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Electrical Simulation of Organic Solar Cell at Different Series Resistances and Different Temperatures

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Abstract: *The bulk heterojunction organic solar cell has been electrically simulated by OPVDM software at different series resistances and different device temperatures. Organic bulk heterojunction solar cell consists of mixture of P3HT and PCBM as active layer materials, ITO is a transparent electrode, PEDOT: PSS is electron blocking layer and Al is a back electrode. In this study the electrical simulation has been done at different series resistances 1Ω, 2Ω, 3Ω, 4 Ω and 5Ω, and different device temperatures 250K, 275K, 300K, and 350K respectively. We observed that J-V characteristics are affected by the series resistance and device temperature. The best J-V characteristic is obtained at 300K temperature and 1Ω series resistance.*
Key words: *OPVDM software, Series resistance, temperature, Bulk heterojunction, Organic solar cell.*

I. Introduction

Organic semiconductors have proved to be quite different material for organic solar cell as they have applications for thin, flexible, light weight, and low cost fabrication [1]. Organic solar cells offer considerable promise for use in new solar energy technology due to their flexible material properties and low –cost manufacture [2]. Organic Solar cells based on a bulk heterojunction (BHJ) of conjugate polymers P3HT (poly 3-hexylthiophene) and PCBM (phynyl-C_{61} butyric acid methyl ester) have been reported amongst the highest performing material and has been considered as the largest in researchers investigation and studies [3-8] for improving their power conversion efficiencies.

Bulk heterojunction (BHJ) formed by an interpenetrating of a conjugate polymer and electron accepting molecules constitute a very promising route towards cheap and versatile solar cells [9-10] as recently demonstrated in progress of automated roll-to-roll processing and solar cell stability [11-12].The photovoltaic performance of the combination of P3HT and PCBM in organic blends has recently increased approaching 6% energy- conversion efficiency [13] and 6.1% efficiency was achieved using PCDTBT and $PC_{70}BM$ blends. In BHJ solar cell series resistances (Rs) has been identified as one of the key parameters affecting the J-V characteristics performance of organic photovoltaic devices through reduction of solar efficiency and fill factor [14]. For large series resistance values of the short current might decreases. The value of Rs estimated from the current – voltage, J-V curve slope at large forward voltage, when the current flow is not longer limited by the internal carrier recombination but by the potential drop at, ITO (indium tin oxide as transparent electrode) and carrier transporting inter layers of different kind could increase Rs significantly. Interfaces between the active layer material and inter layers (metallic contact) may well add more resistance in series because of partial energy level alignment which affects optimal interface charge transfer. The overall effect of electronic transport mechanisms is identified to have dramatic effect when thick active layer films are used to enhance light harvesting [15], while thinner films are able to exhibit almost conversion of absorbed photon into collected carriers [16]. Thus it is indicating that transport mechanism do-not limit the realizable photocurrent [17], thicker active material layer devices suffer from an incomplete collection of photo -generated charges. It is also known that in real devices the sole analysis of the J-V characteristics not does help discerning, which series mechanism is effectively dominating series resistance (Rs). Therefore the overall performance might be improved by librating operating mechanisms involved in series resistance increases. Here we found the electrical simulation of bulk heterojunction (BHJ) solar cell using OPVDM (organic photovoltaic device model) software at different series resistance and different temperatures.

II. Bulk Hetero Junction

Bulk heterojunction is a mixture of interpenetrating mixture of electron donor (P3HT) and electron acceptor conjugated molecules (PCBM) that allows absorption of light, generation of excitons, splitting of excitons at donor-acceptor interface, and efficient transport of positive and negative charges to opposite electrodes. Bulk heterojunction are mostly created by forming a containing two conjugate polymers, casting and then allowing separating the two phases, usually with the help of annealing step. The two conjugate polymers will self assembled into an interpenetrating network connecting the two electrodes [18]. The structure of bulk heterojunction solar cell is shown in fig.1.

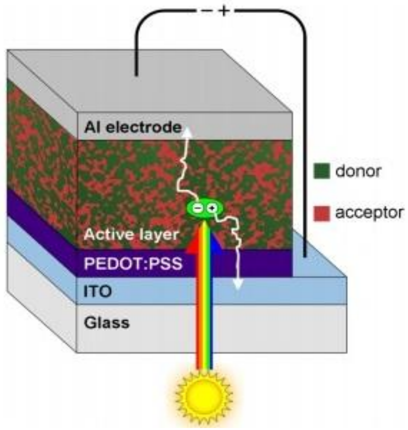

Fig. 1: Bulk Heterojunction solar cell

In ITO/PEDOT: PSS/P3HT : PCBM/Al organic bulk heterojunction solar cells, P3HT (3-hexyl thiophene) is a good electron donor material that effectively transports positive holes, PCBM ([6,6]-phenyl C_{61}-butyric acid methyl ester) is a good electron acceptor materials. It effectively transports electrons from molecule to molecule. The Indium Tin Oxide (ITO) film is used as a transparent electrode. Since, it has high transmittance in visible region and ability of conduction. PEDOT: PSS or poly (3,4-ethylenedioxythiophene) poly (styrenesulfonate) is a electron blocking layer, which may be used as buffer layers between the electrodes and active layer to block the electron and hole transfer in the wrong direction.

III. Electrical Simulation

Bulk heterojunction solar cell ITO/PEDOT:PSS/P3HT:PCBM/Al is simulated by the OPVDM software at different series resistance of the device. OPVDM software is specifically designed to simulate bulk heterojunction organic solar cells, such as those based on the P3HT: PCBM material. This model contains both an electrical and optical properties, enabling both current- voltage characteristics to be simulated as well as optical properties [19-20]. The electrical simulation only covers the active layer of the device. In this model there are two types electrons (holes) involve, free electrons (holes) and trapped electrons (holes). Free electrons (holes) have a finite mobility of μ_e^0 (μ_h^0) and trapped electrons (holes) cannot move at all and have a mobility of zero. To calculate the average mobility, it will be better to take the ratio of free to trapped carriers and multiply it by the free carrier mobility.

$$\mu_e(n) = \frac{\mu_e^0 \, n_{free}}{n_{free} + n_{trap}}$$

Thus if all carriers were free the average mobility would be μ_e^0 and if all carriers were trapped the average mobility would be zero. It should be noted that only μ_e^0 μ_h^0 are used in the model for computation and using μ_e (n) is an output parameter. The electrical simulation window is shown in fig 2.

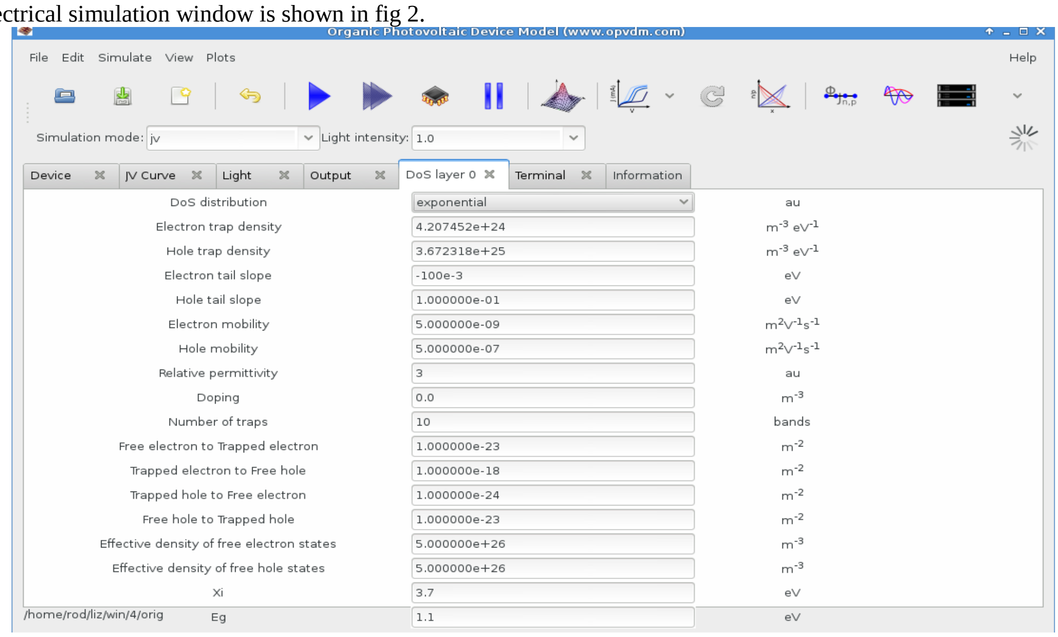

Fig. 2: OPVDM Electrical Simulation window

IV. Result And Discussion

In the present study, we found the J-V characteristics at different series resistances and temperatures of ITO/ PEDOT:PSS/ P3HT : PCBM/ Al, bulk heterojunction solar cell designed by the OPVDM software. The Illumination J-V characteristics are simulated at different resistances 1Ω, 2Ω, 3Ω, 4Ω and 5Ω. The J-V characteristics are shown in the fig.3. It is clear from the figure-3 that the short circuit current and voltage change with increase in resistance the current density is maximum at 4 Ω and it is minimum at 3Ω. The active area makes the photo generated current travel a longer distance, before it is collected at the electrodes. Specifically, the position of the contacts in the device, here the causes of current flow primarily in the x-direction, so resistance should depend only on the length of the device. In this research work a thick grid will be applied to maintain a low effective resistance of the ITO even as the area of the solar cell becomes large. This is shown in fig. 3.

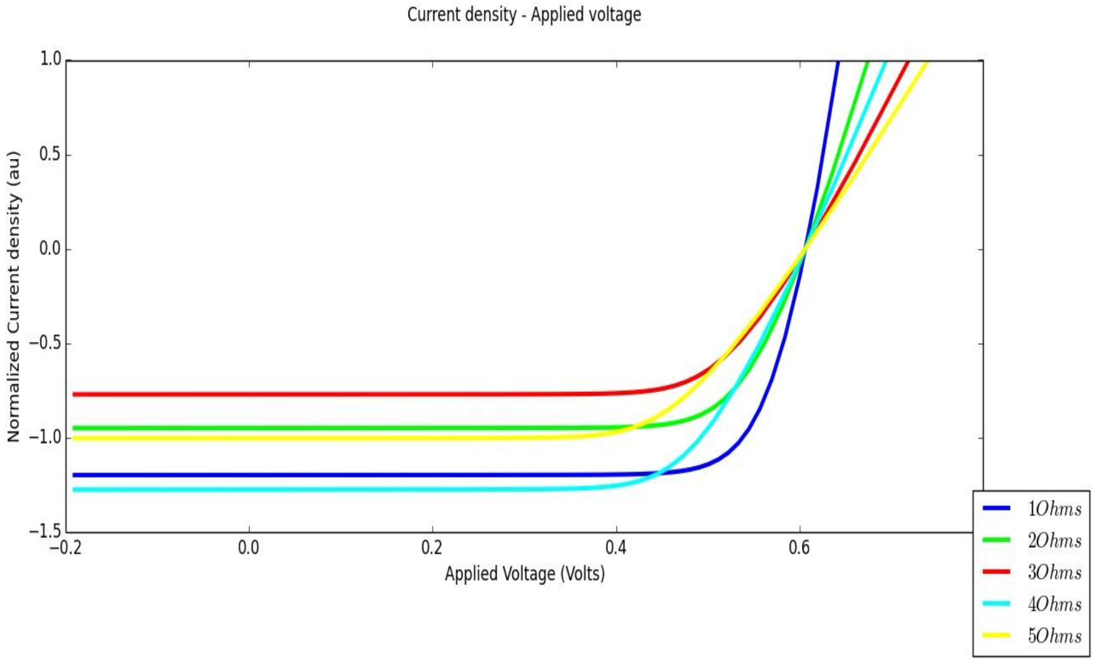

Fig. 3: J-V characteristics at diff. series resistance 1Ω, 2Ω, 3Ω, 4Ω, 5Ω

The illumination J-V characteristics are simulated at different temperatures 225K, 250K, 275K, 300K, and 350K, which is shown in fig. 4. It is clear from the J-V characteristic curves that the short current density is maximum at temperature 300K and minimum at temperature 225K and 250K. The primary cause of temperature dependence is not certain but possible reasons includes a decrease in excitons diffusion length or charge mobility with temperature, a thermal component to excitons dissociation, or charge in absorption with temperature. The change in J-V characteristics may also be related to changes in mobility or additional barriers at contacts that may become important at low temperature, shown in fig. 4.

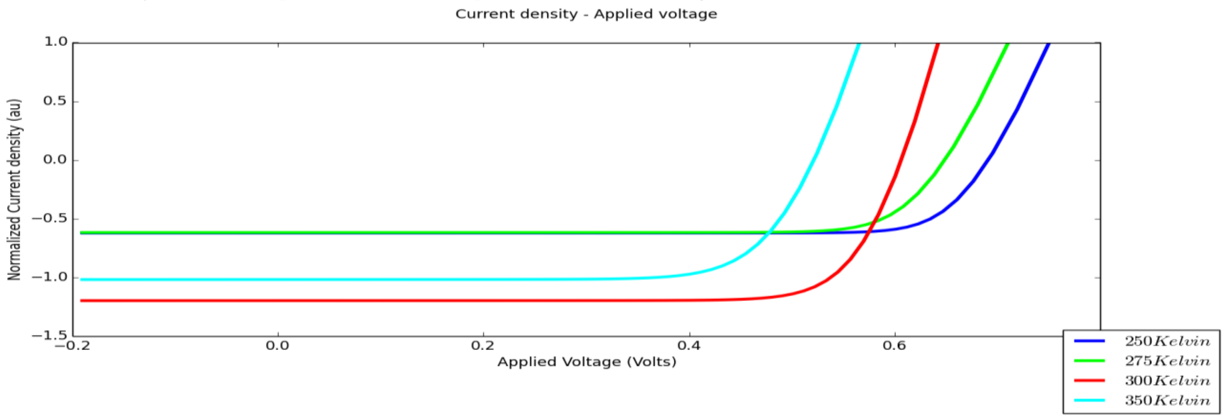

Fig. 4: J-V characteristics at device diff. temp. 250k, 275k, 300k, 350k

V. Conclusion

In this work, we studied electrical simulation of the P3HT: PCBM based bulk heterojunction solar cell. It is concluded that the J-V characteristics of organic solar cell vary for different series resistances and different device temperatures. At 1Ω resistance and 300K temperature, we get smooth curve at which the maximum efficiency is obtained. It has been shown by using different cathode contacts that high frequency resistances only depends on the active layer blend composition, and not on the outer contact structure. It is clear by the result that the series resistance and temperature is affected the J-V characteristics of organic solar cell.

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