

Electrical Simulation of Organic Solar Cell at Different Charge Carrier Mobility

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Abstract: The organic photovoltaic device has been electrically simulated by GPVDM software model at different charge carrier mobility. Organic bulk heterojunction solar cell consists of the mixture of electron donor (P3HT) and electron acceptor (PCBM) materials as active layer, ITO (indium tin oxide) 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 charge mobility $0.5 \times 10^{-4} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$, $0.5 \times 10^{-5} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$, $0.5 \times 10^{-6} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$ and $0.5 \times 10^{-7} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$ respectively. It is observed that J-V characteristics are affected by charge carrier mobility and it is concluded that the best J-V characteristic is obtained at $0.5 \times 10^{-6} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$ carrier mobility.

Keywords: GPVDM software, Bulk heterojunction, Organic solar cell, charge carrier mobility

I. Introduction

Photovoltaic cell is the electronic device that converts sun light directly into the electrical energy. Now day's organic photovoltaic (OPV) devices attract more and more interest for researchers. Organic semiconductors have proved to be quite different material for organic solar cell, as these have applications for thin film structure, room temperature processing, flexible substrate, 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) composites of conjugate polymers P3HT (poly 3-hexylthiophene) and PCBM (phynyl-C₇₀ butyric acid methyl ester) that allow the maximum absorption of light and have been reported among the highest performing material for researchers investigation and studies [3-8] for improving their power conversion efficiencies. In organic solar cell, bulk heterojunction (BHJ) formed by an interpenetrating of a conjugate polymer and electron accepting molecules constitute a very promising route towards cheap and flexible solar cells [9-10] as recently exhibited in progress of automated roll-to-roll processing and solar cell stability [11-12]. The energy conversion efficiency of bulk heterojunction solar cell based on P3HT and PC₇₀BM organic materials is nearly 6% and 6.1% efficiency achieved when using PCDTBT and PC₇₀BM organic materials. The advantage of the BHJ structure is that the maximum photons are absorbed by the active layer and most of the generated excitons (electron-hole pair) reach a nearby donor - acceptor interface where they dissociate into free charge carriers (electrons and holes). These efficient excitons harvesting leads to higher power conversion efficiencies for BHJ solar cells. In BHJ solar cell the mobility is identified as one of the key factor, which affects j-v characteristics of organic photovoltaic devices through reduction of the efficiency of solar cell and fill factor [14]. The overall result of electronic transport mechanisms is recognized to have a good effect when thin active layer films are used to increase for the harvesting of light [15]. While thin films of the active materials are able to exhibit almost conversion of absorbed photon into collected charge carriers [16]. For organic solar cell, in case of blends, it was assumed that the electron and hole mobility should be used. It has been observed that the charge carriers mainly governed by the recombination process in the blends, since the fastest charge carriers cannot cross the interface due to the energy between the donor and acceptor, it must wait for the slowest carriers in order to recombine [17]. The organic solar cell has two competing process, extraction and recombination of the charge carriers, both process are conducted by the mobility of the charge carrier. As increase charge carrier mobility would have a positive effect on transport, facilitating extraction, but on other hand it increases the bimolecular recombination. In this research article, we study the dependence of solar cell j-v characteristics on charge carrier mobility. We found electrical simulation of bulk heterojunction (BHJ) solar cell using GPVDM (General purpose photovoltaic device model) software at different charge mobility.

Bulk heterojunction:

In an organic solar cell, Bulk heterojunction is a mixture of interpenetrating of electron donor (P3HT) and electron acceptor conjugated molecules (PCBM) that allows light absorption, generation of excitons,

excitons splitting at donor-acceptor interface and efficiently transportation of positive and negative charges to opposite electrodes. Bulk heterojunction are mostly governed by forming a containing the two semiconductor organic materials, casting and then allowing separating the two phases, usually with the help of annealing process. The two conjugate organic materials will self assembled into an interpenetrating system connecting the two electrodes [18]. The structure of bulk heterojunction ITO/PEDOT:PSS/ P3HT:PCBM/ Al solar cell is shown in figure-1 (a,b).

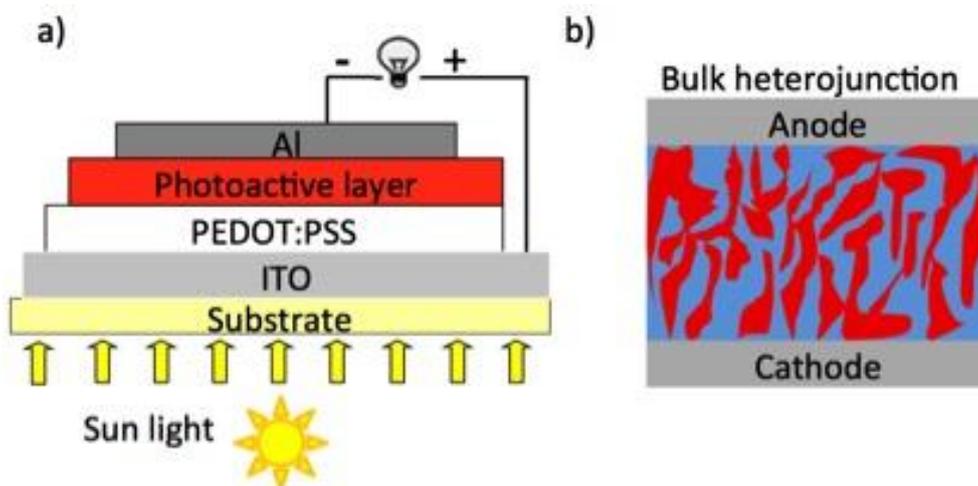


Figure- 1(a, b) Bulk Heterojunction solar cell

In ITO/PEDOT: PSS/P3HT: PCBM/Al bulk heterojunction solar cells, the active layer material P3HT (3-hexyl thiophene) is a good electron donor that effectively transports positive holes and PCBM ([6, 6]-phenyl C₆₁-butyric acid methyl ester) is a good electron acceptor. It efficaciously transports electrons from molecule to molecule. The Indium Tin Oxide (ITO) film is used as a transparent front electrode. Since, it has high transmittance in visible region and ability of conduction. PEDOT: PSS or poly (3, 4-ethylenedioxythiophene) poly (styrenesulfonate) is an electron blocking layer. PDOT: PSS may be used as buffer layers between the electrodes and active layer to block the electron and hole transfer in the wrong direction.

Electrical Simulation:

Bulk heterojunction solar cell ITO/PEDOT: PSS/P3HT: PCBM/Al is electrically simulated by the GPVDM software at different charge carrier's mobility. GPVDM software is specifically developed for the simulation of bulk heterojunction solar cells, which is based on the P3HT: PCBM materials. The model contains two types of properties like as electrical and optical; permitting 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 electrical model, there are two types charge carriers like as electrons (holes), free electrons (holes) and trapped electrons (holes). The 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 find the average mobility of the charge, the ratio of free to trapped carriers will multiply by the free carrier mobility then we found the equation

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

Thus if all the charge carriers were free the average mobility would be μ_e^0 and if all charge 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 $\mu_e(n)$ is an output parameter.

The electrical simulation window is shown in figure- 2.

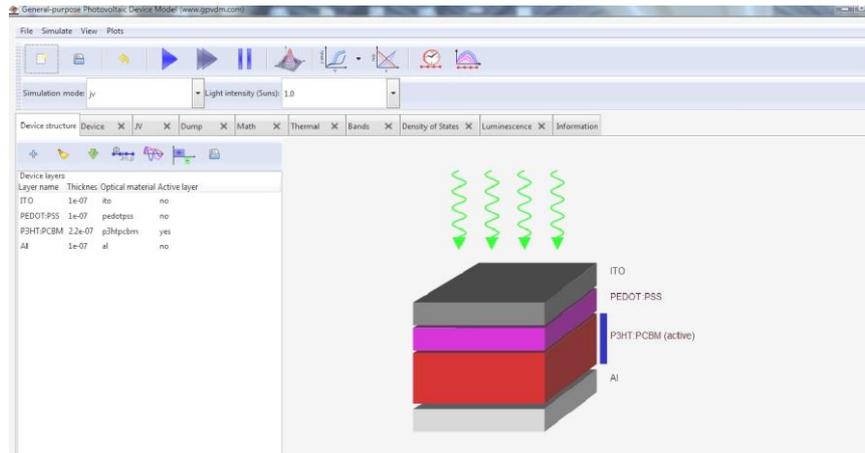


Figure- 2 GPVDM, Electrical Simulation window

II. Result And Discussion

In this research paper, we found the dependence j-v characteristics of solar cell at different charge mobility. In BHJ solar cell, in which the blend is treated as one effective medium with an effective band-gap given by LUMO (lowest unoccupied molecular orbit) of acceptor and HOMO (highest occupied molecular orbit) of donor [21]. We concluded that the best solar cell efficiencies are achieved in mobility range 10^{-6} to $10^{-4} \text{ m}^2\text{v}^{-1}\text{s}^{-1}$. For higher mobility, the efficient extraction of carriers strongly reduces the steady states charge carrier density leading to a reduction of the open-circuit voltage. The j-v characteristics curves at different electron and hole mobilities are shown in the figure- 3 & 4.

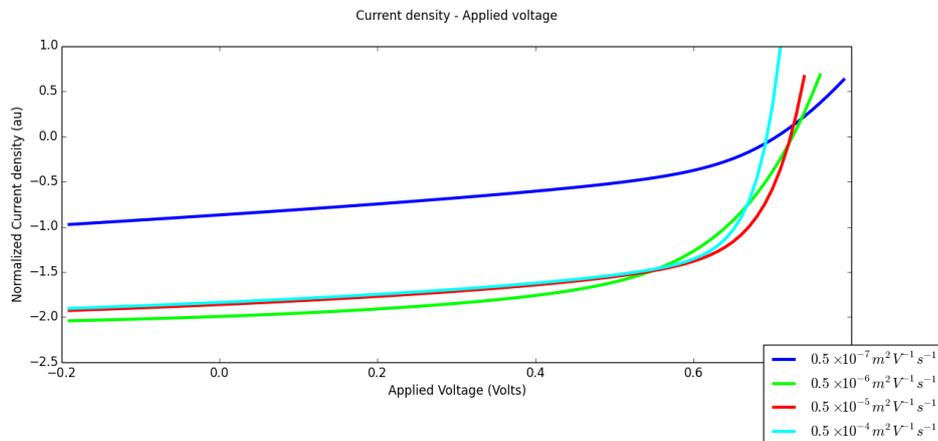


Figure- 3 J-V Characteristics at different electron mobility 0.5×10^{-4} , 0.5×10^{-5} , 0.5×10^{-6} , 0.5×10^{-7}

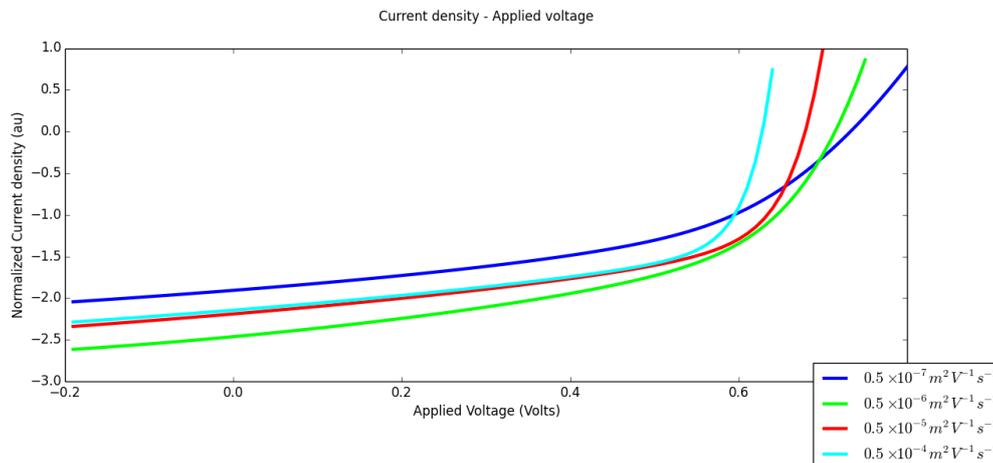


Figure- 4 J-V Characteristics at different hole mobility 0.5×10^{-4} , 0.5×10^{-5} , 0.5×10^{-6} , 0.5×10^{-7}

III. Conclusion

In this research work, the electrical simulation of the bulk heterojunction (P3HT:PCBM) organic solar cell has done. The J-V characteristics curve of organic solar cell varies with mobility of charge carriers. In this study, we obtained the maximum short circuit current at electron and hole mobility $0.5 \times 10^{-6} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$ due to maximum dissociation probability. If the mobility increased or decreased from $0.5 \times 10^{-6} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$, the dissociation probability decrease and the short circuit current also decrease. The optimum efficiency of organic solar cell is obtained at $0.5 \times 10^{-6} \text{ m}^2 \text{ v}^{-1} \text{ s}^{-1}$ charge mobility. It is concluded that the j-v characteristics of organic solar cell affected by the mobility of the charge carrier.

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