

ORGANIC SOLAR CELLS EMBEDDED WITH ZNO NANOPARTICLES

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Abstract: In organic photovoltaics, the thickness of active layer needs to be larger than around 100nm to absorb enough light. There is a trade-off relation between increasing absorption and decreasing series resistant. The optimum thickness is 100nm in previous works because the light absorption length is 100nm and exciton diffusion length is about 20nm[1, 2]. By inserting ZnO nanoparticles, we increased the power conversion efficiency. We suspect this is because the ZnO nanoparticles scatter light effectively so that overall light absorption has been increased.

Keywords: Organic Photovoltaics, ZnO nanoparticles

INTRODUCTION

The organic photovoltaics(OPVs) have been received many attentions due to the low cost and flexibility[3]. The cost of organic materials and manufacturing is generally cheaper than that of the inorganic counterpart. In addition, the OPV can be made on the flexible substrates such as PET(polyethylene terephthalate) or PEN(polyethylene naphthalate)[4].

The OPVs is generally composed of a donor material and an acceptor material. An electron is donated from the donor material to the acceptor material[2]. The donor material needs to be thick to absorb enough photons. Generally speaking, the thickness of the donor material should be around 100 nm or larger for enough light absorption[1]. When a photon absorbed in a OPVs, the exciton, i.e., a pair of an electron and a hole, is generated. The exciton travels in the OPVs by the diffusion process. The traveling length is around 20 nm, which is so called the exciton diffusion length[5, 6]. Only when it sees the interface between the donor and acceptor materials, it dissociate into a hole and an electron. Therefore, there is a contradicting requirement between thick donor material for enough light absorption and thin donor material for efficient charge separation, i.e., exciton dissociation.

To resolve above requirements, research efforts have been focused on optimizing the two contradicting requirements. The bulk-heterojunction, mixture of donor and acceptor materials, OPV has been researched since there are lots of interfaces between the donor and acceptor material while it could absorb enough photons[7, 8]. Also, the heat treatment method has been researched to modify the crystallinity of polymer[9-11] and the nanoimprinting method is getting attention because this method can

make the expressway for electrons to reach the electrode without resistance[12, 13].

In this paper, we used the ZnO nanoparticles for light scattering to increase light absorption without increase the donor thickness. If the straight incident photons hit the nanoparticles, the photons would be refracted and many part of the incident photons would move to the side. This means that a lot of photons can be absorbed under 100nm thickness. So, many excitons can be created nearby acceptor materials, within exciton diffusion length. Consequently the most of excitons can reach the acceptor materials. The energy bandgap of ZnO is about 3.3eV[14, 15], so it scatter light rather than absorb. Therefore, we can reduce the thickness of donor material. By this effect, we improved the power conversion efficiency of OPVs

EXPERIMENTAL

Patterned indium tin oxide (ITO, $\sim 10\Omega/\square$) glass was used as a transparent anode substrate. After cleaning the pattered ITO, poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS) was spin-coated about 40nm thick as a buffer layer on the ITO substrate. We spin coated with dispersed ZnO nanoparticles in IPA after PEDOT:PSS spin-casting. Nanoparticles are mixed with IPA solution and dispersed by ultrasonicator. Then, poly(3-hexylthiophene) (P3HT, Rieke materials) was spin-coated as a donor material (~ 100 nm) and followed by 1-(3-methoxycarbonyl)-propyl-1-phenyl-(6,6)C₆₁ (PCBM, Nano-C) spin-coating as an acceptor(~ 100 nm) layers. After acceptor spin-coating, Al was deposited around 100nm thickness by the thermal evaporator as the metal cathode.

RESULTS AND DISCUSSION

(Fig. 1) shows the J-V curve under AM 1.5G condition. The reference cell, without ZnO nanoparticles, shows mean value of efficiency, $\eta = 2.42\%$. and when ZnO nanoparticles was inserted, $\eta = 2.68\%$ which is 16 times larger than without ZnO cell.

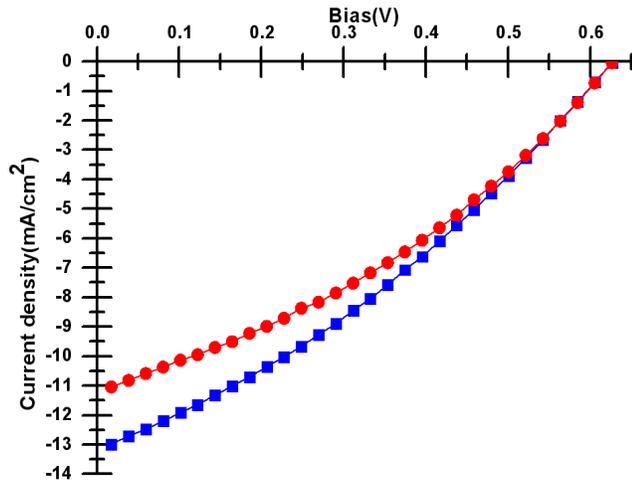


Fig. 1: J-V curves of bilayer cells without ZnO nanoparticles: Reference cell (circles), cells with ZnO nanoparticles (square).

(Fig. 2) shows that efficiencies of the OPVs. In the case of OPVs with nanoparticles, the difference with the maximum and minimum PCE is larger than the value of OPVs without nanoparticles. The error bar indicates deviations efficiencies of multiple OPVs. We speculate that the error comes from the fact that we do not have control over dispersion of the ZnO nanoparticles.

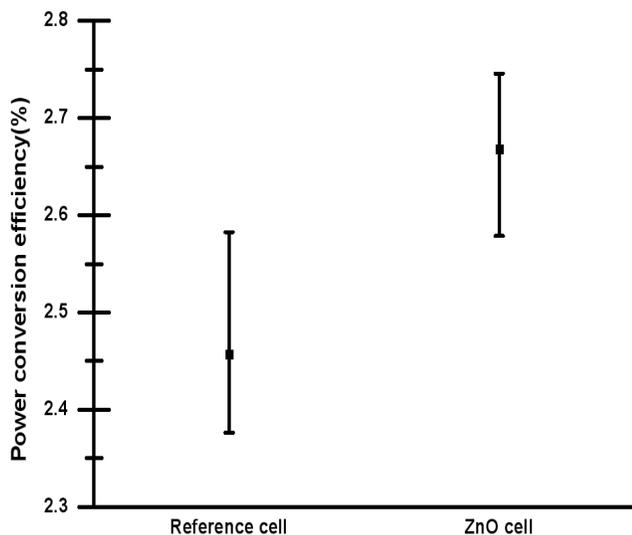


Fig. 2: Device power conversion efficiency with and without ZnO nanoparticles.

Table 1: Mean result of bilayer photovoltaics (a) reference cell, (b) inserting ZnO nanoparticles cell

Cell type	V_{oc} (V)	J_{sc} (mA/cm ²)	FF	η (%)
(a)	0.617	11.8	0.333	2.42
(b)	0.620	12.9	0.335	2.68

Table 1 shows mean values of the reference cell and the cell with embedded nanoparticles. In this table, we can find the mean value of short circuit current, J_{sc} , with ZnO is about 8 times larger than the reference cell. We suspect that the OPV with nanoparticles absorbs more photons and could dissociate more excitons.

ZnO nanoparticles, which is used in our OPVs, are nonmetallic material and have energy bandgap of 3.3eV. Therefore, the nanoparticles should scatter the light rather than absorb.

CONCLUSION

By inserting ZnO nanoparticles in the bilayer PV cells, we have demonstrated increase of energy conversion efficiency of OPVs. The main increase comes from increase in the short circuit current which should indicate that the OPVs with nanoparticles absorb more photons and dissociate more excitons.

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