

Supporting Information

High performance organic photovoltaic utilizing PEDOT:PSS and graphene oxide

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Experimental Section

Anode Interfacial Layer Solutions Preparation. PEDOT:PSS (CLEVIOS P VP Al 4083) was purchased from H. C. Starck and used without any further purification. PEDOT:PSS:WO_x, PEDOT:PSS:MoO_x, PEDOT:PSS:GO, PEDOT:PSS:CNT solutions were prepared by mixing PEDOT:PSS with their respective materials in 1:1, 1:1, 20:1, and 20:1 volume ratio, respectively. Prior to the film deposition, the prepared solutions were filtered through a 0.45 μm hydrophilic filter.

Solar Cell Fabrication. The ITO glass substrate was cleaned by ultrasonic treatment in acetone, methanol, isopropanol, and deionized water sequentially. The pre-cleaned ITO substrate was treated in an ultraviolet-ozone chamber (Ultraviolet Ozone Cleaner, Jetlight Company, USA) for 15 min. All anode interfacial layers (PEDOT:PSS, PEDOT:PSS:WO_x, PEDOT:PSS:MoO_x, PEDOT:PSS:GO, and PEDOT:PSS:CNT) were deposited at 4000 rpm for 25 s on the ITO electrode. The interfacial layer was annealed inside the glove box at 130 °C for 20 min. Later, the photoactive layer was prepared by spin coating (500 rpm) a 1,2-dichlorobenzene solution of PTB7 and a fullerene (PC₇₁BM) (1:1.5 w/w, polymer concentration 12 mg/2mL⁻¹) on the anode interfacial layer for 25 s. The thickness of the active layer was around 90 nm. For the PBDTTT-EFT:PC₇₁BM OPVs, the active layer was spin-coated at 500 rpm for 60 s (1:1.5 w/w, polymer concentration 15 mg/mL) on the anode interfacial layer. The thickness of PBDTTT-EFT:PC₇₁BM was approximately 95 nm. Later, PFN solution was filtered through

a 0.45 μm polyvinylidene fluoride (PVDF) filter and spin-coated at 4000 rpm for 25 s on the photoactive layer. The thickness of the PFN was < 5 nm. Finally, the substrate was transferred to a vacuum chamber and 100 nm of Al was thermally deposited on the PFN cathode buffer layer under a base pressure of 1×10^{-7} Torr. The active area of the device was 0.04 cm^2 .

Solar Cell Measurements. The power conversion efficiencies of the OPVs were measured under the illumination of AM1.5G simulated solar light (Oriel Model 91192) at 100 mW/cm^2 . The current density–voltage (J – V) characteristics were recorded with a Keithley 2410 source unit. The EQE measurements were performed using EQE system (Model 74000) obtained from Newport Oriel Instruments USA and HAMAMATSU calibrated silicon cell photodiode used as a reference diode. The wavelength was controlled with a monochromator 200–1600 nm. For the UPS measurements, the HTLs were deposited on pre-cleaned ITO substrate. The UPS analysis chamber was equipped with a hemispherical electron-energy analyzer (Kratos Ultra Spectrometer), and was maintained at 1.33×10^{-7} Pa. UPS measurements were performed using He I ($h\nu=21.2 \text{ eV}$) source. The electron-energy analyzer was operated at constant pass energy of 10 eV (for UPS). During the UPS measurements, a sample bias of -9 V was used in order to separate the sample and the secondary edge for the analyzer.

Table 1. Photovoltaic parameters of conventional organic photovoltaics with different anode interfacial layers.

Anode interfacial layer	J_{sc} (mA/cm ²)	V_{oc} (V)	FF (%)	PCE (%)	R_s (Ω .cm ²)	R_{sh} (Ω .cm ²)
PEDOT:PSS	14.5	0.75	66.9	7.27	7.62	714.3
PEDOT:PSS:WO _x	14.5	0.73	66.6	7.07	7.55	693.1
PEDOT:PSS:MoO _x	11.4	0.73	64.2	5.33	8.86	457.5
PEDOT:PSS:GO	14.9	0.75	68.3	7.53	7.50	702.9
PEDOT:PSS:CNT	14.8	0.74	68.1	7.48	6.26	533.3

Table 2. Summary of photovoltaic parameters based on PBDTTT-EFT:PC₇₁BM with different anode interfacial layer.

Anode interfacial layer	J_{sc} (mA/cm ²)	V_{oc} (V)	FF (%)	PCE (%)	R_s (Ω .cm ²)	R_{sh} (Ω .cm ²)
PEDOT:PSS	16.1	0.81	66.4	8.75	8.63	675.7
PEDOT:PSS:WO _x	16.6	0.81	65.8	8.85	8.15	574.7
PEDOT:PSS:MoO _x	16.0	0.81	62.7	8.16	9.06	423.7
PEDOT:PSS:GO	16.9	0.81	66.5	9.12	8.94	714.3
PEDOT:PSS:CNT	16.2	0.81	65.8	8.67	8.29	674.3

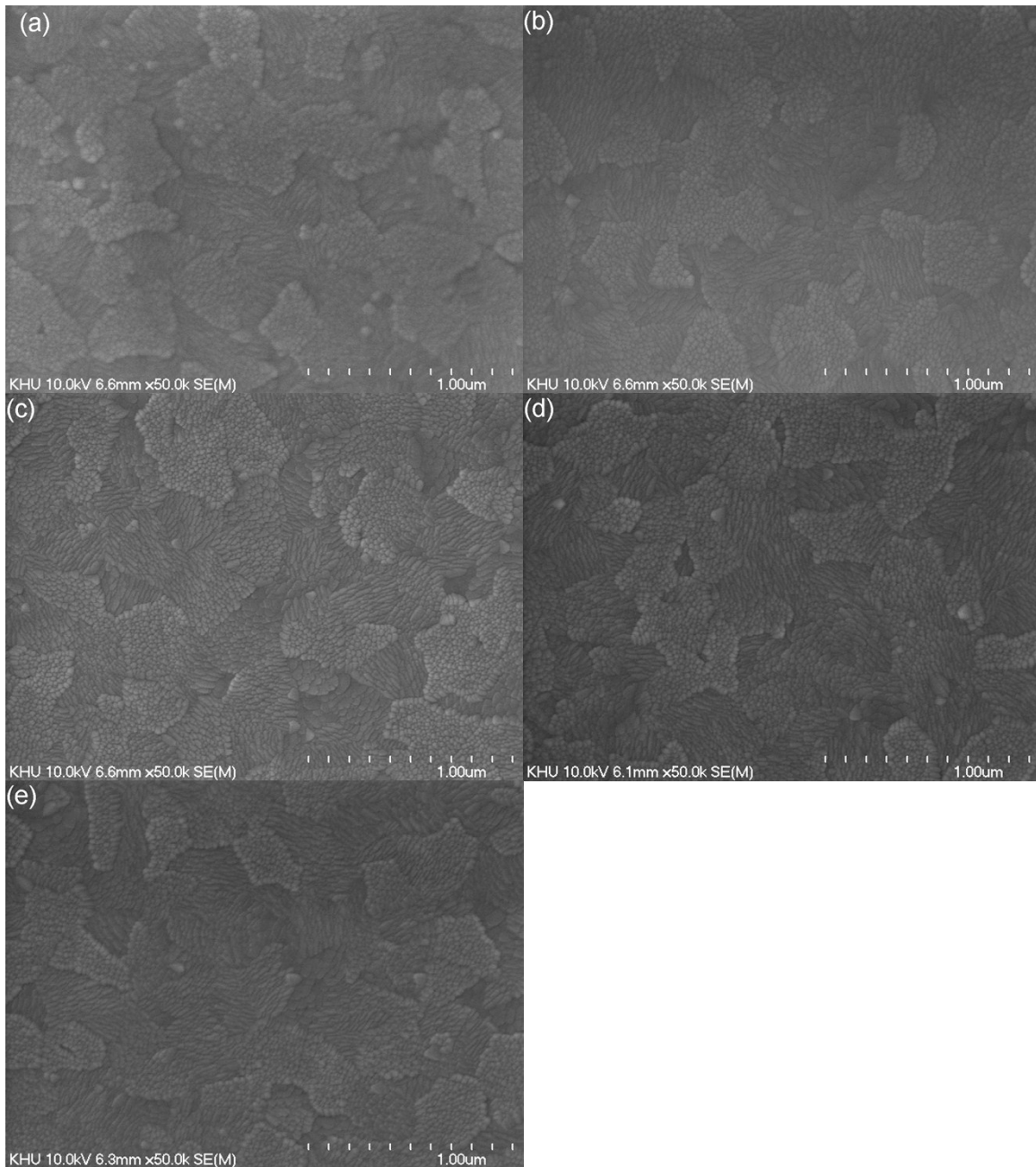
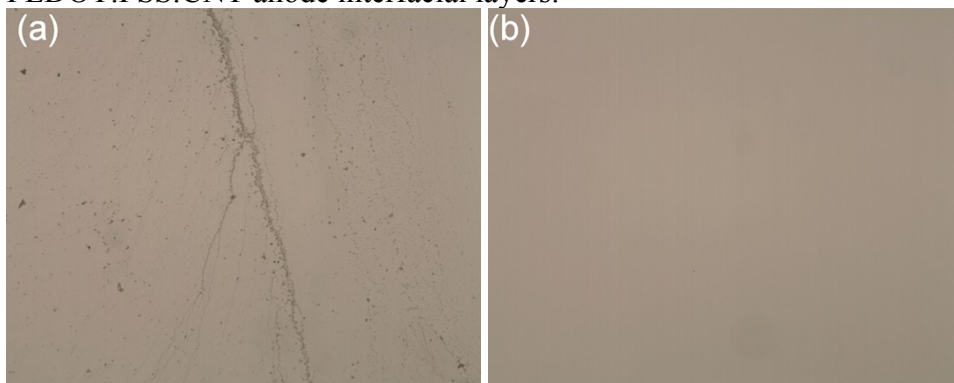
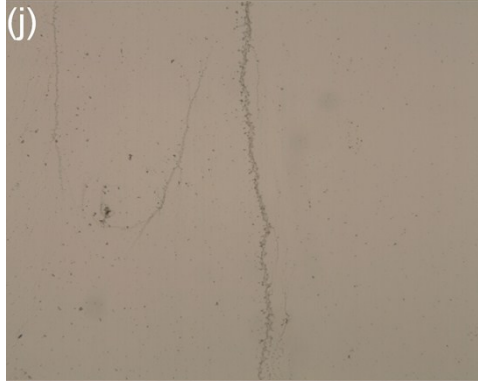
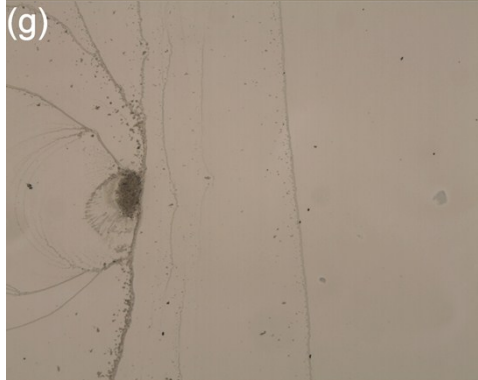
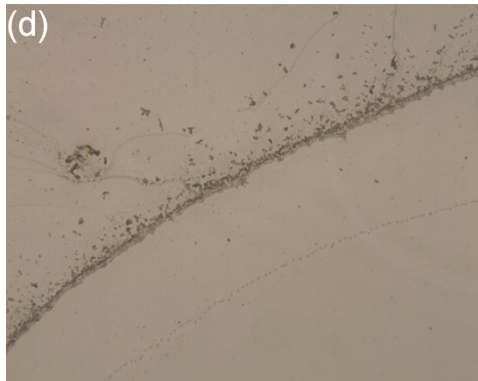


Figure S1. SEM images displaying the different film surface morphologies of (a) PEDOT:PSS, (b) PEDOT:PSS:WO_x, (c) PEDOT:PSS:MoO_x, (d) PEDOT:PSS:GO, and (e) PEDOT:PSS:CNT anode interfacial layers.





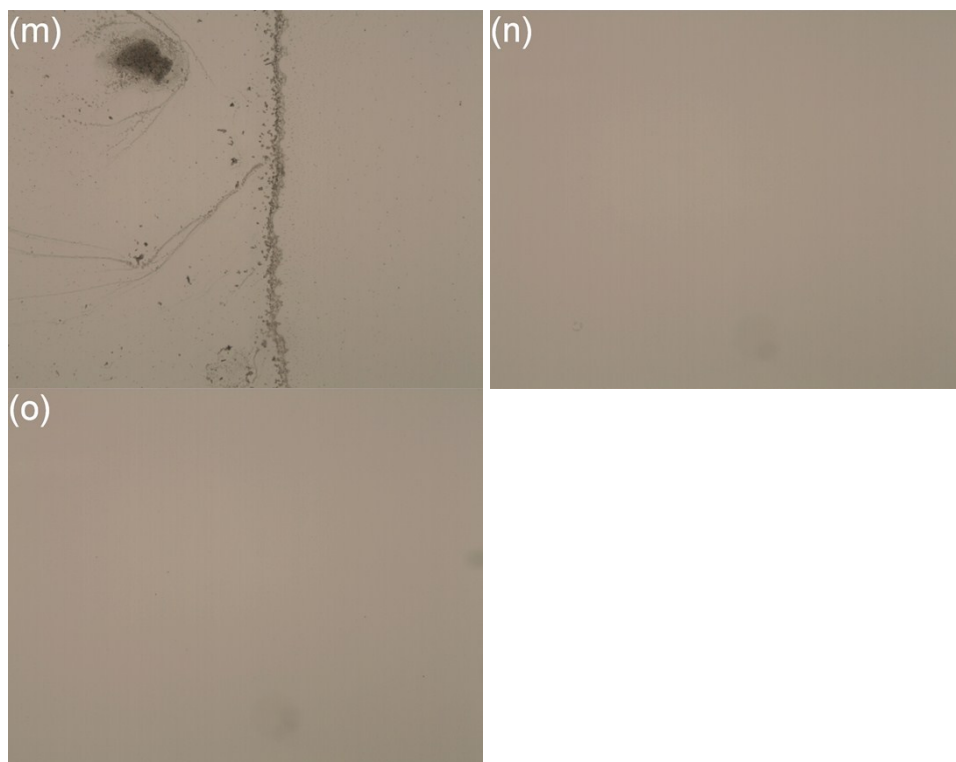


Figure S2. (a,d,g,j,m) PEDOT:PSS, PEDOT:PSS:WO_x, PEDOT:PSS:MoO_x, PEDOT:PSS:CNT, and PEDOT:PSS:GO layers treated with chlorobenzene, (b,e,h,k,n) PEDOT:PSS, PEDOT:PSS:WO_x, PEDOT:PSS:MoO_x, PEDOT:PSS:CNT, and PEDOT:PSS:GO layers treated with dichlorobenzene, and (c,f,i,l,o) PEDOT:PSS, PEDOT:PSS:WO_x, PEDOT:PSS:MoO_x, PEDOT:PSS:CNT, and PEDOT:PSS:GO layers treated with trichlorobenzene.