Supplementary information

High-performance inverted planar perovskite solar cell without hole transport layer via solution process under ambient condition

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1. Experimental Section

Materials: Methylammonium iodide (CH_3NH_3I) was prepared according to previous report work [1]. PbI_2 was supplied by Aladdin reagent (China). The phenyl-C61-butyric acid methyl ester (PCBM) was purchased from American Dye Sources. The above materials were used as received. ITO glass substrates with a sheet resistance of 15Ω/sq were obtained from Shenzhen Display (China).

Solar Cell Fabrication: ITO glass was cleaned in an ultrasonic bath with detergent, ultrapure water, acetone, and isopropyl alcohol for 20 min, respectively. The ITO glass was treated with O_2 plasma for only 1 min to improve the wettability. To form the stoichiometric $CH_3NH_3PbI_3$ precursor solution, the CH_3NH_3I and PbI_2 (1M) were dissolved in a mixture of anhydrous N, N-dimethylformamide (DMF):dimethylsulfoxide (DMSO) (7:3), with 5v/v% N-methyl-2-pyrrolidone (NMP).

Solutions were heated at 70 °C overnight to encourage dissolution of solid material, cooled to room temperature, and then filtered through a 0.22 μm PTFE filter before use. Then, the precursor solution was spin coated onto the treated ITO glass at 4000 rpm for 50 s in laboratory with the relative humidity lower than 30%. During the spin coating, toluene was used to wash the surface to form high quality surface coverage as Seok reported [2]. After thermal treated at 90 ^{o}C for 20 min, a thin layer of PCBM (~40 nm) was spin coated onto the surface of perovskite layer (270~300 nm) with a 15 mg/mL in chlorobenzene solution at a speed of 1500 rpm. The devices were completed after thermal deposition of 100 nm aluminum as cathode at a pressure of 4×10^{-4} Pa. The device area was 0.1 cm^2 for each cell defined by shadow mask.

Measurements: The X-ray diffraction (XRD) pattern was obtained on a Bruker D8 ADVANCE. The absorption spectra of the films on ITO glass were observed by a scanning spectrophotometer (Varian Cary 50 UV/vis) in the range of 250–800 nm. Surface morphological characterizations of the films were characterized by a tapping-mode atomic force microscope (AFM, Agilent 5400) and scanning electron microscopy (SEM, Hitachi S-4800). The thicknesses of the films were measured by Veeco Dektak150 surface profiler. Steady-state photoluminescence (PL) spectra were recorded by a Fluoromax 4 spectrometer (HORIBA JobinYvon) with a photoexcitation at 507 nm. The PL lifetime was measured by time-correlated single-photon counting (TCSPC) in air using a HORIBA-fm-2015. Current density–voltage (*J–V*) characteristics of the devices were measured with a Keithley 2420 source measurement unit under the illumination of AM 1.5G, 100 mW/cm^2 with a Newport

solar simulator. Light intensity was calibrated with a standard silicon solar cell. The *J–V* curves were measured by reverse scan and forward scan with the scan rate was set to 100 ms/10 mV. The external quantum efficiency (EQE) of solar cell was analyzed using a certified Newport incident photon conversion efficiency (IPCE) measurement system.

2. SEM and AFM images

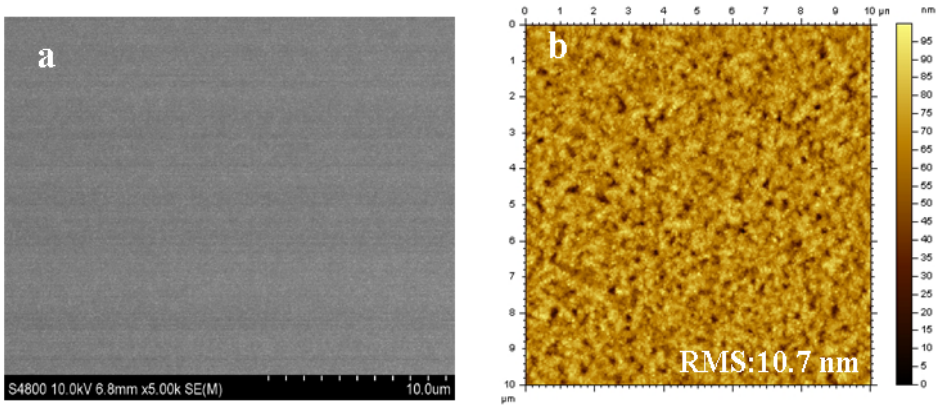

Figure S1 SEM and AFM images of perovskite film with large area scan.

3. PL lifetime of $CH_3NH_3PbI_3$ film on ITO glass

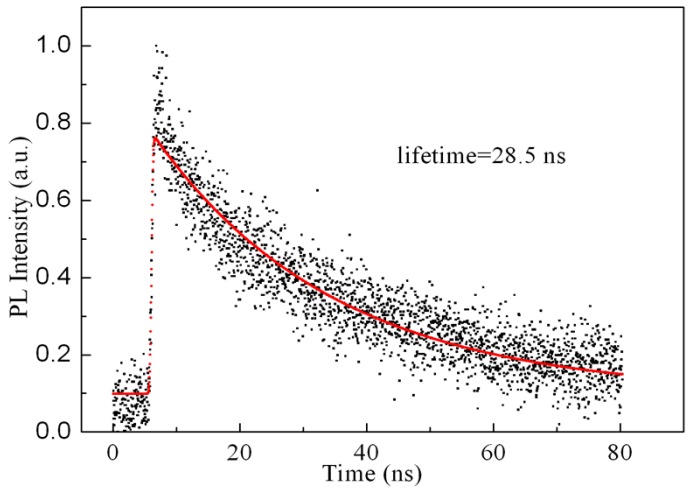

Figure S2 PL lifetime of $CH_3NH_3PbI_3$ on ITO glass

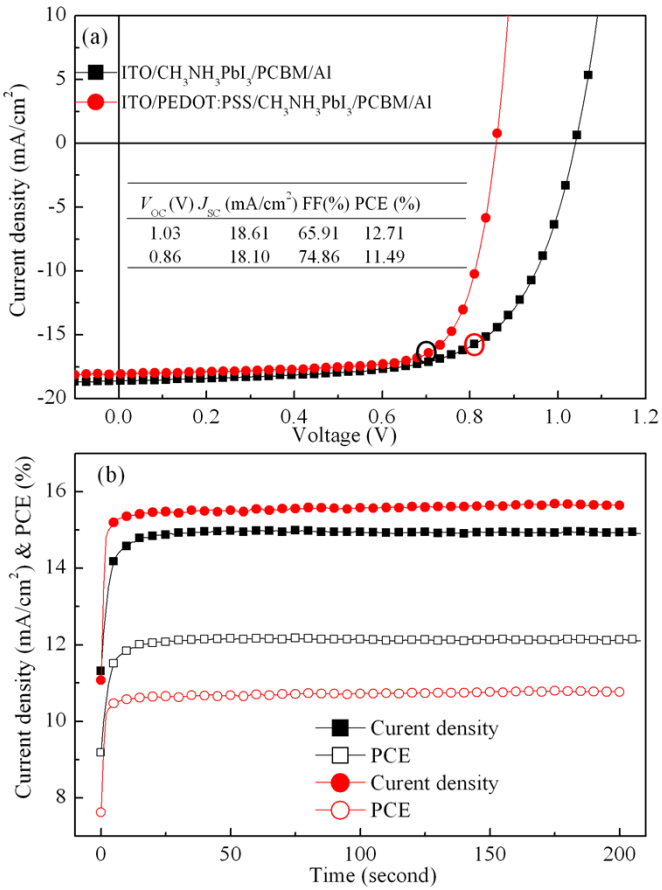

Figure S3 Stabilized power output of the perovskite solar cells. (a) *J-V* curves of perovskite solar cells under the reverse scan, the insert is the device parameters. (b) Photocurrent density and PCE versus time for the corresponding devices under 0.81 V and 0.70 V forward bias, respectively.

References

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