Adequate donor-acceptor concentration gradient for inverted organic solar cells prepared by transfer-printing in air

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In recent years, polymer solar cells (PSCs) have been extensively studied due to their low fabrication cost resulting from solution processed active layer deposition. However, obtaining the adequate vertical donor-acceptor concentration gradient to improve the FF of inverted PSCs (iPSCs) becomes problematic due to the high solubility of PCBM (electron acceptors) in common organic solvents. Devices with an "inverted" concentration gradient demonstrate a large increase in FF.[1] However, the process used (sacrificial layer) is not reproducible. Here, we present our study based on transfer-printing for the sequential deposition of PCBM (electron only)/active layer/ PEDOT:PSS (hole only) trilayers (Fig. 1).

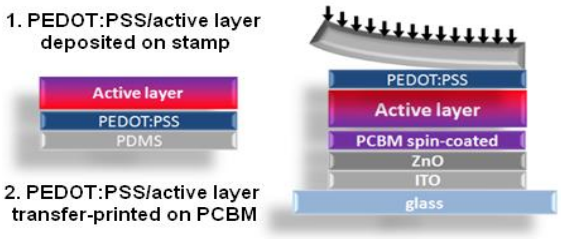

Fig. 1: Schematic representation of the transfer -printing process developed in this study

To successfully use transfer-printing for the fabrication of iPSCs, it is essential to study the interface and surface energies as they play key roles in the two steps of the process:

1. Deposition of high quality films on the stamp;
2. Complete transfer from the stamp to the substrate.

Both calculations and experiments demonstrate that depositing a PEDOT:PSS interlayer on the stamp prior to active layer deposition leads to the formation of high quality films. Furthermore, the insertion of PCBM between the ITO/ZnO substrate and the transferred active layer remarkably increases the transfer probability. Fig. 2 summarizes the device performances of spin-coated and transfer-printed (with and without PCBM layer) iPSCs whose active layers are prepared in air.

	Jsc (mA/cm^2)	Voc (V)	FF (%)	PCE (%)
spin-coated	8.36	0.60	32.2	1.64
printed no PCBM	7.94	0.55	36.9	1.62
printed with PCBM	8.79	0.59	45.2	2.34

Fig. 2: Device parameters of the iPSCs

Our transferred devices with PCBM show a large increase in both FF and PCE compared to the reference spin-coated devices. GI-XRD reveals that during the process (at 150˚C) the underlying PCBM layer induces the diffusion of PCBM in the active layers towards the bottom of the films, thus generating the adequate concentration gradient for iPSCs.

[1] S. Cho et al., Sci. Rep. 2014, *4*, 4306.