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CONTRIBUTION STUDY OF POLYMER ANODE FOR APPLICATION IN ORGANIC PHOTOVOLTAIC DEVICES

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Abstract

In this paper, we report our results on the optical modelling of a multi-layer organic photovoltaic device, in which the incident light of sun is absorbed in the active layer. The influence of the optical parameters and thicknesses of different layers had been taken into account to improve the device performance. A composite of poly(2-methoxy-5-(20-ethylhexyloxy)-1,4phenylenevinylene) (MEH-PPV)/6,6-phenyl C61-butyric acid methyl ester (PCBM) blends are used as photo-active materials, sandwiched between a transparent Indium Tin Oxide (ITO)-electrode and metallic (Ca, Al, Ag) backside contacts. This study aims to show optical effects of an extra interfacial layer of poly(3,4-ethylenedioxythiophene)/(poly(styrenesulfonate) (PEDOT/PSS) on top of the glass to be a future promising substitution for the ITO-electrode .

Our objective is the study of the methods which make it possible the description of the electric field inside the organic solar cells described previously with different deposited layers to make a rigorous modelling of these devices. The basic criterion for optical optimization is to maximize the energy absorption in the active layer according to the distribution of electrical field on the device specially for the new polymer anode.

Key words: organic solar cells, optical modelling, refractive index, polymer anode.

I. INTRODUCTION

In these last years several research was undertaken on the study of the interaction between the incident light with the photovoltaic devices of organic semiconductors. The modelling of optical absorption in organic solar cells has a great importance in the prediction of the electro-optical properties of these devices.

F. Monestier et al [1] have presented a method of optimization of the electromagnetic field in the organic solar cells, and an electro-optical modelling of these cells describing the generation rate of excitons based on the calculation of the profile of absorbed energy. V.V Fillippov and L.M. Serebryakova presented in [2] a concrete analysis of interference effects on the spatial field distibution. Another research group [3, 4] made the minimization of the optical losses in the bulk heterojunction solar cells by using the complex index of refraction and ellipsometry.

The ITO electrode provides many advantages in the fabrication of polymer solar cells, its brittleness and thermal expansion coefficient limit its flexibility and thermal stability on a polymer substrate and are responsible for poor interfacial compatibility between the organic materials and ITO surface and its expensive price is one of their major problems [5]. PEDOT:PSS exhibits significant optical transparency to visible light , and its conductivity can be improved by addition of polyalcohol's or high dielectric solvents to be a future polymer anode [6].

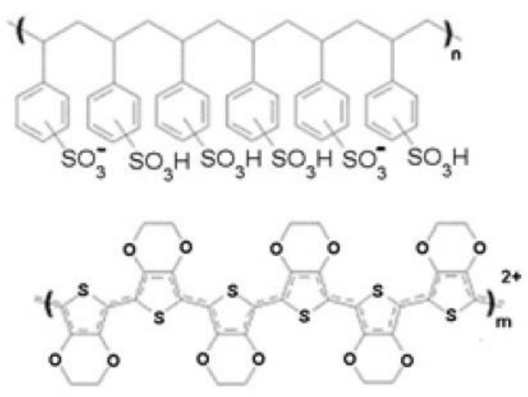

Fig. 1. Chemical structures of PEDOT:PSS transparent electrode

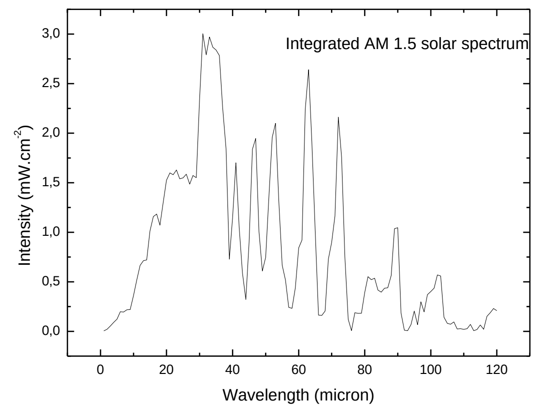

Fig. 3 AM 1.5 solar spectrum, wavelength dependence of light intensity used in simulations

II. OPTICAL MODELLING

The multiplication of the matrixes [7] will describe how the wave propagates by the whole device. Diagram 2 shows the arrangement of propagation of the forwards and towards fields in the back of the device under AM 1.5 solar spectrum demonstrated in fig 3.

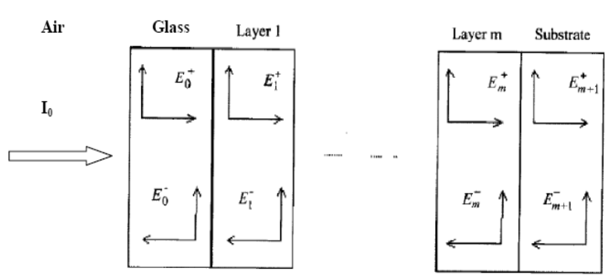

Fig. 2 Arrangement of the fields' propagation forwards and the back of the device.

The equation (1) gives the sum of the electric field in the positive and the negative directions respectively:

$$E_j(x) = E_j^+(x) + E_j^-(x) \qquad (1)$$

Since optical energy is a measurable quantity, the first stage in the calculation of the optical generation rate is to calculate the Poynting vector brought back to an average per hour:

$$\langle P_j \rangle = \frac{1}{2}\left[E_j \times H_j^*\right] \qquad (2)$$

The time average of the energy dissipated per second in layer j at position x is given by:

$$Q_j(x) = \frac{1}{2} c\varepsilon_0 \alpha_j \eta_j \left|E_j(x)\right|^2 \qquad (3)$$

Where c is the speed of light, ε_0 the permittivity of free space, η_j is the refractive index, and the absorption coefficient is

$$\alpha_j = \frac{4\pi k_j}{\lambda} \qquad (4)$$

The relations managing electric and magnetic fields and which allow the direct passage of a layer to other are given by[7]:

$$\begin{vmatrix} E_{j-1} \\ H_{j-1} \end{vmatrix} = \left|\Psi_m\right| \begin{vmatrix} E_j \\ H_j \end{vmatrix} \qquad (5)$$

Where Ψ_m is a 2×2 matrix which contains the permittivity values for each medium.

III. APPLICATION

We can apply the model described previously on the first hand to an organic solar cell composited of Glass / ITO / (PEDOT-PSS)/ (MEH-PPV/PCBM) /(Ca, Al, Ag). The thickness of ITO anode is supposed d=140 nm, layer PEDOT/PSS with also a thickness of 140 nm, the backcontact has generally a thickness of 30 nm, this last material is assumed to be variable and reflective in our simulations, which is the most dominant boundary condition with the various thicknesses of the active layer. Then we replace the ITO anode by PEDOT:PSS.

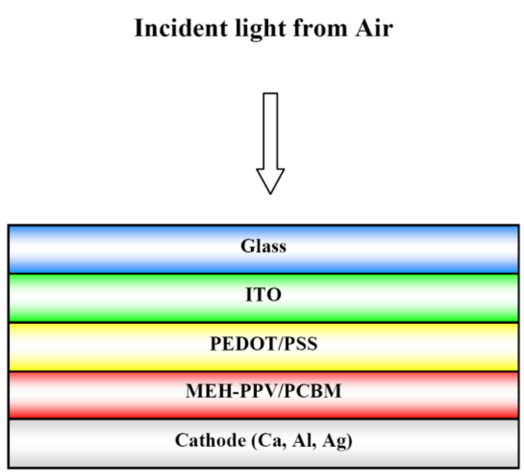

Fig. 4 Diagram of an organic solar cell

IV. RESULTS AND DISCUSSION

Figures 5 and 6 illustrate the profile of the electric field in each layer of the photovoltaic device according to the thickness of the active layer. Firstly, we has choosing BHJ solar cells because there represents the most recent efficient devices. Then we have proved by numerical simulations that the use of Silver materials increases the electric field on the active layer near the metallic electrode.

Figure 6 presents the effects of the protective coating in PEDOT/PSS on the luminous energy transmitted in the active layer when this energy is decreased for very thinner active layers because there is a big region of reflections at the counter electrode in Ag. The new anode in PEDOT:PSS replacing ITO electrode can substitutes this last material but in very thinner thickness i.e; by reducing about 30% of magnitude , and using an angle of incidence of 45°.

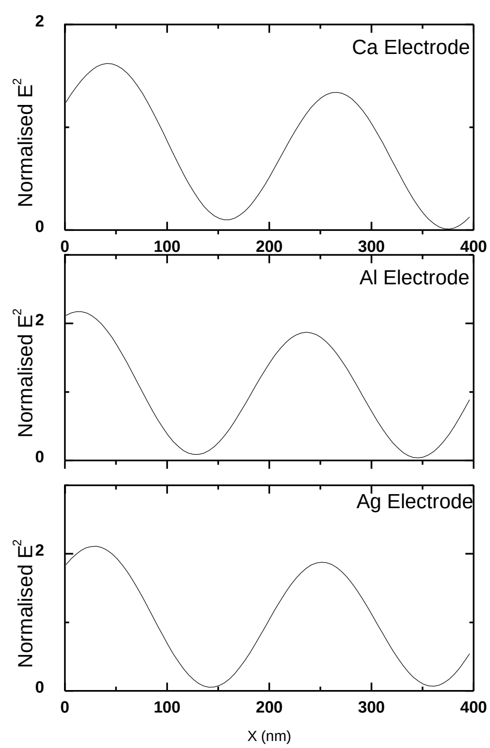

Fig.5 Square of the electrical field in the active layer in Glass/ITO/PEDOT:PSS/MEH-PPV:PCBM/metal organic solar cell with different electrode layers in Ag, Al and Ca.

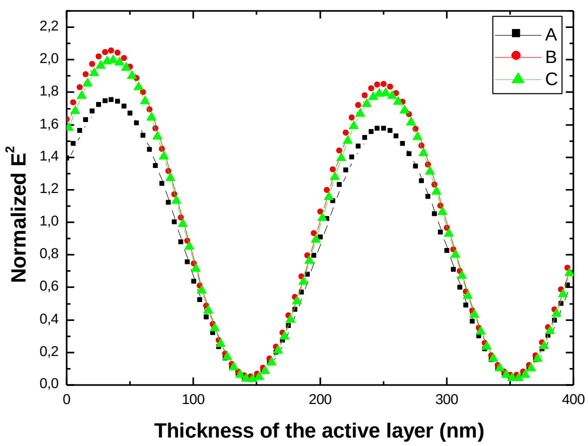

Fig.6 Square of the electrical field in the active layer in Glass/ITO/PEDOT:PSS/MEH-PPV:PCBM/Ag organic solar cell: (A)with, (B)without a protective layer in PEDOT on the top of the ITO electrode, (C)with the new anode.

V. CONCLUSION

In summary, the performances of organic solar cells devices with and without PEDOT-PSS , as protective layer respectively and (Aluminium, Silver, Calicium) as back contacts were investigated and compared by an optical modelling. We presented in this paper the results of modelling and digital simulation which describe the evolution of the magnetic and electric fields in bulk heterojunction solar cells, as well as the optimization of the electric field distribution, according to the thickness of the active layer.

From the results reported here, it is clear that the solar cells in MEH-PPV/PCBM as active layer was a very high distribution of electric field with Silver electrodes, Aluminum is a second optimization material and Calcium is a poor material to be used as metallic electrode. The transparent polymer electrode can be used to manufacturing organic solar cells at very low coast and some ameliorations of the conductivity are necessary.

Our results of simulation are in good agreement with those published in the literature by the use of this recent method. In our work we applied this sofisticated method to enhance the performance of photovoltaic devices.

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