INVERTED POLYMER SOLAR CELLS IMPLEMENTING ZnO AS AN ELECTRON TRANSPORT LAYER

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ABSTRACT—*Zinc Oxide (ZnO) nanorods were implemented as an electron transport layer (ETL) on a low-cost inverted polymer solar cells. The ZnO nanorods were synthesized by hydrothermal method using two growth times, in order to find the optimum time to provide the best power conversion efficiency. The active layer of PC61BM: P3HTwas prepared via spin casting method in an N2 controlled glove box. Silver electrodes were evaporated on the active polymer layer.*

Keywords: ZnO, hydrothermal method, inverted polymer solar cell, power conversion efficiency

INTRODUCTION

The international production rate of oil and gas will decrease with a greater frequency in the near future [1]. Also, their prices are expected to increase with the same rate, which will lead to the implementation of renewable energy sources such as solar energy, wind energy systems, tidal and many other green energy sources as a practical alternative [2].

Solar energy is the energy of the future, due to the fact of it being renewable, cheap and clean. The implementation of solar energy means the utilization of solar cells in order to convert solar energy to electricity. Solar cells can produce approximately twice the amount of the energy produced by fossil fuels and much more than the energy produced by nuclear fission reactors. But the drawback of the implementation of solar energy today, is due to the high cost compared to the relatively low power conversion efficiency (PCE). The commercial solar cells available in the market are silicon-based photovoltaic cells, which are somewhat expensive due to their complex and expensive fabrication. Therefore, there is a trend to use other types of materials to synthesize solar cells apart from silicon, such as dye sensitized solar cells, which were found to be economic and also have a high PCE since they depend on dye sensitizers to absorb the visible light and generate an electron transfer reaction [3]. Perovskite solar cells (PSCs) are another type of economic solar cells, but they are not widely used due to its instability [4]. Organic photovoltaics (OPVs) are also another cost-effective alternative, and have unique properties such as being light weighted, docile, semitransparent, and do not have a complex fabrication process [5]. However, there still exist some issues considering the requirements of the commercialization of OPVs [6].

II. INVERTED POLYMER SOLAR CELLS

A typical OPV consists of a bulk hetero-junction (BHJ) structure, in which the most commonly used photoactive material is a combination of poly(3-hexylthiophene) (P3HT) and the fullerene derivative (6,6)-phenylC61butyric acid methyl ester (PCBM). Generally, there are two types of OPVs; conventional and inverted. The conventional OPV is composed of an anode/hole transport layer/active

material/electron transport layer/cathode. The main issue with conventional OPV is the instability of the device in air. This is known to be closely related to the hole transport layer material poly (3,4ethylenedioxioxythiophene): poly (styrene sulfonate) (PEDOT: PSS) that causes the degradation of both the photoactive material and anode due to its hygroscopicity and acidity. Thus, to resolve this problem, the inverted structure for OPV has been proposed in which the electron transport layer (ETL) and the hole transport layer (HTL) are interchanged to improve the stability. However, the PCE of the inverted OPV is generally lower than that of the conventional OPV. Therefore, the usage of a high quality ETL and optimization of the interfacial characteristics between the pho-to active layer and the electrode is required to increase the PCE of the inverted OPV [7]. A family of metal oxides such as TiO_2 [8–10] and ZnO has been commonly used as the ETL material in the inverted OPV. The TiO2 and ZnO are preferred due their well aligned band gap distribution in the OPV structure. In particular, ZnO is more favored as an ETL in OPV because of its relatively high electron mobility. In addition, 3D nano structuring in the ETL rather than a planar structure has been suggested to achieve a high surface area, which leads to an increase in charge extraction efficiency between the photoactive layer and the cathode [10].

III. MATERIAL AND METHODS

The inverted polymer solar cell was composed of four layers and Ag poles connected at the edges as demonstrated in fig. 1. All the layers were synthesized using inexpensive methods. The first layer was the substrate and it consisted of a glass plate covered by an FTO layer. The second layer was the ZnO seed layer and it was synthesized by the sol-gel method then a spin coating process was applied so as to form a homogeneous ZnO seed layer also, drop cast and deep coat techniques were also used to form the ZnO seed layer. The third layer consisted of ZnO nanorods that were synthesized via the hydrothermal method. The inverted polymer layer consisted of P3HT: PCBM was prepared with a ratio of 1:1. via spins casting method in an N2 controlled glove box. And

finally the Ag electrodes were evaporated on the active polymer layer.

There were two solar cells prepared; the first cell had ZnO nanorods with growth time of 15 minutes, and the second cell had ZnO nanorods with growth time of 30 minutes. The solar cells were subjected to 100mW/cm2 xenon solar simulator lamp and then the optical energy band gap for the samples was calculated by Tauc's equation:

$$E(eV) = \frac{hC}{\lambda} \approx \frac{1240}{\lambda} \qquad (1)$$

Also, the optical band gap of the ZnO nanoparticles, was determined from the UV data using both absorbance and reflectance spectrums. Then, the J-V characteristics were found and hence the fill factor (FF) was found from (2) and the PCE, η was calculated from (3).

$$FF = J_{max}V_{max}/J_{sc}V_{oc} \qquad (2)$$

Where J_{max} is the maximum current density, V_{max} is the maximum voltage, J_{sc} is the short circuit current density and V_{oc} is the open circuit voltage.
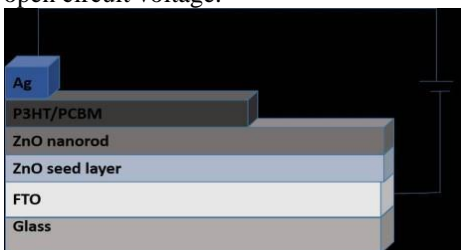

Fig. 1. Block diagram of the inverted polymer solar cell

$$\eta = J_{max}V_{max}/P_{in} \qquad (3)$$

Where P_{in} is the input power

IV. RESULT AND DISCUSSION

The optical energy gap was found to be ~3.4 due to the absorption spectrum of the ZnO nanoparticles as illustrated in Fig. 2. While the optical energy gap of ZnO nanoparticles, which was identified by the reflectance spectrum, was also ~ 3.4 and is displayed in Fig.3. Then ZnO bandgap was calculated using (1) and was found to be ~ 3.42 nm. By The two obtained results using different spectrums were compared and they were found to be almost equal.

The transmission properties of the sample were also evaluated and the result is shown in Fig 4,. and Fig. 5. It was noticed that 60 % of the light is transmitted through the sample at the visible region and most of the light is absorbed at the UV region (< 300 nm).

The J-V characteristics of the ZnO nanorods solar cells, were plotted in Fig. 6, and Fig.7,. and J_{sc}, V_{oc}, FF and PCE were found and shown in the table. 1. And it was found that the open-circuit voltage for the 15 min. growth is

V.   CONCLUSION

By comparing the two inverted polymer solar cells, the 15 min. growth ZnO nanorod inverted polymer solar cell was found to be more efficient with efficiency of 2.65% and fill

factor of 0.56, while the 30 min. growth of ZnO nanorods inverted polymer solar cell had an efficiency of 1.62% and fill factor of 0.46 respectively. This fact proves that the growth time, affects the efficiency and the fill factor of the polymer solar cells.
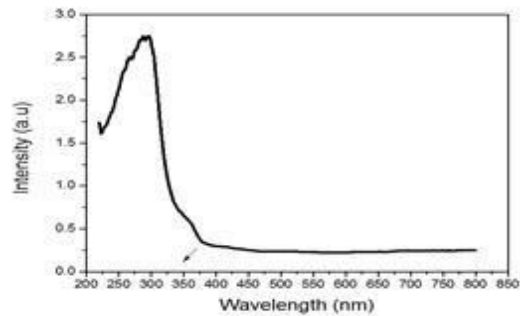

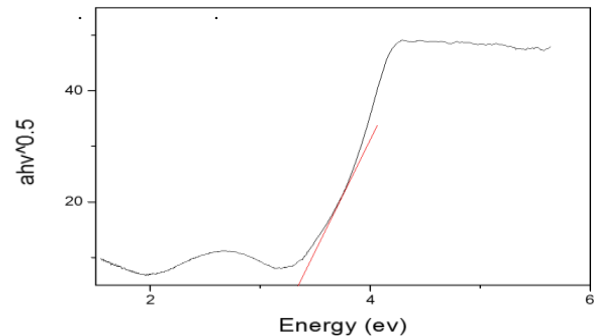Fig. 2. ZnO nanoparticles optical band gap from reflectance spectrum

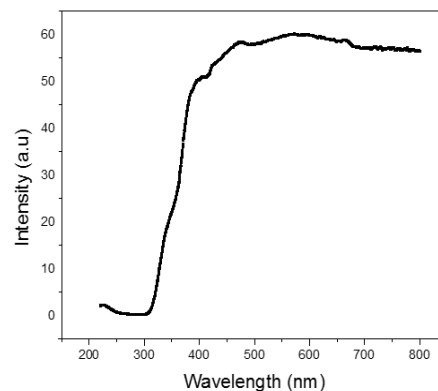**Fig. 3 ZnO nanorods optical band gap from   reflectance spectrum**

Fig 4: **Transmission spectrum** for **ZnO nanorod growth at (15)**
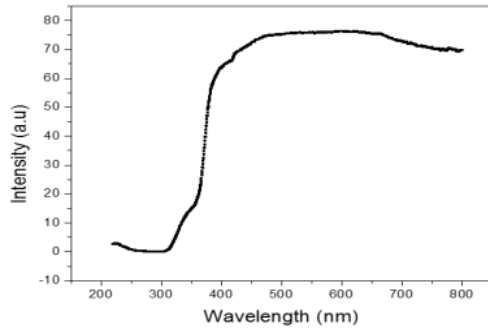
minutes

Fig. 5. Transmission spectrum for ZnO nanorod growth at 30 minutes

TABLE I. Device parameter for ZnO based inverted organic solar cell

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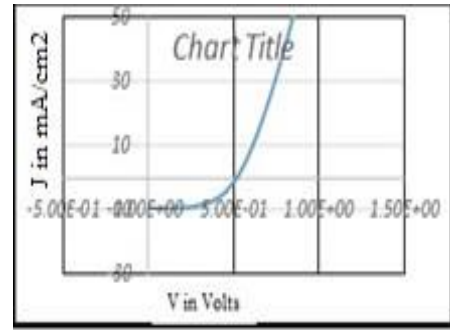| Sample	VOC in Volts	J_{SC} in mA/cm^2	Fill Factor	PCE %
15 min. ZnO nanorods	0.51	9.53	0.56	2.65
30 min. ZnO nanorods	0.48	7.39	0.46	1.62

Fig. 6. J-V characteristic for ZnO nanorod growth at 15 minutes
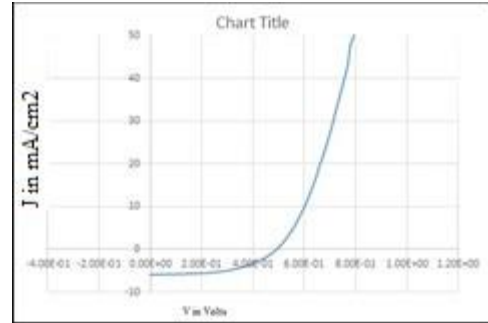

Fig. 7. J-V characteristic for ZnO 30 minutes

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