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EFFECTS OF THICKNESS AND DOPING ON HIGHLY EFFICIENT CIGS SOLAR-CELLS USING SCAPAS

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ABSTRACT

The impact of thinness and doping concentration in CIGS- pedestal Solar-cells on the cell parameters of photovoltaic cells with ZnO and CdS studied using a SCAPS. The layer-by-layer optimization was completed. Our findings found the optimal configuration requires a ZnO as well CdS as a buffer layer and CIGS as an absorber with different thicknesses and doped with a thickness of x = 0.025, 0.05, 0.075 and 4 µm and doped with concentration of 10^{16} cm^{-3} for all same for compositions. Solar-cells with these kinds have a performance of 24.89 % that is potentially higher than previously stated in the CIGS Solar-cell research.

Keywords: CIGS Solar-cell, Thickness Optimization, SCAPAS

INTRODUCTION

Cantered on the conversion efficiency of CIGS thinfilm Solar-cells relative to CdTe thinfilm Solar-cells while CdTe thinfilm Solar-cells did better (CIGS) [1]. The guiding forces behind CIGS are impressive: high performance and low processing resources. To maximize the performance of the thinfilm Solar-cell addressed and to enhance the electrical meta-stability of the Solar-cell, the compatibility and interface between the CIGS and buffer and window layer should be enhanced first [2]. Devices such as the monitor or sensors turn on after being subjected to chemicals absorbed from the filter, they often have p/n buffers that work like old cameras that are oil on glass. There are several different solutions for organic solubilization. In some conditions, however, it has been observed that these unconventional barriers are additional susceptible toward meta-stable properties such as light weather and demonstrate fewer saturation in moist heat testing [3-4].

The optical, electrical, and optical connectivity studies performed so far have been of great help in improving the enactment of CIGS thinfilm Solar-cells. Even, some of the independent studies of the parameters placed by the material of the Solar-cell can create great confidence in the Solar-cell to be an optimized unit. A study was undertaken to show how the textures, thickness as well as doping in a cell's windows, buffer, absorber layers (combine and absorb sunlight) influences the Solar-cells constraints, such as current and OCV. In order to achieve the measurements, the data was run via a SCAPS software allowing numerical mode [5].

Table1. Physic constraints taken for the software simulation with ZnO, CdS, and CIGS processing deposits.

Parameters	E_g	X_e	ε_r	**Nc**	**Nv**
n-ZnO	3.3	4.45	9	2.2×10^{18}	1.8×10^{19}
n-CdS	2.45	4.45	10	2.2×10^{18}	1.8×10^{19}
p-CIGS	1.2	4.5	10	2.2×10^{18}	1.8×10^{19}

* *Note:* $\mu_n = 100$ *and* $\mu_p = 25$ *for all layers*

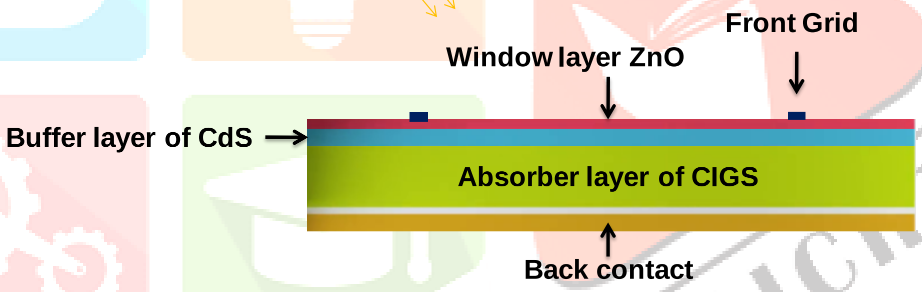

Figure 1. Graphical representation of the CIGS solar-cell construction.

METHODOLOGY OF NUMERICAL SIMULATION

The computer software program that is taken to prototypical the CIGS thinfilm Solar-cell was studied in this analysis in order to figure out how different layers of the CIGS thinfilm Solar-cell influence the overall performance of the CIGS thinfilm Solar-cell device, including specifically the buffer layer, absorption layer, and window layer. If you are using SCAPS 2.8, remember that the configuration of the graded cell can be controlled easily [6-8]. For a summary of produced structures of heterostructure described, which are created by varying a doping profile for each layer of the structure with decreasing doping levels in bulk and increasing doping levels exactly to the peak of the continuum in the interfaces are stated on the substrate. A three-layer CIGS model is the current starting point for the simulation simulations. This design has a thick layer of CdS buffer, a thick layer of ZnO board, and eventually a thick layer of CIGS Solar-cell to create layers. Other products were checked as buffer layers to prevent the existence as part of the Solar-cell of atomic Cd. The strongest outcomes were accomplished with CdS, though, and so this content remains the chosen one. The simulation is carried out by specifying the parameters of the material as input parameters that are then transferred through each defined layer of the device. Within the context that we have been looking at, the recorded ZnO, CdS, and CIGS literature explains the best criteria to attain. In the model requirements, these parameters are used. The analysis of the width as well as doping of two layers is taken care of that produces CIGS Solar-cells. On the third sheet, the doping is increased when the thickness is decreased and the total performance is maximized. This process is able to help us produce high efficiency Solar-cells [9-10].

RESULTS AND DISCUSSION

To optimize the basic pattern of the hetero-junction structure by Zinc, CdS, and CIGS. In addition, the investigation of the effect on the photovoltaic cell constraints involved both the thinness and doping of dissimilar layers of special concern. To investigate the conversion efficiency of zinc selenide, we: (a) formed the ZnO window sheet, (b) adjoined CdSe and CdS on the CdTe buffer layer and (c) integrated CdS onto the CIGS evaporation layer. In order to improve the structures we required to modify the doping and then vary the doping a little, then vary the thickness of solitary layer and hold the most advantageous values of the other two layers unchanged. Using a "breadboard" of solar operation, the sample was analyzed with the wavelength of 1.5 microns, and a temperature of 300 K. We have taken into account the efficiency of the photoconductivity and the capacity of the laminar system to shunt the energy and cancel the action potentials of the transit.

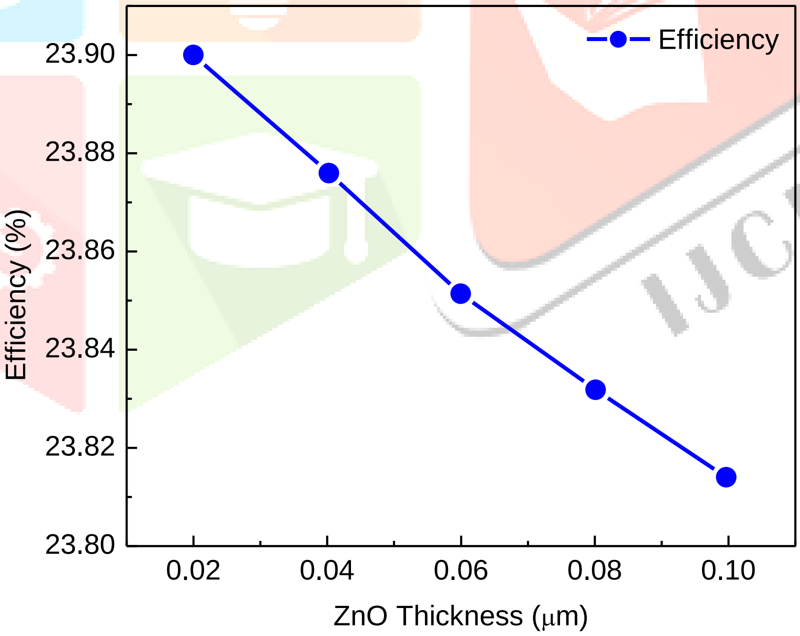

Figure 2. Efficiency (%) vs. ZnO thickness of Solar-cell’s window layer.

Table 2. Solar-cell constraints for numerous thickness of ZnO.

Thickness of ZnO (µm)	**t=0.02**	**t=0.04**	**t=0.06**	**t=0.08**	**t=0.1**
Efficiency%	23.99%	23.97%	23.98%	24.02%	24.05%
FF%	83.12	83.19	83.56	83.55	83.56
J_{sc}	39.8009	39.6710	39.5879	39.4231	39.5937
V_{oc} (V)	0.7350	0.7350	0.7350	0.7350	0.7350

Outcome of doping & layer thickness continuously conversion efficiency

Degradation of the doping output of the ZnO window is not quite noticeable due to the thickness of 200 nm. Note that with an increase in the value of N_D, increases in the efficiency is almost constant at the value of almost ~24 percent for N_D = 10^{15} cm^{-3}. The rise in the amount of dopants will boost the selection of photogenerated carriers and thus lead to increasing electrical performance.

The width of ZnO frame deposit with N_D=10^{16} cm^{-3} objectives (mas) are stated in the results. We have gone from 0.02 to 0.1 µm for the thickness of ZnO. Our results for the cell photovoltaic voltage, current, and thickness are recorded for the various ZnO thicknesses. From our inspection that includes measurements over a short time, it indicates that the ZnO window's thickness between 0.02 and 0.1 µm. The form factor is diminished significantly. With each subject, there were a total of 24 measurements. The time of 24.11 to 23.97 could be significantly seen and it is in line with previous observations in Refs [11-12]. The effect of the ZnO window thickness on the present short-circuit (Jsc) density results in a monotonous decline in Jsc. Regarding the Voc open-circuit voltage, Voc tends to be not susceptible to adjustments in the thickness of the frame layer of ZnO. Because ZnO takes around 3.3eV band gap capacity, it can be assumed that only solar wave-light radiation of less than or equivalent to 0.37µm can be absorbed. As shown in this article, the maximum electrical efficiency for the 0.02µm thickness of ZnO layer may be obtained. In reality, ZnO window layer achieves the first interaction between the photons and the Solar-cell. Increased window thickness thus influences the formation of electron-hole pairs, contributing to a reduction in electrical efficiency. Refs also reported the same notice. Moreover, when the thickness of the frame layer is quite thin, the Solar-cell output degrades. The explanation may be the improved resistance of the series (increase in losses), and the thickness of the sheet, on the other side. The absorption improves as the thickness reduces. Therefore a finest thickness of the ZnO-layer is needed to achieve the best solar battery efficiency.

Table 3.

Thickness of CdS (μm) (Buffer Layer)	Efficiency %	FF %	Jsc (mA/cm^2)	V_{DC} (V)
0.005	24.80	84.55	38.31	0.7907
0.01	24.79	84.45	38.30	0.7907
0.02	24.78	84.37	38.28	0.7907
0.03	24.76	84.23	38.26	0.7907
0.04	24.75	84.23	38.24	0.7907
0.05	24.84	84.23	38.22	0.7907

Doping and buffer layer thickness effect happening conversion performance

Let us nowadays shorten our focus to the effect on Solar-cell performance of doping and buffer thickness. For this reason, we have seen a buffer layer of 0.05 μm in width versus a CdS buffer layer. The sample findings indicate that as dopant concentrations rise, the gain (reduced cost) is increasing [13]. The doping of the CdS buffer layer of the Solar-cell does not substantially affect the efficiency of the Solar-cell greatly. In present case, an N_D is 10^{16} cm^{-3} was selected for that would yield the most effective electricity. Since the impact of CdS barrier layer incapacitating on performance has been demonstrated.

We now illustrate the effect of the CdS buffer thickness on Solar-cell production. In this regard, the photovoltaic cell parameters for different CdS thicknesses vary from 0.005 to 0.05 μm. For the most part, we can see that all numbers that we are looking to test, as far as the CdS sheet is concerned, vary between 0.5 and 1.25 microns. This is in line with the previous findings in references. By growing the thickness of the buffer sheet, it allows for more light into the photocathode. This in essence, allows for fewer photons to be transformed into ionization. As a result, these photons are missed and the amount of photons that enter the absorber layer is limited.

The goal here is to get well the missing photons so as to increase the Solar-cell conversion performance. Because the absorbed light in CdS doesn’t greatly add to the photo-current obtained, it is beneficial that its thickness is tiny. In comparison to the selection of the carriers, rather than the diffusion is carried out by the file. Since there are no strongly doped CdS charge field, and as the lifetime of the carrier minority is extremely limited, the CdS layer is actually "dead" in the photovoltaic perspective. Thus, its thickness is reduced to reduce losses of optical absorption. Photovoltaic cell parameters for separate CIGS window thickness layers.

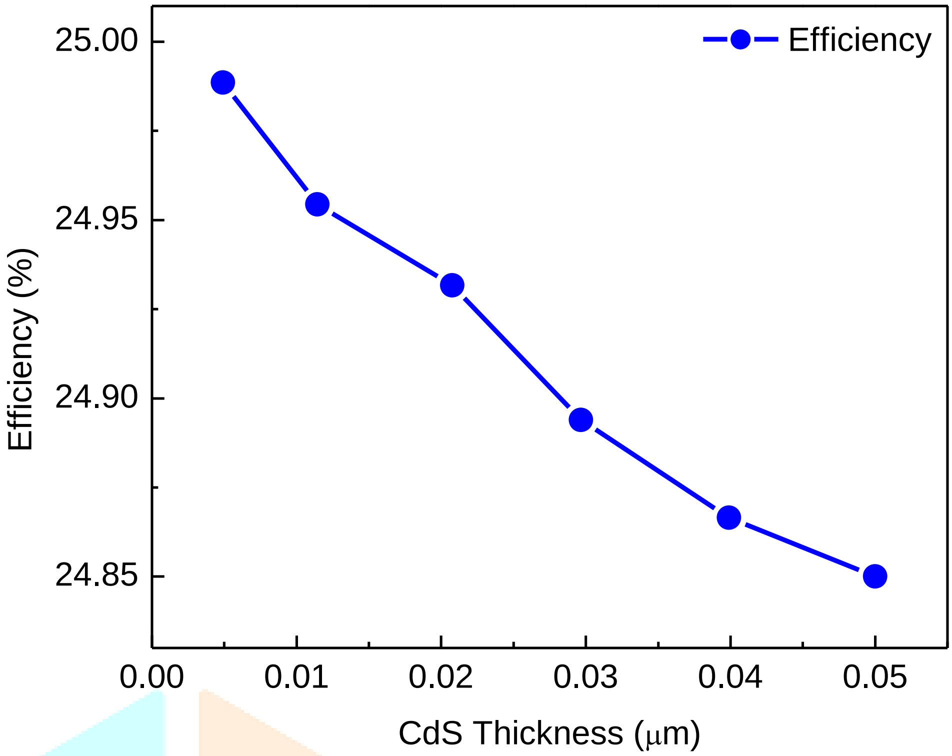

Figure 3. Efficiency (%) vs. CdS thickness of Solar-cell's buffer layer.

Table 4. Solar-cells constraints for various CIGS thickness (window layer).

Thickness of window layer (μm)	Efficiency%	FF%	J_{sc}	V_{oc} (V)
1	20.9	80.80	33.06	0.7477
1.5	21.3	81.22	33.91	0.7510
2	22.85	82.13	34.11	0.7636
2.5	23.22	83.20	35.56	0.7732
3	23.90	84.01	36.12	0.7795
3.5	24.21	84.95	37.54	0.7831
4	25.15	85.12	38.21	0.7978

Doping effect and absorber layer thickness on conversion efficiency

Lastly, as well as researching the capacities of the CIGS absorber sheet, it is also important to look at the changing experiences of incapacitating, and the width of the CIGS absorber deposit. However, we've seen the productivity of this regard as a result of the usage of anabolic steroids. When the NA at 10^{86} cm^{-3} is raised to 10^{16} cm^{-3}, the quality energy improves from evenings to a more pleasant level of 25.15 percent. This study shows that doping the absorber layer of the Solar-cell has a very significant effect on the cell's efficiency. According to this claim, it would be because the increase in doping would enhance the availability of photo-generated transporters to boost the power-driven demand.

The photovoltaic parameters for the different concentrations of CIGS ranging from 10 to 4 μm remain described. We found that the thicker CIGS film allows the Solar-cell to be able to create a higher voltage and shorter circuit. If this mechanism occurs for longer periods of time, it induces a more extreme and more periodic shift in the energy of the laser's light emitted off by the atoms. Studies suggest that increasing the width of the absorber deposit will decrease the Voc and Jsc values for the thinner film. This arises from the recombination step at the back of the Solar-cell in which the difference between energy production and the thermal loading of the CIGS cell causes it to fail. To demonstrate that the efficiency grows tediously and non-linearly with the rises of the thickness of CIGS. The other side of the equation is that more thick Solar-cells are being produced, and the Solar-cell factor is rising, too. This is in line with the previous findings by Tang and Sun mentioned above. As it is also a CIGS, you can see it with a thickness of 4μm. According to their study, the performance of the solar panel would have a substantial 25.81 percent.

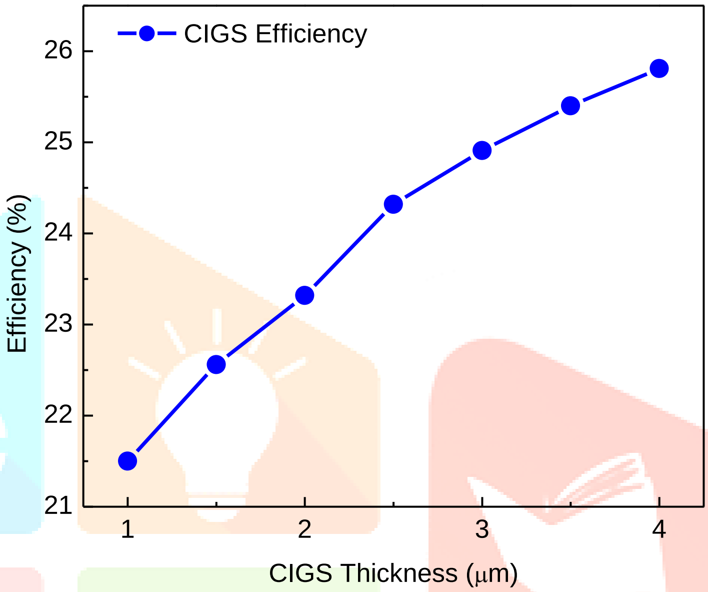

Figure 4. Efficiency (%) vs. CIGS Thickness of absorber layer.

Table 5. Photovoltaics values for CIGS based Solar-cells.

Photovoltaic values	Efficiency%	Fill Factor%	Current density J_{sc} (mA/cm^2)	Voltage of open circuit V_{oc} (V)
Present Work	24.89	84.99	38.58	0.7959
Reference 14	19.2	78	35.7	0.6890
Reference 16	21.8019	83.75	35.00	0.7436
Reference 7	21.32	82	33.5	0.7800

By integrating the optimum parameters of each sheet, the optimal configuration of the Solar-cell of importance has been designed. Our findings are reported in this article. The findings recorded in Refs are also seen for reference. Notice that our performance figures are clearly improved on those stated in the Refs [14-15].

CONCLUSION

The effect of doping, cadmium Sulfide (CdS) buffer layer thickness, and semiconducting inorganic compound (SIG) (CIGS) and on different photovoltaic cell parameters have been examined in this study. We are tuning the parameters for each of the various layers in the solar collector. We have identified the right specifications that allow for the greater output from the device ZnO as well as CdS also CIGS). Our model determines the optimum structure as a stack of four microns thick thin layers of Zinc Oxide (ZnO) with an $N_D = 10^{16}$ cm^{-3} and thickness, a 0.05 μm thick buffer (CdS) layer with an $N_D = 10^{16}$ cm^{-3} and thickness, and a 4 μm thick absorbent (CIGS) layer with a $N_A = 10^{16}$ cm^{-3}. By offering the strongest molecular insulation, size reduction and ionic transport properties, our carriers can remain separated from their surroundings. The electric output of the Solar-cell with such parameters is around 24.89% in aspect of 84.99%, current density is 38.58mA/cm^2 and an open circuit voltage remains 0.7959 V. The CIGS-based solar cell efficiency reported in the literature is lower than the present study's results.

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