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Improvement the Efficiency CIGS Thin Film Solar Cells by Changing the Thickness Layers

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Abstract: *In this study the function of solar cells with the structure of CuIn1-xGaxSe2is examined. CIGS solar cell consists of layers of ZnO (Layer TCO), Cd_S (buffer layer), CIGS (absorbent layer), and Layer MO (substrate), which Cd_S and CIGS layers form a PN Junction. Later using SILVACO software CIGS solar cell is simulated. Then, CIGS solar cell is simulated using SILVACO software, Firstly the thickness of the adsorbent layer is changed. Later thickness of the absorbent layer becomes fixed and the thickness of the Cd_S and ZnO layers are changed respectively and its effect on cell function is discussed and examined. Important parameters of a solar cell that will be discussed here, include open circuit voltage (VOC), short circuit current (ISC), maximum power (Pmax), filling factor (FF) and efficiency (η). After conducted simulations, it was that increasing or decreasing the thickness layers has impact on solar cells function.*

Keywords: Absorbent, efficiency, Photon, Power, Thickness

1. Introduction

One of the main goals of today's PV research and development is making the cells thinner by using less semiconductor material in order to lower production time and reduce the cost due to increased indium prices and composited elements expenses.

The thickness of a solar cell is a very important Parameter, and choosing the optimal thickness is often a function of many conflicting factors. The standard thickness of the CIGS absorber layer in CIGS thin-film solar cells is presently 1.5–2µm. If this thickness could be reduced with no, or only minor, loss in performance, it would lead to even more effective PV cells and in boosting efficiencies to new record levels. Making thinner absorber layer has been associated with recombination losses due to smaller grains and larger grain boundaries. It has been also associated with high probability of back contact recombination due to carrier generation close to the back contact and increased tunneling recombination close to the interface [1].

The question of how thin the absorber thickness should be arises. Using more material unduly increases the cost of the cell, while on the other hand, with too little, part of the important properties of these materials are lost, since, for example, less light is absorbed.

1.2 CIGS Solar Cells Structure

CIGS Solar cell (Copper-Indium-Gallium-Selenium) is a semiconductor I-IIIVI2 with a direct band gap and high absorption coefficient.

The preceding is an alloy between CIS and CGS which is described by the chemical formula $CuIn_{1-x}Ga_xSe_2$, Where X is the ratio between Ga/(Ga+In). By changing x, the concentration of Gallium and Indium will change and as a result would alter the band gap. The value of band gaps change from 1.04ev for x= 0 for the CIS to 1.68ev for x=1, for the CGS, maximized for a Ga content with a value roughly 0.3, resulted in absorber energy band gap values of roughly 1.1–1.2 eV [2].

In these cells, the lowest conduction band has been put

Against the maximum capacity of the tape and has the Highest efficiency compared to other solar cells CIGS Solar cells as shown in Figure 1 is composed of the following layers [3].

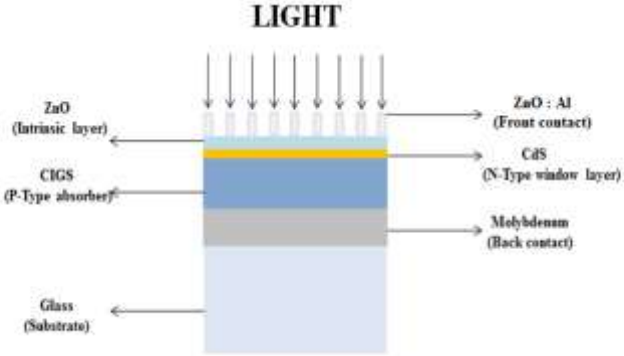

Figure 1: CIGS structure

Layer 1) Impure Aluminium with zinc oxide (ZnO: Al) whose duty it is to guide the photons received.

Layer 2) Layers of zinc oxide (ZnO: i) as layer TCO (Transparent Conductive Oxide) used. TCO layers have a large band gap to ensure maximum absorption of sunlight. It should be a transparent layer that can absorb maximum photons [4].

Layer 3) layers n-Cd_S (Sulphide Cadmium) that is n type semiconductor and acts as a buffer layer between CIGS and TCO layers .These layers will result in better performance of the solar cells. [5].

Layer 4) of the CIGS absorber layer is the core and active layer of the solar cell and a P-type multi crystal semiconductor .It has a direct band gap and its absorption coefficient is about105cm^{-1}.This layer along with the buffer layer form a p-n junction [6].

Layer 5) to be able to form an ohmic contact between a metal and semiconductor, the metal should have a higher work function than that of the semiconductor. Mo is usually used as a back contact in chalcopyrite devices since it is highly anticorrosive and creates a contact with the absorber due to the MoSe2 interlayer formed during its deposition. The back-contract thickness is determined by the resistance requirements of each solar cell [7].

The properties of the Mo layer and the selection of the glass substrate are of critical importance to the quality of the cell because of the role of Na, which diffuses from the glass substrate to the growing layer of the absorber through the Mo layer. This trend has been found to improve crystallographic properties and Doping in CIGS thin-films. By depositing various compounds prior to the deposition of the absorber, the diffusion of Na is controlled and homogeneous, allowing the use of other types of substrates as a back contact without any significant change in the cell's performance, given that a sufficient amount of Na is provided.

Layer 6) the substrate used in these arrangements is usually a common soda-lime glass. The introduction of Na from the glass soda-lime substrate during the growth of the absorber contributes to the quality of the absorber. Although the diffusion mechanism function of Na is not fully understood, its presence in the growth of the absorber is necessary for high efficiency devices. The general specifications that the substrate should meet are mechanical stability and thermal-expansion coefficient congruence with the next deposited layer. The deposition of the absorber requires a substrate temperature of at least 350 C, while the elements with the highest efficiencies have been deposited at the maximum temperature of 550 C, which the glass substrate can withstand without becoming particularly soft. Because the glass composition usually contains various acids, which provide the necessary defects to be diffused into subsequent layers during processing, a process that allows a controlled Na flow it is often preferred. Because of various other defects that the glass substrate may have, experiments with other types of substrates have been done; however, the cost and the wide variation in thermal-expansion coefficients are prohibitive factors for their wide use [8].

A ZnO layer, with a band gap of 3.3 eV, is typically used as the n-type semiconductor, the transparent window layer that facilitates solar radiation's passing through the cell.

The absorption of solar radiation and creation of electron Hole pairs take place in the p-type semiconductor, namely the chalcopyrite characterized as the absorber. High

Absorption coefficients allow the use of thin layers of a few microns thickness with high impurities concentration and intrinsic defects. On the other hand, during the hetero junction formation, the generated interlayers have also high defects percentage, and the carriers' recombination in the interlayer is very likely [9].

The ZnO/CIGS hetero junction is not considered propitious for carriers shift, because ions created during the ZnO preparation reinforce the electron-hole Pairs recombination in the interlayer and can damage the surface of the absorber. For this reason, a very thin Cd_S layer with a band gap of 2.4 eV is used between the ZnO and the absorber layer, and it is usually prepared with the chemical-bath deposition method. Using a buffer layer, we achieve a better band gap adjustment between the window and absorber layer [10].

2. Simulation

Physical parameters used in the simulations Table1 have been identified. Are given in Table1 physical parameters used in the Simulation.

Table 1: Physical Parameters Used In the Simulation [10]

	ZnO	C_dS	CIGS
εr	9	10	13.6
χ_e (eV)	4	3.75	3.89
μ_n (cm^2/Vs)	100	100	100
μ_p (cm^2/Vs)	25	25	25
N_A ($1/cm^3$)	0	0	2e+16
N_D ($1/cm^3$)	1e+18	1e+18	0
N_C ($1/cm^3$)	2.2e+18	2.2e+18	2.2e+18
N_V ($1/cm^3$)	1.8e+19	1.8e+19	1.8e+19
E_g (eV)	3.3	2.4	1.15
Thickness (nm)	100	Variable	1700

3. Results and discussion

The basic model structure of simulated CIGS solar cells is shown in Figure 2.

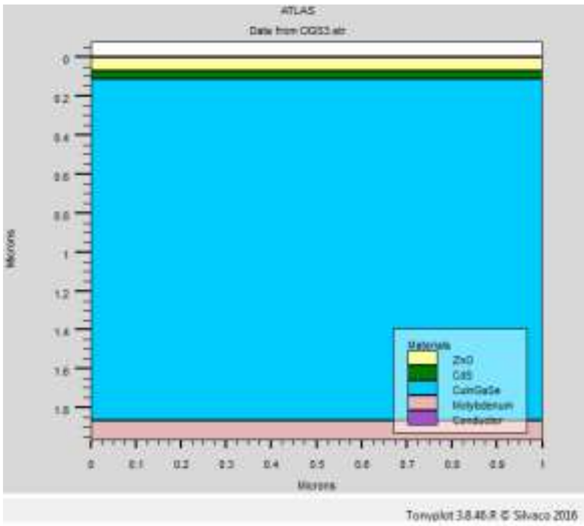

Figure 2: Simulated CIGS Structure

3.1. Changing the thickness of absorbent layer

Simulation is performed for CIGS solar cell will absorbent layer of 500nm, 1000nm and 1750nm respectively. The efficiencies of these solar cells were determined by their I-V Curve and are shown in figure 3.

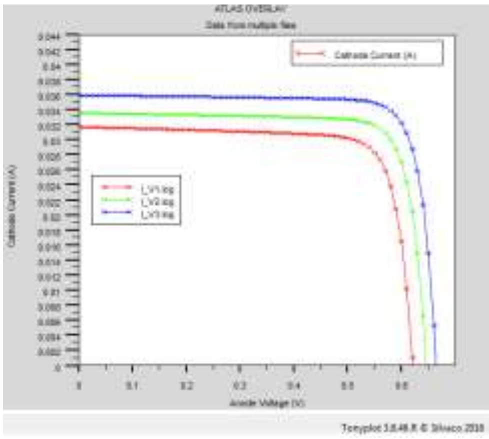

Figure 3: I-V Curves for changing the thickness absorbent layer

Figure 4 and a Figure 5 respectively show curves efficiencies and power.

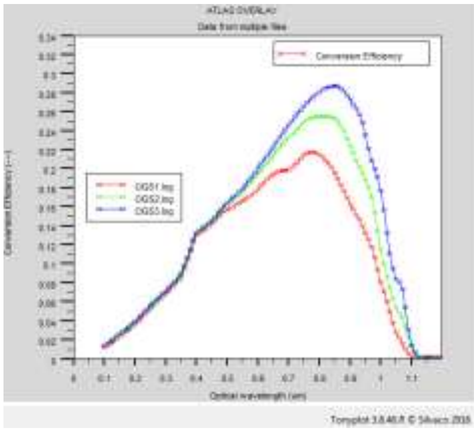

Figure 4: Efficiency curves for changing the thickness absorbent layer

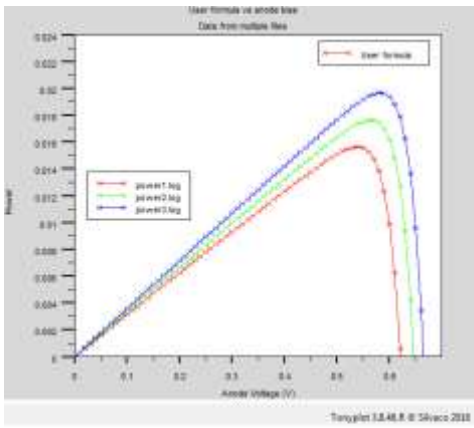

Figure 5: Power curves for changing the thickness absorbent layer

As it can be seen from the results obtained. That efficiencies, power, I_{SC} and V_{OC} will be improved as the absorbent layer increases. As the thickness of absorbent layer increases the possibility of electrons by photons also increases but these values are not proportional the increase in thickness of absorbent layer. As the thickness of the absorbent layers the recombination rate also increases and this causes less photons to reach the end areas of the absorbent areas compared to the higher areas .In fact, most of photons are absorbed by top of absorbent areas .It is concluded increase in absorbent layer also improves solar cell function.

3.2. Changing the thickness of ZnO layer

Simulation is performed for CIGS solar cell will the thickness of ZnO layer of 200nm, 75nm and 40nm respectively. The efficiencies of these solar cells were determined by their I-V curve and are shown in figure 6.

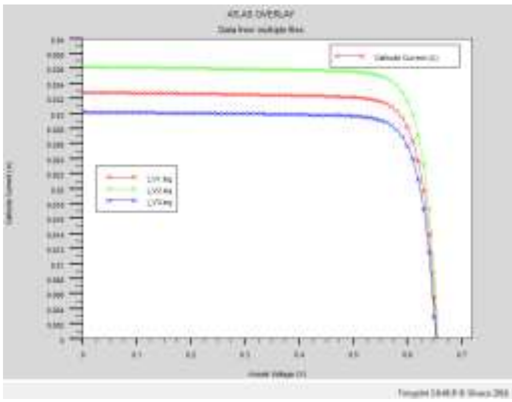

Figure 6: V-I curves for changing the thickness ZnO layer

Figure7 and a Figure8 respectively show curves efficiencies and Power.

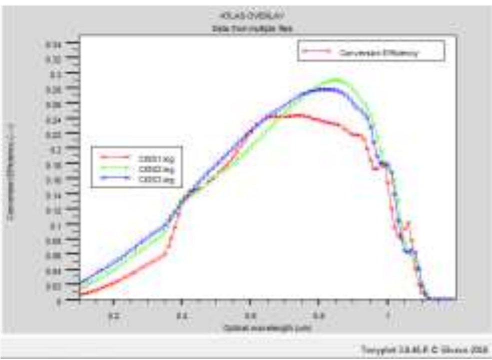

Figure 7: Efficiency curves for changing the thickness ZnO layer

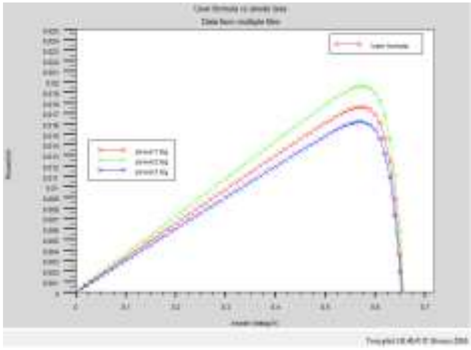

Figure 8: Power curves for changing the thickness ZnO layer

As shown in the charts of power and voltage-current, when ZnO layer is selected not too large or not too small, it would have high power, open circuit voltage (Vco), and short circuit current (Isc). As is seen in the efficiency curve, Increase or decrease excessive ZnO layer cause Efficiency is coming down because If this layer be too thick Less photons Go to cell absorbent layer And cause The efficiency be low, also If The thickness of this layer Too thin Because of reflection Less photons Entered the cells and thus cell efficiency decrease.

3.3. Changing the thickness of Cd_S layer

Simulation is performed for CIGS solar cell will Cd_S layer of 200nm (CIGS1), 100nm (CIGS2) and 10nm (CIGS3) respectively. The efficiencies of these solar cells were determined by their I-V Curve and are shown in figure 9.

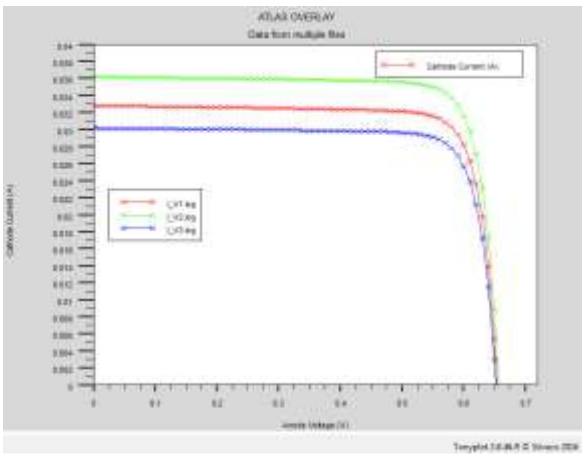

Figure 9: V-I curves for changing the thickness Cd_S layer

Figure 10 and a Figure 11 respectively show curves efficiencies and power.

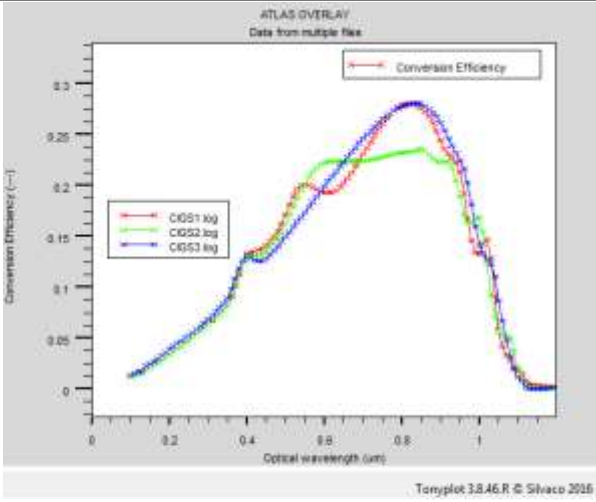

Figure 10: Efficiency curves for changing the thickness Cd_S layer

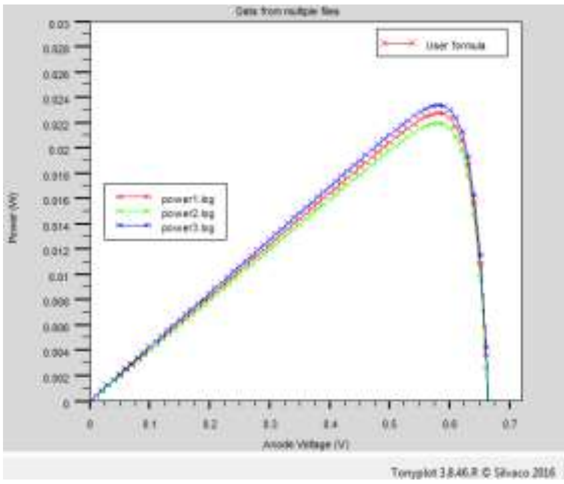

Figure 11: Power curves for changing the thickness Cd_S layer

As it can be seen from the results obtained. That efficiencies, power, I_{SC} and V_{OC} will be decreased as the thickness of Cd_S layer decreases. But if the thickness of Cd_S layer very decreases that efficiencies, power, ISC and VOC will be improved so that more of the initial state. In this case, it can be argued that more photons to the absorbent layer cells, the layer thickness Cd_S decreases which increased the efficiency of the cell. However it should be noted that if too thin, the thickness of this layer is difficult to eat stages of its construction.

The result of Efficiencies concerning the change in thickness layers is given in table 2 and 4 respectively.

Table 2: Results thickness changed the absorbent layer.

	CIGS1	*CIGS2*	*CIGS3*
absorbent Layers Thickness (nm)	500	1000	1750
VOC (V)	0.662	0.645	0.664
ISC (mA/cm^2)	31.7	33.5	35.9
Pmax (mW/cm^2)	15.6	17.6	19.6
FF(%)	74.5	81.4	82.2
Efficiency (%)	21.7	25.5	28.7

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Table 3: Results thickness changed the ZnO layer.

	CIGS1	CIGS2	CIGS3
ZnO Thickness (nm)	200	75	40
Voc (V)	0.653	0.655	0.66
Isc (mA/cm^2)	32.8	36.2	30.5
Pmax (W/cm^2)	17.6	19.6	16.2
FF(%)	82.1	82.6	82.2
Efficiency (%)	24.4	29.08	27.84

Table 4: Results thickness changed the Cd_S layer.

	CIGS1	CIGS2	CIGS3
Cd_S Thickness (nm)	200	100	10
VOC (V)	0.663	0.662	0.664
ISC (mA/cm^2)	41.6	40.4	43.1
Pmax (mW/cm^2)	22.77	22	23.42
FF(%)	82.55	82.25	81.83
Efficiency (%)	28	23.5	28

3. Conclusion

In this paper, by comparing three solar cells of CIGS that were equal in all aspects, except for ZnO layer, we found that too much increase and too much decrease in the thickness of this layer cause decrease in efficiency, open circuit voltage, short circuit current, and cell power. As a result, by accurately selection of ZnO layer thickness, we can improve the efficiency and power of the CIGS solar cell. It was concluded that efficiencies, power, I_{SC} and V_{OC} will be decreased as the thickness of Cd_S layer decreases. But if the thickness of Cd_S layer very decreases that efficiencies, power, ISC and V_{OC} will be improved so that more of the initial state. Should never be forgotten that the thickness of Cd_S layer decreased creates problems in the construction process. It was concluded that cell function improves by increasing the absorbent layer of thickness. However increase in the thickness of the absorbent layer is not proportional to the improvement of the cells. Also this thickness can be increased to a certain amount since after this thickness. We can hardly notice any significant improvement in cell current be considered thin film solar cell any longer. It was clear that extreme increase or decrease in thickness of absorbent layer can effect solar cell parameters also which can improve cell function whilst at the same time can alter some other parameters which are not desirable.

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Authors Profile

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Mohsen Imanieh was born in 1960 in Shiraz, Iran, and holds a Ph.D. in Electrical Engineering from the University of Salford, Manchester, England. He worked at the University of Manchester Research Group for several years in the late 20th century, whose research on semiconductor materials of thin-film solar cells CIS, CGS and CIGS was one of the first researches in this field.

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