

Effect of Variation in Temperature, Band gap and thickness of Active Layer on Efficiency of Organic Solar Cell

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Abstract—The virtual simulation of organic solar cell is carried in General purpose Photovoltaic Device Model (GPVDM) software. In this work performance of Organic solar cell is investigated. Organic solar cell is composed of 3-hexyl thiophene (P3HT:PCBM) a polymer as an active layer. The poly (3, 4-ethylenedioxy thiophene) poly (styrenesulfonate) (PEDOT:PSS) is added as an electron blocking layer and Indium Tin Oxide (ITO) film is used as top layer because of its high conductivity and very low resistance to transmission of light in visible range. GPVDM is used for light harvesting device simulations. It works on basis of Poisson's Equations to equate the device internal parameters that may be electrical or optical. Shockley-Read-Hall (SRH) formulations are used to calculate recombination and carrier trapping or mobility. In this study the temperature, band gap and active layer thickness is studied, how they affect the performance of organic solar cell. Variation in temperature inversely affects the efficiency. With increase in Band Gap efficiency also increase till band gap reaches 1.6eV, moreover increase in band gap increases efficiency but open circuit voltage value gets negative. The optimum value of active layer we got is 20nm which gives high efficiency.

Keywords— GPVDM, organic solar cell, P3HT:PCBM, PEDOT:PSS efficiency of solar cell, temperature effect, band gap effect, thickness of active layer.

I. INTRODUCTION

The photovoltaic energy is clean source of energy and the type organic photovoltaic material which is a type of photovoltaic material gets much attention in recent studies because they are much environmental friendly and a very low cost solution. On the other hand the inorganic materials which are composed of a complex in process of production as well as in equipment's usage and the conversion efficiency almost reached to its most extreme peak points and the research area in inorganic photovoltaic materials are very limited in recent studies. The organic photovoltaic devices are the most consideration devices in the most recent decade due to its applications. The organic photovoltaic materials have shown the most flexible, renewable non-preservationist energy resources [1-2]. The organic solar cell are knows as the most favorable

solar cell. The organic solar cells are considered the alternative solar cell to the inorganic solar cell [3-4]. Following benefits of organic solar cell material that include, it consist of lightweight, having mechanical flexibility and very easy to fabricate at normal temperature as well as the fabrication cost is low. The organic solar cells performances are affected by following factors which are savior that includes the low charging mobility of these materials. Due to this factor it faces very bad conductivity which directly affects its efficiency. The bulk-hetero junction achieves the highest power conversion of organic photo cell.

Many solar cell technologies have been introduced but among them the organic solar cell technology is the advanced technology that exists. A great exploration has been carried out since the exploration of organic materials for photovoltaic application a very efficient method is being made the transfer of charge between organic donors and acceptors. The bulk hetero junction (BHJ) of conjugate polymers P3HT (poly 3-hexylthiophene) and PCBM (phynyl-C70 butyric acid methyl ester) solar cells are recorded the highest performing material and the most advanced, vast and have been considered as largest research studies and investigating material [5-6]. In the organic blends the combination of the P3HT and PCBM are approaching are resent study carried out which is 6% energy- conversion efficiency [7] and 6.1% efficiency was achieved using PCDTBT and PC70BM blends. The BHJ, Bulk Hetero junction Organic Solar Cell are considered as the most generated excitations reach a nearby donor - acceptor interface, where they associate into free charge carriers (electron and hole). Harvesting efficiently excitations in BHJ solar cell will result a huge and highest possible power conversion which will result in a good efficiency output. The general impact of electronic transport component is perceived to have great impact, when thick dynamic layer films are utilized to expand light harvesting [8]. The thinner films can display nearly transformation of assimilated photon into collected carriers [9].

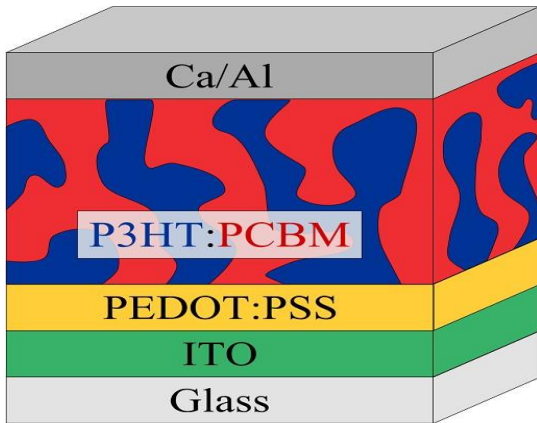


Figure1. Organic Solar Cell

II. DEVICE STRUCTURE

An electron donor polymer (P3HT) with a conjugate polymer an electron acceptor polymer (PCBM) is forming a bulk hetero-junction mixture which permits the light absorption, excitons generation and excitons splitting at the interface of donor and acceptor that is followed by systematic transport of electrons toward positive electrode and holes toward negative electrode. Two conjugate polymers are mostly mixed together to form a bulk hetero-junction. The two conjugate polymers will self-assembled into an interpenetrating system connecting the two electrodes [10]. The Bulk hetero-junction structure is of a great advantage in a way that large number of excitons reaches to nearby interface of donor and acceptor where the excitons are separated into opposite pair of charges (free charge carriers). P3HT chemical formula name 3-hexyl thiophene a polymer in hetero junction solar cell being a good material as electrons donor is a good transporter of positive charges and PCBM chemically known as [6, 6]-phenyl C71- butyric acid methyl ester is a material that can accept electrons at its best. The electrons from a molecule to another molecule are transported effectively in this way. A transparent electrode which is made of Indium Tin Oxide (ITO) film is used because of its high conductivity and very low resistance to transmission of light in visible range. For improvement of ITO work function a layer of PEDOT: PSS or poly (3, 4- ethylenedioxy thiophene) poly (styrenesulfonate) is added. The materials PEDOT: PSS layer of work function 5.2eV is used as an electron blocking layer and hole transporting layer. To block or avoid the wrong direction flow of electrons and holes this layer can be applied between active layer and electrode as a buffer layer. Following figure 2 is showing the bulky hetero junction organic solar cell structure.

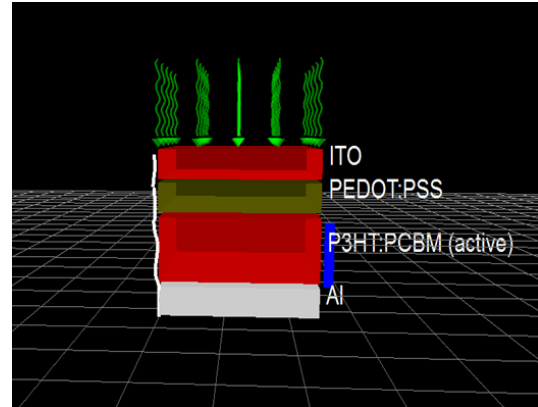


Figure2. Bulk Hetero junction solar cell

III. METHADODOLOGY

In this research work, the bulk hetero junction solar cell is designed by the GPVDM software to study the I-V characteristics at active layer thickness and temperature. The simulation parameters are shown in table 1.

TABLE 1. PARAMETERS FOR SIMULATIONS

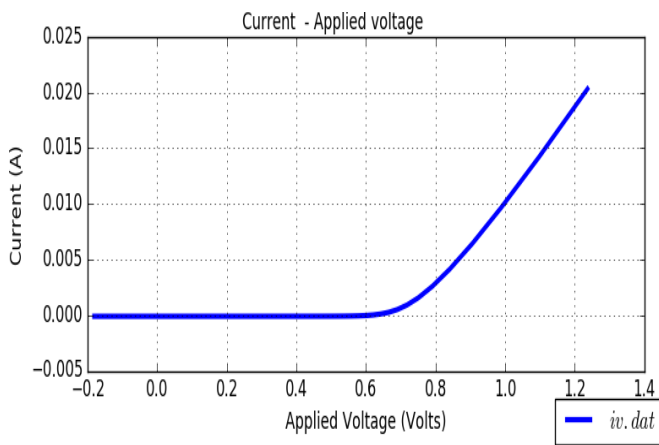
Sr.No	Parameters	Values	Units
1	Electron trap density	3.8×2610	-3-1m eV
2	Hole trap density	1.45×10^{25}	-3-1 m eV
3	Electron mobility	2.48×10^{-7}	m ² V-1S-1
4	Hole mobility	2.48×10^{-7}	m ² V-1S-1
5	Trapped electron to free electron	2.5×10^{-20}	m-2
6	Trapped hole to free electron	4.67×10^{-26}	m-2
7	Free electron to trapped electron	2.5×10^{-20}	m-2
8	Free hole to trapped hole	4.86×10^{-22}	m-2
9	Temperature	300	K
10	Shunt resistance	1.9×10^5	Ω
11	Device breadth	0.003464	M
12	Device width	0.003464	M
13	ITO (electrode) thickness	1×10^{-7}	M
14	PEDOT:PSS layer thickness	1×10^{-7}	M
15	P3HT:PCBM layer thickness	2×10^{-7}	M
16	Aluminum (electrode) thickness	1×10^{-7}	M

A. Effect of Active Layer Thickness on Efficiency

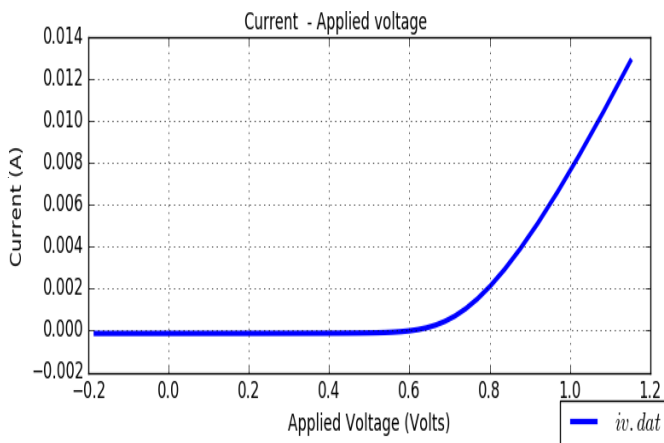
In this work, the simulation was run twice; the first for different P3HT: PCBM set layer thickness and the second for different set of temperature. During the first simulation process, the thickness layer of organic solar cell (P3HT: PCBM) was optimized varying it from 50nm to 400nm in a step of 50nm, i.e. the thickness that gives the highest efficiency of 4.59% is 200nm.

TABLE 2. SOLAR CELL PARAMETERS FOR DIFFERENT ACTIVE LAYER THICKNESS

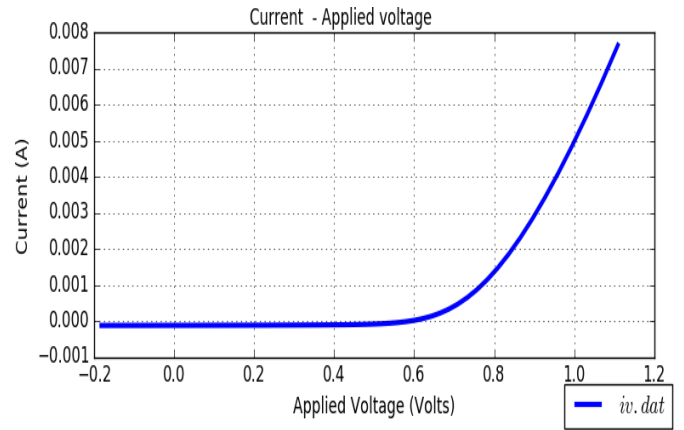
Thickness (nm)	Voc	FF	MPP	Conversion efficiency %
50	0.621	0.78	31.6	3.16
100	0.611	0.76	37.3	3.73
150	0.602	0.72	36.2	3.62
200	0.604	0.68	45.9	4.59
250	0.598	0.65	41.7	4.17
300	0.592	0.62	38.3	3.83
400	0.585	0.57	36.9	3.69



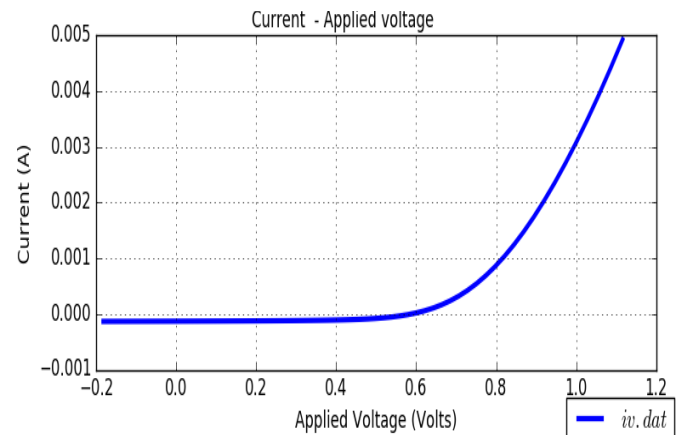
(A)



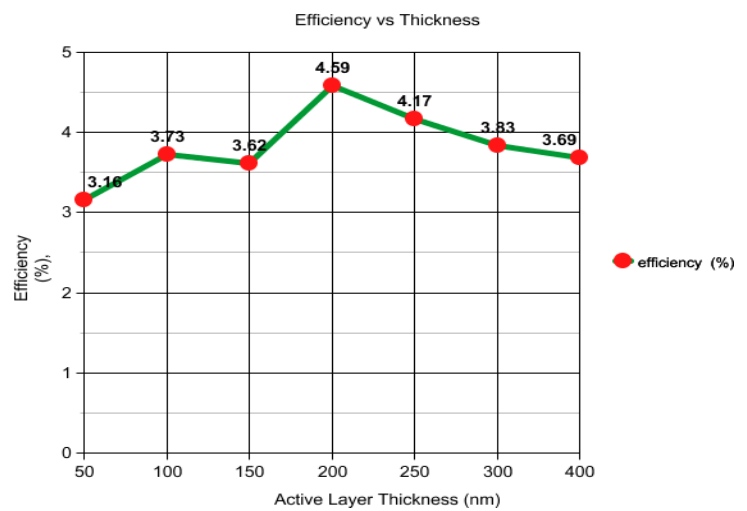
(B)



(C)



(D)



(E)

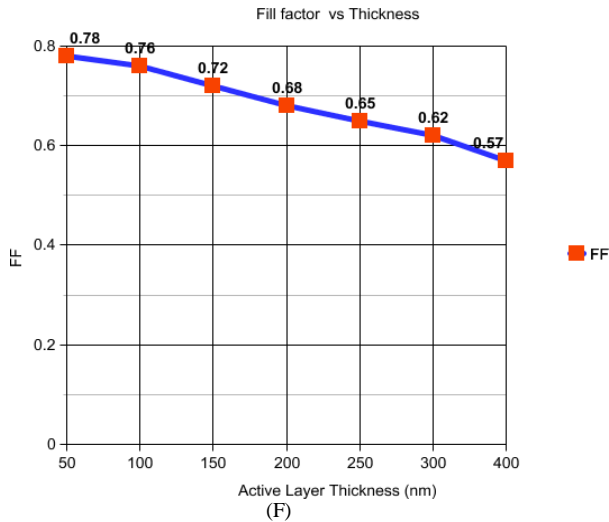


Figure 3. Current-Voltage (I-V) curves with different active layer thickness: (A) 1×10^{-7} m (B) 2×10^{-7} m (C) 3×10^{-7} m (D) 4×10^{-7} m (E) Active layer thickness Vs efficiency (F) Active layer thickness Vs fill factor

B. Effect of Temperature on Efficiency

The optimal thickness obtained in the first simulation was used in the second simulation. Here the temperature was varied from 300K to 350K in a step of 10 K.

TABLE 3. SOLAR CELL PARAMETERS FOR DIFFERENT TEMPERATURE VALUES

Temp (K)	Voc	FF	MPP	Conversion efficiency %
300	0.604	0.681	45.92	4.59
310	0.593	0.687	45.54	4.55
320	0.582	0.688	44.87	4.48
330	0.570	0.691	44.25	4.42
340	0.560	0.690	43.43	4.34
350	0.548	0.692	42.62	4.26

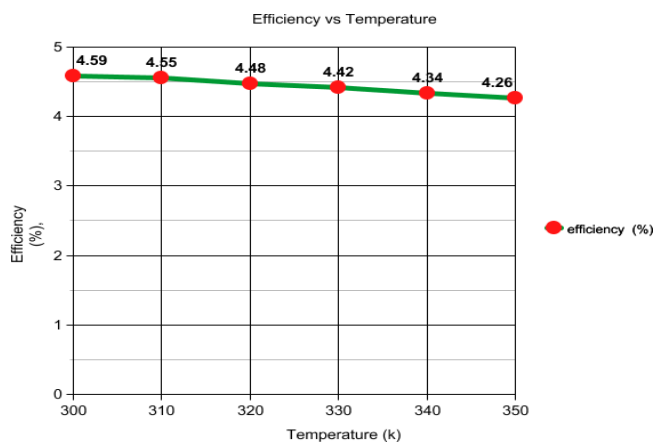


Figure 4. Effect of temperature variation on efficiency

C. Effect of Band gap on Efficiency

The P3HT: PCBM based organic solar cell simulated with GPVDM and performance of varying active layer band gap vs The allowed band gap (E_g) of P3HT: PCBM is

around 1.9 eV, but limit the absorbance to below a wavelength of about 650 nm. From the simulation we identified that varying P3HT: PCBM band gap, short circuit current density (J_{sc}) remains constant and not effected by E_g . Also other parameters studied such as open circuit voltage (V_{oc}) fill factor (FF) and efficiency. V_{oc} increases linearly as the band gap increases. The band gap of active layer is varied from 1.1ev to 1.5ev as shown in figure and a great improvement in efficiency has been achieved. When E_g passes from 1eV to 1.5ev the fill factor reaches a maximum value of 0.74.

TABLE 4. SOLAR CELL PARAMETERS FOR DIFFERENT BAND GAP VALUES

Band gap (E_g)	Voc	FF	Efficiency %
1.1	0.60	0.67	4.5
1.2	0.70	0.69	5.4
1.3	0.80	0.71	6.4
1.4	0.90	0.73	7.4
1.5	1.02	0.74	8.4

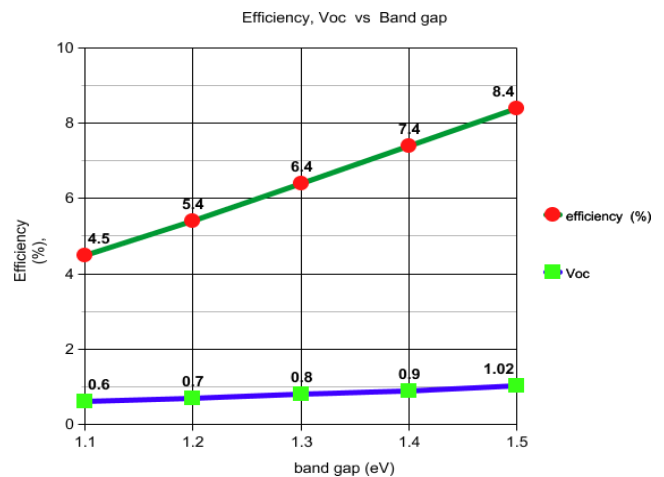


Figure 5. Effect on Efficiency and Open circuit voltage with band gap variation

CONCLUSION

In this work, the P3HT: PCBM based organic solar cell has been studied in ITO/PEDOT: PSS/P3HT: PCBM/Al structure. The simulation was carried out by GPVDM software. The output characteristic I-V curve of organic photovoltaic cell was simulated. The efficiency of device increases as the active layer thickness increases. The optimum thickness layer is 2×10^{-7} m at which efficiency is 4.59%. while the fill factor FF decreases with increase in active layer thickness. Highest fill factor (FF) at active layer thickness of 1×10^{-7} m.

The influence of device temperature also deliberate and the optimal working temperature was found to be 300 K, where power conversion efficiency and FF are 4.59 % and 0.68 respectively. As the temperature of device increases, efficiency and open circuit voltage (V_{oc}) slightly fall down. We noticed a considerable improvement in efficiency with band gap energy increase, at which the efficiency reaches a value of about 8.4%. So as a result it is better to use that material in which energy gap is higher so high efficiency of organic solar cell is achieved.

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