



Improving Efficiency and Stability of Organic Solar Cell

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Received: 05 October, Revised: 15 October, Accepted: 17 October

Abstract— Efficiency and stability are the main challenges of organic solar cells. In this research novel structure is investigated for organic solar cell which has improved efficiency and improved stability. Blend of PTB7 and PCBM elements was used for the active layer of cell. Thickness of this layer was varied from 80nm to 200nm and selected the optimized thickness of 90nm. On which the cell has maximum efficiency of 12.24%. The influence of window layer material such as Zinc oxide (ZnO) and titanium dioxide (TiO₂) with various electrode materials including Indium tin oxide (ITO), Fluorine tin oxide (FTO), aluminum (Al) Silver (Ag) and Gold (Au) with different combinations have been investigated with the objective to enhance the absorption and PCE of the cell. Also varied the thicknesses of these different layers and selected the optimized thickness on which the cell had maximum efficiency. The structure of the proposed scheme was observed with ITO/Al as top and bottom electrode with thicknesses of 125nm and 100nm respectively and found that this holds the highest performance parameters including $J_{sc}=0.130(\text{mA}/\text{m}^2)$, $V_{oc}=1(\text{V})$, $FF=94.1\%$ and $\eta=12.24\%$ respectively as compared to different electrode combination and window layers with the same photoactive absorber material PTB7: PCBM. This indicates that the proposed structure can be a good choice for replacing less efficient in-organic cell.

Keywords— Organic solar cells, Bulk Heterojunction, PIF8BT: PDI, Buffer layer, Power Conversion Efficiency.

I. INTRODUCTION

It is well known that in today's life energy is the need of every person. Because everything around us is running on energy and specially the use of electrical energy is very large [1]. With no doubt Solar energy is a huge and endless amount of energy. Researchers are working from 19th century to make energy (in the form of electrical energy) from sun light which we are receiving at earth surface. The process in which electricity is made from sun light is called photo electric effect. The device with the help of which we convert this light into energy (Electrical Energy) is called solar cell (photo voltaic cell). These cells are divided into many types; among them the two are main types which are 1) organic solar cells, and 2) inorganic solar cells. But the demand of organic solar cells in the market is increasing day by day from the last 20 or 30 years. Because these

cells (organic solar cells) have greater efficiency as compared to other type (inorganic solar cells) [2]. The very first attempt to make inorganic solar cell was first done by bell labs in year 1954. He made cell from silicon material with 6% efficiency [3]. Then many scientists and researchers worked to improve the cell efficiency and they achieved a greater efficiency of 24% up till now [4]. The main difficulties with these cells are their high cost of production, their heavy weight and their complex fabrication process [2]. Contrary to this cell made from organic material (organic solar cells) have much lower production cost, also have less weight in comparison with inorganic cells. Size of cells which are made from organic materials is also thin in comparison with inorganic cells, so their production cost and weight is low. Organic cells are made of organic materials and their blends which can be synthesized easily. The other thing with OSCs is their flexibility. These cells are made of many layers and parts, but the main part is the active part or layer, which is made from organic material and their mixture. Organic cells have also greater absorption capacity of light due to their structure and other properties. In early days scientists were using chlorophyll because of its good properties of light absorbing [5]. But later researchers developed new materials which had good properties of light absorbing and useful use of this light [6, 7]. In 1980 the first organic solar cell was made with very low PCE of 0.1% [8]. Then in 1995 Alan Heeger introduced idea of bulk hetero junction (BHJ) [9]. Bulk hetero junction is a structure in which there are two different materials (mixture of p and n type) in active layer. These materials are separated from each other by very small distance of Nano scale separation. The power conversion efficiency of these materials depends upon the structure and morphology of these [10, 11]. Scientists tried different type of morphologies to develop a good cell but are still working to find the best active layer material for the cell and to find a good morphology [12].

OSCs which are normally available in the market are made from P3HT poly (3-Hexylethiopynes) and fullerene derivatives particularly PCBM phenyl (C-61 Buteric acid methyle ester). P3HT is electron giving (donor) element and Pcbm is electrons acceptor element [13]. P3ht has the property to conduct free charges, and this is because it has single and double bond alternatively. PCBM is derived from fullerene. The placement of electrons in this element is responsible for good charge transfer. Researcher consider these very good for OSCs. Up till now Researchers have obtained about 5% PCE from these materials [14]. The demand and market competition of OSCs

depends upon the production cost, PCE and stability of these structures. So, we need more focus and work on their efficiency and their stability to participate in market competition and show some outstanding performance which is not shown by inorganic cells. Now a days P3HT and PCBM material have attained the stability of up to 5000 hours [15]. But these are very less stable in the air when they are exposed to air. So we should investigate new material which has greater efficiency [16].

II. DEVICE MODELING

The proposed investigated OSC structure is presented in Figure 1. Which consist of mainly five layers. Indium Tin Oxide (ITO) is used as top layer. Which works as electrode. Below ITO Buffer layer is placed which is made of PEDOT: PSS. This is also known as Hole transport layer (HTL) or Electron Blocking Layer (EBL), which helps in the transportation of holes and blocks the movement of electrons. PEDOT: PSS has good stability, high mechanical flexibility and is highly conductive [17-19]. Below the (BL) layer, have placed photo active layer which is made from the blends of different materials such as PIF8: PDI, P3HT: PCBM, PTB7: PCBM and PDTS-DTFBT: PCBM. Thickness of this layer was varied from 80nm to 150nm. Different window layers were used including zinc oxide (ZnO) and titanium dioxide (TiO₂) as these window layers have high transparency, larger excitons binding energy and can enhance transmittance [20, 21].

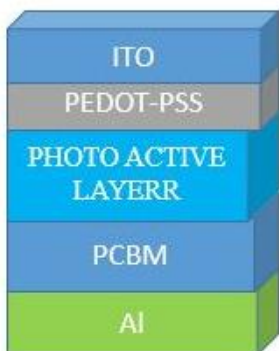


Figure:1 Proposed structure of cell

For simulations GPVDM software was used. This software was used because it is very good software as compared to other softwares because it can give us both optical and electrical properties of the cell very accurately [22, 23]. In proposed structure both electrical and optical properties were investigated. Different equations were used such as poisson equation, Drift diffusion model, and continuity equations for electron-hole. Whereas, for recombination of carrier Shockley-Read-Hall (SRH) is used in 1D- and time domain [24-26].

III. RESULTS AND DISCUSSIONS

For getting the highest efficiency and stability different photoactive materials and their different parameters were investigated and checked. First of all thickness of the photo active layer was varied, and observed the influence of thickness on the Voc, Jsc, FF and η for all materials. The reason for varying the absorber layer thickness is that this layer plays a key role in the overall cell performance of the cell [27, 28]. Different

window layers were used and compared their results with each other. After analysis PEDOT: PSS was selected for window layer because its result was good as compared to other window layers [29]. The variation of efficiency and Jsc was observed. It was found that when the thickness of the absorber layer increases Jsc also increases. This rise in Jsc is due to the fact when the absorber layer thickness is increased the absorption of the photons is increased due to which Jsc is increased [30]. It was also found that when thickness increases, efficiency also increases. This is because larger amount of photons are absorbed in this which results in greater number of excitons and hence efficiency increases [31]. Many structures which were made from different active materials were checked and observed among them one is discussed below.

A. Proposed Structure

PTB7: PCBM material has been used for active layer shown in fig.2. Different parameters which include Voc, Jsc, efficiency etc of the cell were observed.

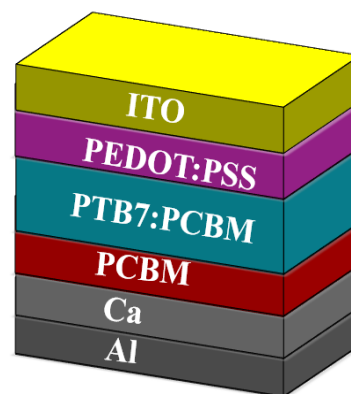


Figure 2: Structure which is made from PTB7: PCBM

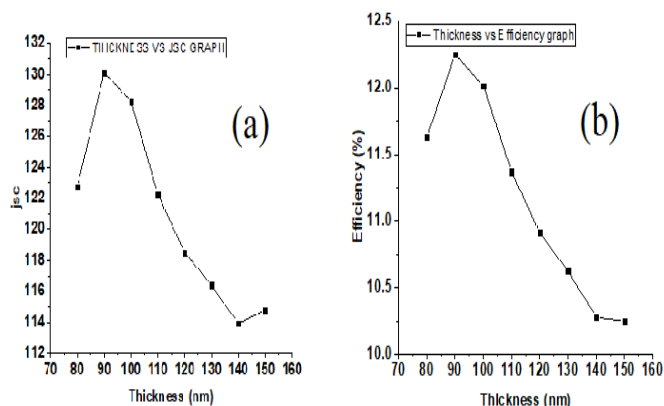


Figure 3: Variation of (a) Jsc (b) η with thickness

When thickness was increased Jsc also increases a little bit which is represented in figure 3a. When thickness was increased from 80nm to 90nm the Jsc increases from 122 to 130 m A/m² as shown in figure 3(a). Upto 90nm Jsc is increases and then it decreases, when thickness reaches to 140nm it again starts

increasing. But 90nm was selected because as for OSCs the width of active layer material should not be greater than 120nm. Also it is shown in figure 3(b) that efficiency also increases with increase in thickness of the active material. When thickness of the proposed material was increased from 80nm to 90nm efficiency increases and when thickness was further increased efficiency decreases upto 140nm. But again 90nm optimized thickness was selected for organic solar cell because further increase for the thickness of active layer is not good. The highest efficiency achieved for this structure was 12.248 at optimized thickness of 90nm.

Performance of the proposed structure was also checked for different values of temperature and is shown in figure 4. Temperature increase in interval of 25 degree was started from 200k and reached upto 450k. It was noticed that as temperature increases from 200k to 250k the efficiency of the cell increases and when further increase the temperature then efficiency starts on decreasing as shown in figure 4(a). Highest achieved efficiency was 12.24% at the optimized temperature of 250k. The effect of temperature on Voc of the cell was also checked which is shown in figure 4(b). Voc first increases with the increase in temperature upto 350k and then decrease with further increase in temperature as shown in the figure. The effect of temperature on other parameters such that fill factor was also checked and it was resulted that with the increase in temperature the performance of the cell is decreasing [37, 38].

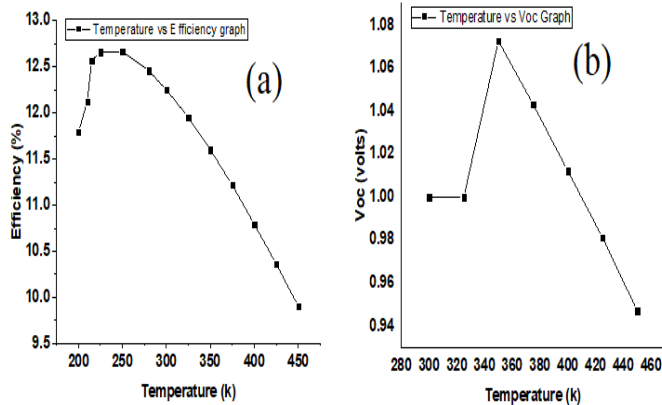


Figure 4: Effect of Temperature on (a) Efficiency (b) Voc

CONCLUSION

The central objective of this research was to obtain a high power conversion efficiency and good stability for OSCs using different substances and different morphologies. Different methods were tried to achieve high efficiency for example architecting and preparing novel electron donor and electron acceptor substances with high proton immersion ability and high mobility, designing and arranging the structure of the photo active layer materials, utilizing different layers such as buffer layers between the active layer and electrodes, designing and making new structures for devices. Different necessary layers made of different materials for cell were used. These layers are made of PEDOT: PSS, MoO₃, TiO₂, V₂O₅ etc. The results for different combinations of active layers with different electron

holes transport layers were checked. Different materials for active layer were checked and finally selected the layer of PTB7: PCBM which absorbs large number of photons and give us good power conversion efficiency. Width of active layer was also checked as well as the width of anode and cathode. Thickness of all layers were varied one by one and at the last selected thicknesses for the layers which gave good power conversion efficiency and good stability. Optimized thickness for active layer was selected which is 90nm on which it has a highest efficiency of $\eta=12.24\%$. Absorption of photons in each layer was also observed. The Recombination of electrons were observed such material was selected which allowed less number of recombination of electrons and holes. All the properties such as short circuit voltage (Voc), fill factor (FF), short circuit current density (Jsc) was observed whose values are $V_{oc}=1$ (V), $FF=94.1\%$, $J_{sc}=0.130$ (mA/m²) respectively.

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How to cite this article:

Muhammad Zeeshan, Improving Efficiency and Stability of Organic Solar Cell, *International Journal of Engineering Works*, Vol. 7, Issue 10, PP. 375-378, October 2020, <https://doi.org/10.34259/ijew.20.710375378>.

