

# Experimental Prediction of Effect of Thickness of Active Layer of Photovoltaic Device on a series of Electrical Parameters using GPVDM Software

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**ABSTRACT:** Electrical simulation at different thickness of active layer of organic photovoltaic devices has been encountered by using GPVDM software. P3HT-PCBM composite material has been selected as active material whereas ITO, PEDOT:PSS and Al has been chosen as front and back electrodes respectively. A comparative study of different electrical parameters has been estimated at different layer thickness. It is found that electrical parameters are strongly affected by active layer width. Current conduction is also influenced strongly with thickness of active layer.

**KEYWORDS:** Organic solar cell, thickness, GPVDM, efficiency, Bulk heterojunction

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## 1. INTRODUCTION

Modern civilization is facing on a strong challenge to fight with the luck of conventional energy sources. Moreover, greenhouse gas emission, burning of fossil fuel, impact of global warming and related issues for which human civilization is responsible enough, are now threatening seriously the Earth life. So researchers are now thinking about some alternative way to get rid of such problem. Therefore, renewable energy sources become very important day by day which leads to the concept of organic solar cell. There are several advantages of using organic solar cell over inorganic one because of their huge availability, low cost maintenance, easy sample preparation technique flexibility etc [1-5]. But still the devices are facing some limitation about their rapid usage and development. Since organic substances are amorphous and disordered in nature, this disordered nature inherently generates trapping problem at the bulk region of the device. Conducting charges are getting trapped at the trap center of the device during conduction. Lowering of conductivity enhances the effect of high resistance. High resistance is a very important parameter which has direct influence on fill factor as well as on efficiency. Due to the high value of series resistance efficiency of organic solar cells is very low. Deschler et al [6] gives a very interesting result of their research that conductivity of the conjugated polymers in active regime can be enhanced by doping. Bulk

Heterojunction (BHJ) formed by incorporation of a conjugate polymer & electron accepting molecules are said to be constitute an active layer that permits maximum absorption of incident light[7-9]. That point of view leads researchers to a very interesting point of research to analyze the device structure of OPV. From above discussions power conservation efficiency should also be dependent on the width of active layer thickness. In the present work, J-V Characteristics of solar cell at several active layer thicknesses has been measured and change of device efficiency at different thickness value has been encountered by using simulating software GPVDM (General Purpose Photovoltaic device model). Dependence of other electrical parameters like open circuit voltage, short circuit current, maximum power at output and fill factors are also measured at those considered layer thickness value [10-12]. The present work is fruitful to enrich the knowledge about the enhancement of solar cell device efficiency and further progressive attempt to improve the device related parameters.

## 2. BULK HETEROJUNCTION SOLAR CELL

Bulk heterojunction solar cell structure has been depicted in Figure 1. PEDOT:PSS and P3HT:PCBM has been sandwiched between Front electrode ITO and back electrode Al. PEDOT:PSS works as buffer layer whereas P3HT:PCBM works as an active layer. Because of high transmittance in visible regime and capability

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of conduction, Indium Tin Oxide (ITO) film is chosen as front electrode and Al metal as back electrode for easy charge collection[13-14].

Donor-acceptor blend of active composite material permits absorption of light and exciton generation. Splitting and hence conduction of generated electrons occur across the interfacial layer of donor-acceptor at

the bulk regime of active material. Here P3HT and PCBM cats as excellent electron donor and electron acceptor respectively. PEDOT:PSS works as a blocking later of wrong directional movement charges so that it is used as a buffer layer between electrodes and active layer.

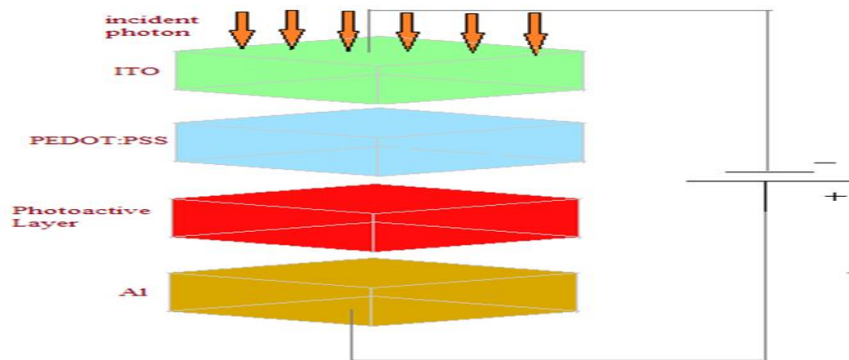


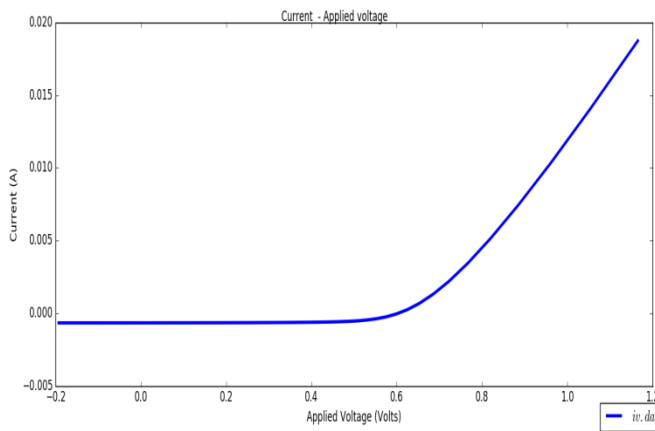
Fig.1. Schematic diagram of Organic Photovoltaic device

### 3. RESULT AND DISCUSSION

Programming of simulation works of the formed device has been experimented for different device active layer thickness. The simulation has been run

using GPVDM (General Purpose Photovoltaic Device Model) software. Performance of electrical simulation of the device covers active layer of such device.

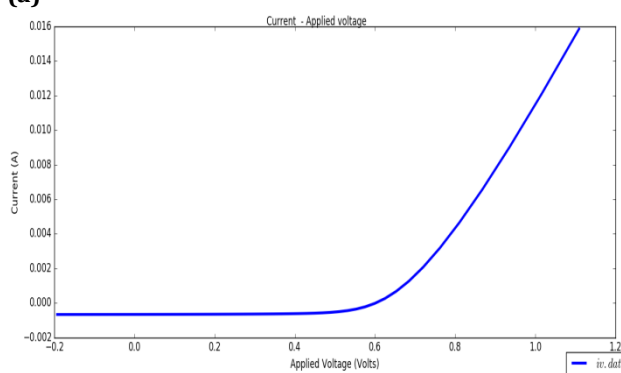
DoS distribution	exponential	au
Electron trap density	3.8e26	m <sup>-3</sup> eV <sup>-1</sup>
Hole trap density	1.45e25	m <sup>-3</sup> eV <sup>-1</sup>
Electron tail slope	40e-3	eV
Hole tail slope	60e-3	eV
Electron mobility	2.48e-7	m <sup>2</sup> V <sup>-1</sup> s <sup>-1</sup>
Hole mobility	2.48e-7	m <sup>2</sup> V <sup>-1</sup> s <sup>-1</sup>
Relative permittivity	3.8	au
Number of traps	20	bands
Free electron to Trapped electron	2.5e-20	m <sup>-2</sup>
Trapped electron to Free hole	1.32e-22	m <sup>-2</sup>
Trapped hole to Free electron	4.67e-26	m <sup>-2</sup>
Free hole to Trapped hole	4.86e-22	m <sup>-2</sup>
Effective density of free electron states	1.28e27	m <sup>-3</sup>



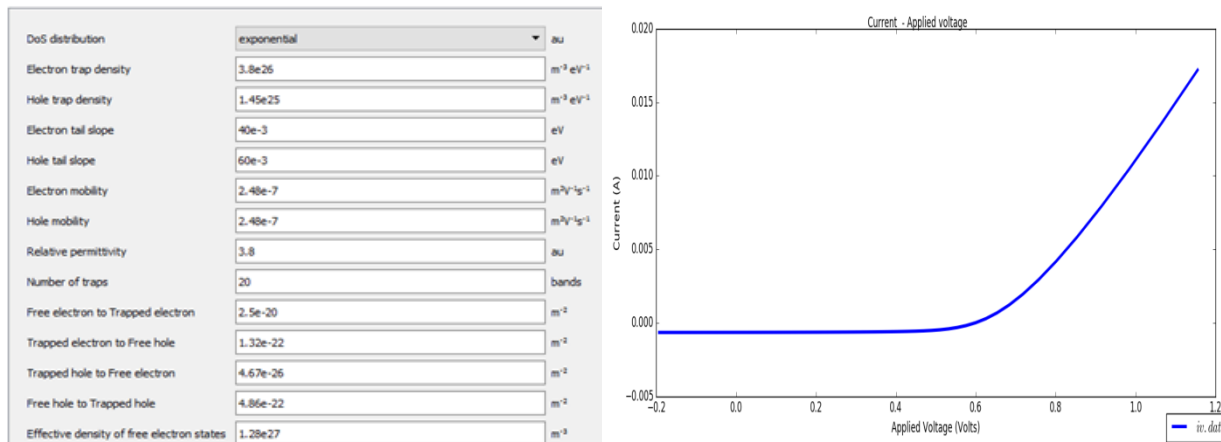
(a)

DoS distribution	exponential	au
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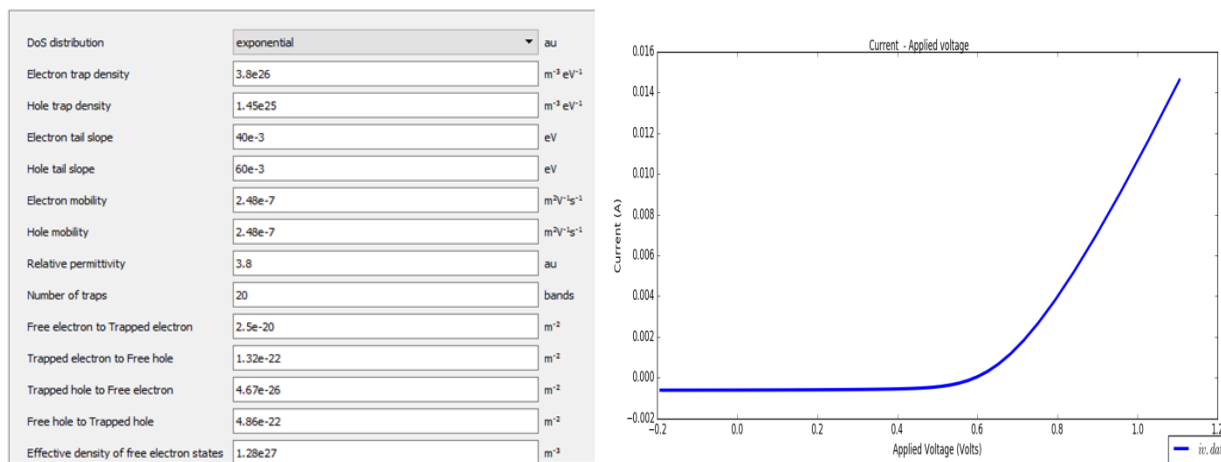
(b)



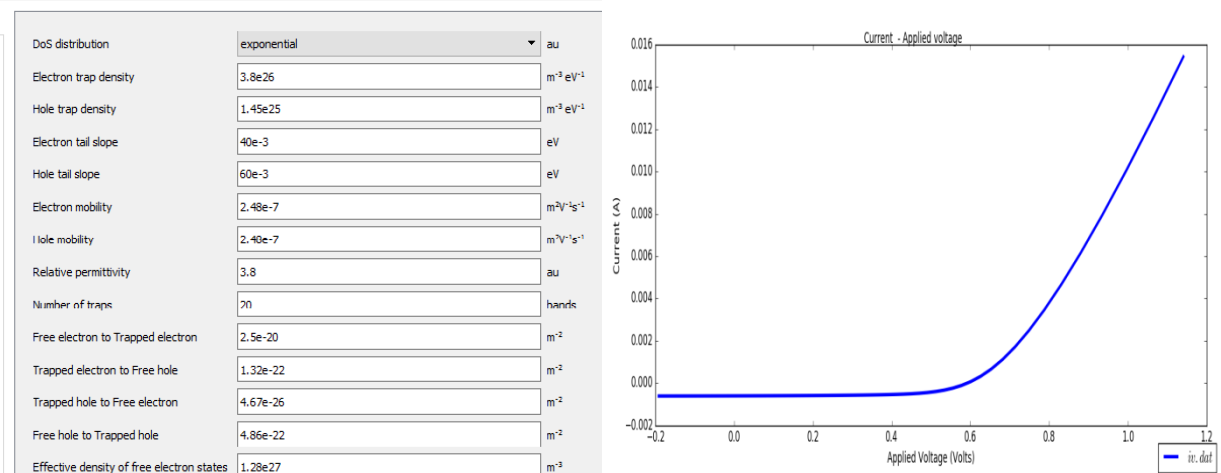
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(c)



(d)



(e)

Fig. 2 simulation data and corresponding I-V characteristics of (a) 200nm (b) 220 nm (c) 240 nm (d) 260 nm and (e) 280 nm

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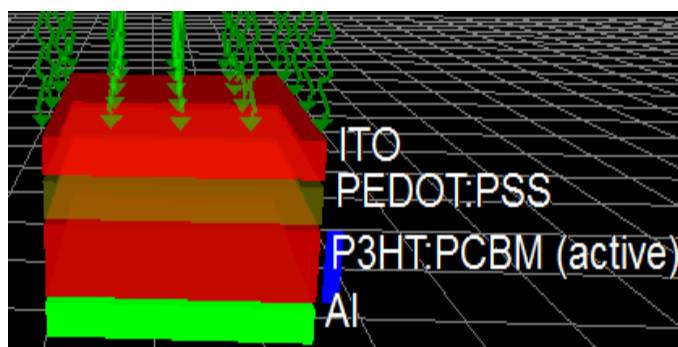


Fig.3 schematic representation of the device in GPVDM

Table 1 Output parameters at different thickness of active layer

Layer thickness(m)	$V_{oc}$	$J_{sc}$	$P_{max}$	$P_{max}$ (voltage)	Fill factor	Device efficiency
$2.0 \times 10^{-7}$	0.604	-111.59	45.93	0.489	68.11	4.59
$2.2 \times 10^{-7}$	0.602	-111.64	45.12	0.469	67.12	4.51
$2.4 \times 10^{-7}$	0.599	-109.92	43.51	0.469	65.97	4.35
$2.6 \times 10^{-7}$	0.595	-102.51	39.53	0.470	64.81	3.95
$2.8 \times 10^{-7}$	0.592	-102.13	38.47	0.449	63.53	3.84

The software has been simulated for different layer thickness ranges between 200nm to 280nm. Range of thickness has been selected for better optical sensitive response. Light absorption cannot be found satisfactory for very thin active layer composition below the range of 200nm and over 300nm thickness frequent charge transport in the mentioned layer is getting hampered due to highly disordered nature of organic materials. Selection of effective thickness is an important issue of photovoltaic measurement. The J-V characteristics and other conducting parameters have been obtained for different layers. Effect of active layer thickness on device efficiency has been encountered. Other electrical parameters like short circuit current ( $J_{sc}$ ), open circuit voltage ( $V_{oc}$ ), maximum power ( $P_{max}$ ), fill factor has also been obtained. Output of the simulation work has been given in the Table below.

It has been found that the device efficiency is maximum for 200 nm device layer thickness and efficiency reduces consequently with increasing thickness of active region. For minimum thickness of active layer the blocking impact of charges is minimum and conducting charges travel a minimum conducting path which inherently reduces the trapping problem [14-17]. Due to the lower effect of trapping energy series resistance effect for abovementioned layer thickness is small enough which enhance the probability of maximum conduction and therefore maximum efficiency is obtained.

#### 4. CONCLUSION

GPVDM software has been introduced for characterization of I-V relationship of organic photovoltaic device at different active layer thickness.

Electrical parameters of the device have been analyzed using the mentioned software. It has been found that electrical parameters like  $V_{oc}$ ,  $J_{sc}$ ,  $P_{max}$  strongly depends on layer thickness. Experimental data reveals that device efficiency decreases with increasing thickness value of active layer. Maximum efficiency has been achieved at 200 nm layer thickness due to small effect of series resistance.

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