The influence of glycerol doped PEDOT: PSS and Ag buffer layer on power conversion efficiency of semitransparent organic photovoltaic devices

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Abstract

By using optimum doping ratio (10 ~ 20 wt%) of glycerol, the power conversion efficiency (PCE) of organic photovoltaic devices based on poly (3-hexylthiophene) and phenyl-C_{61}-butyric acid methyl ester was dramatically increased from 3.23% to 5.03%. Finally, semitransparent organic photovoltaic devices including glycerol doped poly (3,4-ethylenedioxy-thiophene):poly (styrene sulfonate) and thin Ag (< 1 nm) buffer layer typically have shown PCE > 3% with transmittance > 30% in visible ranges.

1. Introduction

Recently, transferring solar power into electrical power has become considerably important because of the crisis in energy depletion and environmental problems. There are a variety of natural resources available to produce energy. Silicon-based solar cell has been a promising technology for the highest efficiency in the past few decades. However, there are several problems to fabricate silicon based solar cell such as high-cost manufacturing process and material limitation for large area devices. Many researchers have been trying to find alternative options such as polymer materials to achieve low-cost and large area solar cell in the past few decades on polymer photovoltaic. Even though great improvements have been achieved, lower power conversion efficiency (PCE) is still considered as one of the problems to solve for applications. The principle of bulk-heterojunction phase is that separation of excitons is allowed through the nanophase of active polymer layer. Typically, power conversion efficiency (PCE) of photovoltaic devices depends on open circuit voltage (V_{oc}), short circuit current (J_{sc}), and fill factor (FF). In this study, we have used glycerol doped poly (3,4-ethylenedioxy-thiophene):poly(styrene sulfonate) (G-PEDOT:PSS) to increase hole carrying ability. Additionally for the improvement of electron carrying ability in semitransparent devices which include calcium/silver (Ca/Ag) cathode, thin Ag (<1 nm) layer was also used as cathode buffer layer instead of LiF to reduce the work-function mismatch between polymer active layer and cathode electrode.

2. Experimental

The organic photovoltaic devices were fabricated using bulk-hetrojuction structure as shown in figure 1. Indium-tin-oxide (ITO, 150nm thickness, 10 Ω/sq. coated glass substrates were cleaned by ultrasonication in acetone, methanol and SC1 (H_2O_2:NH_4OH:H_2O=1:1:5), and etched for transparent anode electrode. Both 40 nm PEDOT: PSS and 10 wt% doped G-PEDOT:PSS were spun over the patterned ITO electrode followed by exposing 5 min. oxygen plasma (O_2-plasma) treatment.

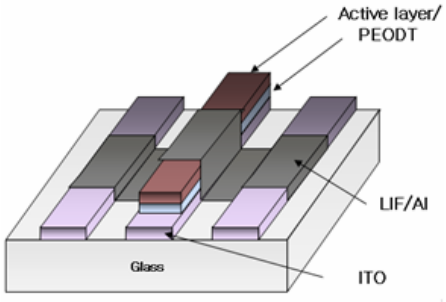

Fig. 1. Schematic diagram of cross-sectional image

The organic active layer was dried in convection oven at 120℃ for 30min. 1:0.7 volume ratios of poly (3-hexylthiophene) (P3HT, Rieke Metals) and phenyl-C_{61}-butyric acid methyl ester (PCBM, American Dye Source) were prepared by using chlorobenzene solvent. Each material was dissolved in chlorobenzene. 80 nm thickness of active layer was spun over the dried PEDOT: PSS and G-PEDOT: PSS layer in N_2 ambient through 0.45μm syringe filter. The bulk-heterojuction organic active layer was annealed at 150℃ for 30min and dried in the glove box during 48 hours. For cathode electrode, LiF (0.6nm) / Al (100nm) was thermally evaporated under vacuum less than 3×10^{-6} torr for the controlled non-transparent devices.

3. Results and discussion

Figure 2 shows conductivity and work-function variations of G-PEDOT: PSS films as a function of glycerol doping ratio.

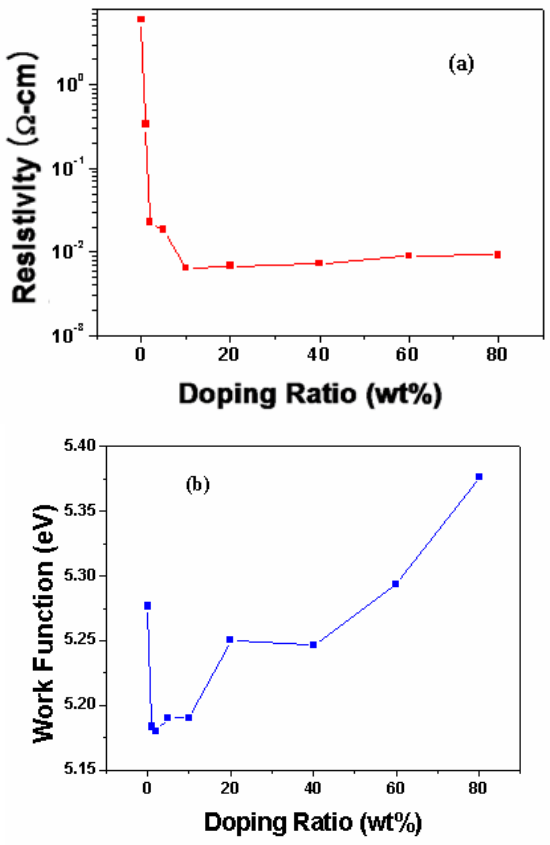

Fig. 2. (a) Conductivity (Resistivity) and (b) work-function of G-PEDOT: PSS layer as a function of glycerol doping ratio

The PCE of the organic photovoltaic devices was significantly increased from 3.235% to 5.032%. The improved power conversion efficiency is possibly due to the considerable enhancement of increased short-circuit current from enhanced hole carrying ability by incorporating a property amount of glycerol into PEDOT layer. This conductive anode can be proved to have an optimized conductivity which makes it possible to achieve better balance of electron, hole currents, and device efficiency.

In the same fabrication processes, we made semitransparent organic photovoltaic device using Ag/Ca/Ag instead of LiF (0.6nm) / Al (100nm). Figure3 shows semitransparent organic photovoltaic devices.

Table 1. Photovoltaic characteristics of the devices using cathode as LiF/Al as a function if glycerol doping ratio

Doping Ratio	Cathode	Voc (V)	J_{sc}(mA/cm^2)	FF (%)	PCE (%)
0 wt%	LiF / Al	0.566	12.694	0.451	3.235
10 wt%	LiF / Al	0.571	22.534	0.391	5.032
20 wt%	LiF / Al	0.569	23.027	0.383	5.011
40 wt%	LiF / Al	0.556	20.634	0.396	4.549
60 wt%	LiF / Al	0.570	20.125	0.382	4.386
80 wt%	LiF / Al	0.573	20.509	0.322	4.081

Table 1 shows PCE for photovoltaic devices with cathode using LiF/Al according to the glycerol doping ratio. The highest power conversion efficiency of 5.032% was obtained with glycerol doping ratio of around 10 ~ 20 wt%.

Fig. 3 Optical micrograph of fabricated OPV device with encapsulation

Table 2. Photovoltaic characteristics of the devices using different buffer layer for semitransparent devices

Doping Ratio	Cathode	Voc (V)	J_{sc} (mA/cm^2)	FF (%)	PCB (%)
20 wt%	Ca/AG	0.457	6.542	0.196	0.586
20 wt%	Ag/Ca/AG	0.521	18.650	0.322	3.131
20 wt%	LiF/Ag/Ca/AG	0.537	15.410	0.318	2.635

Table 2 shows the comparison of results for photovoltaic devices with thin Ag buffer layer, no buffer layer, and LiF buffer layer. By using thin Ag buffer layer, PCE of the semitransparent devices was dramatically improved from 0.586% to 3.131%, possibly due to the barrier height lowering between PCBM and Ca/Ag cathode electrode.

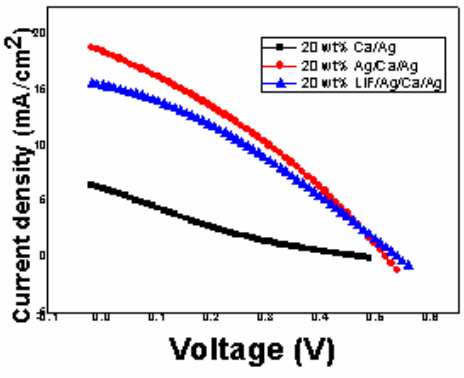

Fig. 3. Electrical characteristics of fabricated OPV device as a function of buffer layers (no, Ag, and LiF) with Ca/Ag cathode of semitransparent device

4. Summary

We investigated the effect of glycerol doping ratio in PEDOT:PSS on the performance of organic bulk heterojunction photovoltaic devices. The power conversion efficiency of 5.032% was obtained with glycerol doping ratio of around 10 ~ 20 wt%. Additionally, thin Ag buffer layer for transparent cathode electrode (Ca/Ag), we have obtained relatively high PCE of 3.131% as well as semitransparent organic bulk-hetrojuction photovoltaic devices with transmittance > 30% in visible ranges

5. Reference

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