

IMPROVING EFFICIENCY (OPTIMIZATION) OF CIGS THIN FILM SOLAR CELL USING ABSORBENT LAYER PROFILE CHANGE

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Abstract

CIGS thin film solar cell of solid solution combination of Copper-indium-selenide (CIS) and copper -Gallium – selenide CGS is an I-III-VI₂ semiconductor which is one of the options to replace silicon solar cell due to high stability and direct band gap, it also has higher yields and lower price compared to other thin film solar cells. In this article, we will initially evaluate the effect of three major factors of thickness, impurity density and band gap of absorber layer which is the most important layer in solar cells on the output parameters including efficiency using AMPS (Analysis of Microelectronic and Photonic Structures) software. Then, for the first time we will provide two important strategies to improve the efficiency of CIGC thin film solar cell. Layers of this type of solar cell are: 1-TCO made of ZnO (zinc oxide) 2- CdS layer gate (cadmium sulphate) with impurities of n 3-CIGS absorber layer with the impurity of p, 4- 5 glass substrate molybdenum layer made of soda. Reduced thickness of the absorbent layer makes the back connection to be closer to the discharge area. J_{sc} , V_{oc} , FF and Quantum efficiency (QE) decrease due to absorption of electrons of electrons to the surface of back connection and their participation in recombination.

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Efficiency increases from 20.3399% to 21.3721% by increasing impurity density of absorbent layer and efficiency increases to 28.9266% and the quantum efficiency (QE) doubles by increasing the band gap of absorber layer which is a result of increasing the amount of gallium in CIGS cell. Then, we will achieve the efficiency of 34.1512% which has improved by 5.2246% compared to previous state by providing a way to reduce recombination at the intersection of absorbent / final connection by adding an extra layer made of absorbent layer with more impurities. In the final step, we improved the efficiency by 3.8581% (38.0093%) for the first time by increasing the band gap of CIGS layer. The solar cell used in this cellular thesis has characteristics such as $J_{sc} = 36.7059 \%$, $V_{oc} = 0.6721 \%$, FF = 82.4422% and $\eta = 20.3393\%$.

Keywords: CIGS thin film solar cell, absorbent layer, improving efficiency, quantum efficiency QE, and recombination

1. INTRODUCTION

Considering limited fossil energy reserves and increasing level of energy consumption in the world and increasing environmental pollution, we no longer can rely on available resources of energy. For this reason, humans in modern times have always been looking for a way to provide renewable energy due to issues and challenges including increasing efficiency, reducing price, durability and energy storage which are faced by renewable energy sources. This energy has been the object of many evaluations. Photovoltaic system is one of the appropriate methods to use the renewable energy sources. This system is based on conversion of solar energy into electrical energy [Partain et al, 1995]. Energy conversion involves the absorption of light (photons) by a semiconductor and production of electron-hole pairs and the separation of charge carriers. In most cases, a p-n junction is used in order to separate charge carriers. This system is currently the only solar power generation system which can have power generation applications as well as non-power generation applications. Solar cell is the basic unit of this system. In most cases, semiconductors are used as materials used in solar cells. Semiconductors such as silicon and gallium arsenide are the main element in the manufacture of solar cells. A large percentage of incident lights are reflected from the surface of cells and are destroyed during sunlight on the cell surface and only lights that have a certain energy are absorbed and a low percent will also be recombined. All of these factors lead to decreased cell efficiency. Thus, solar arrays are required in large range to enhance the performance of solar cells due to these factors. Thus,

manufacturing cost will increase [Prentice, 1982]. On the other hand, improving the efficiency of solar cells in addition to the fact that its manufacturing costs must be kept down are among the important goals of Solar cell industry. Using thin film technology is an important way of reducing the price of the cell which is known as the second generation of solar cells and provides the ability of manufacturing panels at large-scale with lower cost compared to first-generation cells. The most important step in the simulation of a solar cell is having the necessary knowledge of the properties and electronic properties of its constituent layers. Since CdTe and CdS and CIGS (copper indium gallium selenide) have attracted the attention of scientists throughout the years of emergence of thin film device fabrication and many studies have been done on them, there is a lot of information available about them and a lot of documents have been published in this field and have been provided to scientists and researchers in this field.

CIGS solar cell components

CIGS solar cell components include: the substrate layer in CIGS: it is a low effective component and it has to be mechanically fixed, be matching with sub layers in terms of thermal expansion coefficient and be immobilized during construction of cell. Solar cells are formed in two ways: arrangement of lower and upper layers. Front connection or transparent conducting layer (TCO) in CIGS: this layer is used to communicate with minor resistance in device and sending the maximum striking light to the absorber layer. Transparent conducting oxides are generally semiconductors aligned with n-type with good conductivity and high transparency in the visible spectrum. Characteristics such as high transparency, conductivity and having a band gap close to the layer of cadmium sulfate are very important due to the location of this layer. ZnO is the material which is used as the front electrode in this article. Window Layer (a window) in CIGS: window Layer is used in a heterojunction in particular to form a connection with the absorbent layer so that it allows a large amount of light to the connection and the absorbing layer. This layer is selected based on its thermodynamic compatibility and special resistance. N-type conduction semiconductor compounds with band gap between 2 and 3.6 eV are applied as a window layer for CIGS solar cells. We will evaluate the CdS as a window layer in this article. Absorber layer in CIGS: absorber layer acts similar to a p-type doped area because the actual production of load carrier only occurs in this layer. This is very important. Absorbent layer can be one or more layers. Due to the extraordinary importance of this layer, material of other layers is selected based on their compatibility with this layer and solar cell is known by the name of its

absorbent layer. CIGS is the absorber layer used in this article. Final connection in the CIGS: The most important goal of the Final connection in the CIGS is creation of an ohmic connection with absorbent layer. The final connection is usually used for p-type semi-conductors and the metal used in final connection must have higher performance than the semiconductor. Molybdenum is generally accepted as an appropriate back connection for substrate CIGS cells (figure 1).

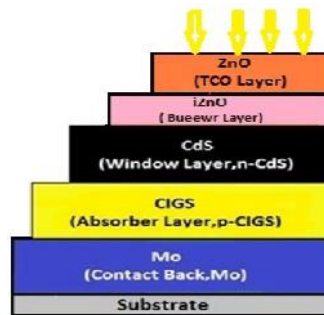


Fig.1. The basic structure of a CIGS thin-film solar cell

The equivalent circuit of solar cells

CIGS solar cell can be modeled as a current source in parallel with a diode (figure 2). When there is no light to generate flow, solar cell acts as a diode. When the cell incident light intensity increases, a flow proportional to the input light intensity is generated by solar cell. This optical flow is divided between the variable resistance of diode and load with ratio depending on the load resistance and the light intensity. In an ideal cell, the total generated flow (I) is equal to photoelectric effect (I_L) minus the diode current (I_D). There are two diodes instead of one diode in a more accurate equivalent circuit of solar cell. The following general equation can be provided with these descriptions and using relations related to the solar cell.

$$I = I_L - I_0 \left(\frac{q[V + IR_S]}{nKT} - 1 \right) - \frac{V + IR_S}{R_{SH}} \quad (1)$$

In this equation, n shows the ideal coefficient of 1 diode (usually between 1 and 2), R_S and R_{SH} respectively show series and parallel resistances which will be explained below.

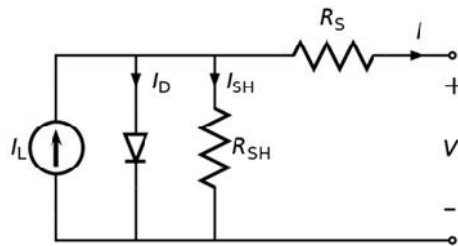


Fig.2. Equivalent circuit of a solar cell

The efficiency of cell reduces during the work on the actual solar cell by power dissipation in internal resistances including contact resistance as well as leakage currents on both sides of the piece. These parasitic resistances can be modeled as a parallel R_{SH} resistance and series R_S resistance. R_{SH} Will be infinite in an ideal cell and no other way will be created to release flow. Also, the R_S will be zero in an ideal cell which in this case it will lead to additional voltage reduction before the load. The V_{OC} drops when R_{SH} decreases while similarly, increased R_S reduces the J_{SC} (Hua and Shen, 1997) (figure 3). Ultimately, the reduction of parallel resistance and increase of the series resistance will reduce the fullness factor (FF) and the maximum power (figure 4).

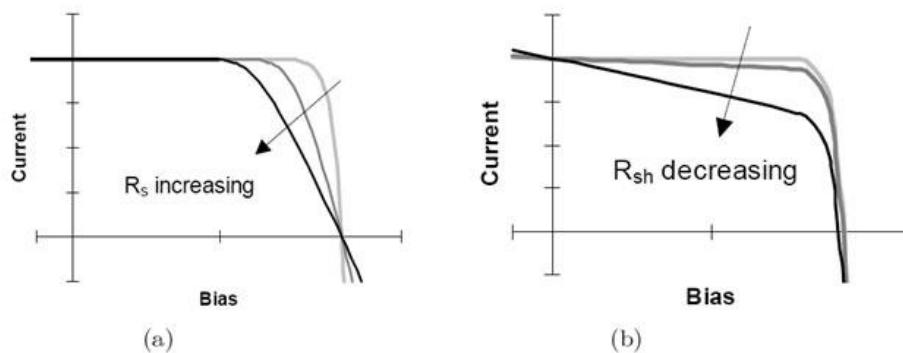


Fig.3. The effect of increasing series resistance and reducing parallel resistance on the maximum power (the outer curves in both cases are for $R_{SH} = 0$ and is $R_{SH} = \infty$). Series and parallel resistances can be almost achieved out of the slope of I - V curve respectively in the V_{OC} and J_{SC} points

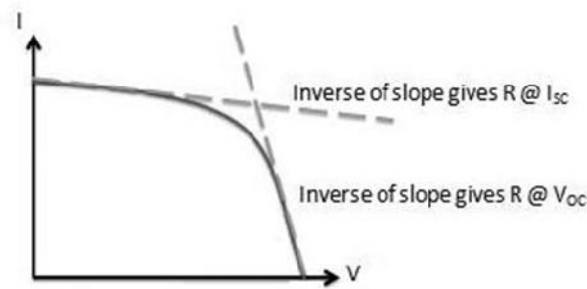


Fig.4. Obtaining parallel and series resistances from I - V curve

Series resistance arising from resistance of cell's material is against the current flow especially through higher level to connections as well as resistance connections. Series resistance in high current density for example under concentrated light is considered as a particular problem. The parallel resistance is also created due to current leakage through the cell around the edges of the piece and between connections of different poles.

Numerical modeling of solar cell

All transmission characteristics of a semiconductor material are resulted from solving Poisson's equation, continuity equations for electrons and holes. But some of the fundamental equations which are used for linked structures must be reformed in hyperlinked structures for modeling different characteristics of materials. The Poisson's equation in a hyperlink structure is as follows:

$$\frac{d^2\varphi}{dx^2} = -\frac{q}{\varepsilon}(p - n + N_D - N_A) - \frac{1}{\varepsilon} \frac{d\varphi}{dx} \frac{d\varepsilon}{dx} \quad (2)$$

In which q is the charge of the electron, n is density of free electrons, p is the density of holes, N_D is impurity density provider, N_A is impurity density receptor and ε is semiconductor dielectric constant. The general form of the equations of continuity in these structures is defined similar to linked structures as follows:

$$\frac{\partial n}{\partial t} - \frac{1}{q} \nabla \cdot J_n = G - R \quad (3)$$

But the electrical components of hyperlinked structures are obtained using the following equations:

$$J_n = -n\mu_n q \nabla(V + \theta_n) + KT\mu_n \nabla n \quad (4)$$

$$J_p = -p\mu_p q \nabla(V + \theta_p) + KT\mu_p \nabla p \quad (5)$$

In a way that θ_n and θ_p are Band parameters in hyperlink structures and are equal to:

$$\theta_n = \frac{\chi_c}{q} - \varphi_0 + \frac{KT}{q} \ln\left(\frac{N_c}{n_i}\right) \quad (6)$$

$$\theta_p = -\frac{1}{q}(\chi_c + E_g) + \varphi_0 + \frac{KT}{q} \ln\left(\frac{N_v}{n_i}\right) \quad (7)$$

In which N_v and N_c are Boltzmann's constant, K is the absolute temperature, T is intrinsic carrier concentration, n_i is energy gap, E_g is electron affinity, φ_0 is the electrostatic potential, is Valence band and energy conduction band states and χ_c is the Reference potential which is Constant [Mosoum and Dehbonei,2000].

2. SIMULATION RESULTS

Analysis of Microelectronic and Photonic Structures (AMPS) software has been used to perform simulation. G1.5 AM Light is applied to the cell. Material parameters that are used in simulation of base cell have been mentioned in the tables (1) and (2):

Table 1. Parameters used in simulation of CIGS base cell at a temperature of T = 300 ° k [Brooks and Irvine, 2012].

layer properties	n-ZnO	n-CdS	P-CIGS
layer thickness w (nm)	200	50	3000
Affinity (ev)	4	4.4	4.5
Relative permittivity , ϵ_r	9	10	13.6
Electron mobility , $\mu_n(\text{cm}^2/\text{V} \cdot \text{s})$	100	100	100
Hole mobility , $\mu_p(\text{cm}^2/\text{V} \cdot \text{s})$	25	25	25
Acceptor or Donor concentration (cm^{-3})	Nd=10e18	Nd=2.2e19	Na=1e17
band gap Energy Eg(ev)	3.3	2.42	1.15
Effective density of state, $N_c(\text{cm}^{-3})$	2.20E+18	2.20E+18	2.20E+18
Effective density of state, $N_v(\text{cm}^{-3})$	1.80E+19	1.80E+19	1.80E+19

Table 2. Parameters used in the simulation of CIGS cell

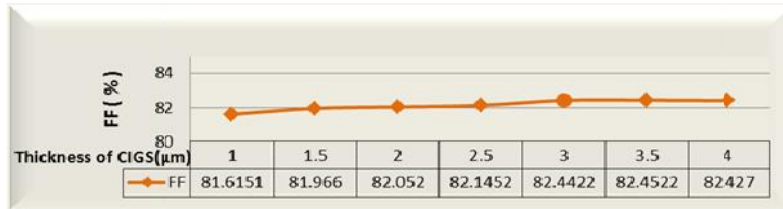
layer properties	n-	
	i-ZnO	MgZnO
layer thickness w (nm)	50	300
Affinity (ev)	4.6	4.05
Relative permittivity, ϵ_r	9	10.5
Electron mobility, $\mu_n(\text{cm}^2/\text{V} \cdot \text{s})$	100	300
Hole mobility, $\mu_p(\text{cm}^2/\text{V} \cdot \text{s})$	25	20
Acceptor or Donor concentration (cm^{-3})	$N_d=1\text{e}14$	$N_a=1\text{e}18$
band gap Energy $E_g(\text{ev})$	3.3	4.1
Effective density of state, $N_c(\text{cm}^{-3})$	$2.20\text{E}+18$	$2.20\text{E}+18$
Effective density of state, $N_v(\text{cm}^{-3})$	$1.80\text{E}+19$	$1.80\text{E}+19$

Evaluating the effect of CIGS absorber layer thickness on output parameters including efficiency

Reduced thickness of the absorbent layer leads the back connection surface to be closer to the discharge area. Thus electrons are easily absorbed by the back connection surface and the electrons affecting the efficiency will become lower due to their participation in recombination and as a result J_{sc} , V_{oc} and FF will reduce (figure 5-A, B and C). Since light absorption and actual production of charge carriers occur only in this layer. This layer is very important. Thus, the thickness of this layer cannot be less than a certain value. Therefore, the optimum thickness of this layer is 3 μm based on the optimization and economic issues and the results of the simulation. Efficiency will not have a significant increase by further increase of the thickness of this layers (figure 5).



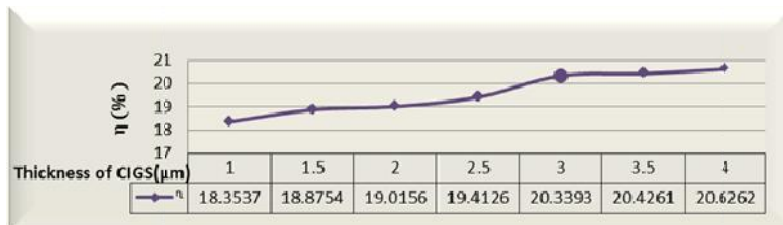
(A)



(B)



(C)



(D)

Fig.5. CIGS cell performance as a function of CIGS layer’s thickness

Evaluating the effect of CIGS thickness on QE

By increasing the thickness of adsorbent layer, the number of absorbed photons increases, longer wavelengths are emitted from light and thus, a higher number of electron-hole pairs are produced in the absorbed photons and quantum efficiency (QE) increases (figure 6).

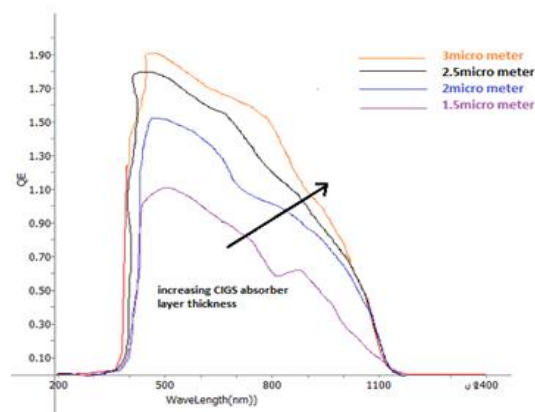


Fig.6. the curve of quantum efficiency changes

Improving efficiency by increasing the impurity density of the absorbent layer

We achieved the efficiency of 20.3393% by selecting the optimal thickness of the absorbent layer (3 microns). Figures 7 and 8 show the effect of changes of absorbent layer's impurity density on efficiency and performance of CIGS cell. Since the bipolar around the p-n transplant must have an equal number with loads of both sides, density increase of the hole will reduce the width of discharge area on the side of P. As we know carriers which are created in the discharge are or within one distribution length of it will be separated by an electric field and will lead to flow in the external circuit. But density increase of the hole will reduce the width of discharge area and less carriers can be collected in connections and it will result in reduction of short circuit current decrease (figure 8). On the other hand, the larger impurity density of the hole results in a lower concentration of minority absorbent carriers which will lead to reduction of recombination partners and thus, reduction of recombination rate in semiconductor. Thus, the open circuit voltage of cell increases by increased impurity density of the hole (figure 8). The effect of voltage increase is initially more than its current losses due to the increase in absorbing impurity and thus, increased density of the hole can improve the efficiency of cell and FF (figure 7). But when the amount of absorbent density becomes close to the impurity density of window layer or gets higher than it, absorption occurs in the window layer due to high impurity density of the absorbent. So, the reduction of flow prevails the increased voltage in this case and efficiency reduces sharply (table 3). The dominant parameters are marked in red in the table.

Table 3. The effect of changes in impurity density of absorbent layer on cell's output parameters

Nd CdS(constant)(cm ⁻³)	Na CIGS(cm ⁻³)	Jsc(Ma/cm ²)	Voc(v)	FF(%)	η(%)
2.20E+19	1.00E+17	36.7059	0.6721	82.4422	20.3393
2.20E+19	1.00E+18	34.5133	0.741	83.5603	21.3721
2.20E+19	1.00E+19	33.4173	0.7883	76.689	20.2025
2.20E+19	2.00E+19	33.191	0.7807	65.0095	16.8444
2.20E+19	2.20E+19	33.158	0.7425	60.8501	14.9808

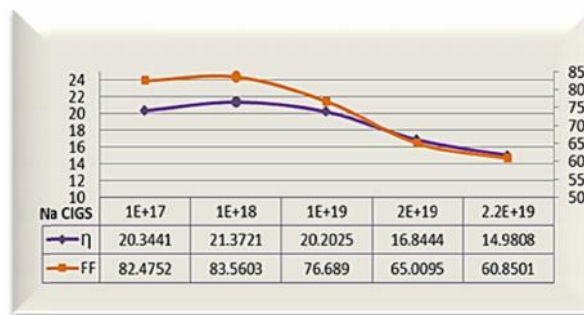


Fig.7. the effect of increased impurity of CIGS on FF and η

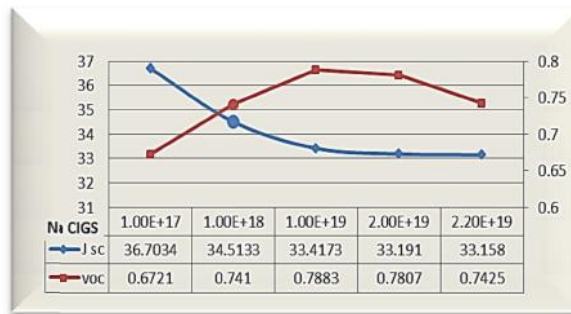


Fig.8. the effect of increased impurity of CIGS on Jsc and Voc

Figures 9 and 10: show improving efficiency by increasing the impurity density of the absorber

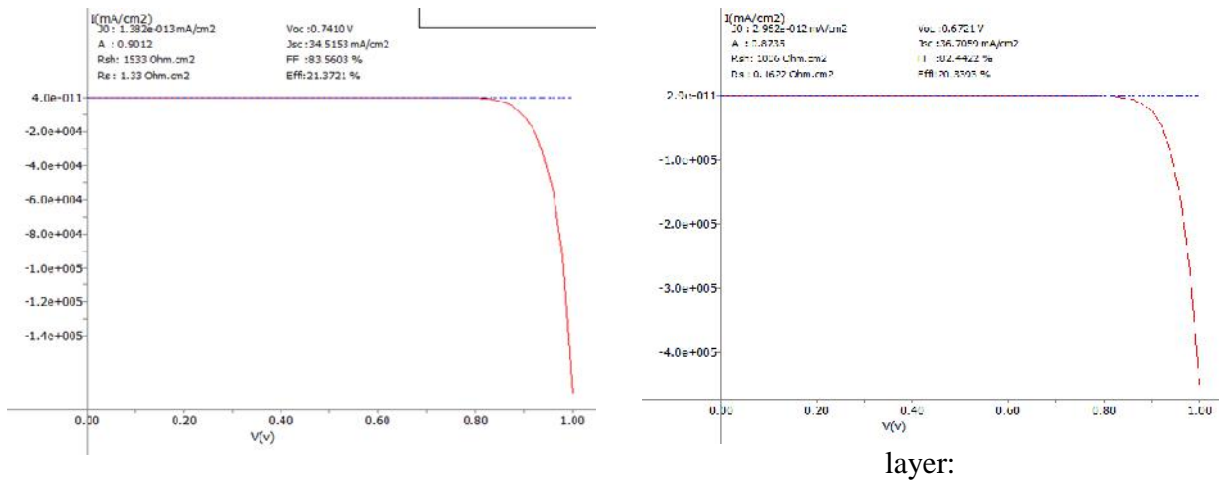


Fig.9. Improving efficiency by increasing the impurity density of the absorber layer

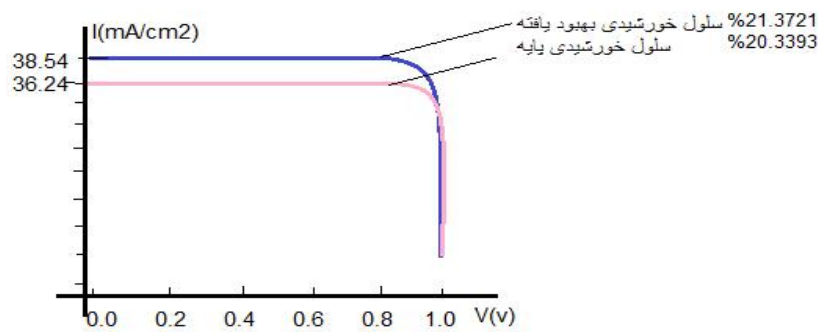


Fig.10. i-v curve (efficiency) and improving efficiency by increasing the impurity density of the absorber layer

Improving efficiency by increasing the band gap of absorber layer

Constant: $W_p = 3 \mu m$, $W_n = 50 nm$, $E_{gCdS} = 2.42 eV$

Variable: $E_{gCIS} = 1 eV$ to $E_{gCIS} = 2 eV$

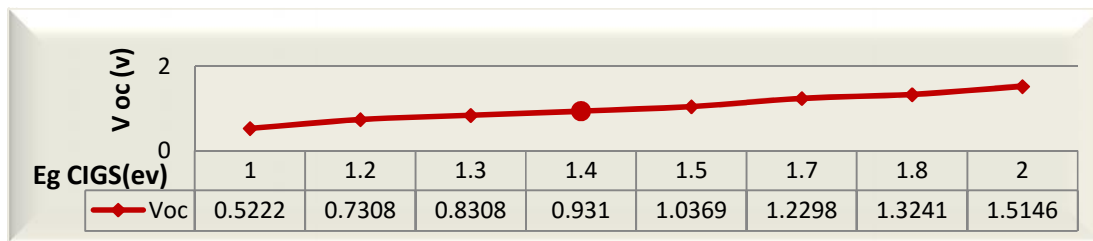
E_g is about 1 eV for CIS layer [Priyanka Singh and Ravindra, 2012] in which band gap can change up to 1.7 eV by adding Ga to CIS model, we will change the band gap from about 1 eV to about 2 eV by changing the amount of GA in CIGS cell from (CIS) $X=0$ to (CIS) $X=1$. It will be observed according to the results of the simulation that increased band gap of absorber layer will

reduce the light absorption of this layer which will lead to J_{sc} reduction (figure 11-A). We will select the optimal value of 1.4 for Eg by establishing a compromise between reducing current and increasing voltage (figure 11- B and C) whatever the amounts of V_{oc} and FF linearly change and increase by increased band gap and by this change of Eg of solar cell (from 1.15 ev to 1.4 ev), efficiency rate improves from 21.3721% to 28.9266% and by 7.5545% (figure 11).

(A)



(B)



(C)

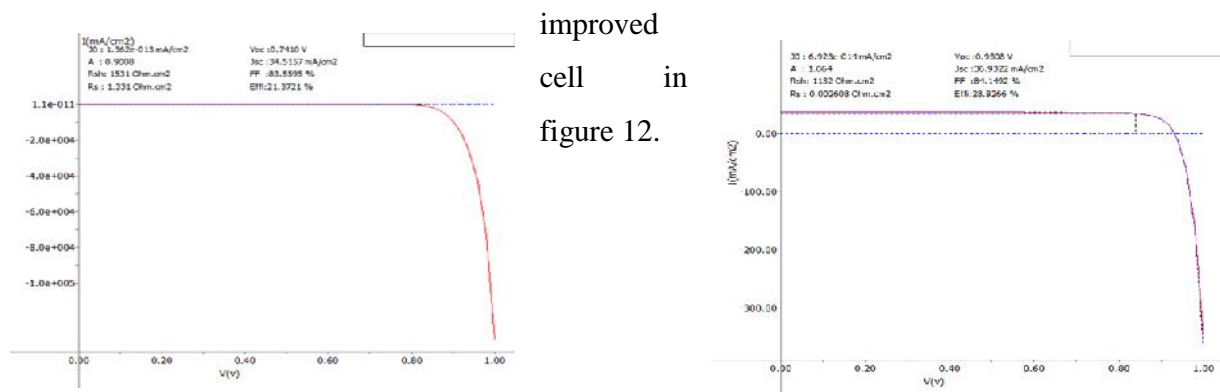


(D)



Fig.11. Performance of CIGS cell as a function of the band gap energy of CIGS absorber layer

We have compared I in terms of V (efficiency) and other parameters of primary cell with the



improved cell in figure 12.

⇒

Fig.12. Improving efficiency by changing the band gap of absorber layer

Improving quantum efficiency (QE) with increasing band gap of cell’s absorber layer

We have shown the QE diagram in wavelength for two different values of absorber layer’s band gap in figure 13. It can be observed that the light absorption frequency range does not change by increasing the band gap of absorber layer but the amount of QE almost doubles.

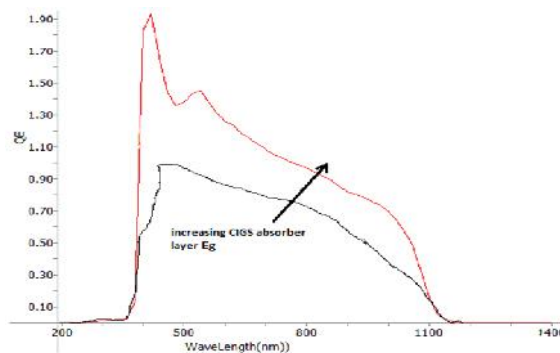


Fig.13. Improving quantum efficiency (QE) by increasing the Eg of absorber layer

The high speed of surface recombination (10^{87} cm / s) in the final connection of the cell is among the main causes of casualties of carriers in CIGS solar cells [Priyanka Singh and Ravindra, 2012]. Reduced recombination in back connection of CIGS cell can help in reduction of thickness of the adsorbed layer and thus, cost reduction of this element. Thus, many method have been evaluated for reduction of recombination in back connection of CIGS cells in numerous

articles. Making the band gap of CIGS absorber gradual or creating a back surface field on the interface between the absorber and the back cell connection are among these. The back surface field can be created at the interface of CIGS / Mo by adding a layer with a Ga concentration greater than Ga concentration of absorbent or use of deposition of a different material with energy gap larger than absorbent [Malmstrom,2005]. But one of the most effective ways to increase back field connection is adding a layer with high impurity density (a layer of P+) at the end of the absorbent layer which has been evaluated in this article.

Generally adding a layer with high impurity density after absorbent layer will create additional field at the back connection. This field pushes electrons from back connection to the absorber. Thus, the recombination reduces in the back connection which will lead to increased open circuit voltage of the cell. Also, the length of carrier's distribution increases by creating an additional field in the absorber which leads to increased optical flow of the cell and also the reduction of back connection's recombination leads to collection of a higher number of carriers in the connections and thus, the flow rate and efficiency increase. In this section, we have placed a layer of absorbent layer (CIGS) at the end of the adsorbent with different thickness and impurity (CIGS+). But in the meantime, in the meantime depends on in the meantime of CIGS and CIGS+ layers. Selecting the correct amount of impurity and thickness of the layer P to improve performance and increase efficiency requires the evaluation of 4 below modes:

- Thickness and impurity of the P+ layer be higher than thickness and impurity of the P layer.
- Thickness and impurity of the P+ layer be lower than thickness and impurity of the P layer.
- Thickness of P+ layer be lower than thickness of P layer and impurity of P+ layer be higher than impurity of P layer
- Thickness of P+ layer be higher than thickness of P layer and impurity of P+ layer be lower than impurity of P layer

Following three important results can be obtained by evaluation of comparison of parameters obtained for four above modes:

1. The thickness of P+ layer must be higher than the thickness of p layer where the optimal thickness for P+ was considered to be 2.6 μm and the optimal thickness for P was considered to be 0.4 μm .

2. The impurity of P+ layer must be higher than the impurity of p layer where the optimal impurity for P+ was obtained to be $20e2$ and the optimal impurity for P was obtained to be $14e1$.

3. We must change the thickness of these two layers in a way that the whole adsorbent is kept at the constant value of $3 \text{ m}\mu$, we will reach the efficiency of 34.1512% from the efficiency obtained from the previous step (28.9266) by adding a layer of adsorbent layer with larger thickness and impurity in interface of back connection and the adsorbent layer which has increased by 5.2246% compared to previous rate. It is necessary to point that we have considered the amount of Eg of CIGS+ layer (additional adsorbent layer) to be its common value in base solar cell (1.15 ev) (figure 14).

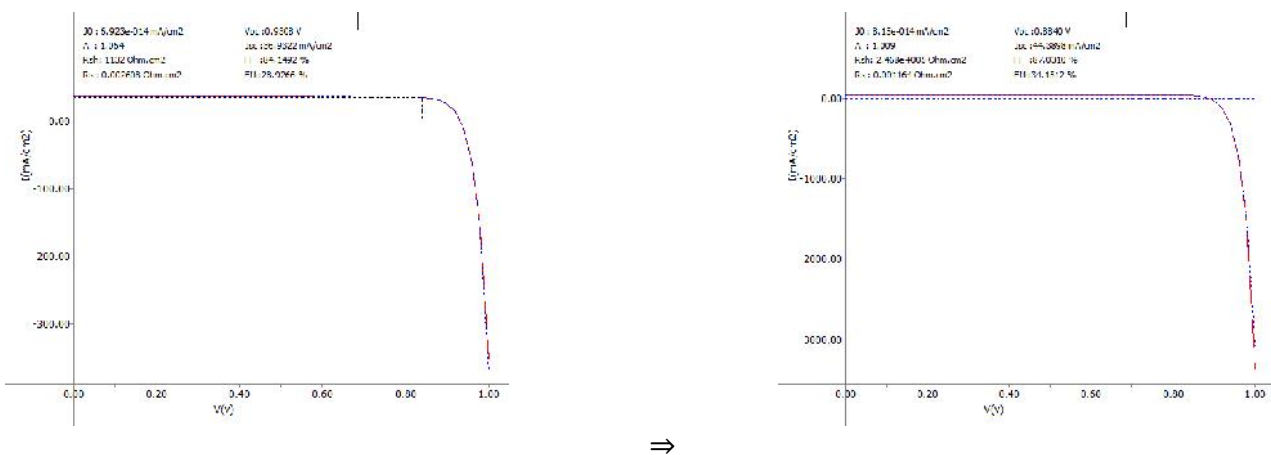


Fig.14. Improving cell efficiency by adding a layer of CIGS (p +)

Evaluating the effect of changes in Eg of CIGS+ layer and its effect on improving cell efficiency with optimized structure

We have achieved an optimal structure with efficiency of 34.1512% after taking the above steps. We will evaluate the results obtained from increasing the band gap of the p+ layer. J_{sc} , V_{oc} , FF will increase by increasing the band gap of additional layer. In respectively figures 15 A, B and C, efficiency will significantly increase by increasing the E_g from 1.15 ev to 1.6 ev. However, with further increase of band gap of, the efficiency is almost constant and increase is in tenths of a percent (figure 15-D). Given that the excessive increase of E_g with damage the overall performance of the cell, we will select 1.6 ev for optimal E_g of p+ layer, the efficiency will rise to 38.0093% by this amount of E_g which has improved by 3.8581% compared to the previous state.

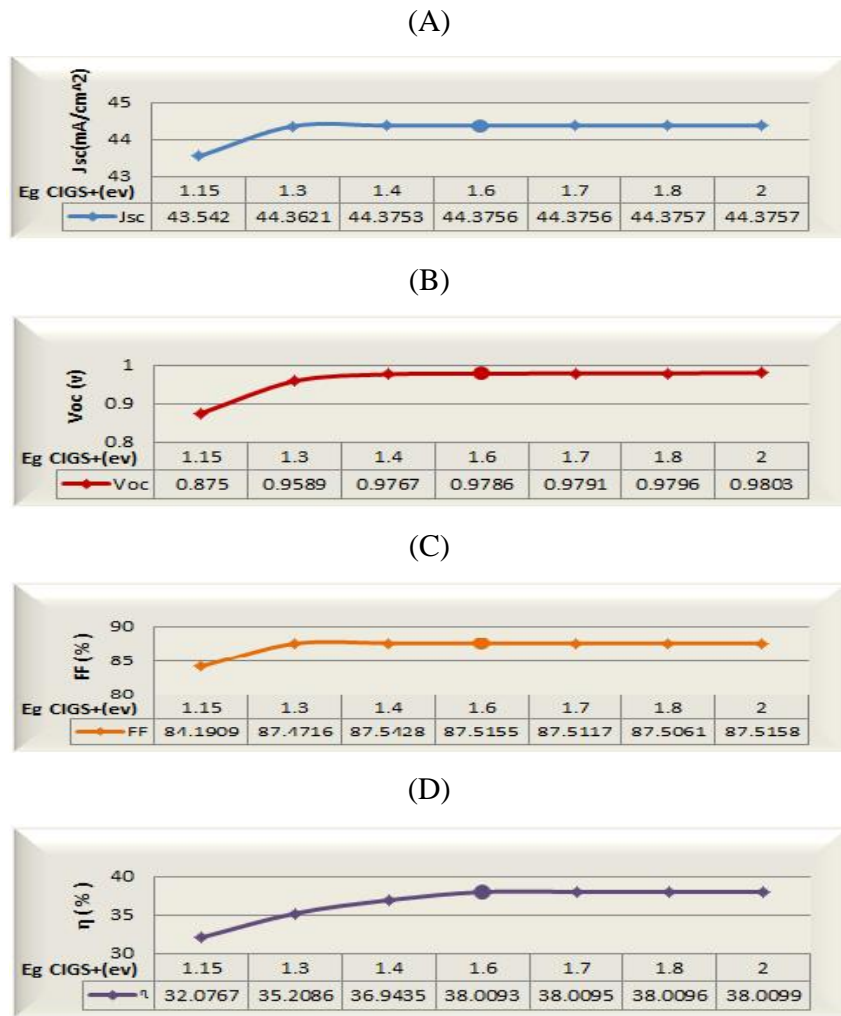


Fig.15. Performance of CIGS cell as a function of band gap energy of CIGS layer additional (P+)

We have compared the diagram I in terms of V (efficiency) and other parameters of primary cell with the improved cell in figure 16.

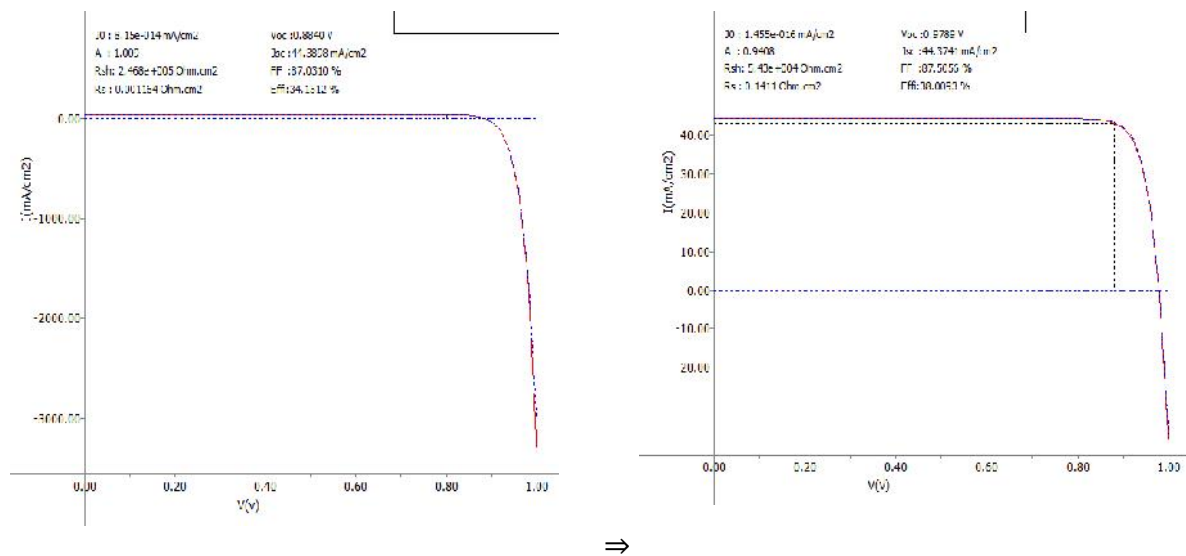


Fig.16. Improving the efficiency by changing the amount of Eg of additional CIGS layer (p +)

Discussion and conclusion

We initially evaluated the overview of each solar panel and parameters affecting them and specifications of different layers in this article. Then, we simulated a CIGS cell by evaluation of performance of CIGS nanostructured solar cells using AMPS software. The thicknesses of TCO, buffer and absorbent layers are respectively 200 nm, 50 nm and 3 μm . The efficiency of the base CIGS cell is 20.3441%.

Increasing the thickness of the absorbent layer will increase the QE and increasing the impurity density of the absorbent layer will increase the Voc and Jsc and the efficiency will be improved by 1.028% (21.3721%). Increasing more than this value will make the effect of flow reduction prevailing the voltage increase and will lead to sharp decrease of efficiency. Eg of the absorbent layer is another factor affecting the efficiency. In this step, the QE increases by increasing the Eg to 1.4 eV and efficiency is improved by 7.5545%. Excessive increase of Eg will damage cell's function. A high level of light reaches the back contact in thin film CIGS solar cells due to very low thickness of the absorber and buffer layer. The high speed of carriers (10^7 cm / s) and surface recombination are the main causes of casualties and reduced efficiency of these cells and On the other hand, transparent oxide layer of ZnO which is a n-type semiconductor is another factor in causing cell casualties by creating Schottky barrier in connection point to the Metal

contact (Cathode). We will lead Electrons to the absorbent layer in order to reduce the recombination of carriers in the back connection to improve the efficiency of these cells using doping increase method of a part of the absorbent layer to create a level field where we will achieve a thickness of 2.6 μm and impurity of $20e2$ by adding this layer and thickness and impurity of the absorbent layer will reach to 0.4 μm and $14e1$ and the efficiency will reach to 34.1512%. Now we have achieved a CIGS solar cell with the optimal structure and we will evaluate the effect of increasing E_g of the additional layer on the efficiency. The results of the simulation show that the efficiency will be increased by 3.8581 by increasing the E_g of the additional layer to 1.6 eV (38.0093%).

The following items are suggested for improving the solar cells in process of manufacturing and increasing the efficiency: 1. the use of nanostructures to build layers of CdS, CdTe TiO₂ in thin film solar cells 2. Reduction of reflection and absorption of more light in the cell and increasing the short-circuit current and thus the efficiency by placing an anti-reflection layer between the glass substrate and the silicon thin film solar cell transparent semiconductor oxide. The use of the new hydrogen and anti-reflective technique which has led to creation of an inexpensive spray coating to solve the problem of reflection as well as using three layers of Ag as the transparent electrode (TCO) and the anti-reflective layer in solar cell 3. Improving thermal - attenuation stability and increasing the lifetime and efficiency of CIGS solar cell using one layer sediment at the top of the solar cell by forming a barrier against water penetration 4. Adding a layer with Ga concentration greater than the Ga concentration of absorbent 5. Deposition of a different material on the absorber layer with E_g greater than E_g of the absorbent 6. Use of two or more layers of different materials with different band gap is another strategy to increase the efficiency 7. A high level of light reaches the back contact in thin film CIGS solar cells due to very low thickness of the absorber and buffer layer. The high speed of carriers and surface recombination are the main causes of casualties and reduced efficiency of these cells and On the other hand, transparent oxide layer of ZnO which is a n-type semiconductor is another factor in causing cell casualties by creating Schottky barrier in connection point to the Metal contact (Cathode). We can add an n⁺ layer to the transparent oxide and convert the metal-semiconductor connection to the ohmic contact to reduce the effect of Schottky barrier and series cell resistance in addition to the method mentioned in this thesis with was based on increasing doping of a part of the absorbent layer in order to create the surface field and leading electrons to the absorbent layer in order to

reduce the recombination of carriers in the back contact 8. Covering the cell by a metal grid 9. Keeping the surface of the cell clean and placing the cell in the shadow

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