Role of Quarterthiophene and Ruthenium based dyes in enhancing the performance of Hybrid Titanium dioxide / Polymer solar cells

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ABSTRACT

Conjugated polymers and metal oxides are potential combinations of materials for cost-efficient hybrid solar cells. However, the power conversion efficiency of these hybrid solar cells is restricted due to several factors such as poor chemical compatibility of inorganic metal oxides with polymer, carrier recombination at the interface, limited spectral response and charge transport of polymer. Various strategies have been reported to enhance the efficiency of hybrid metal oxide/ polymer solar cells. This work focuses on the role of quarterthiophene and ruthenium based dyes in enhancing the performance of hybrid Titanium dioxide (TiO_2)/ Poly(3-hexylthiophene) (P3HT) solar cells as interface modifiers. Two newly synthesized dyes, namely quarterthiophene (4T) and ruthenium (RuC) based dyes, were employed separately as interface modifiers at the TiO_2/P3HT interface. The insertion of RuC dye at the hybrid TiO_2/P3HT interface plays multiple roles, through the extension of the spectral response in the near UV region and reduction of interfacial carrier recombination as evidenced by the extended external quantum efficiency (EQE) spectra and photoluminescence (PL) quenching, respectively. The insertion of 4T dye at the hybrid TiO_2/P3HT interface increased carrier generation as evidenced by high short circuit current density (J_{SC}) found in hybrid TiO_2/P3HT device due to extended spectral response of the TiO_2/4T/P3HT nanocomposite. The low dark current upon dye insertion ensured the suppression of interfacial carrier recombination which in turn increased the open circuit voltage. The efficiency of the TiO_2/4T/P3HT hybrid solar cells was further enhanced by replacing pristine P3HT polymer with Lithium (Li) doped P3HT. The optimized devices with 4T dye and Lithium doped P3HT showed efficiency (3.95 %) of nearly a factor of four times higher than the pristine P3HT based control TiO_2/4T/P3HT devices (1.04 %). The enhancement in efficiency may be attributed to highly efficient charge collection due to improved charge transport and greater light harvesting properties of Li doped P3HT polymer. The resulting high J_{SC} over 13 mA/cm^2 was also confirmed by both the broadened EQE spectrum and significant PL quenching upon replacement of pristine P3HT with Li doped P3HT on 4T dye-treated TiO_2 electrode. Similar devices with Lithium doped Spiro-OMeTAD instead of Lithium doped P3HT showed efficiencies over 3.30 %.

Keywords: Hybrid polymer solar cells, Titanium dioxide, Lithium doped Poly(3-hexylthiophene), Interface modification, Ruthenium and Thiophene dyes, Hole transport, External quantum efficiency, Photoluminescence.