Optimization of charge carrier transport balance for high efficient polymer solar cells

Polymer solar cells (PSCs) with poly (diketopyrrolopyrrole - terthiophene) (PDPP3T): [6,6] - phenyl - C71 - butyric acid methyl ester ($PC_{71}BM$) as active layers were fabricated from different temperature solutions. The champion power conversion efficiency (PCE) of PSCs prepared from hot solution is 6.22%, which is better than that of 5.54% for PSCs prepared from cool (room temperature) solution and 5.85% for PSCs prepared from cool solution with 1,8-diiodooctane (DIO) solvent additive. The underlying reasons on PCE improvement of PSCs prepared from hot solution can be attributed to the more dispersive donor and acceptor distribution in the active layer, resulting in the better bi-continuous interpenetrating network for exciton dissociation and charge carrier transport. The more balance of electron and charge carrier transport can be obtained in the PSCs prepared from hot solution, which is demonstrated from the *J-V* curves of the related hole-only and electron-only devices.

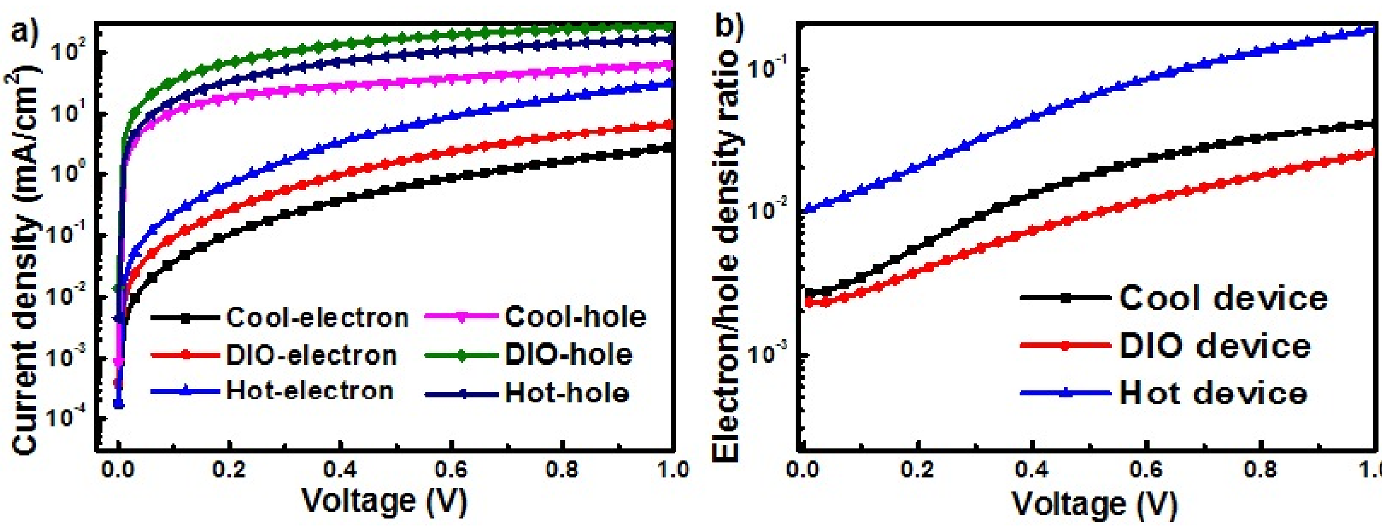

Fig. 1. a) The J-V characteristic curves of hole- and electron-only devices, b) the calculated current density ratios of electron to hole of devices.

To clarify the charge carrier transport character and their balance on the performance improvement of PSCs, the hole-only ITO/PEDOT:PSS/active layers/MoO_3 (10 nm)/Ag (50 nm) and electron-only ITO/Al (10 nm)/LiF (1 nm)/active layers/LiF (1 nm)/Al (100 nm) devices were fabricated according to the related PSCs. The *J-V* curves of hole-only and electron-only devices were measured in the dark conditions and are shown in Fig. 1a. It is apparent that hole transport ability is larger than electron transport ability in the three kinds of active layers prepared from different solutions. It means that the performance of PSCs was restricted by the relative weak electron transport ability. It is worth noting that the hole current density of hole-only devices prepared from hot solution was only moderately increased compared with the device prepared from cool solution under the same applied voltage. According to the *J-V* curves of electron-only devices, the electron-only devices prepared from hot solution show the largest current density under the same applied voltage, which means that the electron transport channels can be well formed in the active layers prepared from hot solution. For the PSCs prepared from hot solution or cool solution with DIO additive, the increased hole and electron transport ability is important reason for the performance improvement of PSCs. The current density ratios of electron to hole were calculated and are shown in the Fig. 2b. It is apparent the hole and electron transport balance in active layer prepared from hot solution is improved significantly compared with the other active layers. The simultaneously improved charge carrier transport and their balance lead to the largest PCE of 6.22% in the PSCs prepared from hot solution. The balance between hole and electron transport in the active layer can be efficiently optimized by using hot solution. This strategy may provide a simple and effective method to adjust phase separation of donor and acceptor materials for improving the performance of PSCs.

Publication

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