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Analysis of the pv efficiency according to the caracteristics of silicon solar cells

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***Abstract*— The analysis of the obtained results from the variation of the technological parameters of two solar cells with silicon, on their photovoltaic production, worth knowing the one designed by two structures polycristalline and monocrystalline (region N and P) called cell1 and the other one designed by two monocrystalline structures called cell2 showed a narrow relation between the initial conditions of manufacturing of cells, and the photovoltaic parameters resulting during their functioning.**

Keywords- Efficiency, polycrystalline Silicon, monocrystalline Silicon.

I. Introduction

Solar PV cells are electronic devices that use P-N junctions to directly convert sunlight into electrical power [1]. A complex relationship between voltage and current is exhibited by the P-N junction in the solar cell. The voltage and current both, being a function of the light falling on the cell, and experimental conditions of manufacturing of cells. The use of a digital simulation highlights the optimization of the dominating parameters to obtain a maximal efficiency for two photovoltaic cells having for structure : poly-Si(N)/c-Si(P) called Cell1 et c-Si(N)/c-Si(P) called Cell2. For this we used an applied SILVACO program for equations and relative relations for the structures used in the conception of the photovoltaic cells.

The parameters that will be improved in this work are the technological parameters, the size's thickness and the doping. This optimization includes the influence of these parameters on the two cells in order to obtain a structure with a high efficiency.

At first, we use the SILVACO software to determine the photovoltaic current considered practically equal to current of short circuit. And, secondly we use the MATLAB software to determine the parameter's photovoltaic such as photocurrent, open circuit-voltage and efficiency.

II. Method

The simulation by SILVACO is based on the digital resolution of three fundamental equations of transport of carriers in semiconductors which are respectively the equation of Poisson and the equations of continuity and transport for electrons and holes [2]. After the definition of the meshing of the studied structure the materials and models, the simulator estimates numerically the resolution of these equations in every knot of the meshing [3, 4], and determine the current of short circuit under the standard conditions of illumination (AM1.5G) in 300°K.

The simulation by MATLAB, consists in drafting a program into which we introduce the equations of a real model to the solar cell, by exploiting the results obtained from the software SILVACO. All the work is based on the study of the influence of the thickness size (that is in the zone N or in the zone P) on the photovoltaic parameters for every cell. Three parameters are important in analyzing the performance of solar cells: the short-circuit photocurrent, the open-circuit photovoltage, and the efficiency [5, 6], and the influence of the variation of the doping in every region on these parameters.

III. Results and Discussion

Fig. 1, presents the technological structures of the studied cells obtained from the software SILVACO [7].

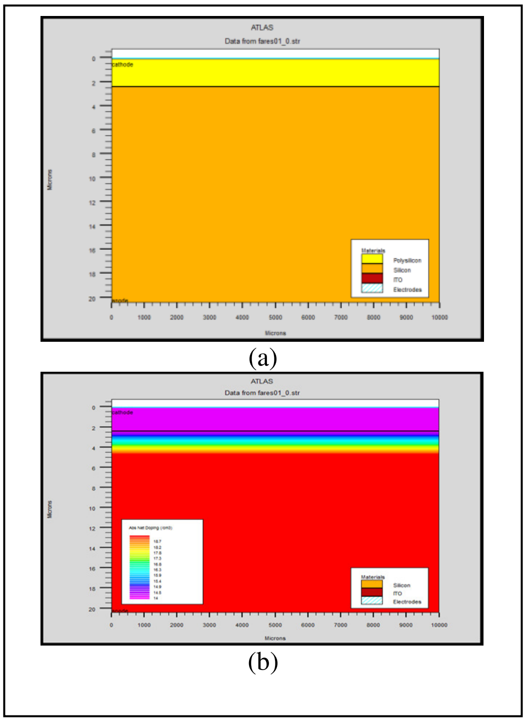

Fig. 1. Technological structures with the software SILVACO, (a) Cell1: Si-poly(N)/c-Si(P), (b) Cell2 : c-Si (N)/c-Si(P).

The characteristics of these cells are included in the Table 1:

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Table 1: Characteristics of Cells

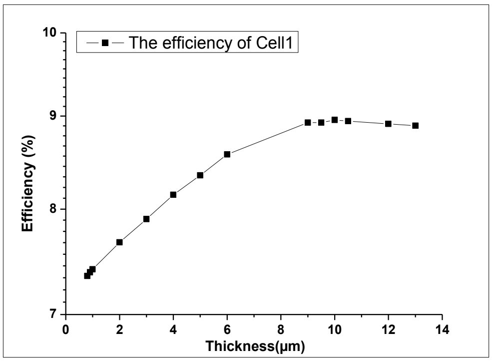
	Zone	Thickness (µm)	Dopage (cm^3)
Cell1	N	0.8	10E14
	P	20	10E16
Cell2	N	0.1	10E14
	P	20	10E16

A. *Impact of thickness*

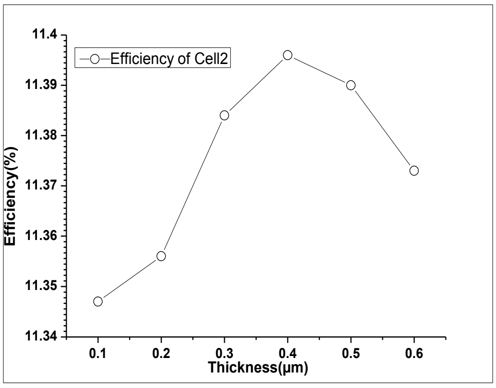
1) *Influence of the thickness in the zone N*

We arrange the thickness of 0.8µm until 13 µm of the layer N, by maintaining the other constant parameters.

In Fig. 2, we show the evolution of the photovoltaic efficiency according to the variation in thickness of layer N of the cell1. For the varying values of thickness from 0,8 to 10 µm, there is an increase of short circuit current ~ photovoltaic current and open circuit voltage, the curent crosses from 14.317 mA to 17.287 mA, and the voltage appears constant. For the values of thickness varying from 10 to 13 µm, we notice a decrease into two parameters; the efficiency obtained for a thickness of 0.8 µm is 7.35 % as for the thickness of 10 µm, it gives a 8.96 % efficiency. Reaching 13 µm, it falls in 8.89 %. The maximal efficiency is 8.9557%, corresponds to the value of thickness 10 µm.



(a)



(b)

Fig. 2. Influence of the thickness in the zone N. For (a) Cell1 and (b) Cell2 on the efficiency.

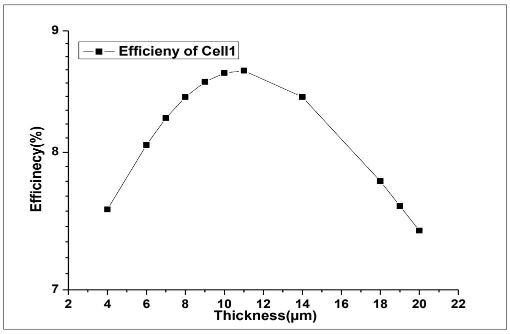
For the cell2, we vary the thickness of 0.1µm until 0.6 µm. For the values of thickness varying from 0,1 to 0.4 µm, we notice an increase of photocurent; It passes from 20.497 mA to 20.58mA. And from 0.4 to 0.6 µm, the photocurent decrease; it spends 20.58 mA to 20.541 mA.

We notice that the obtained efficiency for a thickness of 0.1 µm is 11.35 % as for the thickness of 0.4 µm, it gives 11.4 %. Reaching, we notice that the efficiency obtained for a thickness of 0.1 µm is 11.35 % as for the thickness of 0.4 µm, it gives 11.4 % efficiency. Reaching 0.6 µm, it falls to 11.37 %. The maximal efficiency is 11.396%, corresponds to the value of thickness 0.4 µm. At 0.6 µm, it falls in 11.37 %.

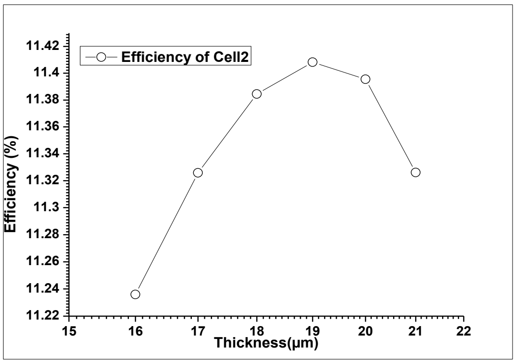
2) *Influence of the thickness in the zone P*

For the cell 1, we vary the thickness of 4µm until 20µm of the P layer, by maintaining the other parameters constant (see Fig.3). A proportional increase of the photovoltaic parameters with the thickness of the P layer is noticed, and it until the value 11µm, after, all the values decrease. So, the obtained best efficiency is 8.6585% for the value of 11µm.

For the cell2, we arrange the thickness of 4 µm until 20 µm, the maximal values of the photovoltaic parameters are reached when the value of the thickness in the P layer achieves 19µm (11.4083%), beyond this value, it decrease.



(a)



(b)

Fig. 3. Influence of the thickness in the zone P. For (a) Cell1 and (b) Cell2 on the efficiency.

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B. *Impact of the dopage*

1) *Influence of the dopage N*

For the cell1, we arrange the doping Nd=1×10^{10} cm^{-3} until 1×10^{14}cm^{-3} (Na=1×10^{16} /cm^{3}). According to obtained curves on Fig. 4, we notice that the photovoltaic parameters increase with the increase of the dopants concentration Nd (Nd Na=1×10^{16}/cm^{3}). The increase of the doping allows a remarkable improvement of the photovoltaic conversion. This can be explained by the fact that the increase of doping increases the life expectancy of the minority carriers, as well as their mobility.

The best obtained efficiency is 8.9557 % for the values of doping Na=1×10^{16}/cm^{3} and Nd=1×10^{14}/cm^{3}. For the cell2, we vary the doping Nd of 1×10^{10}/cm^{3} until 1×10^{14}cm^{-3} (Na=1×10^{16} / cm^{3}). We notice that the increase of the concentration of the doping Nd, led an increase in the values of the various photovoltaic parameters; the best efficiency obtained with this structure is 11.3903 % for the values of doping Na=1×10^{16}/cm^{3} and Nd=1×10^{14} / cm^{3}.

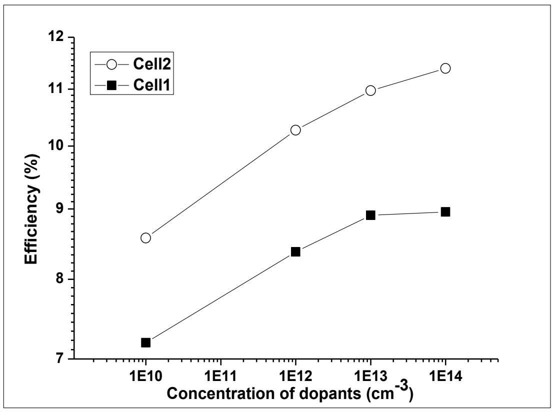

Fig. 4. Influence of the amount of dopants in the zone N on the efficiency

2) *Influence of the dopage P*

We vary the doping Na=1×10^{15}cm^{-3} until 1×10^{20}cm^{-3} (Nd=1×10^{14}/cm^{3}). The results illustrated on Fig.5, show a progressive increase of the photovoltaic parameters according to the doping of the zone P in cell1 and cell2. The optimal values are obtained at concentration of 1×10^{17}cm^{-3} (8.7962%) in the cell1. After this concentration, all parameter's photovoltaic decrease at the same time following by decreasing, and decrease after this concentration.

For the cell2, we vary the doping Na= 1×10^{16} cm^{-3} until 1×10^{19}cm^{-3}, and take the doping Nd=1×10^{14}/cm^{3}. We notice that all the photovoltaic parameters undergo a reduction during the increase of the dopants concentration in the P layer of 1×10^{16}/cm^{3} to 1×10^{19}/cm^{3} by maintaining constant the layer N at 1×10^{14}/cm^{3}.

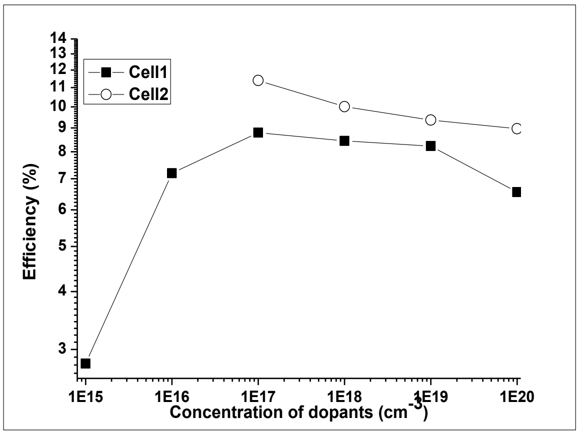

Fig. 5. Influence of the amount of dopants in the zone P on the efficiency

The comparison between the efficiencies obtained from both studied cells such as represented on Figures, show a clear difference between curves, the photovoltaic quality of cell2 is better than that obtained for cell1.

The analysis of the results obtained from the variation of the thickness for every zone of the junction, showed that when the lengths of distribution of the photo-generated carriers are upper to the traveled distances, the photovoltaic conversion increases until a maximal value in a certain value of thickness, then for high values of thickness, the length of distribution of the photo-carriers becomes small compared with the thickness [6-8]; The photo-generated carriers have to travel distances bigger than their lengthes of distribution, what leads drives to a strong rate of recombination because of their weak life expectancy decreasing the photovoltaic quality[9,10].

While the increase of the doping improves all the photovoltaic parameters occurring in the efficiency on conversion of every studied solar cell; Indeed the variation as well of the open circuit voltage as the density of photo-current, evolve in the same sense as the evolution of the values of the doping of the layer N. However, the increase of the doping of the layer P shows an inverse phenomenon for cell2. This is may be due to the gradient of concentration raised between both N layers and P layer (Nd=1×10^{14}cm^{-3} and Na=1×10^{16}cm^{-3} to 1×10^{18}cm^{-3}) [8]. For cell1, the obtained results are better for a doping of 1×10^{17}cm^{-3}, and beyond this value they fall. That confirms our results which are in good agreement with other work [11].

IV. CONCLUSION

The obtained results in this work, allowed to determine the influence of two important parameters: the size and the rate of doping characterizing two solar cells; the analysis showed that an important improvement of the photovoltaic efficiency is possible from an adequate choice of the material and these two parameters.

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