**Electronic supplementary information**

# Efficient planar perovskite solar cells using room-temperature vacuum-processed $C_{60}$ electron selective layers

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**Experimental Section**

Device Fabrication:

The Vacuum-processed $C_{60}$ (Luminescence Technology Co., Ltd, >99.5%) electron selective layers were deposited on FTO coated soda-lime glass substrates by thermal evaporation at a rate of 0.02 nm/s. The different thicknesses of the $C_{60}$ films were controlled by the deposition time. The solution-processed $C_{60}$ electron selective layers were prepared by spin-coating method, according to the literature reports.[1] 460 mg/mL $PbI_2$ (Sigma, 99.999%) dissolved in DMF was stirred at 60 °C for 24h. Perovskite $CH_3NH_3PbI_3$ films were prepared by a typical two-step dip-coating method.[2] FTO substrates were heated on a hotplate at 60 °C for 30min. The hot $PbI_2$ solution was quickly applied drop-wise and spin-coated on the FTO substrates without and with the $C_{60}$ interface layers at 500 rpm for 1s and then 3000 rpm for 30 s. The substrates covered with the $PbI_2$ films were annealed at 100 °C for 10 min. The dried $PbI_2$ films were dipped into a solution of 200 mg $CH_3NH_3I$ dissolved in 20 ml 2-propanol at 55 °C for 5 min and then were quickly rinsed with clean 2-propanol. The films were finally annealed at 100 °C for 10 min. The finished perovskite films were spin-coated with a solution of electron blocking material at 500 rpm for 1s and then 6000 rpm for 60 s. The electron blocking material consisted of 26 mM Li-TFSI (Sigma, 99.95%), 55 mM TBP (Sigma, 96%), and 68 mM spiro-OMeTAD (Shenzhen Feiming Science and Technology Co., Ltd., 99.0%) dissolved in a mixed solvent of chlorobenzene and acetonitrile with a volume ratio of 10:1. The devices were finally completed by evaporating 60 nm Au electrodes. The active areas of the cells defined by the Au

electrodes were 0.08 $cm^2$.

Film and Device Characterization:

The crystal structure of the prepared $CH_3NH_3PbI_3$ film on the FTO substrates covered with a $C_{60}$ interface layer was examined by XRD (Rigaku Ultima III) with Cu Kα radiation under operation conditions of 40 kV and 44 mA. Absorption spectrum of the perovskite $CH_3NH_3PbI_3$ film on the substrate covered with a $C_{60}$ interface layer and transmission spectra of the substrates without and with a $C_{60}$ interface layers in different thicknesses were measured by an ultraviolet–visible spectrophotometer (CARY5000, Varian, Australia). AFM images of the substrates without and with a $C_{60}$ interface layer were characterized by a Veeco Nanoscope IIIA instrument. The morphologies of the device and the perovskite film were characterized by a high-resolution field emission SEM (Hitachi S-4800). $V_{oc}$ decay curves and QE spectra were performed on an electrochemical workstation (Solartron Modulab) and a QE system (PV Measurements Inc.), respectively. All the *J-V* curves were measured by a Keithley Model 2400 under AM1.5 simulated irradiation with a standard solar simulator (PV Measurements Inc.).

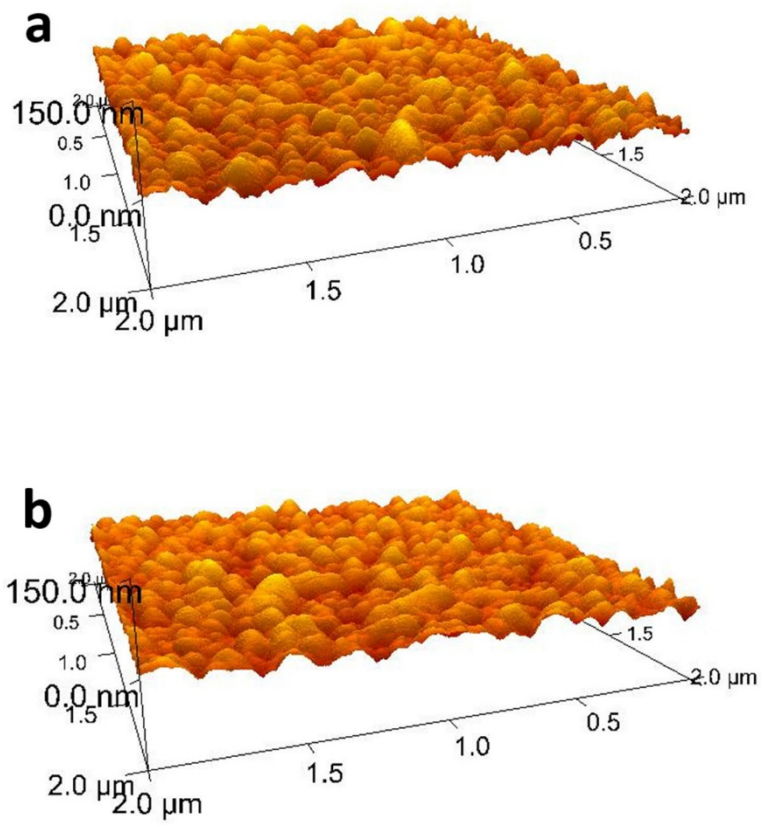


**Fig. S1.** AFM images of 3-dimensional patterns of the FTO substrates (a) without and (b) with a 7.5 nm $C_{60}$ interface layer.

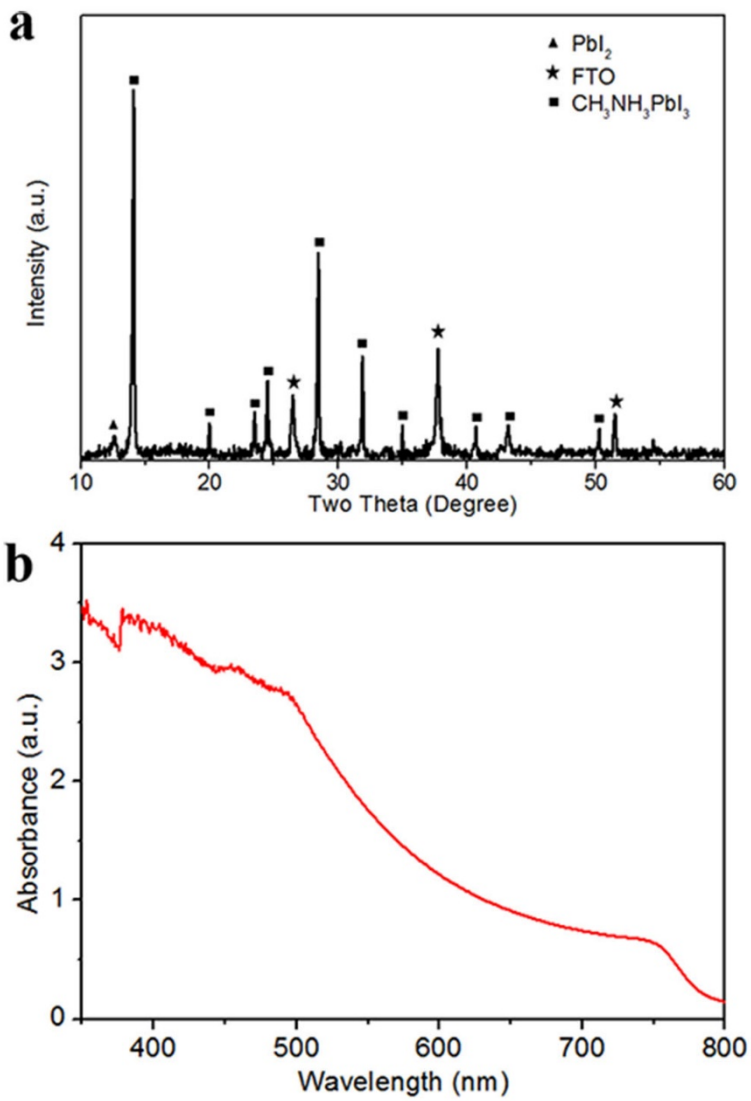


**Fig. S2.** (a) XRD pattern and (b) ultraviolet–visible absorbance spectrum of a perovskite film on an FTO substrate covered with a 7.5 nm $C_{60}$ interface layer.

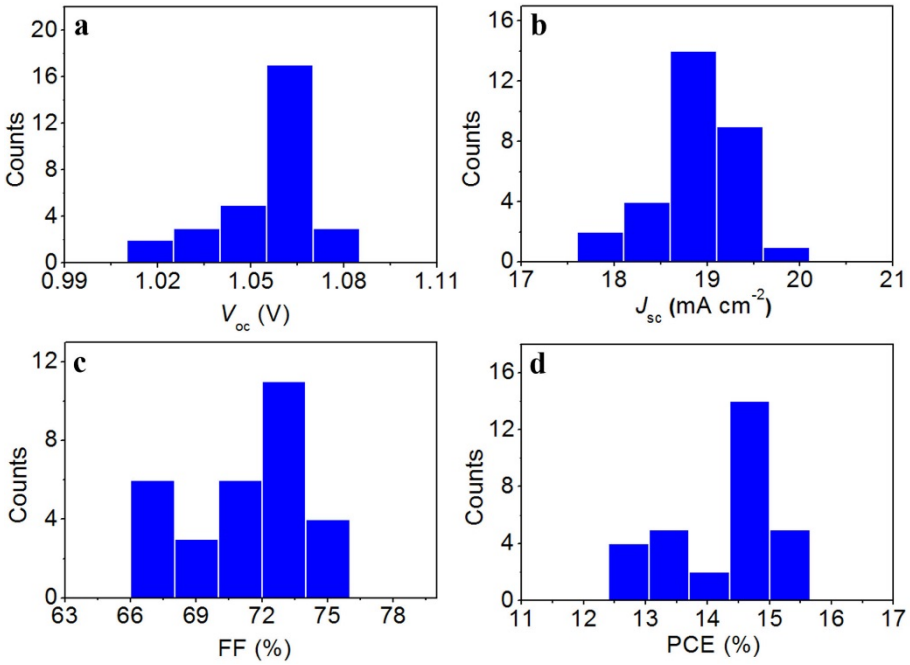


**Fig. S3.** Histograms of (a) $V_{oc}$'s, (b) $J_{sc}$'s, (c) FFs, and (d) PCEs for 30 cells using the vacuum-processed $C_{60}$ electron selective layers measured under reverse voltage scanning.

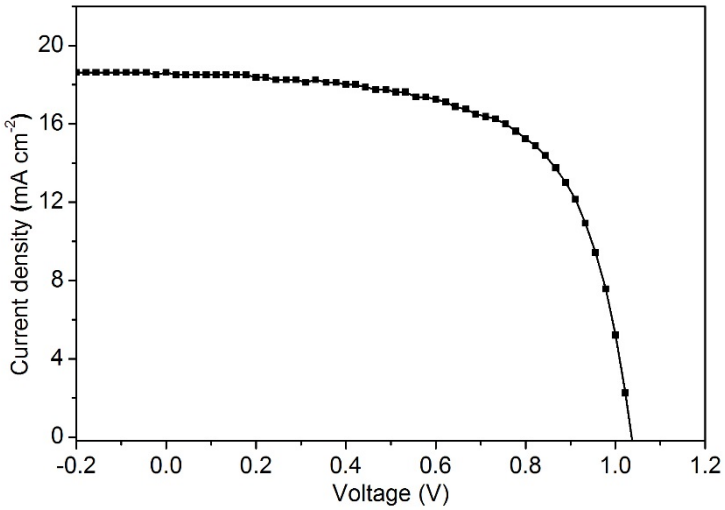


**Fig. S4.** *J-V* curve of the best-performing perovskite solar cell using a solution-processed $C_{60}$ electron selective layer measured under reverse voltage scanning.

References

1. K. Wojciechowski, T. Leijtens, S. Spirova, C. Schlueter, M. Hoerantner, J. T.-W. Wang, C.-Z. Li, A. K.-Y. Jen, T.-L. Lee and H. J. Snaith, *J. Phys. Chem. Lett.*, 2015, **6**, 2399–2405.
2. W. Ke, G. Fang, J. Wang, P. Qin, H. Tao, H. Lei, Q. Liu, X. Dai and X. Zhao, *ACS Appl. Mater. Interfaces*, 2014, **6**, 15959-15965.