UCT JOURNAL OF RESEARCH IN SCIENCE, ENGINEERING AND TECHNOLOGY 2018(03)

Available online at http://journals.researchub.org

Improvement performance CIGS thin film solar cells by changing the thickness Cd_S layer

Hashem Firoozi[1]* and Mohsen Imanieh[2]

[1]*Department of Electrical and Computer, Technical and Vocational University College,Hfiroozi1365@gmail.com, Fasa, Iran*
[2]*Department of Electrical Engineering, Fasa Branch, Islamic Azad University, Imaniehm1960@yahoo.com, Fasa, Iran*

ARTICLE INFO

Article history:
Received 07 Apr. 2018
Accepted 17 May 2018
Published 23 July. 2018

Keywords:
Efficiency,
open circuit voltage,
Photon,
short circuit current,
Solar Cell,
Power,
Thickness

ABSTRACT

In this study the function of solar cells with the structure of $CuIn_{1-x}Ga_xSe_2$ is 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, the thickness of the Cd_S layer is changed. Important parameters of a solar cell that will be discussed here, include open circuit voltage (V_{OC}), short circuit current (I_{SC}), maximum power (P_{max}), filling factor (FF) and efficiency (η). After conducted simulations, it was that changing Cd_S layer thickness has impact on solar cells function.

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.

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. [5].

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 [5].

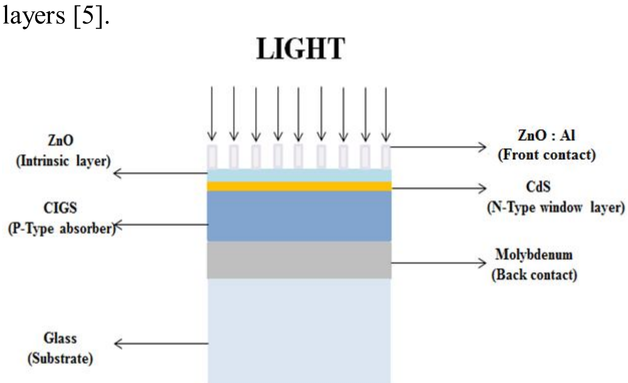

Figure 1. CIGS structure

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

**Corresponding author:* Hashem.Firoozi@gmail.com
DOI: https://doi.org/10.24200/jrset.vol6iss03pp11-14

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 [7].
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. [8].
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 [3].
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.
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. [9]
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.
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.
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.

2. Simulation

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

Table1. 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	Variabl e	1700

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

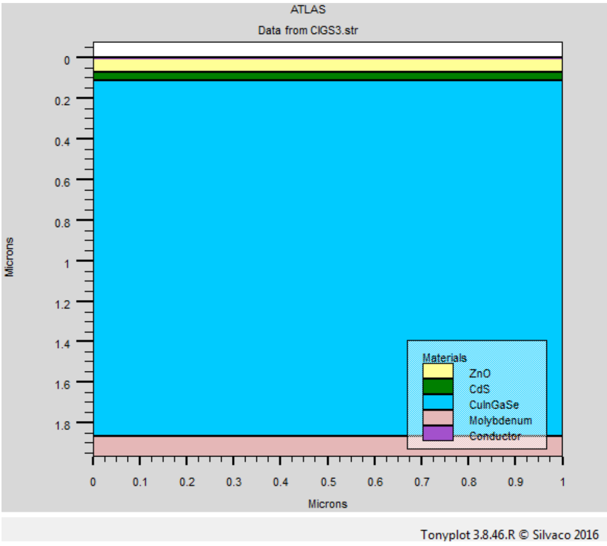

Figure 2. Simulated CIGS Structure

2.1. 1.1. 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 3.

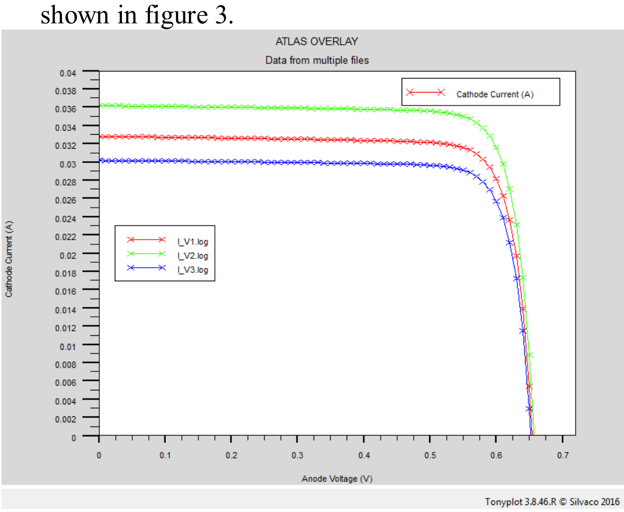

Figure 3. V-I curves for changing the thickness Cd_S layer

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

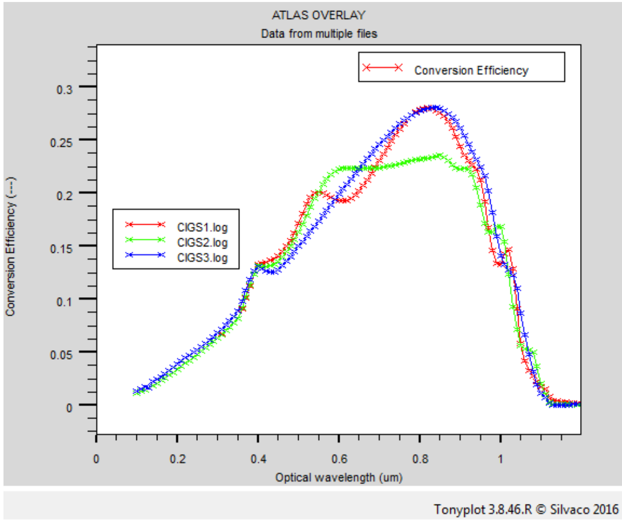

Figure 4. Efficiency curves for changing the thickness Cd_S layer

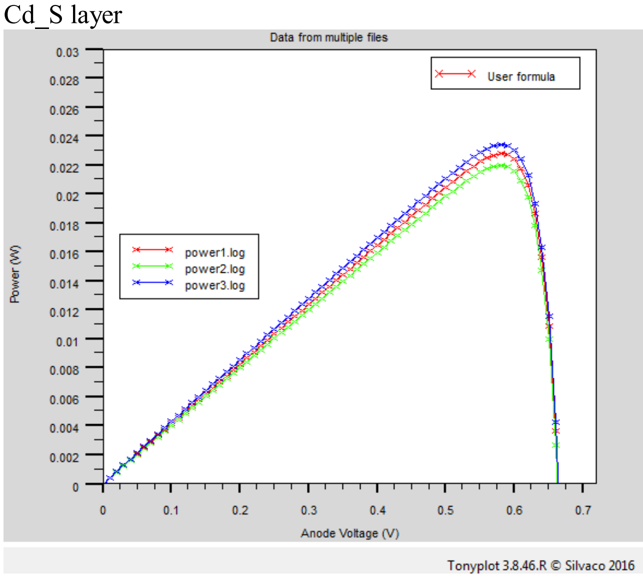

Figure 5. Power curves for changing the thickness Cd_S layer

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.

3. Results

The result of Efficiencies concerning the change in thickness Cd_S layer is given in table 2.

Table 2. Results thickness change the Cd_S layer

4. Conclusion

	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

In This paper, 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.

5. Discussion

In this paper, by changing the thickness Cd_S layer reached efficiency 28% compared with the efficiencies achieved in previous experiments about more 1 to 2 percent.

However, most studies on solar cells CIGS absorber layer carried on in this article do something different compared to the others, and it was also examined on Cd_S layer.

References

[1] A. R. Jeong et al., “Synthesis and physical properties of Cu(In,Ga)Se2 nanoparticles and CuGaSe2 thin-films for tandem cell photovoltaic applications,” 35th IEEE Photovoltaic Specialists Conf., Honolulu, HI, June 20–25, 2010.

[2] Patrick Reinhard, “Review of Progress Toward 20% Efficiency Flexible CIGS Solar Cells and Manufacturing Issues of Solar Modules”, IEEE JOURNAL OFPHOTOVOLTAICS, (2013), VOL.3 , NO.1

[3] Z. Beiley, A. Bowring, M. D. McGehee, “ Mode ling low-cost hybrid tandem Photo voltaic with power conversion efficiencies exceeding 20%,” 38th IEEE Photovoltaic Specialists Conf., Austin, TX, June 3–8, 2012.

[4] Ajeet Rohatgi , “High-Throughput Ion-Implantation for Low-Cost High-Efficiency Silicon Solar Cells” ,Energy Procedia , (2013) , vol.15 , pp. 10-19 .

[5] Y. G. Xiao et al., “Modeling of CdZnTe nad CIGS and tandem solar cells,” 35th IEEE Photovoltaic Specialists Conf., Honolulu, HI, June 20–25, 2010.

[6] Fraas Lewis, Partain Larry, Solar Cells and Their Applications, Second Edition, John Wiley & Sons, Inc.,(2010).

[7] K. Raman athan, M.A. Contreras, C.L. Perkins, S. Asher, F.S. Hasoon,J. Keane, D. Young, M. Romero,W. Metzger, R.Noufi, J.Ward, and A Duda, Properties of 19.2% Efficiency ZnO/CdS/CuInGaSe2 Thin Film Solar Cells, Prog. Photovolt., 2003,11, p 225-230.

[8] Jackson, P., Hariskos, D., Lotter, E., Paetel, S.,Wuerz, R., Menner, R., et aI., "New world record efficiency for Cu (In, Ga) Se2 thin film solar cells beyond 20%,"Progress in Photo voltaic: Research and Applications, 2012.

[9] Jiyon Song , Sheng S. Li , "Device modeling and simulation of the performance of Cu(In1_x,Gax)Se2 solar cells" , Solid-State Electronics , (2004) , vol.48 , pp.73-79.

[10] J. Song et al., “Modeling and simulation of a CuGaSe2/Cu(In,Ga)Se2 tandem solar cell,” Proc. of 3rd World Conf. on Photovoltaic Energy Conversion, Osaka, Japan, May 18, vol. 1, pp. 555–558, 2003.

[11] Huang CH,“ Effects of Ga content on Cu(In,Ga)Se2 solar cells studied by numerical modeling studied bynumberic modeling”, J. Phys. Chem. Solids 2002; 96 :330-4.

[12] Ingrid Repins, Stephen Glynn, Joel Duenow, Timothy J. Coutts, Wyatt K. Metzger and Miguel A. Contreras, “Required Material Properties for High-Efficiency CIGS Modules”, National Renewable EnergyLaboratory,2002 .