducibility.

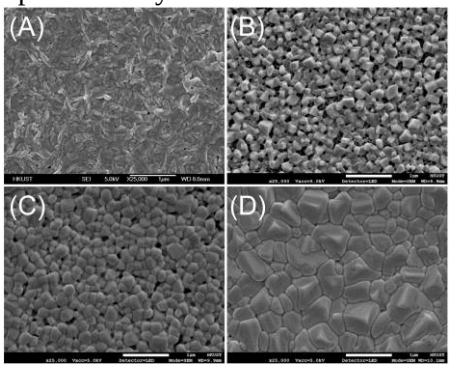

Figure 1. The top-view SEM images of a) PbI2; b) CH3NH3PbI3 film fabricated from the immersion (c) CH3NH3PbI3 film fabricated from the spin coating (d) CH3NH3PbI3 film fabricated from the immersion in the solution, followed by the spin coating.

The the Jsc, Voc, FF, and power-conversion efficiency (PCE) of morphology Figure 1(b) are determined to be 15.9 mA cm-2, 940 mV, 66%, and 9.9%, respectively. A typical device based on Figure 1c is shown with PCE =6.2%, Jsc=11 mA cm-2, Voc=1040 mV and FF=54%. Significant improvement of the Voc is observed, but the rising series resistance calculated from the J-V curve slope at the open-circuit condition gives rise to the lower FF, probably arising from the unreacted PbI2. Meanwhile, the Jsc is also found decreased, suggesting insufficient light absorption and inefficient carrier collection. As expected, the solar cell based on Figure 1d shows a Jsc of 18.5 mA cm-2, Voc of 1058mV and FF of 73.7%, the conversion efficiency is successfully increased up to 14.4%. The highest-performing device based on the bilayer structure achieves a conversion efficiency of 15.2%, with Jsc, Voc and FF of 19.2 mA cm-2, 1060 mV and 74.5% respectively.

References

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