

INFLUENCE OF CdS CONTENT ON PERFORMANCE OF MEH-PPV/CdS HYBRID SOLAR CELLS

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Introduction

Electronic devices based on organic materials have attracted much interest and competed with inorganic based devices with potential applications such as organic light emitting diodes, organic field effect transistors, solar cells, etc. Among these applications, dye-sensitized solar cells (DSSCs) based on nanoporous titanium dioxide (TiO₂) particles and organic dyes have demonstrated energy conversion efficiencies of around 10%, comparable to amorphous silicon based solar cells [1]. Although TiO₂ nanocrystalline DSSCs show excellent power conversion performance, they require the use of a liquid electrolyte which results in difficulties in outdoor applications due to problems related to sealing, evaporation of the electrolyte, and the degradation of the electrolyte or the dye. For the DSSCs to overcome disadvantages of having the liquid electrolyte system, several solid state DSSCs have been investigated using solid polymer electrolytes [2] or conducting polymers [3].

The current investigation demonstrates our attempt to optimize benefits of layered and bulk heterojunction hybrid inorganic-organic solar cell (HSC) structures consisting of TiO₂ thin film prepared by sol-gel dip-coating technique and Poly(2-methoxy-5-(2'-ethylhexyloxy)-*p*-phenylene vinylene) (MEH-PPV) conjugated polymers as well as bulk heterojunction solar cells consisting inorganic cadmium sulfide (CdS) semiconducting nanorods blended with MEH-PPV conjugated polymers.

Experimental

Materials

MEH-PPV was synthesized in-house following Gilch's method [4]. Its molecular weight (M_w) as determined by GPC was 31,139. To obtain a stable TiO₂ sol, a precursor solution was prepared following Legrand-Buscema et al. [5]. Firstly, 1.6 M titanium (IV) isopropoxide (Fluka) was dissolved in isopropanol (Fluka) and stirred at room temperature for 30 minutes. Then, acetylacetone (Merck) was added to make 10:1 molar ratio of titanium (IV) isopropoxide to acetylacetone. The mixture was used as chelating agent to stabilize the solution. The mixture was then stirred

for 10 minutes more. Acetic acid (Lab-scan) was added afterward to help initializing hydrolysis by creating esterification reaction with isopropanol. Finally, 0.3 g of poly (ethylene glycol) (PEG) having M_w of 3000 g.mol⁻¹ was added to 180 ml of titanium dioxide-containing sol. The sol was then dip coated on to commercial indium tin oxide (ITO) coated glass substrates. The films were dried at 60 °C overnight before calcination at 450 °C for 4 hours in air.

CdS nanorods were prepared via precipitation from homogenous solution technique, similar to reported elsewhere [6]. 0.28 g CdCl₂ · 2.5H₂O and 0.4 g 1-pyrrolidine dithio carboxylic acid ammonium salt were added into 25 ml ethylenediamine. The mixture solution was placed in the typical microwave (850 W) with a close reflux system and the reaction was performed under ambient air for 5 min. After cooled to room temperature, the yellow precipitates were centrifuged, washed with distilled water and absolute ethanol, and dried in the air. After cooled to room temperature, the yellow precipitates were centrifuged, washed with distilled water and absolute ethanol, and dried in the air.

Apparatus and Procedure

The front transparent conducting oxide (TCO) electrode used was commercial glass substrate coated by ITO thin film. The TiO₂ thin film was prepared following steps described above. Then, blends of 0.0, 1.0, 2.0, 3.0 mg/ml of CdS nanorods and 10 mg/ml of MEH-PPV in 1, 2 dichlorobenzene were prepared and spin cast onto the TiO₂ films using a P-6000 spin coater (Specialty Coating Systems, INC). A spin speed used to cast MEH-PPV layers were 2500 rpm resulting in ~100 nm in layer thickness. The ~ 100 nm-thick back aluminum and gold electrodes were deposited on the polymer films by vacuum deposition at 10⁻⁴ Torr. Film thickness was determined using a surface profiler (Dektak 3 st). The I-V characteristics of the solar cells were obtained using a source meter (Keithley model 6430) under AM 1.5 simulated solar radiation at 1 sun intensity.

Results and Discussion

Fig. 1 shows that the ITO/MEH-PPV/Au device does not have diode property because ITO/MEH-PPV and

MEH-PPV/Au interface were regarded as ohmic contacts. The ITO/MEH-PPV/Al device has diode property because the existence of the Schottky barrier at the MEH-PPV/Al interface.

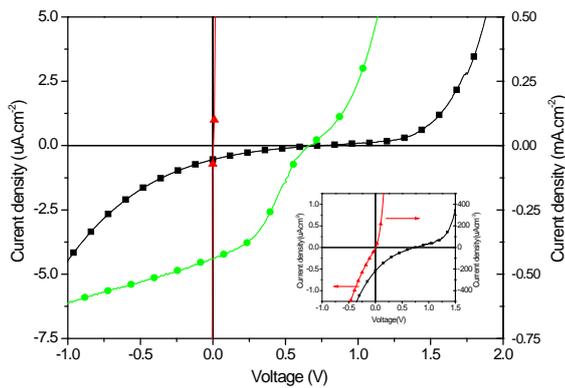


Fig.1: J-V characteristic of ITO/MEH-PPV/Au (- -), ITO/MEH-PPV/Al (- -), and ITO/TiO₂ prepared with 3000 g.mol⁻¹ M_w PEG/MEH-PPV/Au (- -) are showed (ITO/TiO₂ prepared with 3000 g.mol⁻¹ M_w PEG/MEH-PPV/Au use right perpendicular axis only). In the small box, ITO/MEH-PPV/Au and ITO/MEH-PPV/Al current density shows on right and left perpendicular axis respectively.

It is well-known that the MEH-PPV is a good exciton generator but the exciton diffusion length is very short at around 20 nm in the polymer films. The addition of TiO₂ layer helps improving the device efficiency due to its n-type semiconducting nature and high surface areas. Nanoscale pores at the TiO₂/MEH-PPV interfaces create high interfacial contact areas between n-type TiO₂ and p-type MEH-PPV creating p-n junctions and, hence, reducing carrier recombination significantly. Inserting the TiO₂ film between ITO and MEH-PPV films helps charge separation and electron transport in devices. When the charges are separated at the TiO₂/MEH-PPV interfaces in the ITO/TiO₂/MEH-PPV/Au solar cells, holes and electrons are transferred in MEH-PPV films and in TiO₂ films, respectively, because electron affinity of TiO₂ is higher than that of the MEH-PPV [7].

More efficiency can be received by inserting bulk heterojunction MEH-PPV blended with CdS nanorods active layer in the ITO/TiO₂/MEH-PPV/Au solar cells. Table 1 summarizes short circuit currents, open circuit voltages, fill factors and efficiencies of the solar cells fabricated.

For the best cell, current-voltage measurements at AM1.5 show a short-circuit current density of 0.6 mA/cm², an open-circuit voltage of 820 mV, a fill factor of 0.48 and a power conversion efficiency of 0.24. Increasing of efficiency is related to an increase in the CdS solid content. An increase in CdS nanorods results in a lower electron-hole recombination rate.

Table 1: Influence of increasing CdS solid content on ITO/TiO₂ prepared with 3000 g.mol⁻¹ M_w PEG/blended MEH-PPV: CdS/Au solar cells.

CdS solid content (mg/ml)	J _{sc} (mA.cm ⁻²)	V _{oc} (V)	F.F	(%)
0	0.442	0.66	0.37	0.11
0.1	0.625	0.64	0.44	0.18
0.2	0.583	0.83	0.45	0.22
0.3	0.608	0.82	0.48	0.24

Conclusion

We demonstrated that interfacial contact area between n-type TiO₂ thin film prepared using PEG having M_w of 3000 g.mol⁻¹ and p-type MEH-PPV in ITO/TiO₂/MEH-PPV/Au solar cell is the highest among all samples investigated. Because nanoscale pores at the TiO₂/MEH-PPV interfaces create high interfacial contact areas between n-type TiO₂ and p-type MEH-PPV creating p-n junctions and, hence, reducing carrier recombination significantly. Bulk heterojunction active layer consisting of a blend of MEH-PPV and CdS nanorods was found to improve the efficiency. An increase in CdS solid content was also found to further improve the solar cell efficiency.

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