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High Fill Factor and Conversion Efficiency in Organic Photovoltaic Cells with PEDOT: PSS / C60

T. Sahdane[1], B. Azize[2], A. Laghrabli[3], R. Benallal[4], H. Bougharraf[5], B. Kabouchi[6]

Molecular Spectronomy, Optics and Laser Instrumentation Team, Mohammed V University in Rabat,
Faculty of Sciences, Agdal, Rabat, Morocco[1, 2, 3, 4, 5, 6]

Abstract: The organic thin-film solar cells based on flexible substrates were studied theoretically. poly(3,4-ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) as the donor layer and fullerene (C60) as the acceptor layer are used. The theoretical results show that the absorption of light can greatly influence the short circuit current, the open circuit voltage, the fill factor and the energy conversion efficiency. It was found that the thickness of C60 acceptor layer has a great influence on the performance of organic solar cell. When the thickness of acceptor layer was 200 nm, the energy conversion efficiency reached 7.95%.

Keywords: Energy conversion efficiency, organic photovoltaic cells, PEDOT: PSS, C60, open circuit voltage, short-circuit current

I. INTRODUCTION

Conjugated conductive polymer materials have great potential commercial application value because of their machinability and flexibility as well as the properties of inorganic semiconductors or metal conductivity [1-2]. In recent years, the rapid development of conductive polymers makes research and development of low-cost organic solar cells possible. The key to the preparation of high-performance solar cells is to improve the efficiency of energy conversion [3-4].
Polymer solar cells because of its wide range of raw materials, the price is relatively low, the production process is simple, can be prepared for large area advantages, if you can achieve further breakthroughs in performance, the energy conversion efficiency to near commercial inorganic Materials, the level of solar cells, there will be a wide range of large-scale applications, the market prospects are enormous. Flexible solar cells, is the second generation of thin-film solar cells is an important type of roll-to-volume process has a distinct cost advantage. The substrate is a plastic sheet or metal foil, different from other glass substrates of thin film solar cells. Features are light weight, flexible, suitable for integration in a variety of curved objects.

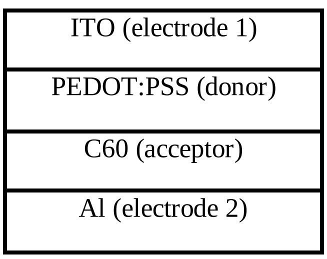

Fig.1. Two-layer organic photovoltaic cell

II. THEORETICAL METHODOLOGY

The power conversion efficiency (η) is mainly determined by the short-circuit current density (Jsc) and the open circuit photo voltage (V_{oc}). The η can be expressed by the following equation [5-6]:

$$\eta = \frac{FF.V_{OC}.J_{SC}}{P_{in}}$$

Where, P_{in} is the incident power density, FF is the fill factor and J_{sc} is the short circuit current.
For the short-circuit current density Jsc it is determined as [7]:

$$J_{SC} = q\int_{\lambda} b_S(\lambda)\, QE(\lambda)\, d\lambda$$

where $b_S(\lambda)$ is the incident photon flux density and $QE(\lambda)$ is the quantum efficiency (QE) of the cells.

The QE is the ratio of the number of charge carrier collected by electrodes to the number of total incident photons, relevant for the characteristics of materials such as absorption coefficient and efficiency of exciton dissociation.

For the fill factor FF it is determined as [8]:

$$FF = \frac{V_{mpp}.J_{mpp}}{V_{OC}.J_{SC}}$$

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To analyze the relationship between V_{oc} (Open-circuit photovoltage) and the energy of LUMO (E_{LUMO}) of the compounds based on electron injection from LUMO to the conduction band (E_{CB}) of the semi-conductor [9]. Circuit diagram has been given in Figure 2 [10].

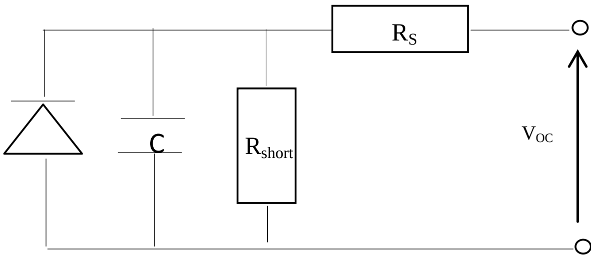

Fig.2. Equivalent circuit of organic solar cell

III. RESULTS AND DISCUSSION

For good understand the reason for the increased efficiency of the bilayer devices, we using gpvdm capable of simulating both the electrical and optical properties of the bilayer structures. Materials used for the design and bandwidth values data of materials are given in Table 1.

Table 1. Layers of solar cells, optical material used for layers and bandwidth values

Layer	Optical Material	Thickness (nm)
ITO (electrode 1)	ITO	100
PEDOT:PSS	Generic_Organic	100
C60	Generic_Organic	200
Al (electrode 2)	Al	100

Figure 3 shows the effect of thickness of C60 on output characteristics. It can be seen from this figure that when the thickness of the polymer layer becomes smaller (100 nm), the current in the polymer layer becomes smaller, because the cell of two single-layer components can achieve better current matching, The open-circuit voltage of the laminated solar cell can reach the superposition of the single-layer battery.

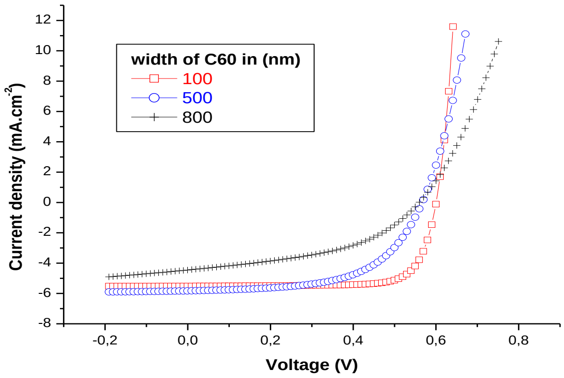

Fig.3. J-V characteristics of PEDOT: PSS / C60 solar cells under various thickness of C60

J–V curves under different light intensities are shown in figure 4. reported the used intensity range is ultra-low and is below the range of most typical power dependent measurements. There are no distinct features at intensities above 1 mW.cm-2.

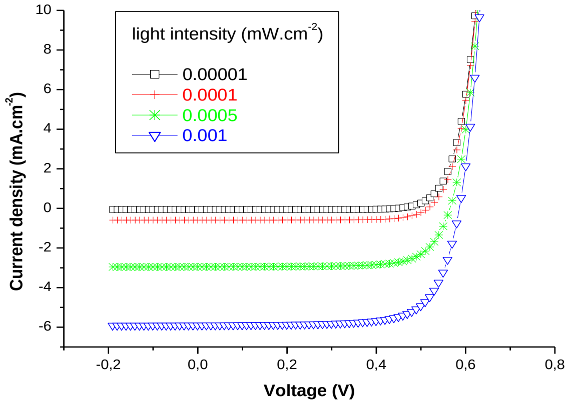

Fig.4. J-V characteristics of PEDOT: PSS / C60 solar cells under various light intensities

The open-circuit voltage (V_{OC}) depends on the light intensity as shown in figure 5.

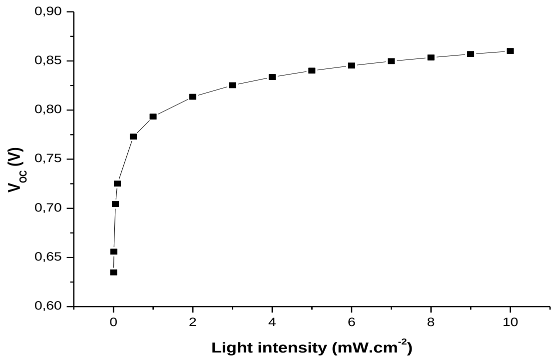

Fig.5. Influence of light intensity on open circuit voltage (V_{OC}) of PEDOT: PSS / C60 solar cells

The fill factor (FF) is mainly affected by light intensity (figure 6). FF decreases when the light intensity increases.

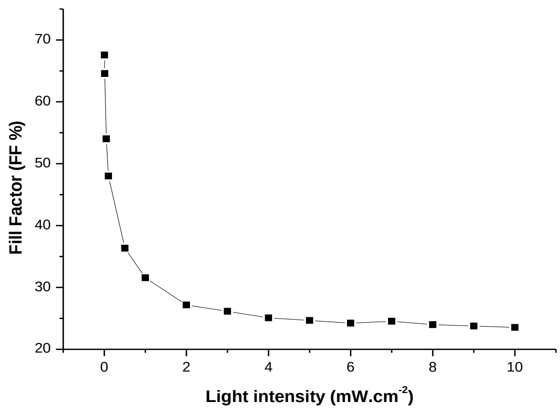

Fig.6. Influence of light intensity on fill factor (FF) of PEDOT: PSS / C60 solar cells

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Effect of light intensity on short-circuits photocurrent density (J_{SC}), open-circuit voltage (V_{OC}), fill factor (FF), and conversion efficiency (η) is given in table 2.

Table 2 Electrical Parameters of the PEDOT: PSS / C60 Solar Cells with light intensity

Light intensity ($mW.cm^{-2}$)	J_{SC} ($mA.cm^{-2}$)	V_{OC} (V)	FF (%)	η (%)
0.005	1.854	0.634	67.570	7.954
0.01	1.848	0.655	64.581	7.829
0.05	1.806	0.704	54.020	6.871
0.1	1.742	0.725	48.012	6.065
0.5	1.277	0.772	36.347	3.589
1.0	0.999	0.793	31.560	2.503
5.0	0.375	0.840	24.665	0.777
10	0.212	0.859	23.539	0.430

Photon density and absorption energy variance of organic solar cell layers are given in figure 7 and 8.

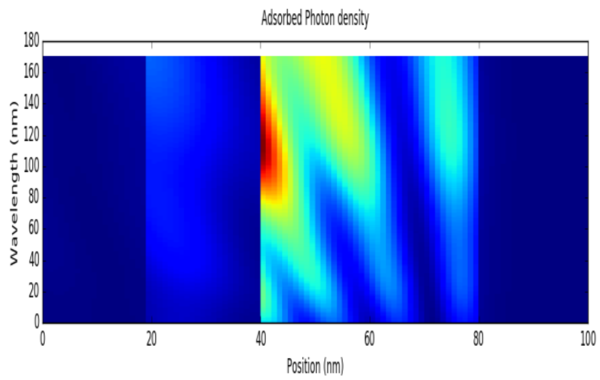

Fig.7. Adsorbed photon density

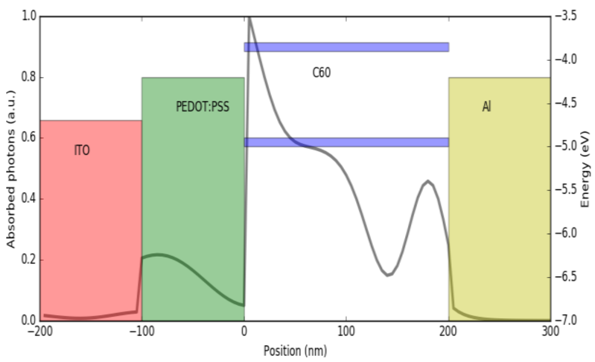

Fig.8. Photon absorption –location- energy variance of analyzed organic solar cell

To examine if the change in light intensity could explain the increase in percent efficiency, a curve were simulated with the calibrated model using different light intensity and the resulting device efficiency plotted. The results can be view in figure 9.

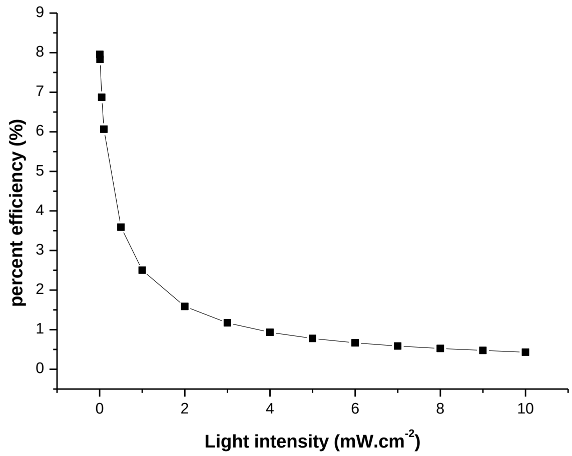

Fig.9. Influence of light intensity on percent efficiency

IV. CONCLUSION

A better understanding of organic photovoltaic cell were analyzed, and the simulation system of current-voltage (I-V) characteristics of organic photovoltaic cell was established by gpvdm software. Using numerical modeling we show that the increase in efficiency is caused by optical absorption in the pure polymer layer and hence efficient charge separation at the polymer bulk-heterojunction interface between the poly(3,4ethylenedioxythiophene):poly(styrenesulfonate) (PEDOT:PSS) and fullerene (C60) layer. The effect of light intensity and thickness of C60 on its I-V characteristics, open circuit voltage and short-circuit current was quantitatively simulated.

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