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Simple Planar Pervoskite Solar Cells with a Dopant-free Benzodithiophene Conjugated Polymer as Hole Transporting Material

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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 poly[(4,8-bis-(2-ethylhexyloxy)ben-zo[1,2-b;4,5-b']di-thiophene)-2,6-diyl-alt-(4-(2-elethylhexanoyl)-thieno[3,4-b]th-iopene)-2,6-diyl] (PBDTTT-C) and poly(3-hexylthiophene) (P3HT) were purchased from Solarmer Inc. and Luminescence Technology Corp., recpectively. 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. The 1M perovskite precursor

solution was prepared according to Seok method [2]. Then, the precursor solution was spin coated onto the treated ITO glass at 4000 rpm for 50 s in air with the relative humidity lower than 30%. During the spin coating, toluene was used to wash the surface to form high quality surface coverage. After thermal treatment at 100 ^{o}C for 10 min, a thin layer of HTM was spin coated onto the surface of perovskite layer with a 6 mg/mL in chlorobenzene solution under different speeds. The devices were completed after thermal deposition of 5 nm molybdenum oxide (MoO_3) and 80 nm silver (Ag) 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 absorption spectra of the films on ITO glass were observed by a scanning spectrophotometer (Varian Cary 50 UV/vis) in the range of 400–800 nm. Surface morphological characterizations of the films were characterized by a tapping-mode atomic force microscope (AFM, Agilent 5400). The thickness of the films was measured by Veeco Dektak150 surface profiler. Photoluminescence spectra were recorded by a Fluoromax 4 spectrometer (HORIBA Jobin Yvon) with a photo-excitation at 600 nm. Current density–voltage (*J–V*) characteristics of the devices were measured with a Keithley 2420 source measurement in dark or under the illumination of AM 1.5G, 100 $mWcm^{-2}$ with a Newport solar simulator. The scan rate for these *J-V* curves was 0.1 Vs^{-1}. Light intensity was calibrated with a standard silicon solar cell. The external quantum efficiency (EQE) of solar cell was analyzed

using a certified Newport incident photon conversion efficiency (IPCE) measurement system.

The proof concept devices with a classical planar configuration of FTO/c-TiO_2/$CH_3NH_3PbI_3$/P3HT/MoO_3/Ag were fabricated. A PCE of 7.52% was achieved with J_{SC} of 16.16 mA cm^{-2}, V_{OC} of 0.921 V and FF of 50.53%. The J-V curve of this device is show in Fig S1.

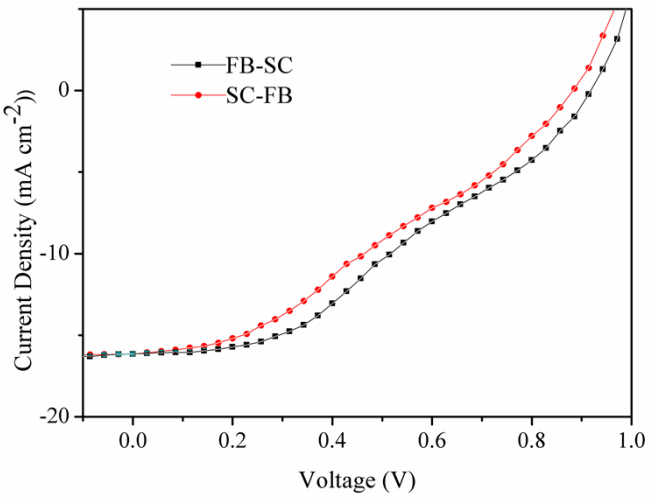

Fig. S1 Forward bias to short circuit (FB-SC) and short circuit to forward bias (SC-FB) current−voltage curves measured under simulated AM 1.5G 100 mW cm^{-2} sun light with a scan rate of 0.1 V s^{-1}

Table S1 The device performance of the perovskite solar cells with different thickness of PBDTTT-C HTL.

Rotation Speed (r/s)	HTL Thickness (nm)	V_{OC} (V)	J_{SC} (mA cm^{-2})	FF (%)	PCE (%)
600	50.37	0.815	13.55	57.44	6.34
700	38.31	0.801	13.71	60.18	6.60
800	32.11	0.868	17.68	64.83	9.95
1000	22.34	0.856	15.02	69.32	8.90
1250	10.14	0.842	16.15	63.50	8.63
1500	4.35	0.823	13.44	66.87	7.44

References:

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2. N. J. Jeon, J. H. Noh, Y. C. Kim, W. S. Yang, S. Ryu, and S. I. Seok, *Nat. Mater.*, **2014**, 13, 897–903.