Effects of Zinc Oxide used as an alternative for Organic Polymer in Single Layer Organic Solar Cells: Simulation Study

Effets de l'utilisation de l'oxyde de zinc comme alternative au polymère organique dans les cellules solaires organiques monocouches : Simulation

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ABSTRACT. The present work aims to study the effects of using Zinc oxide in organic solar cell, as an alternative for organic polymer in active layer, in layer by layer type, which is responsible for many factors related to performance of the cell and the efficiency, such as the recombination time, fill factor, and open circuit voltage, the maximum current produced by the cell, the efficiency of the cell, and comparison between results for both models, ZnO & PCBM, with keeping the thickness of the active layer equaled, the results showed a clear differences in some factors, not big variations in others, all data was collected by using simulation software, which is help in reducing time and efforts in real experiments in the Lab.

RÉSUMÉ. Le présent travail vise à étudier les effets de l'utilisation de l'oxyde de zinc dans les cellules solaires organiques, comme alternative au polymère organique en couche active, dans le type couche par couche, qui est responsable de nombreux facteurs liés à la performance de la cellule et à l'efficacité, tels que le temps de recombinaison, le facteur de remplissage et la tension en circuit ouvert. Le courant maximal produit par la cellule, l'efficacité de la cellule et la comparaison entre les résultats pour les deux modèles, ZnO et PCBM, en gardant l'épaisseur de la couche active égale, les résultats ont montré des différences claires dans certains facteurs, pas de grandes variations dans d'autres, toutes les données ont été collectées à l'aide d'un logiciel de simulation, ce qui aide à réduire le temps et les efforts dans les expériences réelles en laboratoire.

KEYWORDS. Organic solar Cells, Simulation, Zinc Oxide, organic polymers, Cell Efficiency, Fill Factor.

MOTS-CLÉS. Cellules solaires organiques, Simulation, Oxyde de zinc, Polymères organiques, Efficacité cellulaire, Facteur de remplissage.

1. Introduction

During last few years, the Organic Solar Cells (OSC), attracted researchers around the world, due to less cost production, easier processing, their materials are more friendly to environment, by compared with Silicon solar cell, where the Silicon wafer needs a high temperature (≈ 1800^0 C) to treat it [1-4], The global efforts to reduce Carbon emissions considered as another factor raised of OSC importance [5], most of these gases emissions source is a fossil fuels, energy generating, and using it as an electrical supply for most economic activities [8-4].

The first architecture of OSC was reported bilayer planer heterojunction (PHJ) as an active layer, which needs difficult fabrication conditions, to overcome these critical process conditions, the researchers reported another type of fabrication called Bulk heterojunction (BHJ), to prepare the active layer by solution mixed processing of donor and acceptor, this technique raises the power conversion efficiency (PCE) to 18% [2], although with this advantages for BHJ, they need a lot of work to justify the D-A ratios, in addition to crystallization of this mixture over the thin film, causes to drawback this type of technique, leads to new fabrication method called layer by layer (LBL), easier than previous techniques in processing and fabrication of new OSC (see Figure 1, [2]). The great success in design architecture of OCSs leaded to increasing in power conversion efficiency, from point of fabrication technique, layer by layer deposition of materials in cell has many advantages rather than other methods, and hence it was selected in present study. The substitution of PCBM by ZnO was aided as well.

1.1. *The Structure of OSC:*

The general structure for the OSC is organic materials layer, coated over a transparent ITO glass substrate [3], the organic layer works as an electron donor after they absorb the light spectrum in the visible range, the electrons transported from HOMO (highest occupied molecular orbital) to LOMO (lowest unoccupied molecular orbital), this causes generation excitons, Figure 1 shows the different structures of OSC according to its type and fabrication process [9]:

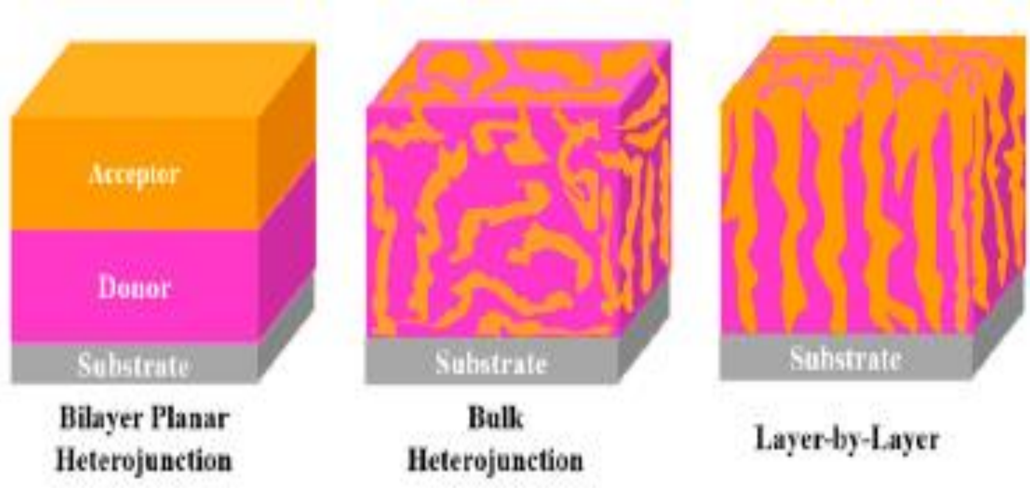


Figure 1. *Diagram of PHJ, BHJ and LBL of the active layer processing*

2. Materials and Methods

We assumed two organic solar cells with the same composition except the active layer, as shown in Figure 2 (a & b), the active layer composed from P-3HT/PCBM in (a) Cell, while its composed from P-3HT/ZnO in (b) cell, with the same layer thickness of 0.22 **μ**m, the measured parameters including maximum power generated by the cells, performance cell efficiency, fill factor, closed circuit current and open circuit voltage, the simulation study done by solving the drift diffusion equations, by finite differences method, applied by OghmaNano software [9].

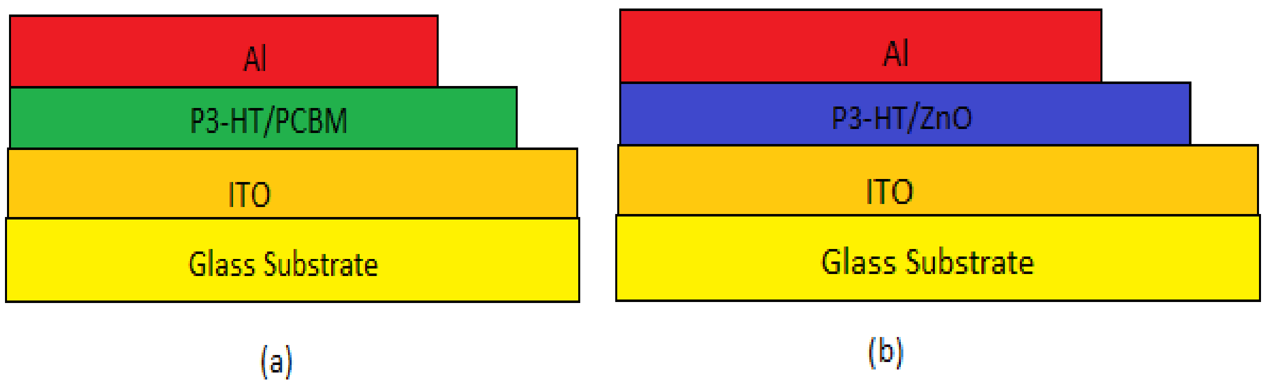


Figure 2. *Schematic illustration cells layers, (a) For P3-HT/PCBM Layer, (b) for P3-HT/ ZnO Layer.*

3. Results

The vital parameters such as, the maximum power produced by the cell (P_{max}), Performance cell efficiency (PCE %), Fill Factor (FF), short circuit current (J_{sc}), The open Circuit voltage (V_{os}), were calculated for both cells, (see Figures 3-5) which show the results of both cells obtained. The above results where summarized in Table (1).

Cell	Thickness of Active Layer (m)	Max Power (Wm^{-2})	Performance Cell Efficiency (PCE%)	Fill Factor FF (a.u)	Short circuit Current J_{sc} (A/m^{-2})	Open Circuit Voltage V_{os} (V)
a	2.2×10^{-7}	46.290	4.6290	0.6715	-1.1410	0.6041
b	2.2×10^{-7}	7.9694	0.7969	0.5843	-2.5244	0.5402

Table 1. *The Measured Values of Cells Parameters.*

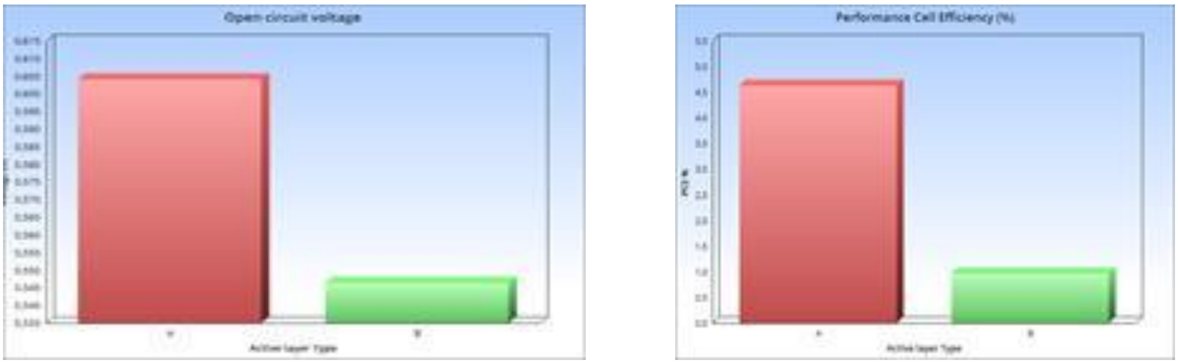


Figure 3. *Charts of PCE% and open circuit voltage*

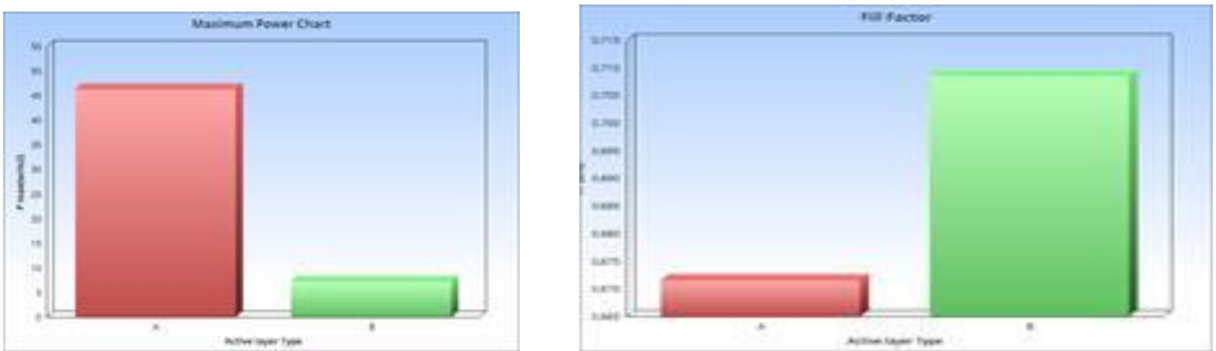
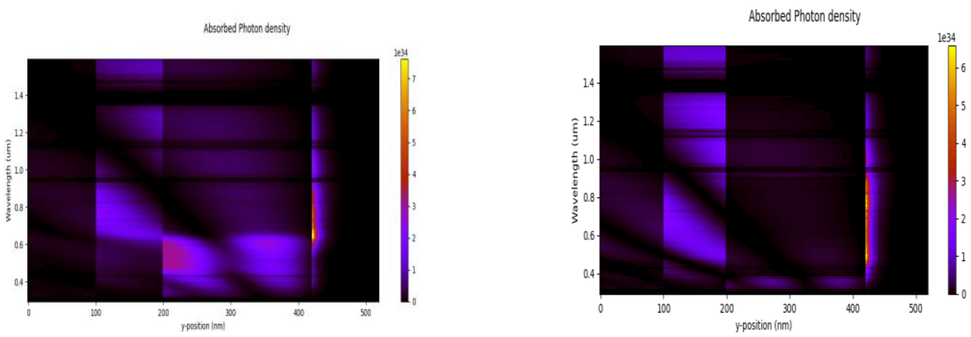


Figure 4. *maximum power and fill factor*



(A) **(B)**

Figure 5. *Schematic diagram for absorbed photons, (a) For P3-HT/PCBM Layer and (b) for P3-HT/ ZnO Layer*

4. Discussion

The above results shows a clearly difference between both used models especially in maximum power produced by the cell, where the P-3HT/PCBM active layer cell (a) has higher value than P3-HT/ZnO active layer cell (b), which is effected on the performance cell efficiency percentage, other factors such as, the Fill Factor which is represents the ratio of the maximum power output of the cell to its theoretical power output, was found in the rang values for both cells. In the cell active materials, the short circuit current which it's the maximum current can the device produce, and it's dependence on both the absorption efficiency and length of exciton diffusion materials in the cell, a little difference between the cells, with more value for the cell (b) rather than cell (a) was observed. Moreover, the open circuit voltage values which is the maximum possible voltage across an OSC device (V_{os}) was nears for both of them, a cell (a) has higher value than other one. The absorbance spectrum range for cell (a) is wider than absorbed spectrum range for the cell (b).

5. Conclusion

We can consider as a general conclusion the cell with active layer composed from P3-HT/PCBM has more efficiency than the cell with active layer composed from P3-HT/ZnO.

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