Supplementary Information

Smooth $CH_3NH_3PbI_3$ from controlled solid-gas reaction for photovoltaic applications

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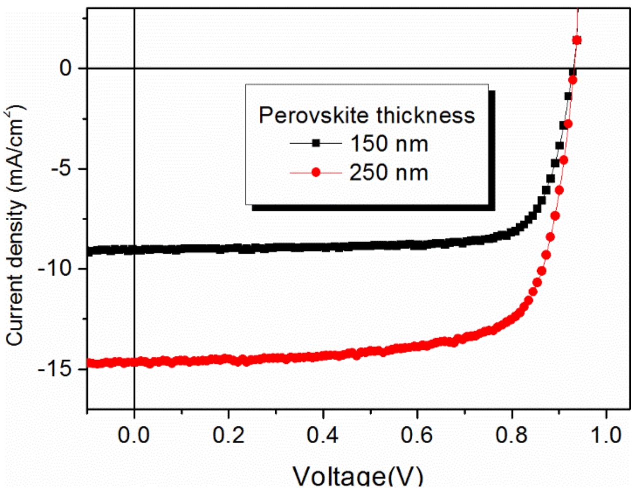
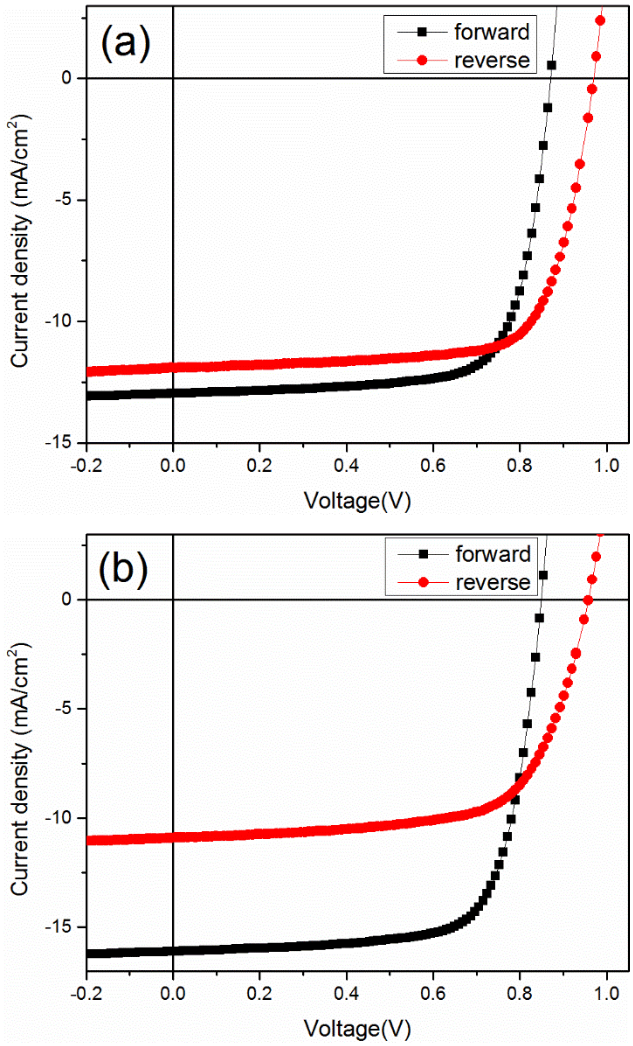


SI1. J-V curves of perovskite solar cells with active layer thickness of 150 nm and 250nm.



SI2. J-V curve of 250nm perovskite from CH_3NH_3I evaporation rate of 0.9 Å/s (a) and 1.3 Å/s (b).

We propose that the hysteresis in perovskite solar cells from MAI evaporation rate of 0.9 Å/s and 1.3 Å/s might be movement of defect, such as MA interstitial, I interstitial, and Pb vacancy. These defects are reported with low formation energy[1] and are easy to form. Higher evaporation rate of MAI leads to faster reaction between MAI and PbI_2 and quick crystallization of formed perovskite. The quick crystallization results in imperfect perovskite crystal with defects. The charged defects move to the interface between perovskite and carrier transporting layer under bias. The accumulated defects at interface result in built-in potential opposite to external bias and thus contribute to hysteresis in perovskite solar cells. However, when the reaction between MAI and PbI_2 is low, the crystallization of perovskite is slow, resulting in minimal defects. Accordingly, the hysteresis is not obvious.

1. W. J. Yin, T. T. Shi and Y. F. Yan, *Appl. Phys. Lett.*, 2014, **104**, 063903.