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Temperature Effect on the Organic Solar Cells Parameters

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***Abstract*—**In this work, the influence of temperature on the different parameters of solar cells based on organic semiconductors are studied. The short circuit current Isc increases so monotonous with temperature and then saturates to a maximum value before decreasing at high temperatures. The open circuit voltage Vco decreases linearly with temperature. The fill factor FF and efficiency, which are directly related with Isc and Vco follow the variations of the letters. The phenomena are explained by the behaviour of the mobility which is a temperature activated process**.**

***Keywords*—**cells parameters, organic materials, solar cells, temperature effect

I. Introduction

ORGANIC solar cells offer great technological potential as an alternative source of renewable energy [1]. During the ten years back, many efforts are dedicated to the development of solar cells based on conjugated polymers, this is mainly due to the advantages that organic solar cells present compared to their inorganic counterparts (including cell based on the crystalline silicon). They are flexible; they may be developed on plastic substrates with low cost of manufacturing. The best performance was obtained using a composite of two organic materials: a donor and an acceptor, in a balk interpenetrated network. This concept is very investigated because it allows a large interfacial surface witch provide a good excitons separation. The best efficiencies are allowed from the cells which use a mixture of (polly-3 hexylthiophene) P3HT and ([6-6]-

phenyl C_{61} butyric acid methyl ester PCBM, which allows a return of 5% [2].

II. Short-Circuit Current I_{SC}

In a solar cell, at any point depth z in the bulk of the device, the density of the current J(Z) is proportional at the difference between the rate of generation of free charge carriers G(z) and the recombination rate R (z):

$$\frac{1}{q}\frac{dJ(z)}{dz} = R(z) - G(z) \qquad (1)$$

In the hetero-junction structure devices, the recombination in the bulk are of two types:

A. The first order recombination:

The first order recombination is due to the presence of impurities in the mixtures of the active layer of the solar cell. They depend on the density of the impurities, which are traps for the generated free carriers.
If we consider the case of electrons, the first order recombination is given by:

$$R(z) = \frac{n(z)}{\tau} \qquad (2)$$

Where n (z) represent the density of electrons at a depth z and τ is the lifetime of electrons.

B. Bimolecular recombination:

They depend on the density of free carriers, electrons and holes. They can be expressed by [3]:

$$R(z) = K\, n(z)\, p(z) \qquad (3)$$

n (z) and p (z) are the density of electrons and holes respectively and K the is the bimolecular coefficient.
In the organic solar cells, the generation of the free carriers is the result of two processes: generation of excitons in the donor material in the active layer and Review Stage separation of these excitons at donor/acceptor interfaces. Thus, the generation rate G(z) depends on the diffusion length of the excitons, the absorption coefficient of the materials of the active layer and the intensity of incident light.
The current density that flows in a PN junction under illumination is given by:

$$J = J_0\left[\exp(\frac{qV}{KT}) - 1\right] - J_L \quad (4)$$

where:
J_L is the density of photo generated current

K is the Boltzmen constant
J_0 is the saturation current density which is given by:

$$J_0 = N_v\ N_c\ KT \exp\left(\frac{-Eg}{KT}\right)\left(\frac{L_n}{n\tau_n} + \frac{L_p}{p\tau_p}\right) \quad (5)$$

N_c and N_v are the density of states in the conduction and valence band respectively, p and n are the density of the electrons and hols, Ln and Lp are the diffusion length , τ_n ,τ_p are the lifetimes of electrons and holes.
At V = 0 volts (the short-circuited cell) the density the current J_{cc} generated by the cell is:

$$J_{sc} = -J_L$$

In some studies [5], the short circuit current found to be dependent on the temperature. They found that the short circuit current Icc increases with temperature and tends to be saturated at a maximum value followed by a decrease at high temperatures. This can be explained by considering that the current delivered by the cell is proportional to the number of free charges carriers generated and their mobility. For the organic semiconductors, the transfer of charges occurs via localized sites. The transfer of the charges from one site to another nearby site is associated with phonons. The conductivity is thermally activated, otherwise say, increases with temperature. The increase of the mobility with temperature is supposed to be a hoping phenomenon enabled by the phonons. This hypothesis can be verified by considering that for organic materials, the conductivity is given by:

$$\sigma = \sigma_0 \exp(\frac{-\Delta E}{2KT}) \quad (6)$$

and the mobility by:

$$\mu = \frac{\sigma}{en} \quad (7)$$

Where ΔE is the activation energy of the process. The activation energy ΔE is a contribution of two factors, value of the gap energy (the energy required to excite an electron from highest occupied molecular orbital HOMO to lowest unoccupied molecular orbital LUMO) and the energy of delocalisation of the charges carriers (energy required for an electron to outside a trap).

At low temperatures, the probability of a phonon with an energy that allows a jump from a site to another nearby site is low, therefore, the mobility is low at low temperatures. Please submit your manuscript electronically for review as e-mail attachments. When you submit your initial full paper version, prepare it in two-column format, including figures and tables.

III. OPEN CIRCUIT VOLTAGE V_{OC}

The open circuit voltage of a solar cell is the current flowing through the cell is zero bias. For photovoltaic cells based on organic materials, it depends directly on the band gap energy of Eg. The open circuit voltage of a solar cell based PN junction is given by:

$$V_{oc} = \frac{nKT}{q}\ln(\frac{I_{sc}}{I_s} + 1) \quad (8)$$

Taking into account that the short- circuit current I_{sc} is greater than the saturation current Is and substituting the expression for Is in V_{CO} equation we get:

$$V_{oc}\ \frac{nEg}{q} - \frac{nKT}{q}\ln[(\frac{qNc\ \ Nv}{Icc})(\frac{Ln}{n\tau_n} + \frac{Lp}{p\tau_p})] \quad (9)$$

$$Voc = a - bT \quad (10)$$

$$a = Voc(T = 0K) = \frac{nEg}{q} \quad (11)$$

and

$$b = \frac{dVoc}{dT} \quad (12)$$

The slope of the equation of the short circuit voltage as a function of temperature is negative thus assuming that V_{oc} decreases linearly with temperature.
From (9), we see clearly that the open circuit voltage V_{oc} is largely depends on the temperature, diffusion length, the lifetime and the density of charges carriers and slightly dependent of the materials used for the cathode.

To improve the open circuit voltage of a solar cell based on organic materials, we can introduce new device structures such as the bulk interpenetrating networks between the two materials, the first is a good electron conductor and the second has a good holes mobility to multiply the number the dissociation area of excitons to prevent their recombination.

V.THE FILL FACTOR FF

View of the prospects for improving the efficiency of organic solar cells, the most critical factor for a large impact on the different strategies depends on better fill factor FF which is given by:

$$FF = \frac{V_{\max}\ I_{\max}}{V_{oc}\ \ I_{sc}} \quad (14)$$

Where:
V_{max} and I_{max} are the voltage and the current at maximum energy awarded by the cell extract of the characteristic current -voltage I (V) of the cells.

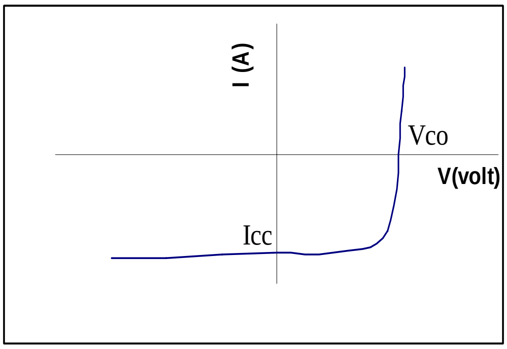

Fig. 1: I (v) characteristic of a solar cell.

The fill factor is the most sensitive parameter in a solar cell in comparison with the open circuit voltage of the Voc and are short circuit current Isc.

It depends on the material properties of the active layer (mobility of charge carriers and there lifetime), the morphology of the active layer and the physical and chemical properties of the interface active layer / cathode. The important role of the active layer/ cathode interface depends on the cathode deposit conditions, which may cause a variety of chemical and physical defects, which will subsequently traps for charge carriers. In organic solar cells, the photogeneration of free charge carriers come through the dissociation of excitons at interfaces donor / acceptors with efficiency η. The excitons are electron-hole pairs bounded by important Colombian attractions. The rate of collection of charges not reach a unity because the excitons in organic materials are a life very limited (about 30ns [7]), which promotes the recombination of excitons before separating.

III. THE EFFICIENCY

The performance of organic solar cells is one of the factors impeding there commercialization. It is given by:

$$\eta = \frac{Isc\ \ Voc\ \ FF}{Pin} \quad (13)$$

Where P_{in} is the power of the incident light .

VI. CONCLUSION

In this paper, we have studied the influence of temperature on the organic solar cells parameters. The open circuit voltage decreases linearly with temperature with a negative slope dVco / dT. The short circuit current at Isc first increases with temperature before reaching a maximum value of saturation and then decreases for highest temperatures. The fill factor FF and the efficiency ere given by (13) and (14) respectively follow the changes of the open circuit voltage Vco and the short circuit current Isc. These variations are explained by the charges carriers against the temperature behaviour of the mobility of.

REFERENCES

[1] A Pivrikas, P. Stadler “substituting the post production treatement for bulk heterojonction solar cells using chemical additives” organic electronics 2008.
[2] M. Urien , L.Vignau, E.Cloutet “Effect of the regularity of poly(3-hexythiophene) on the performances of organic photovoltaic devices” polymer int 2008.
[3] S. Amon, O.HABA “head to tail regularity of poly(3-hexylthiphene) in oxidative coupling polymerisation with FeCl3” journal of polymer science 1999.
[4] F.Monestier, J-J.Simon”Modeling the shorte ciruit current density of polymer solar cells based on P3HT:PCBM blend”solar energy materials and solar cells 2007.
[5] D. Chirvase, Z. Chiguvare,a) M. Knipper, J. Parisi, dependent characteristics of poly.3 hexylthiophene.-fullerene based heterojunction organic solar cells >Journal of applied physics, 2003.
[6] S.Alem-Boujeline : « réalisation et caractérisation de cellules photovoltaïques plastiques » thèse doctorat novembre – université d’angers 2004.