Improved performance in flexible organic solar cells by using copolymeric phase-separation modulators

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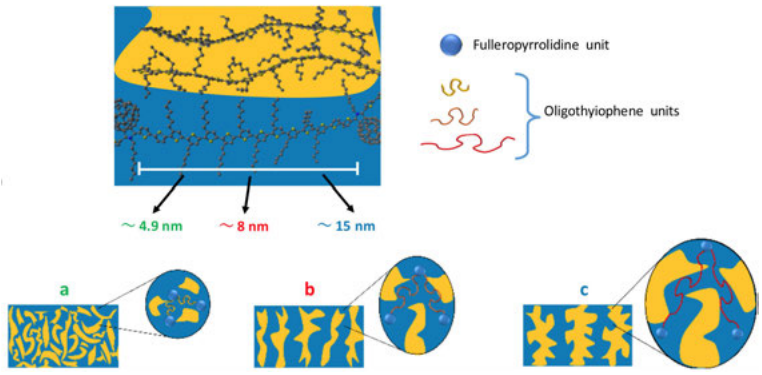
One of the main problems related to the low performance of the organic solar cells (OSCs), concerns the low mobility of the materials constituting the heterojunction. Indeed, the poor charge transport in the active layer is the principal cause of a competition between separation and recombination of the photogenerated carriers. In this regard, a major obstacle to enhance OSCs efficiency is developing strategies to optimize the exciton dissociation and, consequently, the charge collection at the electrodes. Donor and acceptor systems must be well mixed on the length scale of 5 – 20 nm (exciton diffusion length) to meet the criteria for efficient exciton dissociation. In addition, the network structure should involve continuous donor-acceptor pathways for efficient carrier transport. The most common practice to achieve this goal is by thermal or solvent annealing of active layer.[1] However, this approach often leads to an unwanted phase segregation with formation of large domains where only a small fraction of excitons could diffuse to the donor-acceptor interface.[2] In this work, we show how this challenge is achievable by incorporating phase-separation modulators into bulk heterojunction (BHJ). In particular, three copolymers based on polythiophene and C_{60} units have been designed, easily synthesized, characterized, and employed as additive in P3HT:PCBM devices. The effect of the thienyl spacer length between C_{60} monomers on optoelectronic properties, morphology, and structure of heterojunction has been examined using several techniques (NMR, FTIR, XPS, XRD and AFM). We observed that small quantities of these systems can play a critical role in tuning the device morphology by improving the phase separation in thin film heterojunction.[3] In particular, these copolymers act as phase separation modulators by controlling the growth of donor/acceptor domains in the heterojunction, during the thermal annealing process. Indeed, by employing copolymers containing oligothiophenic chains with size of about 8 nm, a large number of domains with a size comparable to the length scale of exciton diffusion are generated, resulting in the highest power conversion efficiency (PCE) (4.46 %) and short current density (J_{SC}) (16.15 mA cm^{-2}) values reported so far for P3HT:PCBM solar cells on plastic substrates. Moreover, the results obtained in preliminary investigations on the other devices containing different fullerene acceptors seem to show the effectiveness and the generality of our approach. Finally, bending tests showed that OSCs with copolymers maintain higher level of performance than reference devices, thus giving new perspectives to applications of flexible photovoltaics.



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