Sciences & Technologie **A** – **N°25**, Juin. (2007), pp. 63-66

THE EFFECTS OF PARASITIC RESISTANCES ON ORGANIC SOLAR CELL'S PERFORMANCE

Reçu le 13/03/2004 – Accepté le 05/03/2006

Résumé

L'objet de cette publication est de présenter une étude de la caractéristique courant-tension d'une cellule solaire organique à base d'un composite poly (2-methoxy-5-(2'-ethylhexyloxy)-1, 4-phenylenevinylene (MEH-PPV) avec [6, 6]-phenyl C60 butyric acid methyl ester (PCBM) en fonction de l'intensité d'illumination. La variation du photocourant, du facteur de forme, de la tension en circuit ouvert, du courant de saturation ainsi que de la puissance maximale de sortie sous différentes intensités lumineuses (100 mW/cm2, 60 mW/cm2 et 24 mW/cm2), sont examinés expérimentalement. Il est observé que pour des valeurs données de la résistance série et/ou la résistance shunt, le facteur de forme est déterminé par le courant inverse de saturation et le facteur d'idéalité de la cellule solaire. Les effets de ces composants, dans l'ensemble de performance photovoltaïque, sont discutés.

Mots clés: résistance série, résistance shunt, cellule solaire organique, caractéristique courant-tension.

Abstract

This publication aims to present a study of the current–voltage characteristics of organic solar cell based on a composite of poly (2-methoxy-5-(2'-ethylhexyloxy)-1, 4-phenylenevinylene (MEH-PPV) with [6, 6]-phenyl C60 butyric acid methyl ester (PCBM) as a function of illumination intensity. The variation of the photocurrent, the fill factor, the open-circuit voltage, the saturation current and the maximum output power under different light intensity values (100 mW/cm2, 60 mW/cm2 and 24 mW/cm2), were investigated experimentally. It is observed that for given values of series and/or shunt resistance, the fill factor is determined by reverse saturation current and diode quality factor of the solar cell. The effects of these components on the overall photovoltaic performance are discussed.

Keywords: series resistance, shunt resistance, organic solar cell, current-voltage characteristic

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ملخص

يهدف هذا النشر لتقديم دراسة للخاصية تيار-جهد لخلية عضوية شمسية على الأساس المركب poly (2-methoxy-5-(2'-ethylhexyloxy)-1, 4-phenylenevinylene (MEH-PPV) avec [6, 6]-phenyl C_{60} butyric acid methyl ester (PCBM) بدلالة شدة الاستنارة. تفحص تجريبيا تغيرات كل من التيار الضوئي، عامل الشكل، جهد الدارة المفتوحة، تيار التشبع وكذا الاستطاعة الأعظمية لشدات ضوئية مختلفة (100ميلي واط /سم2، 60ميلي واط /سم2 و 24ميلي واط /سم2). يلاحظ أن عامل الشكل يحدد بالتيار العكسي للتشبع وكذا عامل المثالية للخلية بالنسبة لقيم محددة للمقاومة التسلسلية و/أو المقاومة المتوازية. تناقش تأثيرات هذه المكونات على مجموع المأثرة الفوتوفولتية.

الكلمات المفتاحيـــة : المقاومة التسلسلية، المقاومة المتوازية، خلية عضوية شمسية، الخاصية تيار-جهد

Organic solar cell research has developed during the past 30 years, but especially in the last decade it has attracted scientific and economic interest triggered by a rapid increase in power conversion efficiencies. This was achieved by the introduction of new materials, improved materials engineering, and more sophisticated device structures. Today, solar power conversion efficiencies in excess of 3% have been accomplished with several device concepts. Though efficiencies of these thin-film organic devices have not yet reached those of their inorganic counterparts; the perspective of cheap production (employing, e.g., roll-to-roll processes) drives the development of organic photovoltaic devices further in a dynamic way [1]. Photovoltaic (PV) cells based on organic semiconductors are focus of increasing research effort by the possibility to realize large area, light-weight and low-cost flexible solar cells taking advantage of the processability of organic materials [2-4].

In this paper, we aim to study the parasitic resistances effects on the organic cell's performance. The photovoltaic device, consisting of 5 layers prepared as follows [5]:

Indium-tin-oxide (ITO)-coated glass substrate, purchased from SOLEMS, with 50 Ω/□ surface resistance, was first cleaned in ultrasonic bath for 10 minutes in Deconex detergent for 2 times in distilled water and acetone, and was then dried in an oven at 100 °C. UV-Ozone treatment was then performed for 15 minutes. A thin film (~30 nm thick) of poly (ethylene dioxythiophene) (PEDOT-Baytron P®) was coated on the pre-cleaned ITO substrate and was then dried for 5 minutes at 100°C.

A solution, of MEH-PPV conjugated polymer (purchased from ADS) and PCBM fullerene derivative, in 1, 2-dichlorobenzene solvent, was prepared with the appropriate mass ratio of MEH-PPV to PCBM. The concentration of MEH-PPV was 7 mg/ml. The bilayer cathode, consisting of 100 nm Al, on top of 0.6 nm LiF, was thermally evaporated through a shadow mask on the active layer in vacuum of 10-6 mbar, resulting in cells with an active area of 34 mm2.

A Keithley 236 unit was used to acquire the current density-voltage (J-V) plots, in dark and under illumination with an AM1.5 solar simulator (Steuernagel Solar constant 575). The device was illuminated through the transparent ITO anode. The incident photon to current efficiency (IPCE) was measured at a chopping frequency of 100 Hz with a Perkin Elmer 7225 lock-in amplifier after illumination with the monochromatic light from a tungsten lamp (Acton Spectra Pro150).

1. Theory

To understand the electronic behavior of a solar cell, particularly under illumination, the device can be modelled by an electrical circuit based on discrete electrical components described by the circuit shown in Figure1.

Really, the current in the circuit is:

$$I\left(1+\frac{R_S}{R_{SH}}\right)-\frac{V}{R_{SH}}+I_L=I_S\left(\exp\left(\frac{e}{nkT}(V-IR_S)\right)-1\right) \qquad (1)$$

where

IL originates from the charge generated by illumination.

IS is the saturation current under reverse bias.

RL is the resistance of external circuit.

RS and RSH are respectively series resistance and shunt resistance.

n is the ideality factor

e is the electron charge

k is the Boltzmann constant

T is the temperature

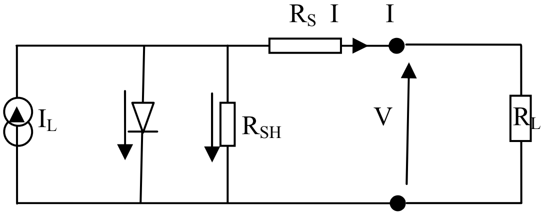

Fig1 Equivalent circuit of a real solar cell under illumination

In real cells power is dissipated through the resistance of the contacts and through leakage currents around the sides of the device. These effects are equivalent electrically to two parasitic resistances in series (RS) and in parallel (RSH) with the cell [6-8].

The series and shunt resistances are linked as shown in the following relation:

$$I_{SC}=I_L-\frac{I_{SC}R_S}{R_{SH}}$$

(2)

where ISC is the short circuit current

J..P.Charles expressed the series and the shunt resistances [9] as:

$$\begin{cases} R_S = R_{SO} - \dfrac{1}{{}^{1}\!/_{R_{SH}} + \dfrac{1}{n\,U_T}\left[\dfrac{I_{SC}\left(1+{}^{R_S}\!/_{R_{SH}}\right)-{}^{V_{OC}}\!/_{R_{SH}}}{\exp\left(\dfrac{V_{OC}}{nU_T}\right)-\exp\left(\dfrac{R_S I_{SC}}{nU_T}\right)}\right]\exp\left(\dfrac{V_{OC}}{nU_T}\right)} \\ R_{SH} = \dfrac{1}{\lambda - \dfrac{1}{n\,U_T}\left[\dfrac{I_{SC}\left(1+{}^{R_S}\!/_{R_{SH}}\right)-{}^{V_{OC}}\!/_{R_{SH}}}{\exp\left(\dfrac{V_{OC}}{n\,U_T}\right)-\exp\left(\dfrac{R_S I_{SC}}{nU_T}\right)}\right]\exp\left(\dfrac{R_S I_{SC}}{n\,U_T}\right)} \end{cases} \qquad (3)$$

with

$$\lambda=\frac{1}{\mathrm{R_{SH0}}-\mathrm{R_S}} \quad \text{and} \quad U_T=\frac{kT}{e}$$

and RS0 and RSH0 are the experimental values of the dynamic resistance which express the behaviour of the current-voltage curve around the open-circuit voltage and around the short-circuit points as:

$$R_{SH0} = -\left(\frac{dV}{dI}\right)_{I=I_{SC}} \qquad (4)$$

and

$$\mathrm{R}_{\mathrm{S0}} = -\left(\frac{\mathrm{dV}}{\mathrm{dI}}\right)_{\mathrm{V=V_{OC}}} \qquad (5)$$

Very important point in current-voltage characteristic is the maximal power point corresponding to the Maximum allowable power output noted Pm. In practice we can seldom reach this point, because at higher light intensity even the cell temperature increases, and consequently decreasing the output power. As a measure for solar cell quality fill-factor - FF is used. It can be expressed by the following equation:

$$FF = \frac{P_m}{I_{sc}V_{OC}} \qquad (6)$$

2. Results and discussion

Using the equivalent circuit model developed for inorganic pn-junction solar cells, the current density J and the dynamic resistance R for each experimental voltage V (N), were determined. The calculated parameters with experimental counterparts are illustrated in Table 1 for three different illumination intensities.

It is noticed that the reduction in shunt resistance and increase in diode reverse saturation current density are observed upon increase of the light intensity for 24, 60 and 100 mW/cm2 illumination intensities [5] (Fig.2).

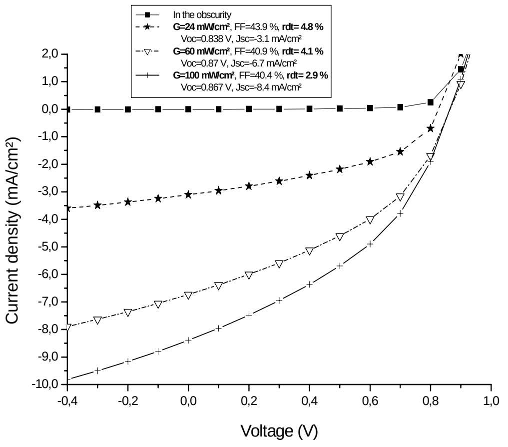

Fig.2 Current density-voltage characteristic under different AM1.5 solar simulator light intensities of an optimised MEH-PPV: PCBM device.

The main impact of series resistance is to reduce the fill factor (FF), although excessively high values may also reduce the short-circuit current (ISH). I.e the high-series resistance cell, however, exhibits successively more rounded characteristics at increasing light intensities, and the short circuit current deviates from the light generated current already at.100 mW cm2 of solar irradiance The cause for the deviation of the short circuit current from the light generated current at high light intensity and with large series resistance, particularly with large diffused layer sheet resistance, lies in the voltage drop across this series resistance. This voltage drop can result in an appreciable voltage across the junction in portions of the cell, although zero voltage condition exists at the terminals [10].

Also, it is noticed that an increase in RS leads to a reduced FF and the maximum allowable power output Pmax.

Furthermore, a simulation done on silicon solar cell, at the same conditions, shows that series and shunt resistances affect more performances in organic solar cell than others in a.Si[11].

Table 1: Calculated parameters based on simulated curves for MEH-PPV/PCBM organic solar cell working under different incident powers: (1) 100 mW/cm2, (2) 60 mW/cm2 and (3) 24 mW/cm2.

CONCLUSION

In this study, the effect of parasitic resistances on organic solar cells was investigated.

Results obtained show that an increase in series resistance leads to a reduced fill factor and Maximum allowable power output. The decreasing in shunt resistance reduces both fill factor and Maximum allowable power output. This study shows also that series and shunt resistances affect more performances in organic solar cell than others in a.Si [11].

It is of vital importance for the researchers in this recent area-organic solar cell- to modelling this kind of solar cell by minimizing the effects of these parasitic resistances and taking them in consideration when employing organic solar cell in systems and when analysing performance degradation.

* Calculated value using methods cited in references [10], [12].

Entry No.	Parameter	Incident power	Single-diode model	Experimental value(Organic device)	Simulated silicon solar cell
(i)	$R_s(\Omega)$	(1) (2) (3)	96.2 95.2 95.002	98.85* 98.65 98	4.2 4.19 4.18
(ii)	$R_{sh}(\Omega)$	(1) (2) (3)	720 718 717.12	736* 735.25 734.12	13800 13801 13801.5
(iii)	$J_0(mA/cm^2)$	(1) (2) (3)	$2.50\text{x}10^{-11}$ $2.52\text{x}10^{-11}$ $2.55\text{x}10^{-11}$	--- --- ---	$1.7 \text{ x } 10^{-9}$ $1.7 \text{ x } 10^{-9}$ $1.7 \text{ x } 10^{-9}$
(v)	J_L (mA/cm^2)	(1) (2) (3)	7.2 5.9 2.3	8.3 6.8 3.2	25 24 21
(vi)	V_{OC} (V)	(1) (2) (3)	0.850 0.790 0.71	0.875 0.875 0.813	0.62 0.59 0.57
(vii)	P_m: Maximum allowable power output (mW/cm^2)	(1) (2) (3)	2.35 1.97 0.74	2.934 2.394 1.146	12.1 11.95 11.82
(viii)	FF (%) (=Pm/V_{OC}.J_{SC})	(1) (2) (3)	38.39 42.26 45.31	40.4 40.9 43.9	78.06 84.39 98.74

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