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ARTICLE

A low temperature gradual annealing scheme for achieving high performance perovskite solar cells with no hysteresis

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$CH_3NH_3PbI_3$ is commonly used in perovskite solar cells due to its long diffusion length and good crystallinity. In this paper, in the one-step approach using CH_3NH_3I and $PbCl_2$ for forming the perovskite, we present a new low temperature annealing approach of gradually increasing the temperature to fabricate perovskite films. Various temperatures and temperature ranges for the formation of perovskite films have been studied. Using the gradual annealing process, we can tune the amount of chlorine in the atomic ratio of chlorine/iodine from 1.2 to 4.0%. Meanwhile, the gradual annealing process influences the quality of perovskite film and importantly the device performance. The results show that through the optimized process, the film quality is improved with high surface coverage and good photoluminescence and reproducibility. We find that relatively higher amount of chlorine in the perovskite film plays a positive role on the device performance in the approach for achieving the power conversion efficiency of 14.9% with no obvious hysteresis.

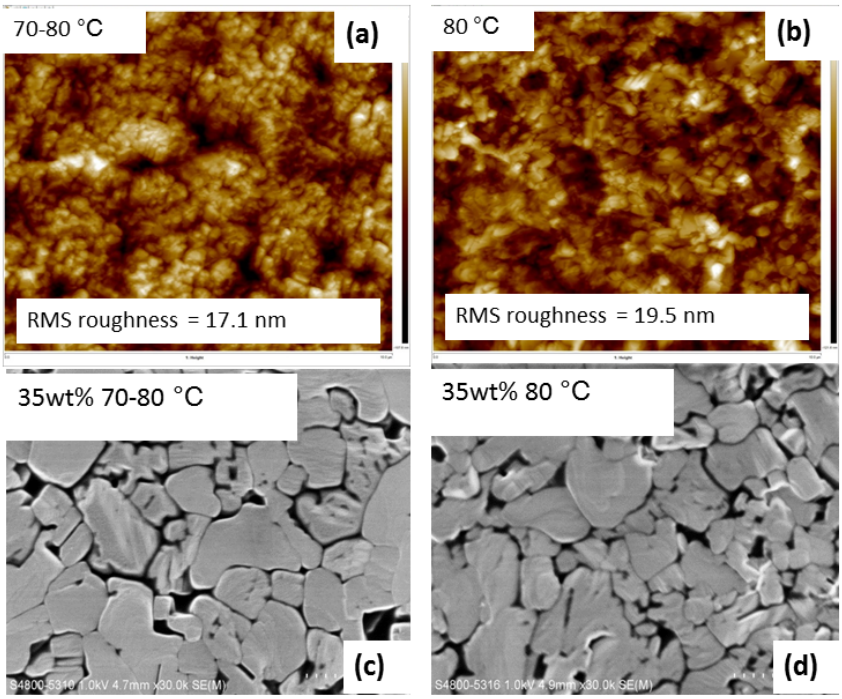

Figure S1 AFM height images of perovskite films with gradually annealing at 70-80 °C (a) and (b)

annealing at 100 °C. SEM images of perovskite films formed on ITO/PEDOT:PSS substrates with gradually annealing of (c) 70-80 °C and annealing at (d) 100 °C as reference.

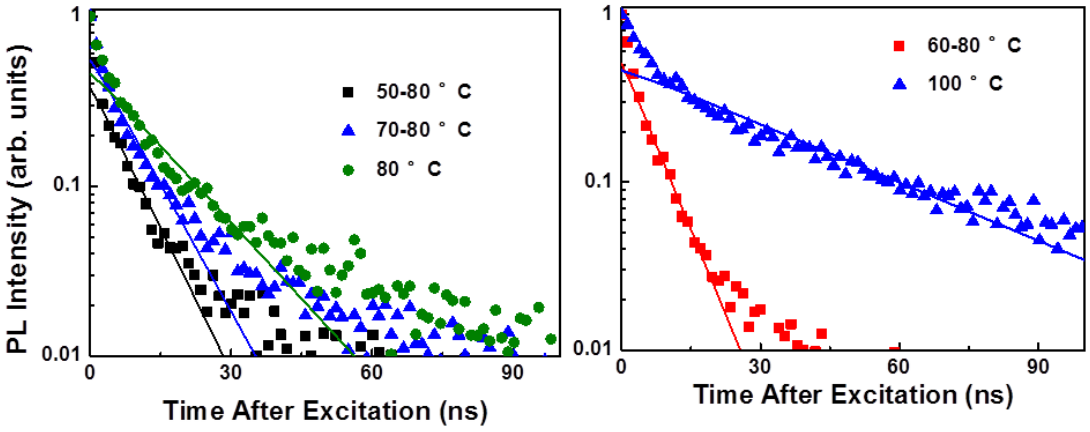

Figure S2 PL measurements fits to the diffusion model for the $CH_3NH_3PbI_{3-x}Cl_x$ for gradually annealing at 50-80°C, 60-80°C, 70-80°C and annealing at 80°C, 100°C with an structure of ITO/PEDOT:PSS/Perovskite/PCBM. The pulsed (3.8 MHz) excitation source is 400 nm.

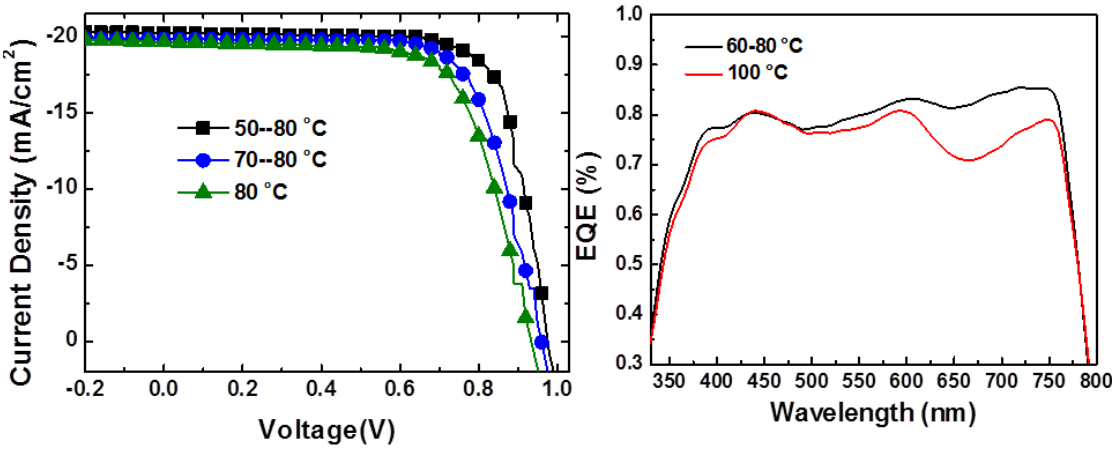

Figure S3 (a) *J-V* curves under AM 1.5 illumination of devices made with different annealing process. (b) EQE spectra of gradual annealing at 60-80 °C and annealing at 100 °C based solar cells.