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***Research Article***

# COMPARING THE EXTRACTED PARAMETERS IN CONDITIONS BEFORE AND AFTER THE SHADOW ON THE ORGANIC SOLAR CELLS

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## ABSTRACT
This research studies the effective parameters in designing solar panels using Lambert function. Using this function and the experimental results, we reviewed the temperature effects and realized that increasing temperature leads to voltage decrease of open circuit as well as reverse saturation current of the first diode and also results in increase of efficiency, filling factor, short-circuit current, the recomposition of carriers, carrier mobility, photo diode saturation current produced in the cell, and the saturation current of the second diode in solar cell.

***Keywords:*** *Temperature, Lambert Function, Organic Solar Cell*

## INTRODUCTION
Due to the benefits such as production cost, low costs of electric energy generation, and the ability to use flexible layers, organic solar cells, compared to inorganic solar cells, are good alternative conjugated polymers for inorganic semiconductors. This is the reason why solar cells have drawn a lot of attention in recent years (Chang and Wang, 2008) However, with regard to much efforts for increasing the efficiency of power conversion, this parameter is still less than the silicon solar cells (Katza *et al.*, 2001). The temperature effect is of effective factors on the efficiency of solar cells. There are different models to theoretically review the photovoltaic cells. In this work, the two-diode model was used to define the structure of solar cells (Bonkoungou *et al.*, 2004).
Knowing about the parameters of solar cells such as the reverse saturation current of the diodes, parallel resistors, the ideal factor, and the photocurrent give us important information on their quality control performance determination.
There are different ways to determine the parameters of solar cells including five-parameter method (Bonkoungou *et al.*, 2007), a new method based on optimization (Chegaara *et al.*, 2004), using compatible and improved development (Gong and Caia, 2013), genetic algorithm (Amani *et al.*, 2001), parameter extraction using Lambert method (Romero *et al.*, 2012), etc.
In this work, using the Lambert method we investigated the success of finding solar cell parameters and were able to find information about that, such as the reverse saturation current of the first and second diode, the first and second parallel resistance, the ideal factor od the first and second diode as well as the photocurrent.

***Model***
Several models have been introduced to determine the current-voltage behavior of solar cells. One of these models is two-diode equivalent-circuit model which has modeled the wastes in the est way (Figure 1). As seen, the electric equivalent circuit, including diode $d_2$and a parallel resistant$R_{p2}$, has been located in a parallel form with the standard one-diode circuit which includes a current source, and series $R_S$and parallel resistants $R_{sh}$.
$I_{RP2}, I_{RP1} R_s, R_{p2}, R_{p1}, I_{d2}, I_{d1}, I_{PH}$ are photocurrent, current passed through the first diode, current passed through the second diode, the first parallel resistant, the second parallel resistant, current passed through the first parallel resistant, and current passed through the first parallel resistant (Romero *et al.*, 2012).

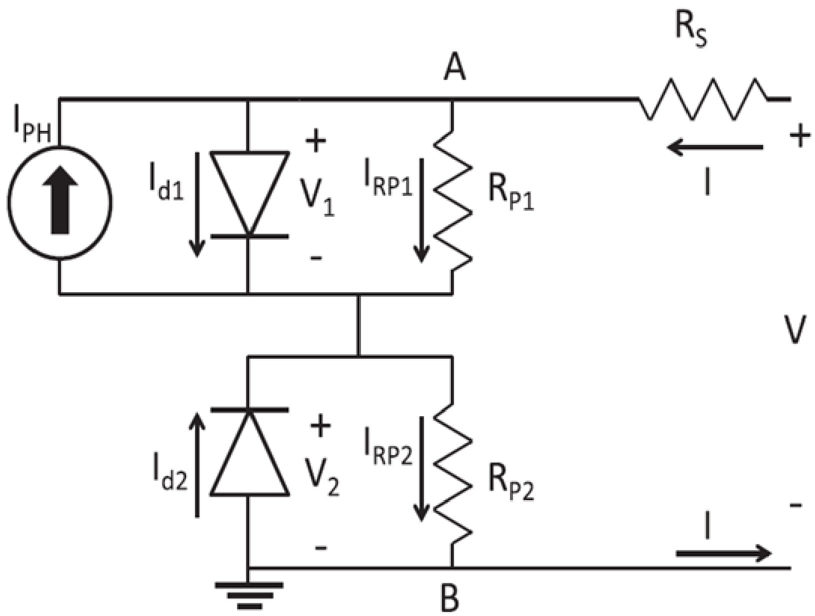


**Figure 1: The equivalent circuit of solar cells irradiated based on two-diode model**

Using Kirchhoff's circuit laws, the relation between current and voltage in nodes A and B of this circuit can be written as equations (2) and (3):

$$V = IR_s + V_1 + V_2 \quad (1)$$

$$I = I_{01}\left[pex\left(\frac{V_1}{n_1KT}\right) - 1\right] + \frac{V_1}{R_{p1}} - I_{ph} \quad (2)$$

$$I = I_{01}\,exp\left(\frac{V_1}{n_1KT}\right) - I_{01} + \frac{V_1}{R_{p1}} - I_{ph} \quad (3)$$

In order to replace in the relation (1) we use expressions (3) to order voltages V1 and V2 in terms of Lambert function (Corless *et al.*, 1996). Therefore we have the following relations:

$$V_1 = \left(I + I_{ph} + I_{01}\right)R_{p1} - n_1KTW\left[\frac{I_{01}}{n_1KT}exp\left(\frac{\left(I + I_{ph} + I_{01}\right)R_{p1}}{n_1KT}\right)\right] \quad (4)$$

$$V_2 = n_2KTW\,I_{02}R_{p2}\,exp\frac{-(I - I_{02})R_{p2}}{n_2KT} + -(I - I_{02})R_{p2} \quad (5)$$

Now we put these two relations in equation (1).

$$V = \left(I + I_{ph} + I_{01}\right)R_{p1} - n_1KTW\left[\frac{I_{01}}{n_1KT}exp\left(\frac{\left(I + I_{ph} + I_{01}\right)R_{p1}}{n_1KT}\right)\right] + n_2KTW\,I_{02}R_{p2}\,exp\frac{-(I - I_{02})R_{p2}}{n_2KT} \quad (6)$$

***Extracting the Parameters***

The way of extracting parameters is that we use Digitizer software to separate the voltage-current data from the experimental curve (Romero *et al.*, 2012) (Figure 2) and enter the data in a program we wrote in MATLAB. Then, we extract the effective parameters in designing ($I_{RP2}, R_s, R_{p2}, R_{p1}, I_{d2}, I_{d1}, I_{PH}$) solar cells.

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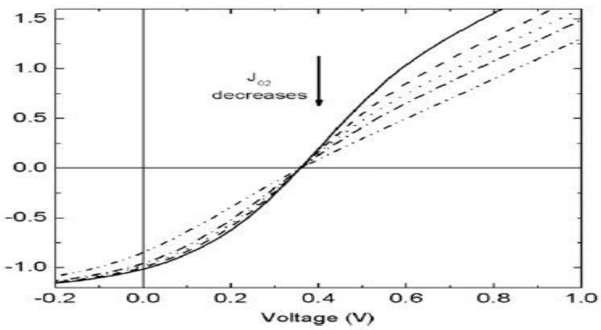



**Figure 2: Voltage-current density curve**

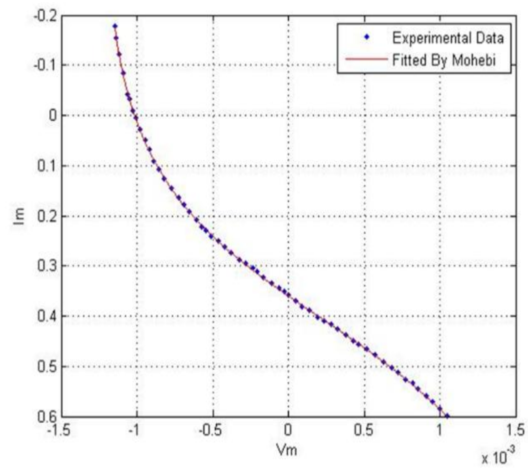



**Figure 3: Extracted curve by software using Lambert method**

Table 1: Shows the experimental extracted values from the article and the calculated data by MATLAB.

**Table 1: Comparison of calculated parameters by the software and article for solar cell**

| $n_2$ | $n_1$ | $R_{p2}$ | $R_{p1}$ | $J_{02}$ mA/cm2 | $J_{01}$ mA/cm2 | $I_{ph}$ mA/cm2 | |
|---|---|---|---|---|---|---|---|
| **3** | 6.5 | 1.6 $K\Omega$ | 0.7 $M\Omega$ | 0.86 | 0.14 | 1.1 | Article data |
| **2.27** | 6.35 | 0.34 $K\Omega.cm^2$ | 0.012 $M\Omega.cm^2$ | 0.75 | 0.13 | 1.07 | software data |

***Temperatures***

We investigated the effect of different temperatures $C^0$80= a ، $C^0$120=b ،$C^0$220=d on the effective parameters of asymmetric organic solar cells P3HT/PCBM. We realized that increasing the temperature of system increases the kinetic energy of production excitons and therefore increases the distribution length of excitons.

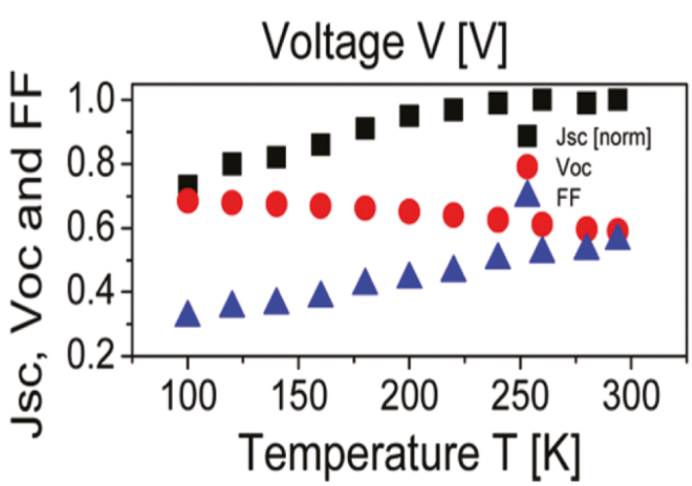



**Figure 3: Increase of short circuit current and open circuit voltage and filling factor by temperature [60]**

Thus, the possibility of reaching free charge carriers to the separation border will increase which leads to an increase in the output current. On the other hand, increase in the density of free charge carriers lead to increase the possibility of recombination. It means that increase in temperature leads to increase in the number of charge carriers and increase of charge carriers lead to increase of recombination. However, it should be noted that increase of temperature to a certain degree instigates some atom of the system. Therefore, the possibility that the resulted excitons experience recombination decreases. But if the temperature goes higher than a certain degree, majority of atoms are affected. Although more excitons are produced, the increase in possibility of recombination leads to decrease in production of free charge carriers. Therefore, the current will decrease. As seen in Figure (3), there is a linear increase in interval 0.7 $mA$ to 1 $mA$ for four temperature intervals. According to Figure (3) we realize that the temperature effects and realized that increasing temperature leads to voltage decrease of open circuit as well as reverse saturation current of the first diode and also results in increase of efficiency, filling factor, short-circuit current, the recomposition of carriers, carrier mobility, photo diode saturation current produced in the cell, and the saturation current of the second diode in solar cell.
As seen in Figure (6) and Table (2), the effective parameters in designing solar cells have been extracted using Lambert function and the experimental data extracted from the current voltage curve (Ralf *et al.*, 2010) in Figure (5).

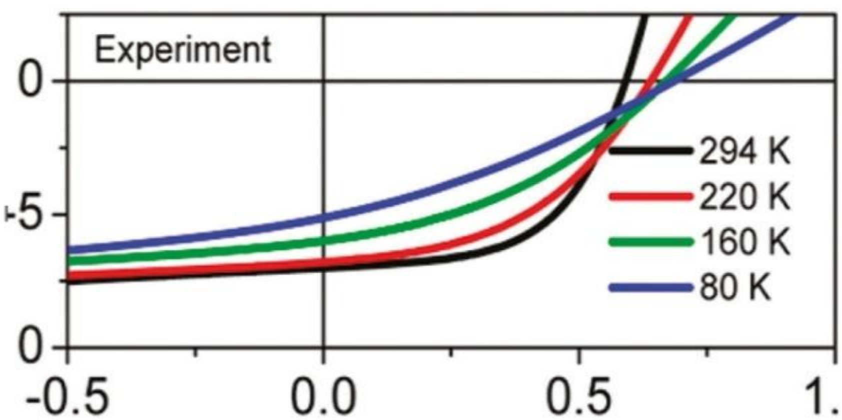
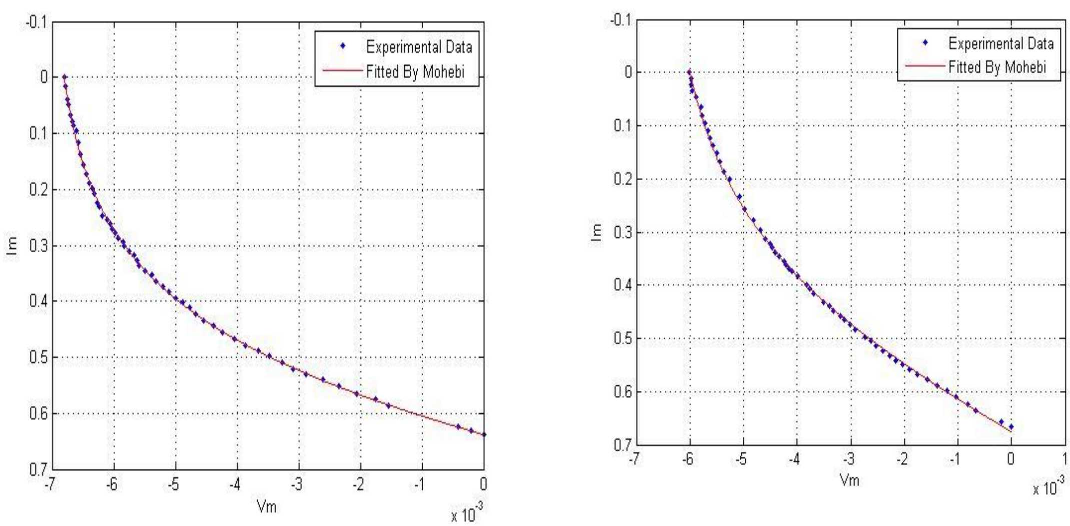
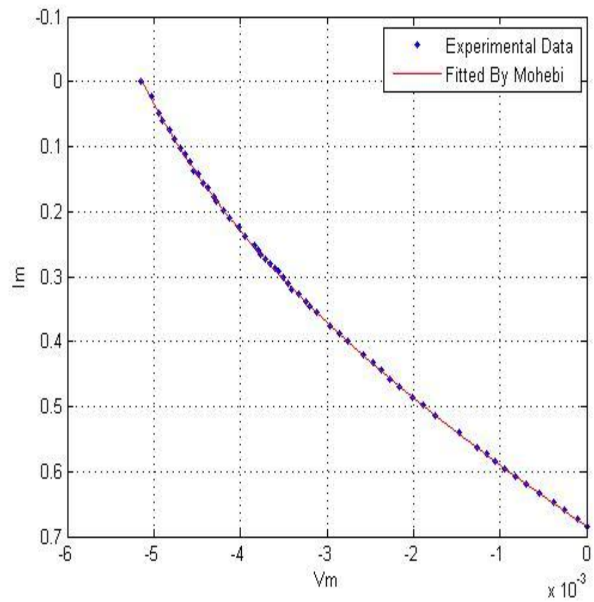



**Figure 5: The current voltage curve in temperature 160 $C^0$, 80 $C^0$, and 220 $C^0$(Ralf *et al.*, 2010)**




**a** **b**




***d***

**Figure 6: Extracted curve by software using Lambert method in different temperatures. $a$ - 220C$^0$ . $b$ - ،160C$^0$، $-d$80C$^0$**

**Table 2: The fitted parameters are calculated for heterogeneous organic solar cells (p3ht / pcbm) for three different temperatures**

| $n_2$ | $n_1$ | $R_{p2}$ $\Omega.cm^2$ | $R_{p1}$ $\Omega.cm^2$ | $I_{02}$ $A/cm^2$ | $I_{01}$ $A/cm^2$ | $I_{ph}$ $A/cm^2$ | C$^0$ |
|---|---|---|---|---|---|---|---|
| *8.11* | *10* | $5.399 \times 10^1$ | $1.053 \times 10^4$ | $3.191 \times 10^{-4}$ | $4.402 \times 10^{-4}$ | $5.83 \times 10^{-3}$ | **80** |
| *8.8* | *7.7* | $1 \times 10^2$ | $1.150 \times 10^4$ | $5.18 \times 10^{-3}$ | $2.162 \times 10^{-4}$ | $6.22 \times 10^{-3}$ | **160** |
| *3.8* | *6.4* | $2.709 \times 10^2$ | $1.192 \times 10^4$ | $1.232 \times 10^{-2}$ | $1.491 \times 10^{-4}$ | $6.846 \times 10^{-3}$ | **220** |

The results show an increase in temperature leads to increase in optical absorption and it increases the optical flow of cells. We also know that increase of temperature leads to increase of kinetic energy of excitons. On the other hand, it leads to increase diffusion length of excitons. Therefore, the possibility free charge carriers to reach the separation border will increase which leads to increase in the current density. Also, we realize that the temperature effects and realized that increasing temperature leads to voltage decrease of open circuit as well as reverse saturation current of the first diode and also results in increase of efficiency, filling factor, short-circuit current, the recomposition of carriers, carrier mobility, photo diode saturation current produced in the cell, and the saturation current of the second diode in solar cell.

***Conclusion***

With regard to the results, we realize that the temperature effects and realized that increasing temperature leads to voltage decrease of open circuit as well as reverse saturation current of the first diode and also results in increase of efficiency, filling factor, short-circuit current, the recomposition of carriers, carrier mobility, photo diode saturation current produced in the cell, and the saturation current of the second diode in solar cell.

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