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Versatile dual organic interface layer for performance enhancement of polymer solar cells

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HIGHLIGHTS

- Dual molecular buffer layer is proposed in polymer solar cells.
- The energy barrier for electron transport is reduced.
- The balanced charge transfer of electron and hole is achieved.
- Well contact of active layer and electrode is realized.
- Electron extraction improvement by a good energy levels alignment.

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ABSTRACT

The electron transport layer plays a crucial role on determining electron injection and extraction, resulting from the effect of balancing charge transport and reducing the interfacial energy barrier. Decreasing the inherent incompatibility and enhancing electrical contact via employing appropriate buffer layer at the surface of hydrophobic organic active layer and hydrophilic inorganic electrode are also essential for charge collection. Herein, we demonstrate that an efficient dual polyelectrolytes interfacial layer composed of polyethylenimine (PEI) and conducting poly(9,9–dihexylfluorenyl-2,7-diyl) (PDHFD) is incorporated to investigate the interface energetics and electron transport in polymer solar cells (PSCs). The composited PEI/PDHFD interface layer (PPIL) overcomed the low conductivity of bare PEI polymer, which decreased series resistance and facilitated electron extraction at the ITO/PPIL–active layer interface. The introduction of the interface energy state of the PPIL reduced the work function of ITO so that it can mate the top of the valence band of the photoactive materials and promoted the formation of ohmic contact at ITO electrode interface. As a result, the composited PPIL tuned energy alignment and accelerated the electron transfer, leading to significantly increased photocurrent and power conversion efficiency (PCE) of the devices based on various representative polymer:fullerene systems.

1. Introduction

Inverted structure polymer solar cells (PSCs) with the high-work-function metal such as silver (Ag) or gold (Au) as the top anode and a transparent indium-tin-oxide (ITO) as the cathode, are under intense investigation in both companies and academies due to their better long-term ambient stability [1–11]. PSCs can also make utmost of the vertical phase separation and concentration gradient of the active layer, which is naturally self-encapsulated by air-stable metals used as the top electrode [12,13]. Despite of these clear advantages, introduction of ITO cathode normally hampers the ohmic contact for electron transport between the active layer and ITO cathode because of its high work function (WF) [14]. Thus, the n-type metal oxides or metal carbonates including titanium oxide, zinc oxide, caesium carbonate, conjugated polyelectrolyte,

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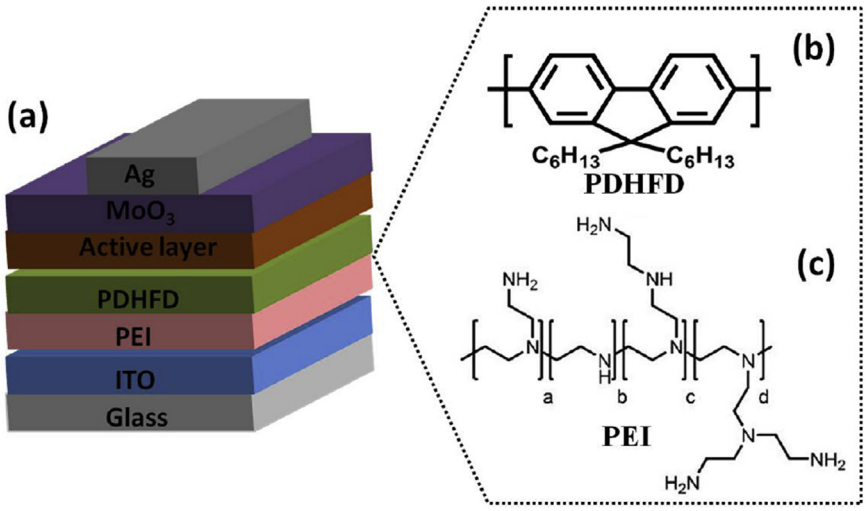

Fig. 1. (a) The device structure of the inverted PSCs, and the chemical structures of (b) PEI and (c) PDHFD.

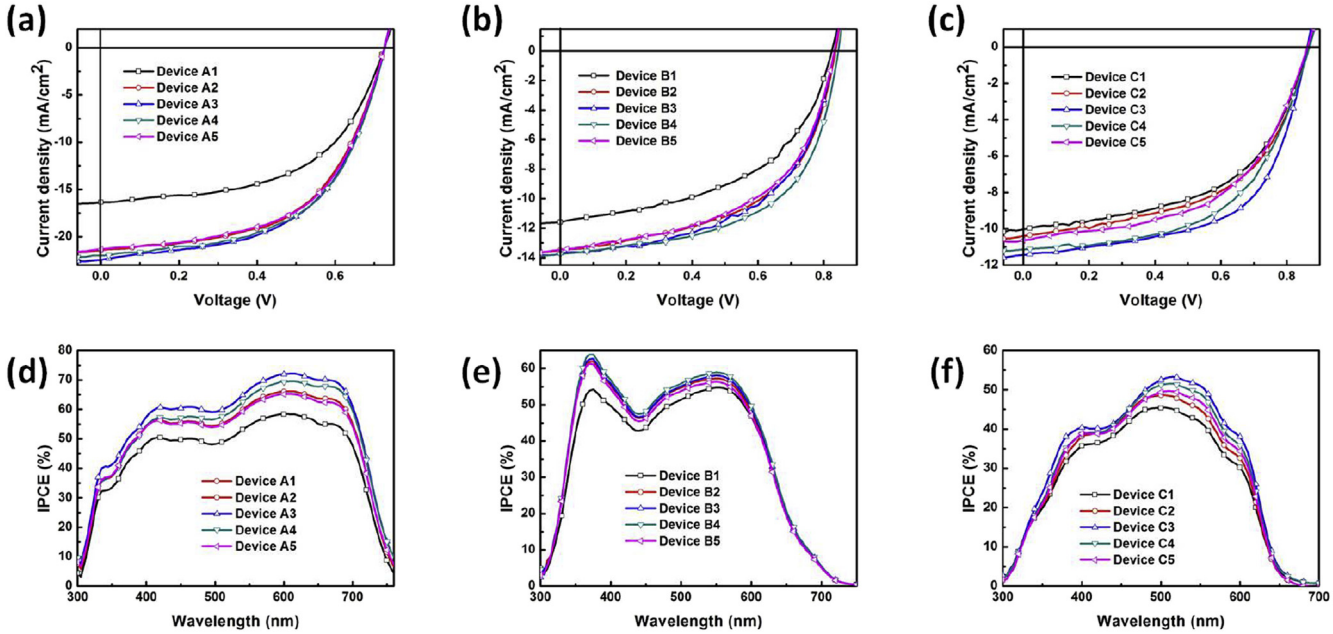

Fig. 2. J–V characteristic of (a) PTB7:$PC_{71}BM$, (b) PCDTBT:$PC_{71}BM$, and (c) P3HT:ICBA based devices with various thickness of PDHFD. IPCEs of (d) PTB7:$PC_{71}BM$, (e) PCDTBT:$PC_{71}BM$, and (f) P3HT:ICBA based devices with various thickness of PDHFD.

Table 1
Device performance data of the inverted solar cells based on different kinds of donor:acceptor system with various interfacial layers on ITO cathodes.

Materials	Device	Thickness of PDHFD (nm)	V_{oc} (V)	J_{sc} (mA/cm^2)	FF (%)	PCE (%)
PTB7:$PC_{71}BM$	A1	0	0.73	16.36	54.81	6.51
	A2	7	0.73	21.42	55.7	8.70
	A3	12	0.73	22.25	56.69	9.17
	A4	17	0.73	21.99	56.09	8.97
	A5	20	0.73	21.32	56.37	8.72
PCDTBT:$PC_{71}BM$	B1	0	0.82	11.59	50.29	4.81
	B2	7	0.83	13.50	54.02	6.09
	B3	12	0.83	13.69	55.06	6.27
	B4	17	0.84	13.76	57.04	6.62
	B5	20	0.83	13.46	53.00	5.94
P3HT:ICBA	C1	0	0.86	10.03	53.25	4.60
	C2	7	0.86	10.40	53.19	4.79
	C3	12	0.86	11.45	59.21	5.85
	C4	17	0.87	11.14	55.47	5.37
	C5	20	0.86	10.63	52.98	4.86