

Supporting information

Low-Temperature and Solution-Processed Copper Iodide as Hole Transport Layer for Inverted Planar Perovskite Solar Cells

Weihai Sun,^{a,b} Senyun Ye,^a Haixiao Rao,^a Yunlong Li,^a Zhiwei Liu,^{*a} Lixin Xiao,^b

Zhijian Chen,^b Zuqiang Bian^{*a} and Chunhui Huang^a

^aBeijing National Laboratory for Molecular Sciences, State Key Laboratory of Rare Earth Materials Chemistry and Applications, Peking University, Beijing, 100871, P. R. China.

^bInstitute of Modern Optics and State Key Laboratory for Artificial Microstructure and Mesoscopic Physics, School of Physics, Peking University, Beijing 100871, P. R. China.

Experimental section

Materials and method. Methylammonium iodide ($\text{CH}_3\text{NH}_3\text{I}$) was synthesized according to the procedure reported previously. Indium tin oxide (ITO) coated glass substrates with a sheet resistance of $8\ \Omega/\text{sq}$ and ITO thickness of 180 nm were purchased from Huayulianhe Co., Ltd. CuI (purity >99%), PEDOT:PSS (Clevios P VP AI 4083), PbI_2 (99.9985%), C_{60} (99.9%) and 2,9-dimethyl-4,7-diphenyl-1,10-phenanthroline (BCP) (99.9%) were purchased from Sigma-Aldrich, H. C. Stark Company, Alfa Aesar, Puyang Yongxin Fullerene Technology Co., Ltd and Xi'an Polymer Light Technology Corp. (PLT), respectively. All these commercially available materials were used as received without any further purification.

Device fabrication and characterization. The ITO coated glass substrates were

cleaned ultrasonically in detergent, deionized water, acetone and isopropyl alcohol sequentially and ultraviolet-ozone treated for 10 minutes. The CuI films (~30 nm) were deposited by spin-coating copper iodide acetonitrile solution (10 mg/mL) at 3000 rpm for 60 s on the ITO electrode. The PEDOT:PSS aqueous was filtered through a 0.45 μm filter prior to being spin-coated at 4000 rpm for 60 s on the anode ITO electrode. Subsequently, the PEDOT:PSS layer (~40 nm) was baked at 140 $^{\circ}\text{C}$ for 20 min in the oven. The perovskite precursor solution (40 wt%) was prepared by mixing the PbI_2 with $\text{CH}_3\text{NH}_3\text{I}$ (1:1 molar ratio) in anhydrous N,N-dimethylformamide (DMF) and stirring until to produce a clear and transparent perovskite solution. Afterwards, the perovskite precursor solution was dropped onto the anode buffer layer (PEDOT:PSS or CuI) and spin-coated with a speed of 4000 rpm for 60 s. After about several seconds (3.5 s, 4.5 s, 5.5 s) of spin-coating the perovskite solution, a 200 μL anhydrous chlorobenzene was quickly dropped onto the center of the substrate. The pristine perovskite films were annealed at 100 $^{\circ}\text{C}$ for 10 min. Finally, C_{60} (40 nm), BCP (8 nm) and Ag (100 nm) layers were sequentially deposited on the $\text{CH}_3\text{NH}_3\text{PbI}_3$ film by thermal evaporation under vacuum (10^{-6} mbar). The active area of the devices was 0.100 cm^2 .

All measurements of photovoltaic performance were performed in a glove box. The current-voltage curves of perovskite solar cells were measured using a Keithley 4200 Semiconductor Characterization System (scan speed 300 mV/s). The solar cells were illuminated using an Oriel 300 W solar simulator (Thermo Oriel 91160-1000) as an excitation source (100 mW/cm^2 white light illumination under AM 1.5G conditions). The incident-photo-to-current conversion efficiency was recorded on a Keithley 2400 source meter under an irradiation of a 150 W tungsten lamp with a 1/4 m monochromator (Spectral Product DK 240). Scanning electron microscope (SEM) and atomic force microscope (AFM) images of CuI film and $\text{CH}_3\text{NH}_3\text{PbI}_3$ film were

collected on a Hitachi S-4800 and SPI3800/SPA400 SPM (Seiko Instrument Inc), respectively. The thickness of the thin films was measured with a KLA-Tencor Alpha-Step Surface Profiler. The work function of CuI film and perovskite film were measured by using ultraviolet photoelectron yield spectroscopy (Riken Keiki).

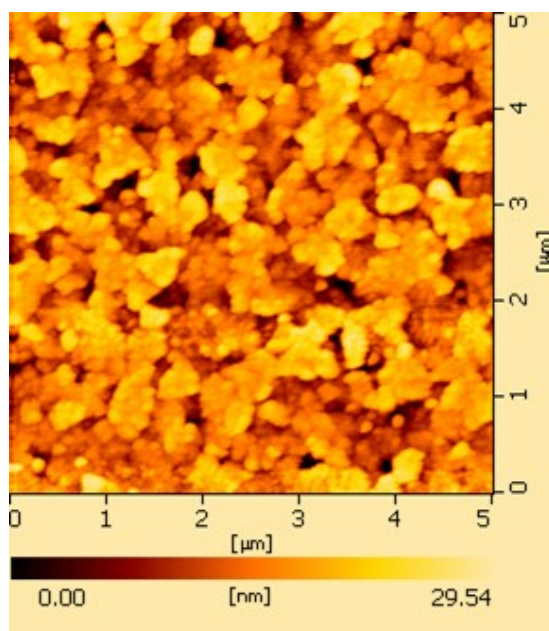
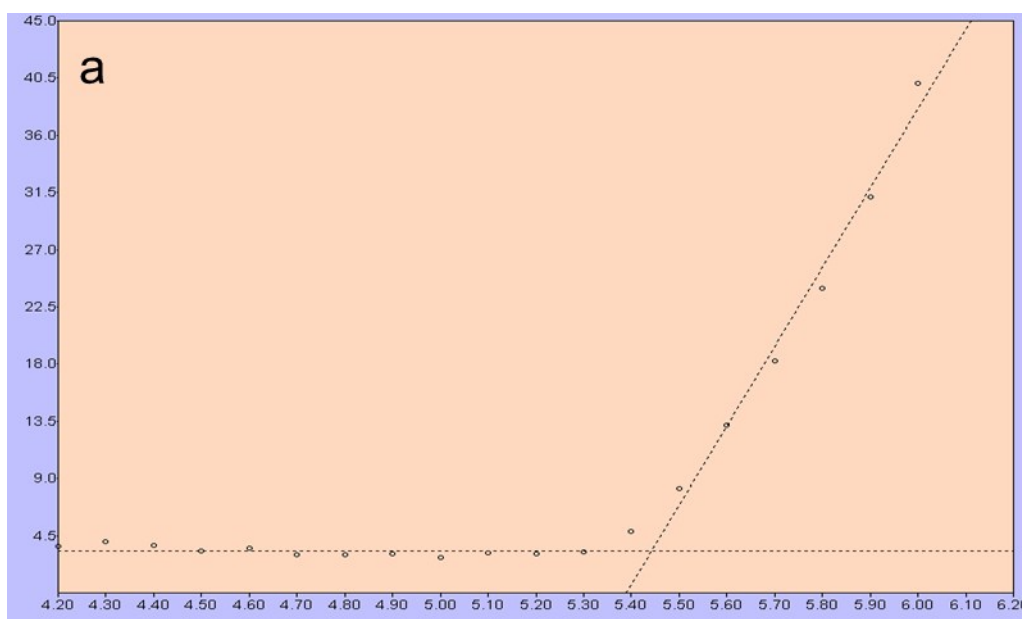


Figure S1. AFM image of bare ITO electrode.



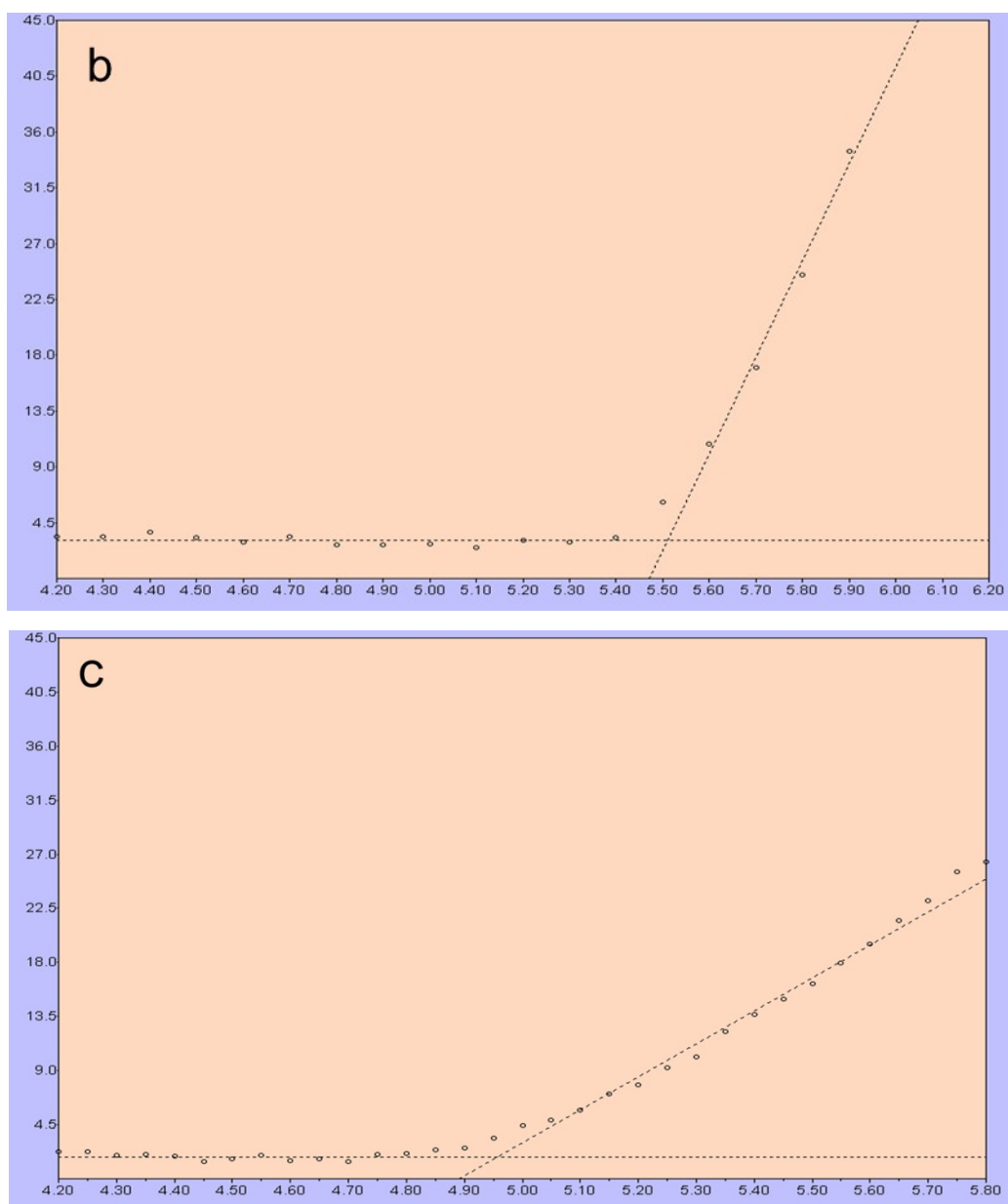


Figure S2. The ultraviolet photoelectron yield spectroscopy of the different anode interfacial layers: (a) CuI; (b) $\text{CH}_3\text{NH}_3\text{PbI}_3$; (c) PEDOT:PSS.

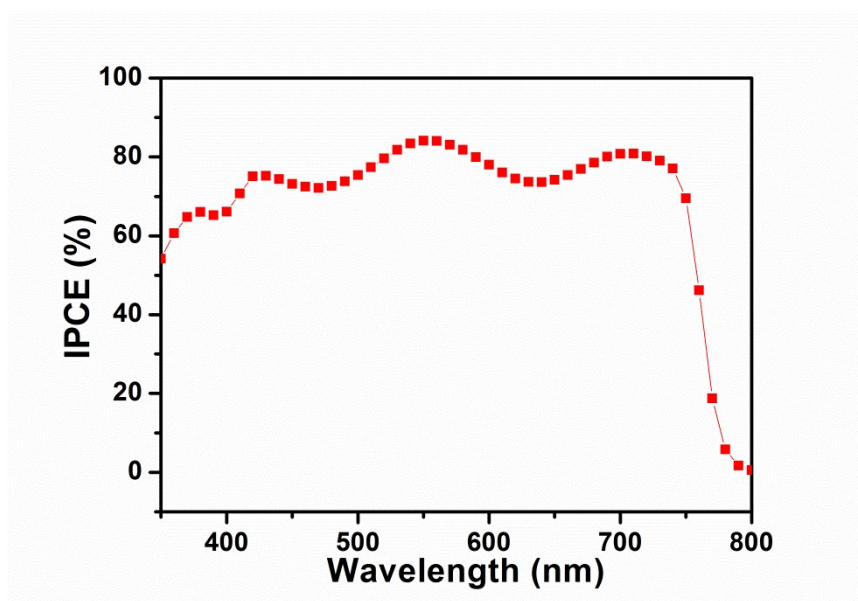


Figure S3. IPCE spectra of the device with PEDOT:PSS HTL.