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Electrical and photovoltaic response of bulk hetero-junction device made from poly (3-phenyl azo methine thiophene) (PPAT) and 1, 1′-diallyl substituted 4, 4′-dipyridine (DADP)

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Abstract

Electrical and photovoltaic properties of donor–acceptor composite system comprised of poly (3-phenyl azo methine thiophene) (PPAT) and 1, 1′–diallyl substituted 4, 4′-dipyridine (DADP) were investigated. A significant enhancement of photocurrent was observed when PPAT was blended with DADP. The increase in photocurrent has been explained in terms of efficient charge separation that resulted from the transfer of photo-excited electrons from PPAT to DADP. The strong quenching of fluorescence of PPAT was caused by the presence of DADP that indicates the photo-induced charge transfer from PPAT to DADP. The open circuit voltage (V_{oc}) generated in the device is independent of the variation of work function of negative metal electrode that has been explained in terms of Fermi level pinning between DADP and metal via surface charges. The electrical characteristics of ITO/PPAT: DADP/Al photovoltaic device were determined by analyzing the dependence of short circuit photocurrent density (J_{sc}) and V_{oc} under illumination at different temperatures. The V_{oc} decreases almost linearly with increasing temperature, while short-circuit photocurrent increases logarithmically with temperature and saturates at higher temperature above 330 K. This dependence of J_{sc} and V_{oc} on temperature has been discussed in terms of possible mechanism that involves the

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photovoltage generation and charge carrier transport in the device under thermally activated state. The photovoltaic device made from PPAT: DADP blend has shown three times higher photosensitivity than that of made from pure PPAT.

Keywords: Bulk heterojunction; Photovoltaic effect; Photoinduced charge transfer; Fluorescence quenching; Space charge limited conduction

1. Introduction

Conjugated polymers are being well identified as potential candidates for electronics and photonics applications such as solar cells, photo detectors, light-emitting diodes and electrochemical sensors. Tailoring of physical, chemical and optical properties is possible by making change at molecular level. In the last couple of years, increased efforts of many research groups were devoted to the development of polymer solar cells (PSCs) based on conjugated polymers made on flexible substrates [1–4]. Several structures and combination of new materials have also been reported using small molecules [5,6] conjugated polymers [7–9], conjugated polymers blends [10–13], polymer–small molecule bi-layer [14–17] and blends [18–23] or combinations of organic–inorganic materials [24–28].

Bi-layer devices consisting of p- and n-type (donor and acceptor, respectively) organic materials were investigated for many combinations [14–17]; however, the conversion efficiency of these devices is limited by the charge generation at donor–acceptor interface (which is only in the range of 5–10 nm), leading to low quantum efficiencies. In order to accelerate the electrical current by absorption of photons in PSCs, the electron–hole pair, generated by photo-excitation, must be separated before recombination process can take place. This can be achieved by blending the absorber (electron donor) with an electron acceptor (bulk hetero-junction), whose electron affinity is higher than that of the donor, but lower than its ionization potential. Additionally, the highest occupied molecular orbital (HOMO) of the acceptor should be lower in the energy than that of the HOMO of donor. The driving force for the photo-induced charges to diffuse towards the opposite electrodes in bulk hetero-junction photovoltaic devices is still not fully clear. Several models have been proposed describing the charge transport either due to electric field-induced drift of charge carriers or their concentration gradient induced diffusion [18,24,29].

The present study deals with the electrical and photovoltaic properties of a new donor–acceptor blend (PPAT: DADP), sandwiched between indium tin oxide (ITO) and metal electrode. Significant enhancement of photocurrent is observed with the thin films of PPAT: DADP composite sandwiched between Al and ITO electrodes in comparison to the pure poly (3-phenyl azo methine thiophene) (PPAT) thin film with same device structure.

1, 1′-diallyl substituted 4, 4′-dipyridine (DADP) is a well-known material that act as an electron acceptor in photosynthesis and photochemistry [30]. It shows very long lifetime in photo-induced charge-separated state and forms charge transfer (CT) complexes with a wide variety of organic donors [31]. In spite of its good properties as an electron acceptor, few works have been reported on the composite system of such materials with conjugated polymers. We have investigated that the PPAT and DADP forms an intermolecular donor acceptor CT charge complex (bulk hetero-junction), and the electrical and photovoltaic