Optical Simulation of Different Photoactive Layer Thickness on Organic Solar Cell

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Abstract : This paper investigated the effect of different layer thickness on the performance of an organic solar cell. Thus, the optical simulations have been performed on organic solar cell based on ITO/PEDOT: PSS/P3HT: PCBM/Al with GPVDM (General-Purpose Photovoltaic Device Model) software 4.8 version 2012. The Optical simulation has been performed with different photoactive layer thickness of 150nm, 170nm, 200nm, 220nm, 230nm, 250nm and 300nm at 355-628nm wavelength. The results show that the active layer thickness affects the Photon Absorption Density as well as Power Conversion Efficiency and the best photon absorption is achieved at 200nm.

IndexTerms -Organic photovoltaic cell, P3HT: PCBM, GPVDM, Photon Absorption Density, Thickness Effect.

I. INTRODUCTION

Global demand of the energy is increasing day by day, as result of that conventional energy will not take long time to exhaust. To satisfy the global demand of energy, it is a great concern to compensate the loss of conventional energy resources with alternative renewable energy resources. As raising the demand of environment friendly, plentiful and sustainable energy, the photovoltaics intends to be the fastest growing power generation technology in the world. An organic solar cell based on bulk heterojunction is formed by a mixture of two forms of P3HT and PCBM conjugated polymers, in which Conjugate polymer P3HT acted as an electron donor, while PCBM acts as an electron acceptor in the instrument. To order to improve power conversion efficiency (PCE), this blend allows for optimum light absorption.

The efficiencies of organic BHJs solemnly depend on the photo-generating exciton capability in reaching the heterojunction between donor and acceptor. In addition, the output is also impacted by the free carrier which is able to escape the electrodes. Once the thin film layer is characterized by annealing which increases the crystallinity of both thin film layers, the carrier's movement in the system can be improved. The thickness of the photoactive layer play an important part in the production of high performance BHJ (Bulk Heterojunction) solar cells as the photon absorption rate is directly proportional to materiel thickness.

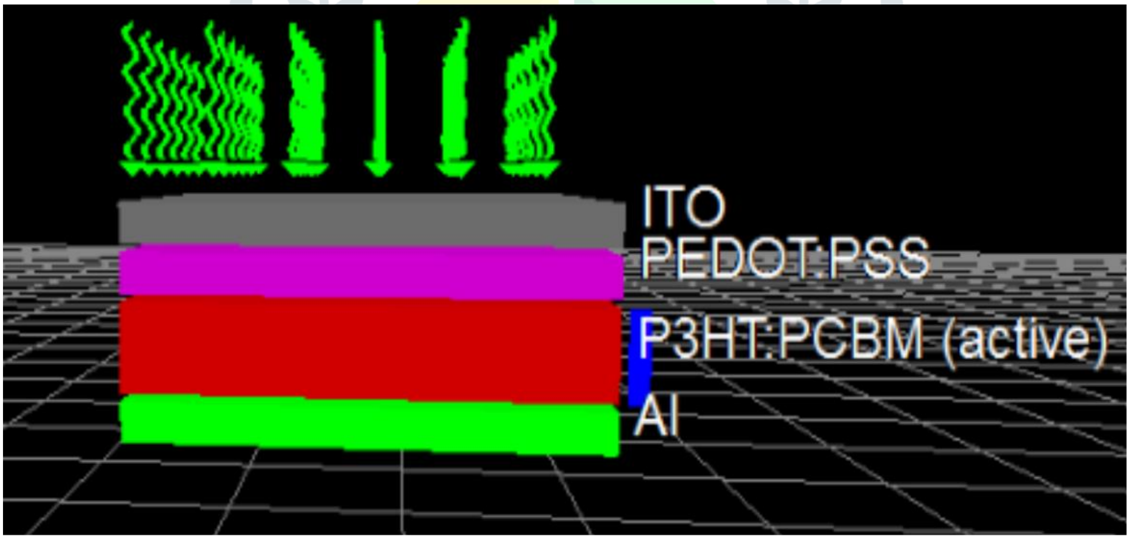

Fig 1 Organic solar cell model

II. OPTICAL SIMULATION

Bulk solar heterojunction ITO / PEDOT: PSS / P3HT: PCBM / Al are simulated in different active layer thickness using the GPVDM software. GPVDM software is specifically designed to simulate organic solar cells with a bulk heterojunction, such as those based on P3HT: PCBM material. The model has both electrical and optical characteristics that allow simulation of both current-voltage and optical properties. The model also solves the equation of Poisson to calculate the potential of internal electrostatics. Recombination and carrier trapping are described in the model using Shockley-Read-Hall (SRH) formalism; it is feasible to arbitrarily define the distribution of trap states. Both equations can be solved in a steady state or in a time domain. The optical model simulation usually includes the transparent electrode ITO, contacts and layers like PEDOT: PSS. Generally only carrier electrical simulation, the active layer of the unit, a normally optical simulation is larger than electrical simulation.

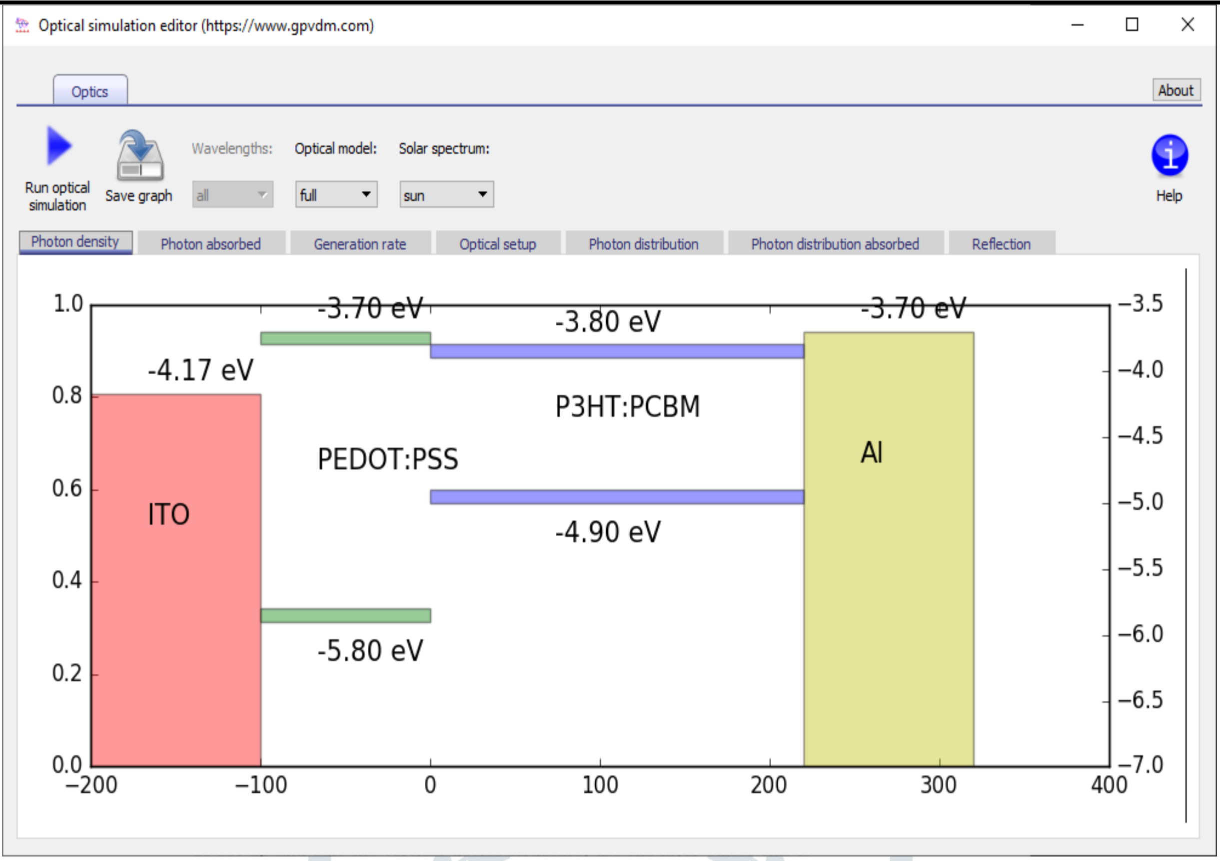

Fig 2 The optical model

III. RESULT AND DISCUSSION

The optical simulation (wavelength 355-628 nm) is made at different active layer thicknesses, ITO thickness 10 nm, PEDOT: PSS thickness 10 nm, Al thickness 10 nm, and active layer (P3HT: PCBM) thickness 150 nm, 170 nm, 200 nm, 220 nm, 230 nm, 250 nm and 300 nm. Figures 3-9 show up the absorptions at different active layer thickness. In this figure we have color scaling where color represents the amount of photon absorbing near the electrode. Here blue represents the less amount of photon absorption, yellow represents the photon absorption occurring between minimum to maximum and red indicates the maximum amount of photon absorption occurring near the electrode.

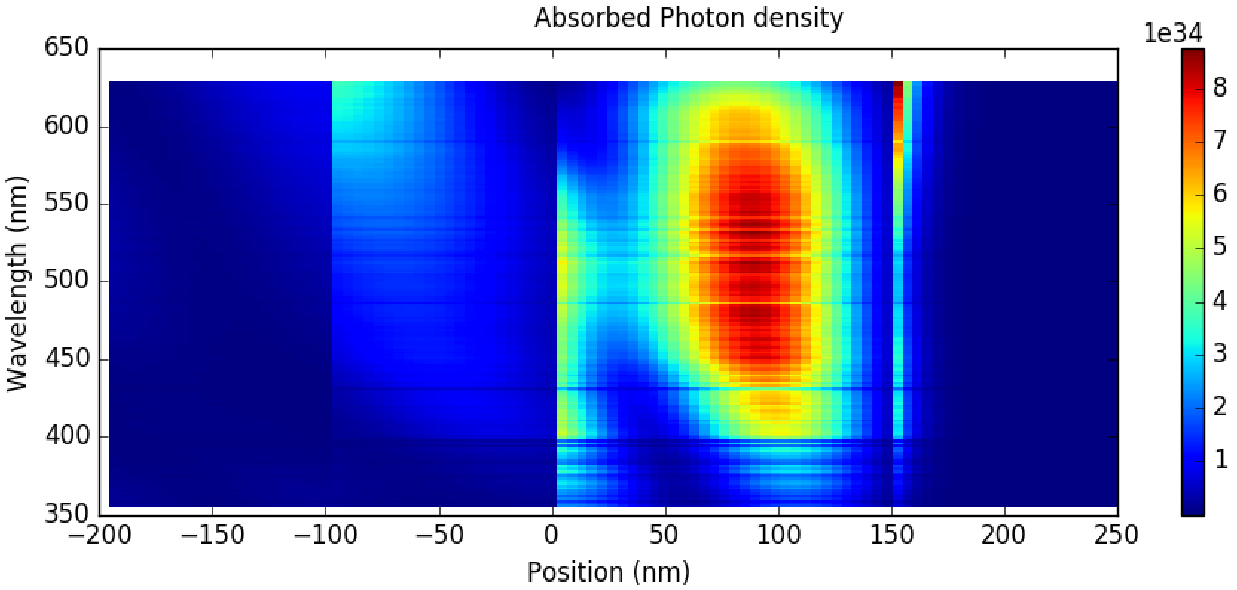

Fig 3 Absorbed Photon distribution in active region at thickness 150nm

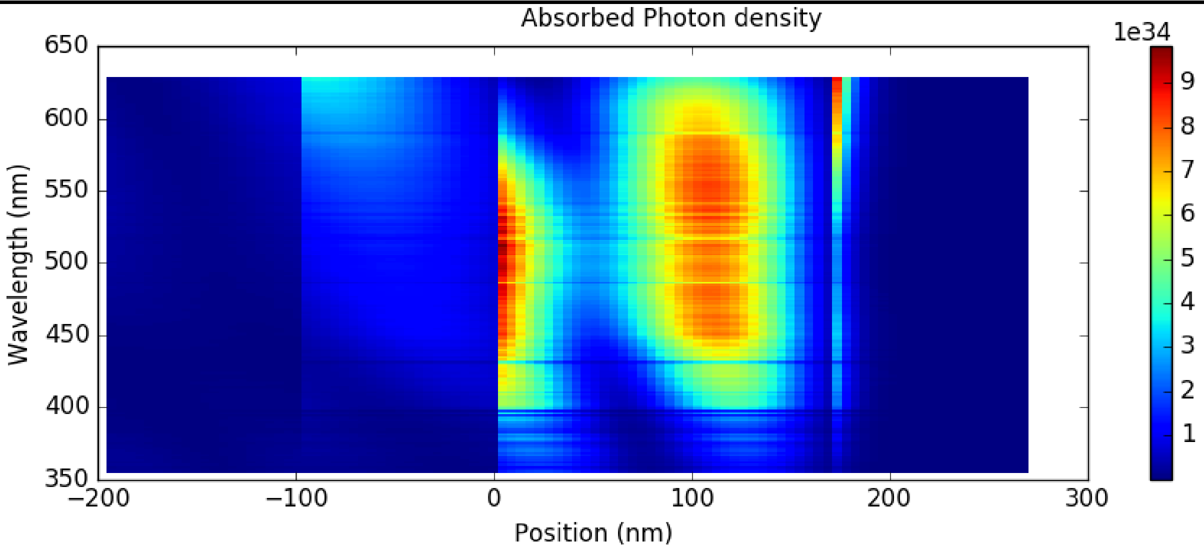

Fig 4 Absorbed Photon distribution in active region at thickness 170nm

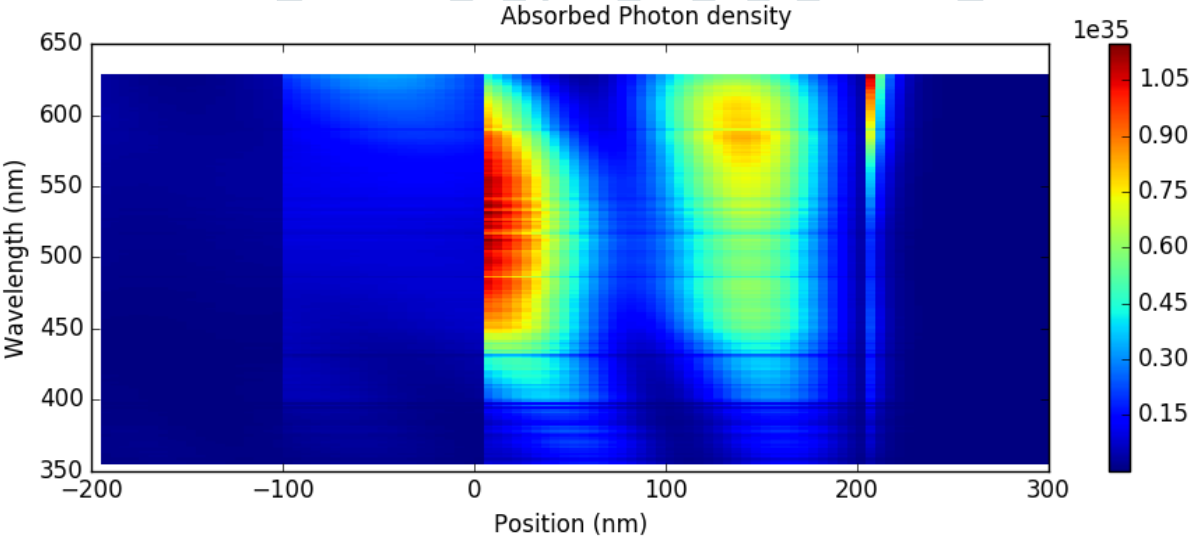

Fig 5 Absorbed Photon distribution in active region at thickness 200nm

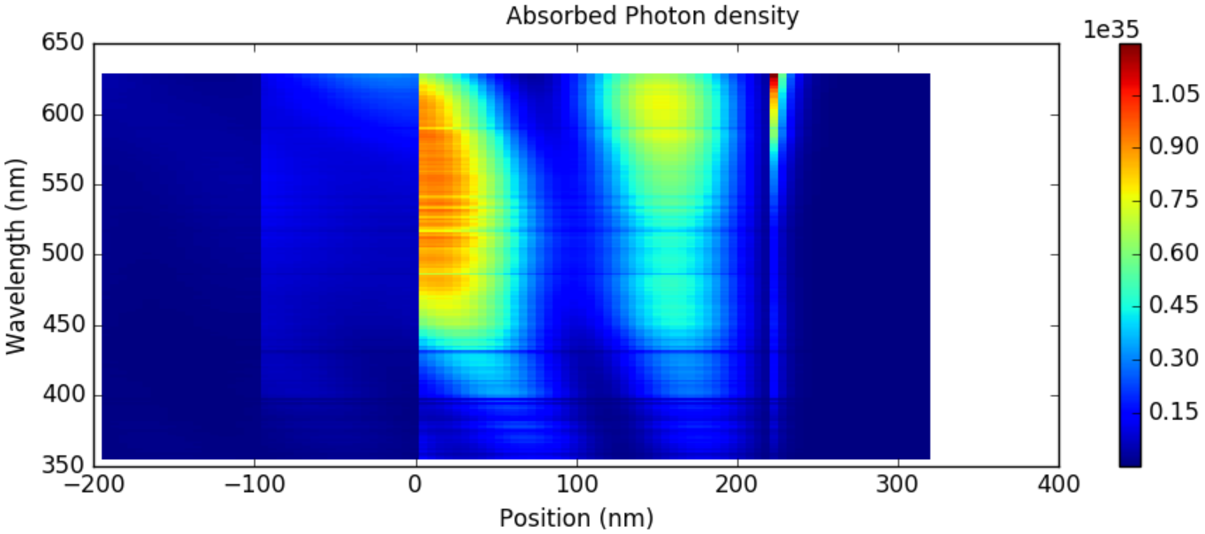

Fig 6 Absorbed Photon distribution in active region at thickness 220nm

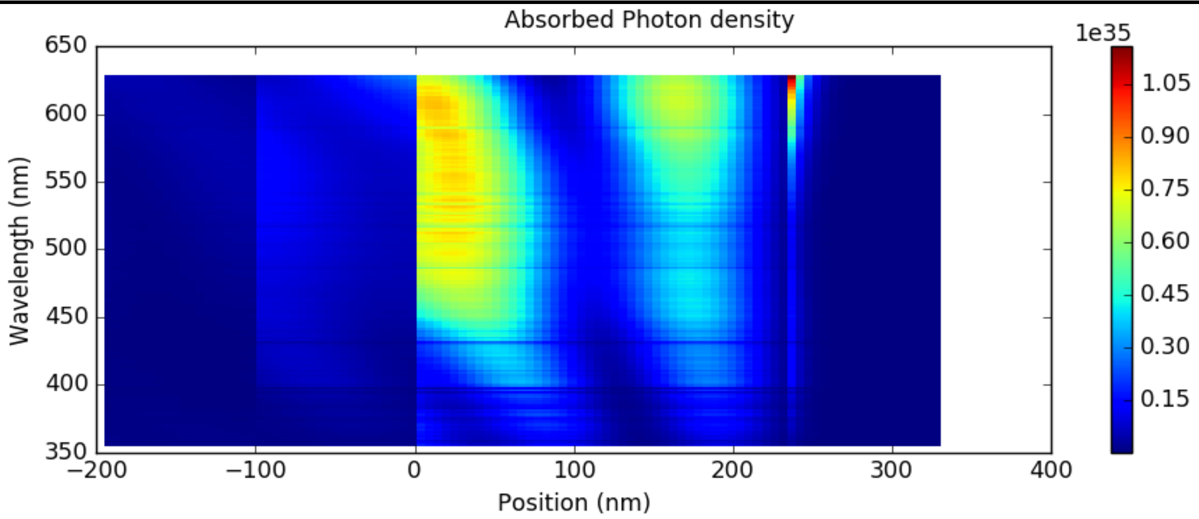

Fig 7 Absorbed Photon distribution in active region at thickness 230nm

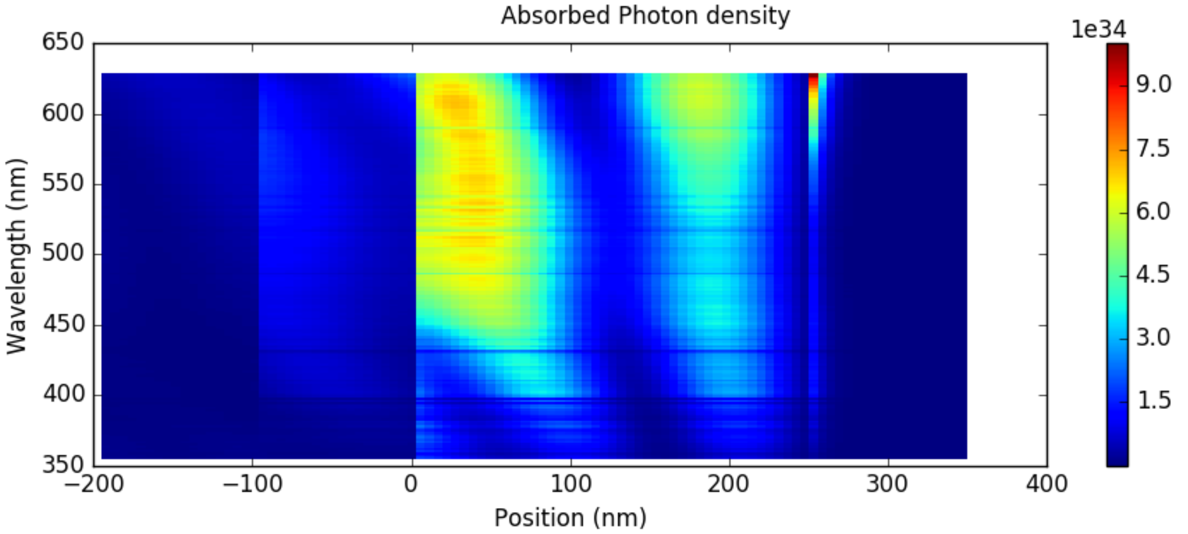

Fig 8 Absorbed Photon distribution in active region at thickness 250nm

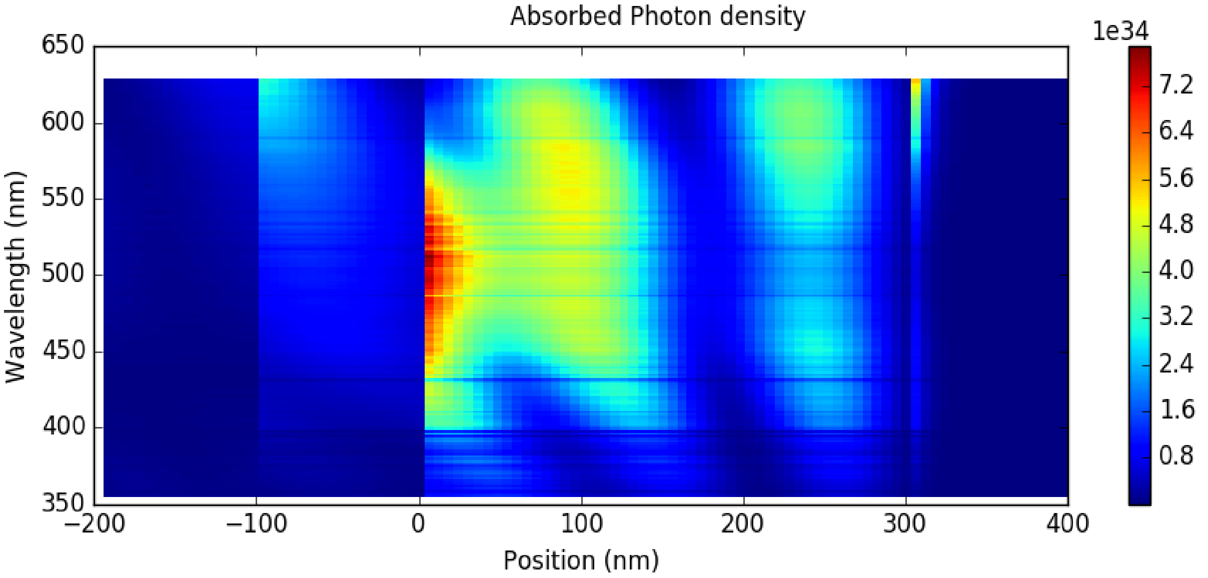

Fig 9 Absorbed Photon distribution in active region at thickness 300nm

Figure 5 shows the absorbed Photon distribution at 200 nm. The highest absorption is observed at the thickness 200 nm and the photon absorption near the electrode is highest as we vary the thickness of bulk heterojunction solar cell active layer. We found different patterns of absorption of photon distribution. The absorption rate is moving towards the electrodes as the thickness increases. Maximum Absorption is observed near the electrodes (ITO and Al) at a thickness of 200 nm. The absorption peak is decreases above the thickness of 200 nm towards the Al electrode. It is concluded that more photons are absorbed by an active layer near to the electrodes at 200 nm and more excitons are produced nearer to the electrodes. Because the charge carrier mobility in organic solar cells is low, it is difficult to spread to the electromagnetic electrode on carriers dissociated from the center of activated layer. The dissociated electron-holes in the active layer nearer to the electrode therefore it contributes to effective absorption.

TABLE1.Variations in Photon Absorption and PCE for different layer thickness of active layer

S.No.	Active Layer Thickness (P3HT: PCBM)	Photon Absorption	PCE Percentage
1.	150nm	4.936	9.47%
2.	170nm	6.109	10.28%
3.	200nm	7.856	11.77%
4.	220nm	8.502	11.66%
5.	230nm	8.571	11.14%
6.	250nm	8.731	10.72%
7.	300nm	9.464	9.78%

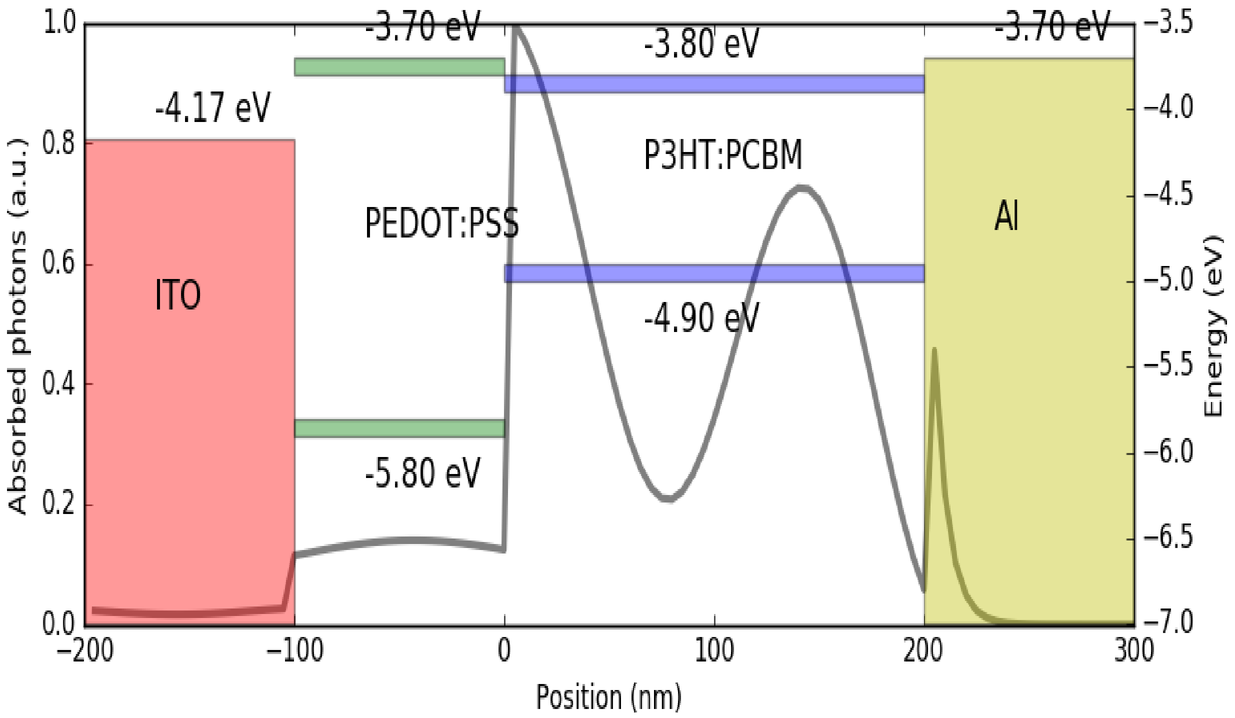

Fig 10 Photon absorbed in active region at thickness 200nm

This result shows that photon absorption increases in organic cells by increasing the active layer thickness, while the PCE decreases after certain value of layer thickness, as large active layer thickness absorbs additional photons and produces additional excitation, thereby increasing the electron and the system's hole density. If we increase the layer thickness of active layer, the exciton has to travel larger distance from generation to dissipation. The dense structure is however internally lined and increases the recombination possibilities due to low ion, electron and hole mobility. Therefore we must balance these two opposite effect of layer thickness. The performance of the organic solar cell is enhanced with decreased photon absorption by growing its active layer thickness according to the simulation tests. Their output is improved and the best absorption of the photon is thus obtained from the optimization with the active region layer thickness at 200 nm and the photon absorption is maximum near the electrode, with the minimum reflective value near to the electrode and maximum with a middle of the active layer.

IV CONCLUSION

Organic solar cell's optical simulation is performed using the GPVDM software 4.8 version 2012. In this research we presented the optical simulation of the solar cell P3HT: PCBM based bulk heterojunction. The absorption pattern of the active layer of organic solar cells varies by thickness for different active layer thicknesses. We get the optimal value of active layer thickness which gives absorption peaks near to the electrodes and good PCE percentage as well as at 200 nm. Thus, the effective absorption of P3HT: PCBM based solar cells can be optimized by adjusting the active layer thickness.

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