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Photovoltaic Characteristics of Junction Using Conducting Polymer-dye Composite

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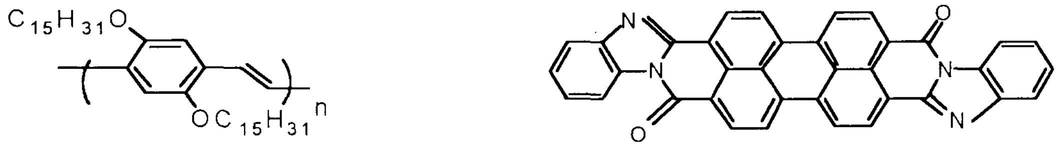
Organic thin film photovoltaic devices based on conducting polymers and dye molecules have been shown to be highly efficient[1-3]. Not only from pure scientific viewpoints but also for their application in solar cells these achievements have attracted a great deal of attention. Organic material are attractive because most of them can be processed from solution via spin coating at room temperature, enabling the manufacture of large area, flexible and light weight devices. The high conversion efficiencies are the result of efficient absorption of light and charge generation inside the device. While photovoltaic devices of a single active conducting polymer layer in general exhibit low efficiency of energy conversion[4], blends and heterojunction having high electron affinity and low ionization potential considerably enhance the efficiency[5,6]. At present, most of research works[7-9] all concentrate on materials design and device structure optimization. The search for new materials with good performance characteristics as well as the improvement in device fabrication has been a subject of importance.

The utility of ROPPV(poly(2,5-dialkoxy-p-phenylene vinylene) as a processible polymer[10] with the electronic and optical properties of a semiconductor has already been demonstrated in heterojunction photovoltaic cells devices which exhibit relatively high efficiency[11]. ROPPV is a member of the family of quasi-one-dimensional conducting polymers which have relatively broad π and π^* bands and can be doped with resulting properties that span the full range from insulator to metal[12]. However, ROPPV is a weak donor which acts as hole transport materials in heterojunction photovoltaic cells devices. In order to be useful for photovoltaic applications, one way of creating a large interfacial area on a scale similar to the exciton diffusion range[13] is to mix an electron donor with an electron acceptor material. N, N'- diphenyl glyoxaline -3, 4, 9, 10 - perylene tetracarboxylic acid diacidamide (PV) is expected to be a promising candidate for electron acceptor material useful in photovoltaic devices[1], because PV exhibits comparably high electron affinity of the large band-gap material, large visible extinction coefficients, photostability and low cost of fabrication[14,15]. The chemical structures of ROPPV and PV are shown in Fig.1.

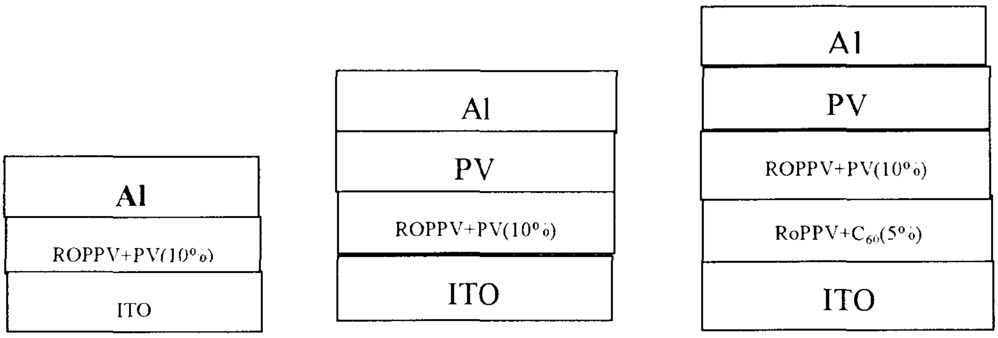


(A) (B)

Fig.1 Molecular structure of poly(2,5-dialkoxy-p-phenylene vinylene) (A) and perylene tetracarboxylic derivative (B)

In the work presented in this paper we prepare the composite film of ROPPV/PV with different ratios. The photovoltaic cells with different architectures using these composites are fabricated and their (I/V) characteristics and photocurrent spectra are discussed.

Junctions made of ROPPV/PV composite and PV have been studied. The device structures of fabricated photovoltaic cells with three different architectures are shown in Fig.2. All of these devices are annealed at 150°C for 1h. Figure 3 shows the spectral dependence of photocurrent of three different architectures devices. Spectra 1, 2 and 3 correspond to the single-layer device, the double-layer device and the three-layer device respectively. From the comparison of the photocurrent spectra of three different architecture devices, following specific features were revealed.



(1) single-layer (2) double-layer (3) three-layer

Fig.2 The three types of junction architectures.

Firstly, the photocurrent spectra of all cells exhibit that the cells are able to utilize light of the entire visible spectrum range. which suggests that most of the bulk of the cell contributes to the generation of the external current. Secondly, the photocurrent of the three-layer architectures devices exhibits the highest peak at around 589nm which is nearly three times as high as that of the double-layer device and nearly 15 times as high as that of the single-layer device. Thirdly, the shape of photocurrent spectra changes from a broad and weak response to a sharp and strong response with the increase of layer numbers, which indicates that the change of device structure and the addition of C_{60} are effective to improve the photovoltaic effect of devices.

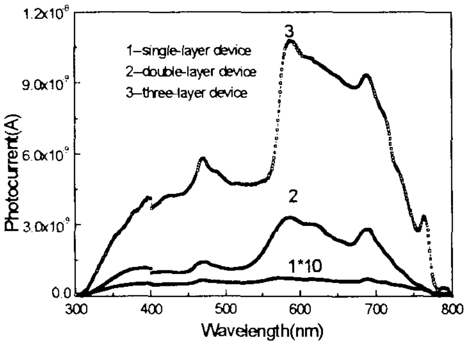


Fig.3 The spectral dependence of photocurrent of three different architectures devices. Spectra 1, 2 and 3 corresponds to single-layer devices, double-layer device and three-layer device respectively.

The corresponding current-voltage characteristics in the dark and under illumination are shown in Fig.4. Figure 4 (1), (2) and (3) correspond to the I-V characteristics of the single-layer device, the double-layer device and the three-layer device respectively. All devices are irradiated with light of 589nm in wavelength and 29μw/cm^2 in intensity from the ITO electrode.

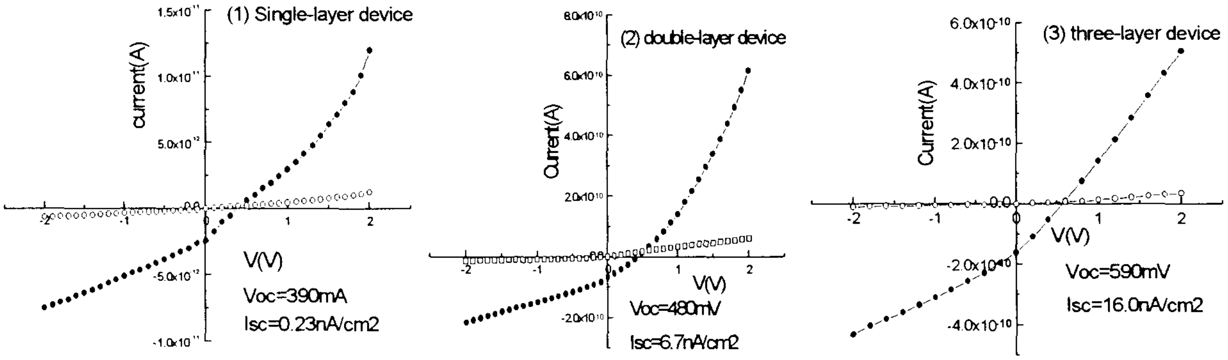


Fig.8 The current-voltage characteristics in the dark(o) and under illumination(•) . (1), (2) and (3) corresponds to the I-V characteristics of single-layer devices, double-layer device and three-layer device respectively.

The results show that all devices exhibit rectifying effect. The open-circuit voltage(Voc) and the short-circuit current(Isc) of devices lie at about 593mv and 16.0nA/cm^2(three-layer), 390mv and 6.73nA/cm^2 (double-layer) as well as 270mv and 0.23nA/cm^2 (single-layer). There is nearly no dependence of the current on the applied electric field in the dark for all devices. However, the forward current strongly depends on the applied electric field under illumination. The experimental results show that the three-layer cell exhibit larger open-circuit voltage and short-current than the two-layer cell and the single-layer cell under irradiation with monochromatic light at 589nm. The higher open-circuit voltage and short-circuit current are possibly attributed to efficient charge separation by successive electron transfer from ROPPV to C_{60} in the C_{60}-doped ROPPV layer and from ROPPV in the composite of ROPPV-PV layer to PV layer.

In conclusion, we have prepared the soluble polymer/dye composite(ROPPV/PV) as a new class of organic semiconducting material that can be used to fabricated a junction photovoltaic cell. The characteristics of the composite films such as spectral range and intensity of the photo-response increase greatly after annealing. X-ray diffraction shows that the annealing is helpful to improving the crystallinity as well as the appearance of the new phase. Heterojunctions made of the composite with three different architectures have also been found to be photosensitive. The enhanced photoconductivity and strongly quenched photoluminescence are explained tentatively by efficient photoinduced charge separation at the interface not only between ROPPV and PV in the composite but also between layers.

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