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Sol-gel derived ZnO as an electron transport layer (ETL) for inverted Organic solar cells

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Abstract. In this work, we present the study of the fabrication process of the sol-gel derived zinc oxide (ZnO) as an electron transport layer (ETL.). The solution processed inverted bulk heterojunction organic solar cells based on a thin film blend of poly (3-hexylthiophene 2, 5-diyl) and [6,6]-phenyl-C_{61}-butyric acid methyl ester is prepared.. ZnO thin films are annealed at different temperature to optimize the solar cell performance and their characterization for their structural and optical properties are carried out. We have observed V_{oc}=70mV, J_{sc}=1.33μA/cm^2 and FF=26% from the inverted heterojunction solar cell.

Keywords: Organic photovoltaic, optical properties and structural properties.
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INTRODUCTION

Organic solar cells (OSCs) are a promising source of energy technology which could overcome the challenge of rising global energy demand. This technology represents a cost-effective alternative to silicon based photovoltaic, due to its potential of providing environmentally safe, flexible, lightweight and inexpensive solar cell. However, their longevity and a relatively low power conversion efficiency compared to inorganic solar cell have been the major limitation for faster commercialization. A bulk heterojunction (BHJ) organic solar cell with conventional structure is fabricated with transparent conductive anode (e.g. Indium tin oxide ITO), an anode buffer layer (e.g. PEDOT: PSS) and low work function metal cathode (e.g. aluminum).

In inverted device geometry, the charge separation and collection is reversed as compared to conventional structure. The enhanced stability of this structure is derived partly from the replacement of PEDOT: PSS with metal oxide buffer layer. Air stable metal oxide such as zinc oxide (ZnO), titanium oxide (TiO2) and cesium carbonate (Cs_2Co_3) have all been investigated in inverted structure device [1].Among these metal oxides, ZnO is the most promising due to its high electron mobility, environmental stability and better optical transparency [2].The sol-gel method is now widely used for (BHJ) solar cell, due to its simple deposition process and low annealing temperature [3]

In this paper, the sol-gel method is employed to prepare ZnO thin films. We have investigated the influence of the sol-gel derived ZnO thin film on the performance of P3HT: PCBM, BHJ organic solar cell.

EXPERIMENTAL DETAIL:

Device Fabrication

The ITO coated-glass substrates were ultrasonically cleaned with deionized water, acetone and isopropyl alcohol (IPA) for 10 min each. The ZnO precursor was prepared by dissolving 0.75M zinc acetate dehydrate {Zn $(CH_3COO)_2$ $2H_2O$} and 0.75M ethanolamine (MEA, $NH_2CH_2CH_2OH$) in 2-methoxyethanol ($CH_3OCH_2CH_2OH$). The mixture was refluxed at 80^0C for 1 hr and then aged at room temperature for 24 hr to form sol-gel. ZnO thin films were obtained by spin coating stored solution at 3000 rpm for 40 s on the top of glass/ITO substrates. The films were annealed on hotplate in air at different temperatures (200^0C, 250^0C and 300^0C) for 30 min and samples were coded as device A, device B and device C.

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The active layer solution was formed by dissolving P3HT: PCBM, mixed with a weight ratio of 1:0.8 at a total concentration of 20mg/ml in 1,2-dichlorobenzene and spin coated over ZnO layer at 600rpm for 60s. All the samples were placed in covered petridish overnight for slow drying. To complete the solar cells, Ag paste was used to make top electrode and device area was kept 0.3 cm^2.

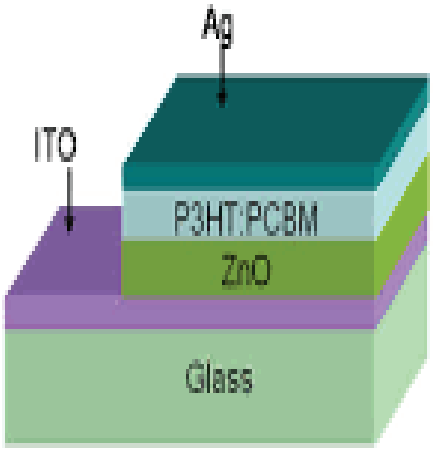

Figure 1 Structure of the fabricated solar cell

CHARACTERIZATION

The transmittance spectra of the ZnO films deposited on glass substrates which were annealed at different temperatures (200 °C, 250 °C and 300 °C) for 30 min are reported in fig.2. The transmittance spectra of the ZnO film shown in fig.2 reveal that the ZnO film is transmitting almost 90% of the incoming light between 400-800 nm. The ZnO layer blocks only light at wavelength shorter than 400 nm and it is very transparent for higher wavelengths.

Since the incoming light has to travel through the ZnO film in the inverted device architecture, the optical properties of ZnO are crucial for the used photoactive layer P3HT: PCBM which shows a good absorption in the range 400-650 nm. The SEM image displayed in Fig. 3 shows a dense but nonporous ZnO film. This indicates that the spin- coating method provide excellent coverage of ZnO thin film over the entire ITO/glass substrate.

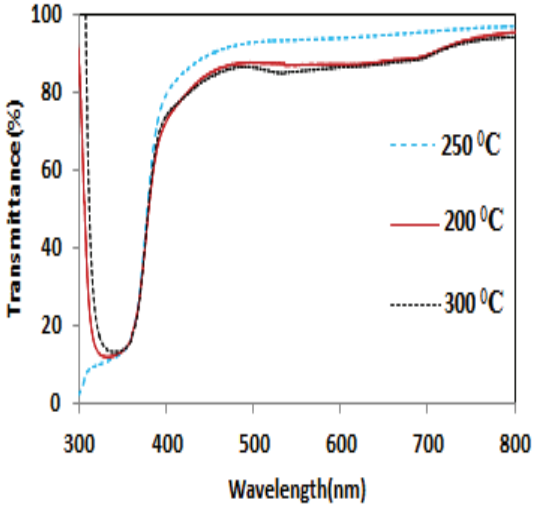

Figure 2 Transmittance spectra of ZnO films coated on a glass substrates and annealed at different temperatures (200 ^{0} C, 250 ^{0}C and 300 ^{0}C) for 30 min.

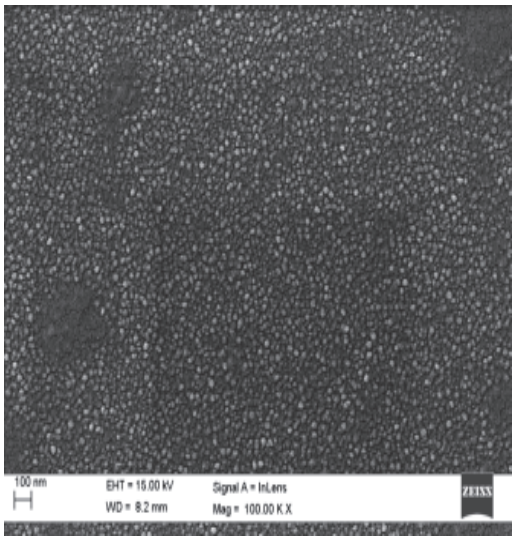

Figure 3 SEM. image of ZnO film annealed at temperature of 250 (200 °C ,250 °C and 300 °C) for 30 min

RESULT AND DISCUSSION

We have fabricated three solar cells with the help of ZnO nanoparticles annealed at different temperatures. These solar cells are known as device A, device B and device C. The solar cells are characterized under illumination of 100mW/cm^2 light. Fig.4. (A) shows J-V curves for solar cell devices A, B and C with ZnO films annealed at different

temperatures (200 °C, 250 °C and 300 °C) for 30 min under dark condition. Fig.4 (B) shows J-V curve of solar cell device B. Solar cell (device B) shows photovoltaic nature with the J_{sc} of 1.33 μA/cm^{2,} V_{oc} of 70 mV and FF of 0.26 under illumination of 100mW/cm^2 light .The photovoltaic properties are not observed for solar cell devices A and C. In sample A, this might be due to amorphous nature of ZnO annealed at a temperature of 200^{0}C, while in sample C it results due to the high resistance of ITO and alteration of grain size in ZnO layer annealed at temperature of 300^{0}C.

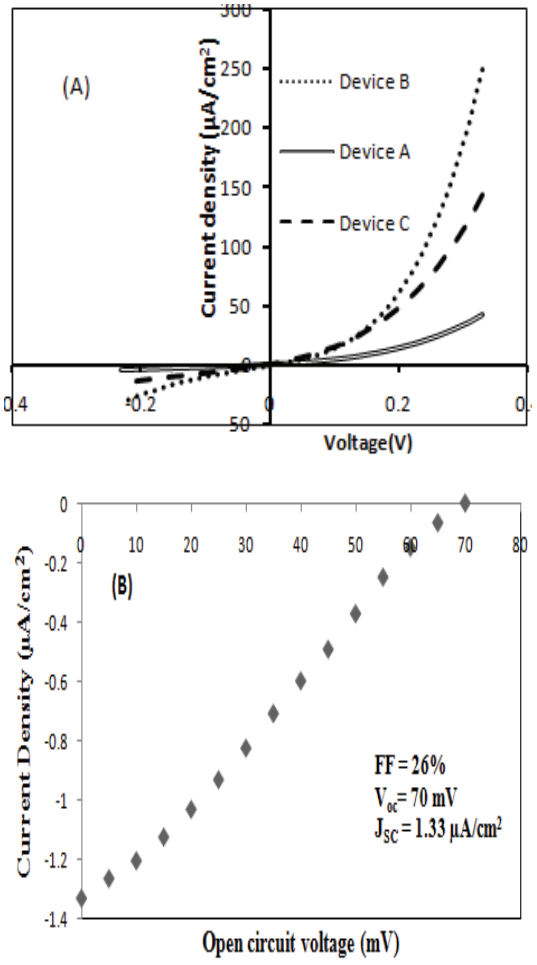

Figure 4 (**A**) J-V curves for solar cell devices A, B and C with ZnO films annealed at different temperatures (200^{0}C, 250^{0}C and 300^{0}C) for 30 min under dark condition. (**B**) J-V curve for Solar cell device B under simulated AM 1.5 G illumination (100mW/cm^2) with ZnO film annealed at temperature of 250^{0}C.

CONCLUSION

In this work, the performances of inverted OSCs, based on a blend of P3HT:PCBM and sol-gel derived ZnO film as ETL, are optimized by evaluating the effects of the annealing temperatures on the properties of the ZnO. We have fabricated OSCs with the structure glass/ITO/ZnO/P3HT: PCBM/Ag paste. The photovoltaic properties are achieved at the optimum annealing temperature of 250 °C with the J_{sc} of 1.33 μA/cm^2, V_{oc} of 70 mV and FF of 0.26 under illumination of 100mW/cm^2 light. All ZnO films show high transmittance almost 90% in the visible range of the optical spectrum.

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