

Influence of absorption property by doping/inserting C545T in Polymer Solar Cell

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1. Introduction

Polymer solar cells are of tremendous interests as a potential source of renewable energy because of their low-cost fabrication in large area and light-weight on flexible substrates. [1]-[4]. The bulk-heterojunction (BHJ) design, consisting of an interpenetrating network of an electron donor (conjugated polymer) as poly(3-hexylthiophene) (P3HT) and an electron acceptor (fullerene) as fullerene derivative [6,6]-phenyl-C₆₁ butyric acid methyl ester (PCBM), can provide an efficient dissociation of excitons within the entire photoactive layer. P3HT has been studied extensively owing to its promising physical properties over other polymers, including the high carrier mobility (around $10^{-3} \text{ cm}^2 \text{ V}^{-1} \text{ s}^{-1}$), an extended absorption spectra in the red-light region, and a good environmental stability [5]-[8]. The thermal annealing of P3HT film, which to obtain a close-packed crystalline structure and a strong inter-chain interaction, has been studied extensively to improve the power conversion efficiency (PCE) of P3HT-based polymer solar cells [9]-[10]. In this work, we proposed an approach to improve the PCE of P3HT-based polymer solar cell by adding a fluorescent material 2,3,6,7-tetrahydro-1,1,7,7-tetramethyl-1H,5H,11H-10(2-benzothiazolyl)quinolizine- [9,9a,1gh] coumarin (C545T) which is commonly used as green-emission dopant in organic light-emitting diode (OLED) [11]-[12].

2. Results and Discussion

The main purpose to use C545T in this work is to enhance the light-absorption at 400-450 nm region which is weak-absorbed in P3HT, as shown in Fig. 1. Furthermore, Fig. 1 shows an apparent overlapping at 500-650 nm in PL spectrum of C545T and absorption spectrum of P3HT. The overlapping in spectrum indicates an effective energy transfer between C545T and P3HT and hence enhances the light-absorption of P3HT. Figure 2 shows the light-absorption spectrum of pure P3HT:PCBM blend film (Sample A) and that with the doping of C545T (Samples B and C). By doping 0.5mg C545T into the P3HT:PCBM blend film (Sample B), the intensity of light-absorption spectrum at 450-600 nm region is increased by a large margin which implies the light-absorption of P3HT is enhanced

under the adding of C545T. However, the spectrum shows a small increased margin in intensity under the 1.5mg doping of C545T (Sample C). It is speculated that the high doping concentration of C545T results in a negative effect in the degree of crystalline property of P3HT, which results in a weak chain-interaction, and hence limit the light-absorption in P3HT:PCBM blend film. Furthermore, compared the inserted 0.5nm C545T layer of P3HT:PCBM film (Sample D) with Sample A the absorption spectrum was red-shift. It was due to the C545T layer photoluminescence overlap with P3HT absorption, which extend the P3HT:PCBM absorbed range.

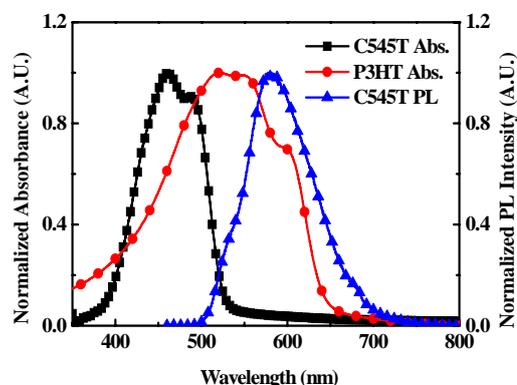


Fig. 1 The absorption spectrum of P3HT and C545T, and PL spectrum of C545T.

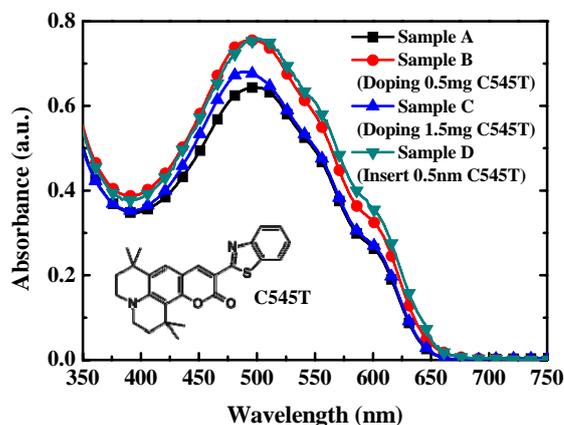


Fig. 2 The absorption spectrum of Samples A, B, C, and D.

Figure 3(a) shows the photocurrent density - voltage (J - V) characteristics of polymer solar cell with pure P3HT:PCBM (Device A) and C545T-doped P3HT:PCBM active layers (Devices B/C). For the device A, the open-circuit voltage (V_{oc}), short-circuit current (J_{sc}), fill factor (FF) and PCE are 0.61 V, 6.50 mA/cm², 0.47, and 1.86%, respectively. Owing to the enhanced light-absorption in P3HT, the J_{sc} of polymer solar cell is increased to 7.4 mA/cm² under the device B. Nevertheless, the V_{oc} and FF of polymer solar cell are decreased to 0.59 V and 0.38, respectively. The possible reason for degraded performance could be the large-sized particle of C545T results in the poor film quality in active layer and hence increases the sheet-resistance of polymer solar cell. When the doping concentration of C545T increases to 1.5mg, the J_{sc} and FF of polymer solar cell are apparently dropped to 3.9 mA/cm² and 0.19, respectively. In our experiment, the increased doping concentration of C545T would result in the increased surface roughness of active layer (not shown here), which indicates the poor contact property between active layer and cathode, and hence the J_{sc} and FF of polymer solar cell are reduced apparently.

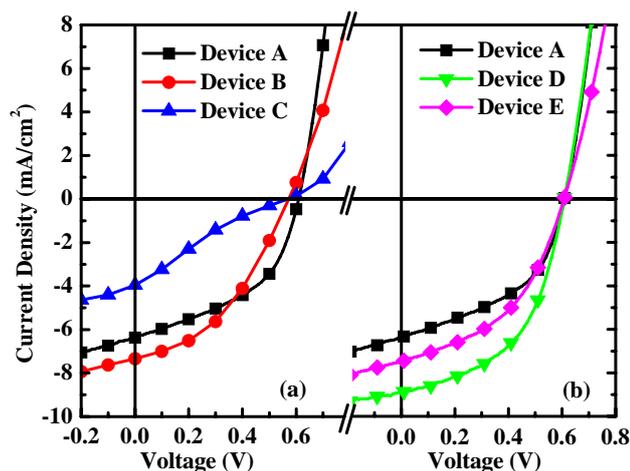


Fig. 3 The photocurrent density-voltage characteristics of polymer solar cells (a) Devices A, B, and C (b) Devices A, D, and E.

To reduce the influence of large-sized particle of C545T on active layer, a thin C545T layer is inserted into active layer and cathode instead of doping into the active layer. Figure 3(b) shows the J - V characteristics of polymer solar cell with/without adding a thin C545T layer. By inserting a 0.5 nm-thick C545T layer (Device D), the J_{sc} of polymer solar cell is increased from 6.5 to 8.8 mA/cm², indicates the enhanced light-absorption in active layer, as observed in the case of doping. The improved J_{sc} and FF result in an increased PCE of 2.68%. Nevertheless, the J_{sc} and FF of polymer solar cell are decreases to 7.4 mA/cm² and 0.45, respectively, when the thickness of C545T layer increases to 1.0 nm (Device E). Compared to the device D, the J - V curve of device E shows an increased slope at x-axis which indicates an increased sheet resistance of polymer solar cell. Due to the low carrier mobility in C545T limits the carrier injection from active layer into cathode and hence reduces the J_{sc} and FF of polymer solar cell.

3. Conclusion

In summary, this work has investigated the polymer solar cell by adding fluorescent material C545T. To enhance the light-absorption in P3HT and an effective energy transfer between P3HT and C545T. The photocurrent density of polymer solar cell is enhanced by inserting a 0.5 nm-thick C545T layer between active layer and cathode. The J_{sc} is 8.8 mA/cm², FF is 0.5, and PCE is 2.68%.

Acknowledgements

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