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Modeling of the Junction CdS (N)/CdTe (P)

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ABSTRACT

To goal to optimize the performances of CdTe/CdS solar cell , we will study the influence of various parameters on the performances of the solar cell.
The choice of the parameters used at summer studied starting from the properties of the layers and the literature.
We modeled the following layers structure: SnO/CdS/CdTe where we studied the effect of the thicknesses, concentration of doping and the defects density in the gap of CdTe layer on the performance of solar cell.

Keywords: CdTe solar cell; Solar cell performance; Thicknesses; Concentration of doping; Defect density.

I. INTRODUCTION

Each material has its own characteristics and properties which make it better to another. The objective of the work which will follow is to study the influence of various parameters on the performances of CdTe solar cell, using SCAPS software. The CdTe solar cells have a significant potential as a source of low cost, high-output solar electricity [1].

The high current level of the research and the development of the thin layer polycrystalline CdS/CdTe solar cell is pulled by the possibility of producing photovoltaic modules with low cost [2].

The semiconductor telluride of cadmium (CdTe) is the active zone of the CdS/CdTe heterojunction where, the majority of the surplus minority carriers are generated. The band gap of CdTe is equal to 1,45 eV, and it can be doped N or of type P, like it was recognized very early like a good layer of absorption of the solar cell because it has a strong optical absorption (direct) above the gap (> 104 cm^{-1})[3].

However, the devices with homo-junction are not very practical because the majority absorption of the solar spectrum occur inside 1-2 um surface of CdTe and this fact the loss of recombination of surface on an unacceptable level. To avoid that, the configuration p-CdTe/n-CdS/TCO/glass was developed [4]

The cadmium sulphide doped N (n-CdS) (Eg = 2,4 eV) form a side of the electric junction and acts like a layer of window.CdS thin, 50-100 Nm,

The layer of window n-CdS is an essential component of the cell p-CdTe/TCO with η>10 % were highlighted [5], this junction is basically lower. Requirements of CdS are that it should be conducting (N ~ 1016 cm^{-3}), thin to allow the transmission high (50-100 Nm) and uniform to avoid effects of short-circuit; therefore it is preferable to allow the optical transmission above variation. CdTe should not be 1-2 µm thickness, but can be more thick to ensure the homogeneity [2,6,7,8**]**.

Numerical modeling is a need for the real description of photovoltaic devices in thin layers. Accordingly, several choices of the tools for digital simulation for the photovoltaic cells in thin layers are currently available, such as AFORS-HET and SCAPS. In the following part one will use the last (SCAPS).

II. PRESENTATION OF THE SNO/CDS/CDTE STRUCTURE

The three layers which are underlined in this simulation are SnO, CdS and CdTe. By integrating the various material parameters in SCAPS for all the aspects of the analysis, the changes in the values of Voc, Jsc, FF and η as well as the effect of the operating temperature are studied.

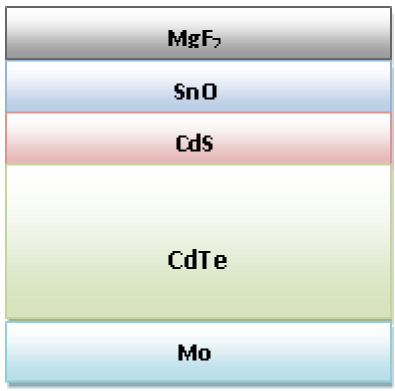

Figure I Structure of the cell modelled

Table I shows the description of the parameters of simulation and the parameters basic which were used in this study.

Table I Parameters of various layers of the structure modelled

Parameter	SnO	CdS	CdTe
Thickness (µm)	0,05	0,01	2
Energy of gap (ev)	3,6	2,4	1,5
electron affinity	4,5	4,5	4,3
dielectric permittivity	9	10	9,4
Effective CB density of states (1/cm^3)	2,È18	2,È18	8 E17
Effective VB density of states (1/cm^3)	1,8E19	1,8E19	1,8E19
electron thermal velocity (cm/s)	1E07	1E07	1E07
hole thermal velocity (cm/s)	1E07	1E07	1E07
electron mobility (cm²/Vs)	100	100	320
hole mobility (cm²/Vs)	25	25	40
shallow donor density ND(y) (1/cm3)	1E19	1E19	0
shallow acceptor density NA(y) (1/cm3)	0	0	È15

For the defects, they are presented on table II

Table II Defects in various layers

Parameter	**SnO**	**CdS**	**CdTe**
		Defect 1	
Type of defect	Neutral	Neutral	Neutral
Energy distribution	simple	simple	Simple
Concentration of defects	1014	1016	1013
Energy of traps (eV)	0,6	1,2	0,65
Sigma N (cm2)	10^{-15}	10^{-15}	10^{-15}
Sigma p (cm2)	10^{-15}	10^{-15}	10^{-15}
		Defect 2	
Type of defect			Acceptor
Energy distribution			Gaussian
Concentration of defects			1016
Energy of traps (eV)			0,5
Sigma N (cm2)			10^{-16}
Sigma p (cm2)			10^{-15}
		Defect 3	
Type of defect			Donor
Energy distribution			Gaussian
Concentration of defects			1017
Energy of traps (eV)			1
Sigma N (cm2)			10^{-15}
Sigma p (cm2)			10^{-17}

III. RESULTS AND DISCUSSION

The result of modeling of the J-v characteristic under illumination is presented under figure II.The performances obtained are: Voc = 870,37 mV, Jsc = 24.13 mA/cm2, FF = 76.12 % and η = 15.99 %.

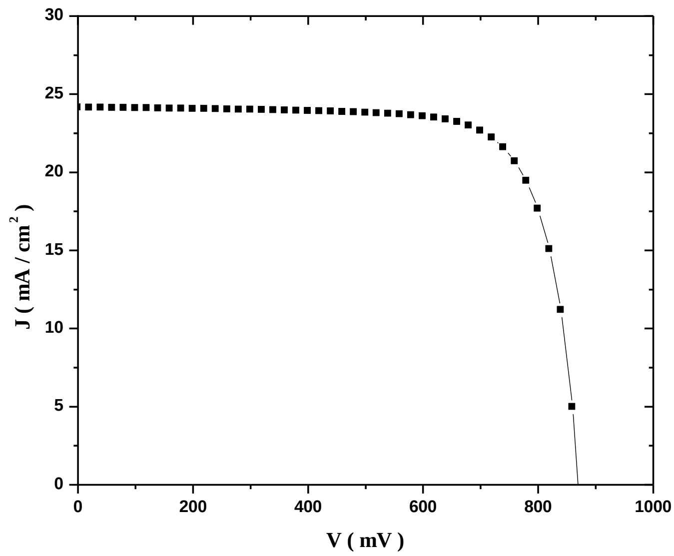

Figure II J-v Characteristic of the cell models CdTe

Optimization thickness of the CdTe absorber and the CdS transmitter

Initially, the thickness of the CdTe absorber was modified to determine the optimal thickness of the structure of CdTe. It was found that the performances (Vco, Jsc, FF and η) of the cell increase with the increase thickness of the CdTe layer. The optimal thickness would be around 2 µm. Figure III, with the thickness of 1000 Nm and 5000 Nm, the output is recorded 14,28% and 19,5% respectively.

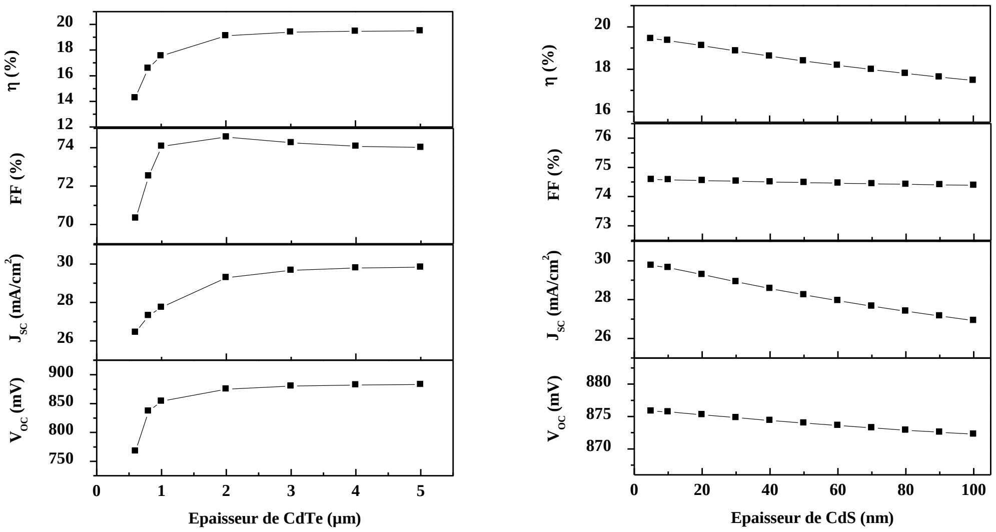

Figure III Effect the thickness of the layers CdTe and CdS on the performances of the cell.

The CdS transmitter constitutes the layer fenestrates in the heterojunction and this denomination refers to the property of transparency of the layer of CdS [9]. This property of transparency should depend on the thickness of the CdS layer, this is why we considered it useful to see the behavior of the cell with the variation thickness of this layer.

The effect of the variation thickness of the plug layer of CdS on the performances of the cell simulated is represented. The thickness of the plug layer of CdS was varied from 5 nm with 100 nm in this simulation. The thickness of the plug layer of 10 nm was used as basic parameters in this study are optimal starting from the results of simulation. The effect in V_{OC}, J_{SC}, FF and η of the solar cell is represented on figure III, where the values are into light fall variable thickness of the plug layer of CdS. Indeed, a thick plug layer will result in a greater loss of photons. When the plug layer is increased, more photons which transport energy is absorbed by this layer. Consequently, it would lead to a reduction in the photons which reached the absorbing layer.

Optimization of the concentration of doping of the CdTe absorber and the emettor CdS

The increase in the concentration of doping for the absorber led to the reduction in the density of current and consequently the tension of open circuit increases, which illustrates in the following equation:

$$J_{obs} = A\left(\frac{qD_n n_i^2}{L_n N_a} + \frac{qD_p n_i^2}{L_p N_d}\right)$$

And

$$V_{co} = \frac{A_0 kT}{q} \ln\left(\frac{J_{ph}}{J_{obs}} + 1\right)$$

According to figure IV we notice that the best performances are that which corresponds to high absorbing doping of the layer, therefore a concentration of doping equal to 10^{16} cm $^{-3}$.

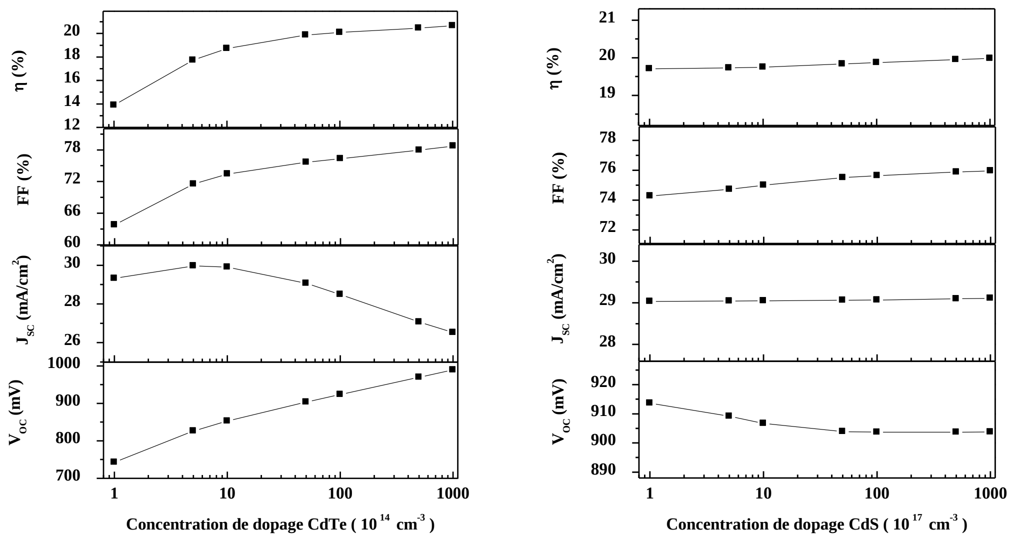

Figure IV Effect of the concentration of doping of the layers CdTe and CdS on the performances of the cell.

The effect of the concentration of doping of CdS on the performances of the cell simulated is represented in figure IV one notices that the three variables Jsc, FF and η are increased very slightly with the increase in the concentration of doping of the CdS. layer For $V_{OC,}$ it has a weak reduction in the departure, then it will be constant. An optimal value equal to 10^{18} cm $^{-3}$ is selected.

The effect of the concentration of defect

The characteristics of semiconductor materials are strongly influenced by the impurities or the defects. Often these defects in the network act like factors of loss, consequently a high concentration of defects decreases the possibility of transport of the carriers, thus reducing the output of conversion.

For the first defect in the prohibited band of the CdTe layer, it is considered neutral, in the medium of the gap. The performances of the cell remain constant until a concentration of defect of 10^{12} cm $^{-3}$, beyond this value, they start to decrease (the recombination is dominated by SRH).

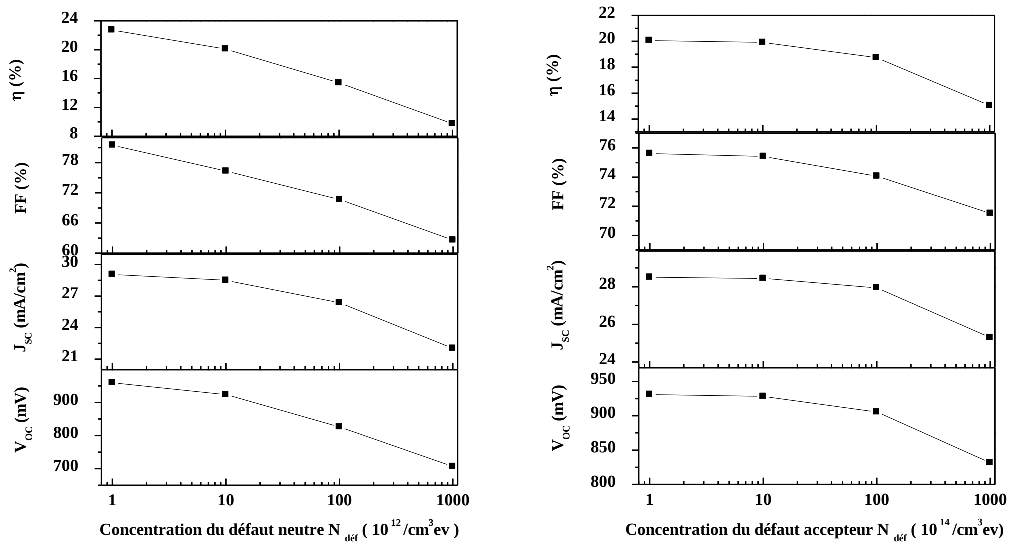

Figure V Effect of the density of the neutral defect and acceptor on the performances of the cell.

For the defect acceptor, the increase in the concentration of defect leads to the reduction in the performances of the cell. Concerning the density of current, that is related to the diffusion length which decreases with the increase in the Jobs.

For the defect donor with trailer, the variation of the concentration of defect does not have any influence. It deferred that the distribution of such a distribution on the current of recombination is negligible.

IV. CONCLUSION

The effects of the thicknesses, concentration of doping and the defects density of different layers on the performance of solar cell have been studied. It is shown that, the performances of the solar cell were influenced with variation in thicknesses, concentration of doping and also in defects density. A record efficiency of 22,3% could be obtained. Relevant parameters values are V_{OC}(960 mV), J_{SC} (28,7 mA/cm2) and FF of 81,5%.

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