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Numerical Simulation and Observationthe Characteristics of CIGS Thin Film Solar Cell using SCAPS-1D

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ABSTRACT : *In this research work, CIGS (n-ZnO/ZnS/CIGS) thin film solar cell has been simulated and investigated by using SCAPS (a Solar Cell Capacitance Simulator), is a one dimensional solar cell simulator in respect to overall performance. The optimum performance and efficiency has been investigated by changing the thickness of Window layer (n-ZnO), Buffer Layer (ZnS), Absorber layer (CIGS) and Back contact (Mo) are 0.2 µm, 0.04 µm, 4.3 µm, 0.5µm respectively. With the optimum thickness of these different kinds of layer the maximum efficiency of 28.66% has been investigated. This type of CIGS solar cell has been proposed as well as can be fabricated and implemented in laboratory which is reflected in this paper.*

Keywords –*Thin film solar cell, CIGS, Buffer Layer, Efficiency and SCAPS-1D.*

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I. INTRODUCTION

Now-a-days, solar energy is another topic that becomes increasingly hot over recent years as the fossil and mineral energy sources are approaching inevitable exhaustion in the coming fifty years[1].People all over the world have investigated different type of silicon (Si) solar cells for many years[2], although it has some disadvantages which may be overcome by thin film solar cell.Renewable energies are gaining considerable interest as an alternative to other sources of energy such as fossil fuels and nuclear energy. Photovoltaic (PV) devices used for the direct conversion of light into electricity are a viable option for a safe and sustainable future[3].The electron, it has been said, is the ultimate currency of modern society. Electricity indeed, being silent, clean, easily transported and converted into work, is the most widely used form of energy[4].For the reason of green power, low cost and availability the renewable energy plays an important role in the world energy specially the solar photovoltaic cell has a great contribution in the world electrical energy[5].Nevertheless in recent years, the photovoltaic market with its fast annual growth rates of over 35% during 1996–2003 has started to attract the attention of investors, looking for new promising investment fields[6].Thesingle crystal Si solar cells have reached an efficiency of 24.7%, compared with the theoretical maximum valueof 30%[7].The world is now developing different kinds of thin film solar cells like amorphous silicon (a-Si), Cadmium telluride (CdTe), Copper indium gallium selenide (CIS/CIGS) and Organic photovoltaic cells (OPC)[8]. Among them CIGS solar cell has different kinds of advantages like flexible, show a better resistance to heat and uses a much lower level of cadmium[9].

CIGS is one of the most promising materials for thin film photovoltaic devices because of its appropriate band gap and high absorption coefficient for solar radiation[10]. The CIGS solar cell's absorber layers were formed using physical vapor deposition [11].Furthermore, most of the energy and cost required to produce CIGS solar cells on glass is used for the substrate and cover glasses. A low-cost, glass-free, and thin substrate together with a thin and flexible encapsulant, would combine the advantages of flexible solar cells and cost-effective production[12]. In his research work, a new type of CIGS solar cell has been simulated and proposed with the optimum efficiency of 28.66 %.

II. PROPOSED MODEL STRUCTURE

The following Fig. 1 shows the proposed CIGS solar cell structure. Here, Ni/Al has been used as grid contact. The optimized layer thicknesses of Window layer (n-ZnO), Buffer Layer (ZnS), Absorber layer (CIGS) and Back contact (Mo) are 0.2 µm, 0.04 µm, 4.3 µm, 0.5µm respectively.

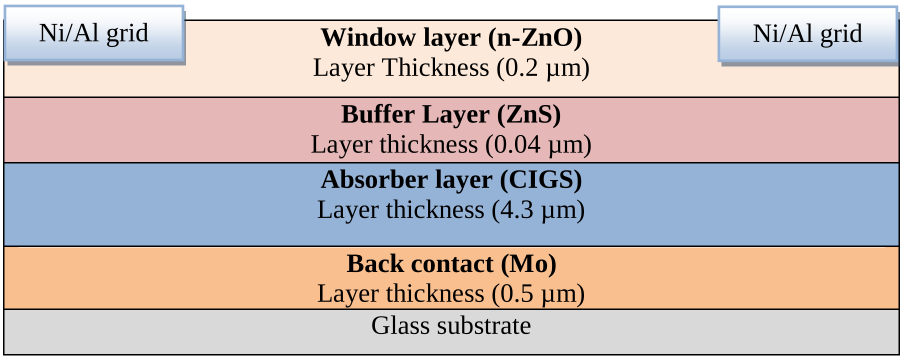

Fig.1 Proposed CIGS solar cell structure

III. SIMULATION PARAMETERS FOR PROPOSED DEVISE

All the simulation parameters that is simulated in SCAPS-1D has been included in table.1 and table.2.

Table 1. Material properties of different layers

Properties	CIGS	ZnS	n-ZnO
Thickness (µm)	1-6	0.01-0.1	0.2
Bandgap (eV)	1.45	3.3	3.3
Electron affinity (eV)	4.6	4.7	4.7
Permittivity	13.5	10	9
CB	2.2E+19	2.0E+19	2.5E+19
VB	1.8E+19	1.8E+19	1.5E+19
Electron mobility (cm^2/Vs)	1.0E+2	2.0E+2	2.5E+2
Hole mobility (cm^2/Vs)	2.2E+1	1.5E1+	1.8E+1
ND ($1/cm^3$)	1.0E+1	2.5E+19	2E+19
NA ($1/cm^3$)	2.0E+16	1.0E+1	1.0E+1

Table 2. Gaussian defect states

Properties	CIGS	ZnS	n-ZnO
Gaussian defect density NGA, NGD (cm^{-3})	1.772E+15	1.772E+15	1.772E+16
Peak energy position E_{GA}, E_{GD} (eV)	0.6	1.2	1.6
Standard energy deviation W_{GA}, W_{GD} (eV)	0.1	0.1	0.1
Electron capture cross section σ_n (cm^2)	1.0E-13	1.00E-13	1.00E-12
Hole capture cross section σ_p (cm^2)	1.0E-15	1.00E-13	1.00E-12

IV. SIMULATION RESULT AND DISCUSSION

A. Impact of Buffer Layer Thickness Variation

The simulation started by choosing the thickness of the absorber layer set to 4.2µm and the thickness of ZnS buffer layer was changed from 0.01µm to 0.09 µm and the variation of the cell performance has been reviewed. As it has been observed from the Fig. 2 Buffer layer thickness vs. open circuit voltage curve (Voc), although the increase of buffer layer thickness causes reduction in open circuit voltage (Voc), short circuit current density (Jsc) (Fig. 3) and efficiency (η%) (Fig. 5) but fill factor (FF) (Fig. 4) is increasing slightly with the increase of buffer layer thickness, it is not significant for Voc and fill factor. These two parameters can be considered almost constant for all amount of buffer layer thickness. The small changes and increment of fill factor with increase of buffer thickness can arise from the valance band discontinuities at the interfaces that appear as spikes. Unlike the changes in Voc and FF, the Jsc reduction caused by the increase of ZnS buffer layer is significant. The reason for this dependency of Jsc to the buffer layer thickness is noticeably fewer photons can reach absorber layer in a cell with thicker buffer layer. More photons are being absorbed within buffer layer especially those with the wave length around the ZnS absorption edge, thus fewer photons can contribute to quantum efficiency. Therefore, it is obvious that the resultant cell efficiency has a downward trend while the buffer layer thickness is increasing. Although the cell with thinner buffer layer shows higher performance, thicknesses less than 40nm currently is not reachable because of fabrication techniques and instruments limitation. Thus, the range of 40nm to 50nm is the preferred and the optimized thickness of the buffer layer in CIGS thin film solar cell.

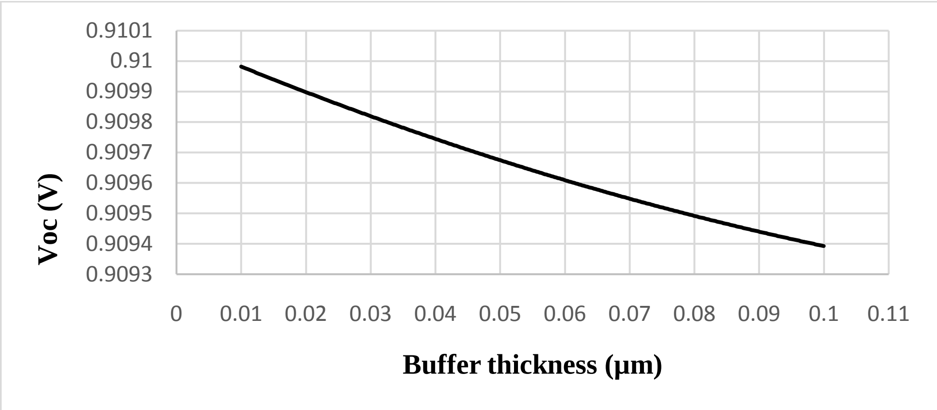

Fig. 2 Buffer layer thickness vs. open circuit voltage curve (Voc)

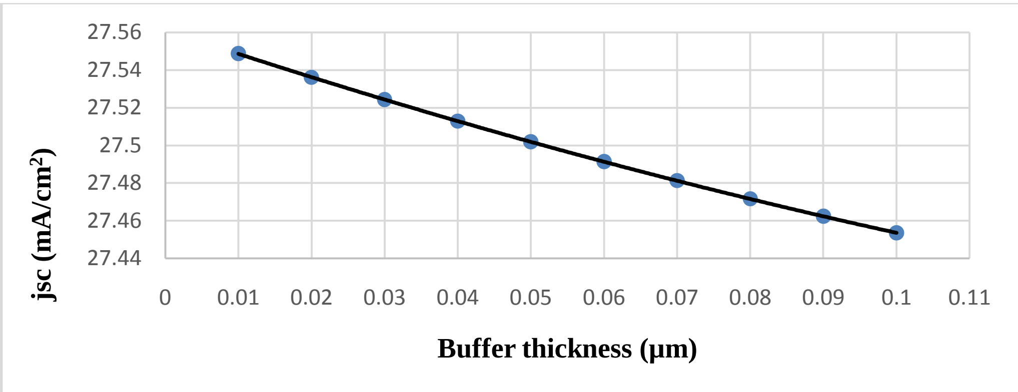

Fig. 3 Buffer layer thickness vs. short circuit current density (Jsc) curve

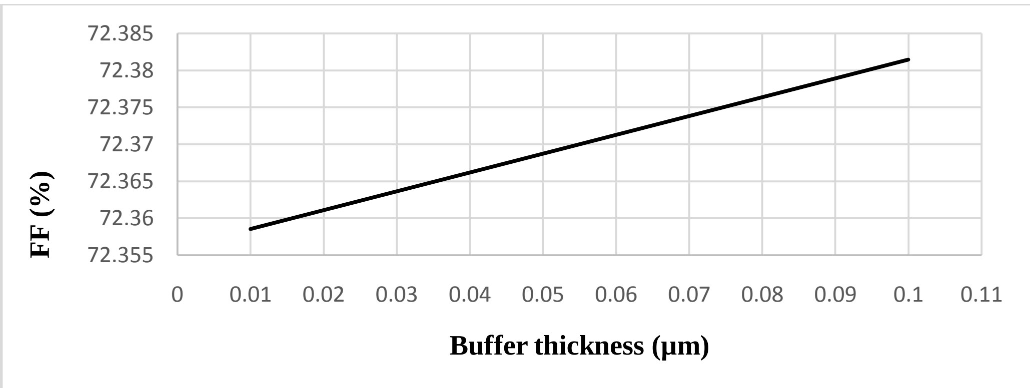

Fig. 4 Buffer layer thickness vs. fill factor (FF) curve

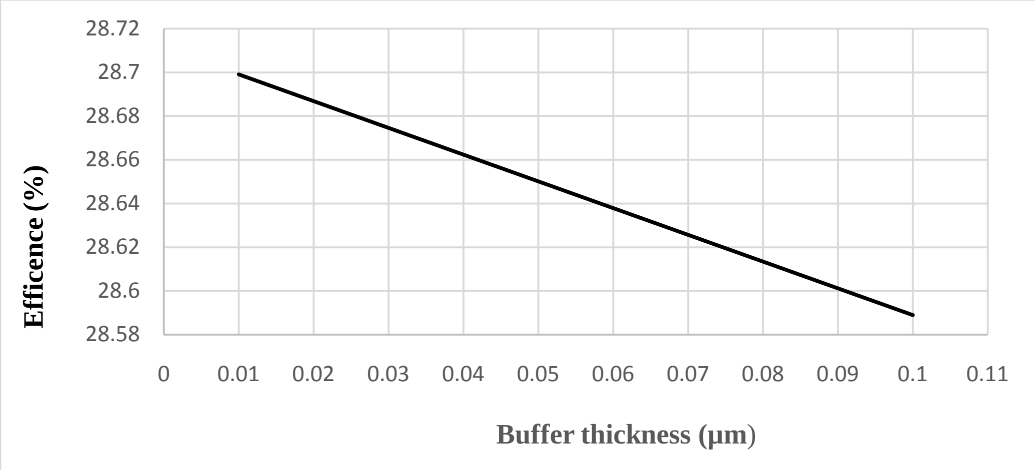

Fig. 5 Buffer layer thickness vs. efficiency curve

B. Impact of Absorber Layer Thickness Variation

In this stage, the thickness of ZnS buffer layer was set to 50nm, the thickness of absorber layer was varied from 1µm to 6µm and the variation of the cell performance has been investigated. The simulation result shows that the general performance of the cell increases to a certain value while the thickness of absorber layer is increased. After that certain value the cell performance decreases with the increase of absorber layer thickness. In this investigation short circuit current density (Jsc) is maximum (27.52 mA/cm^2) for 4µm absorber layer thickness (Fig. 7), whereas open circuit voltage (Voc) is maximum (0.9097 V) at 3µm (Fig. 6) and efficiency is maximum (28.67%) at 4µm (Fig. 9). But only fill factor (FF) has been decreased to a certain value with the increase of absorber layer thickness (Fig. 8). After that value then the fill factor increases with the increase of absorber layer thickness (Fig. 8). Hence the results show that the optimum range for the absorber layer thickness is between 3500nm to 4500nm and cell fabrication with the absorber thicknesses more than this range is not reasonable because of more material consumption without any significant effect on the cell characteristics and efficiency.

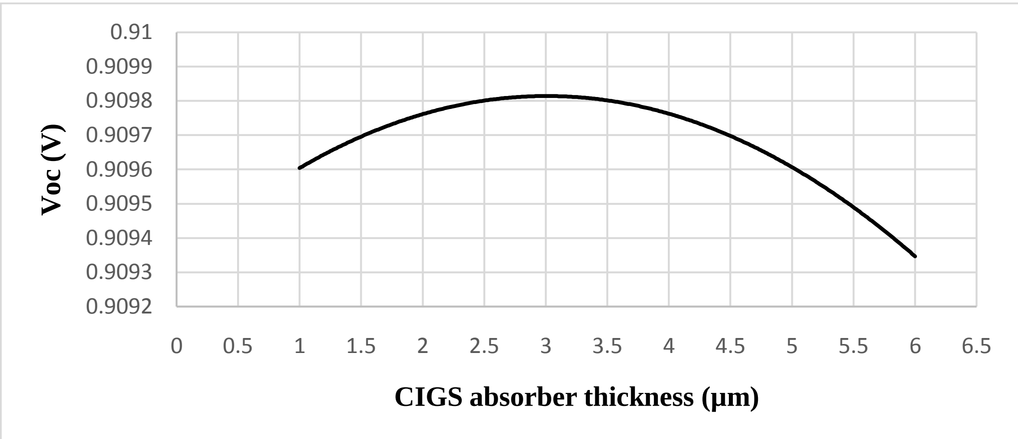

Fig. 6 Open circuit voltage (Voc) vs. CIGS absorber layer thickness curve

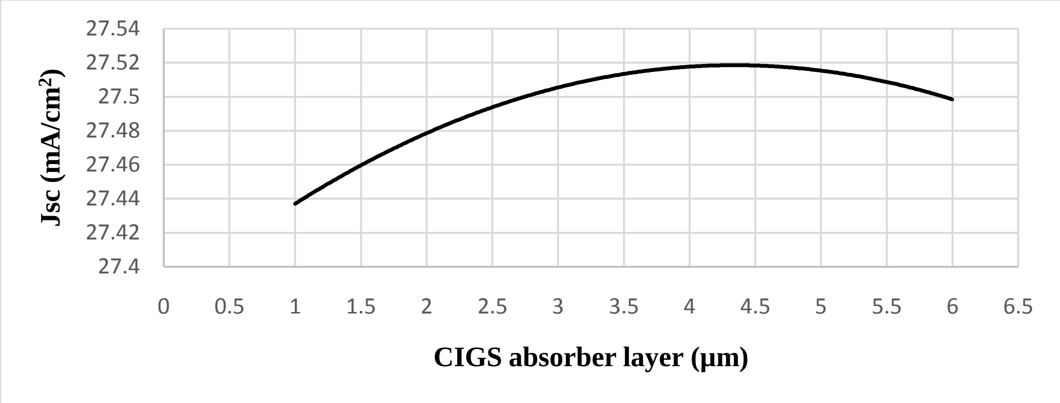

Fig. 7 Short circuit current density (Jsc) vs. CIGS absorber layer thickness curve

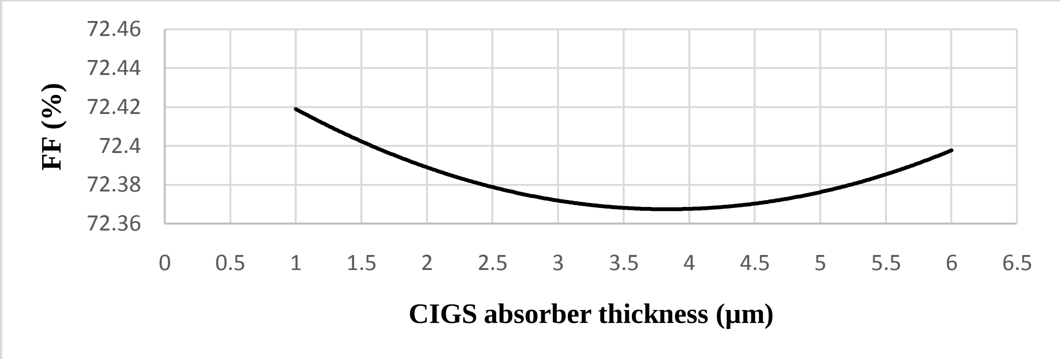

Fig. 8 Fill factor (FF) vs. CIGS absorber layer thickness curve

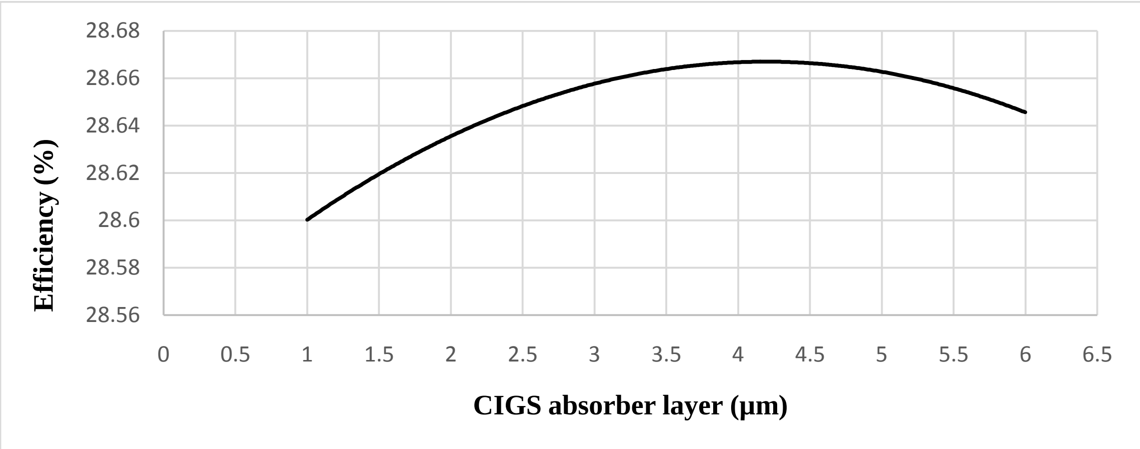

Fig. 9 Efficiency vs. CIGS absorber layer thickness curve

C. *Summary of the Result*

For the optimum value of buffer layer thickness (0.04µm) and absorber layer thickness (4µm), the following simulation result in Table 3 has been observed.

Table 3. Summary of the simulation result

Voc (v)	Jsc (mA/cm^2)	FF(%)	(% η)
0.9097	27.512886	72.37	28.66

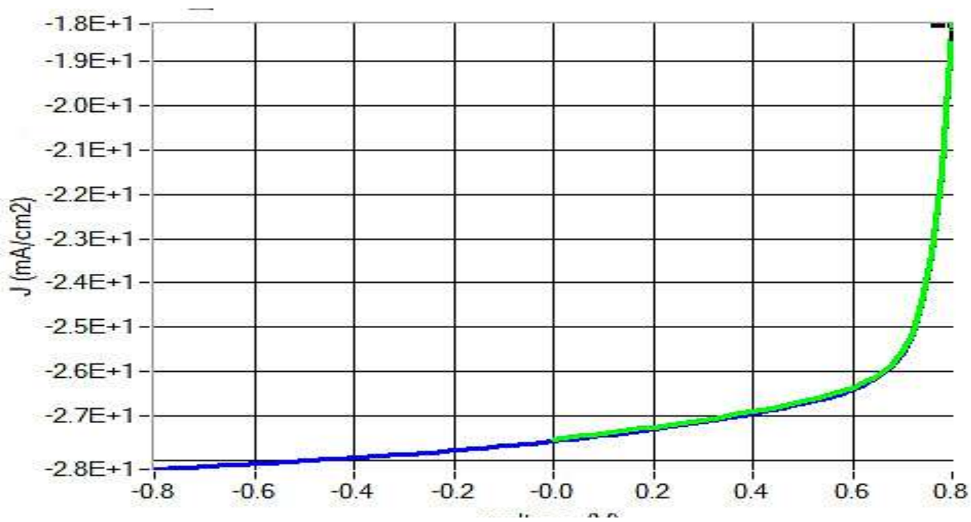

Fig. 10 I-V characteristics curve for CIGS solar cell

The Fig. 10 shows the I-V characteristics curve of the proposed CIGS solar cell. Here, for the optimum value of buffer layer thickness (0.04µm) and absorber layer thickness (4 µm),the open circuit Voltage (Voc) is 0.9097 V, short circuit current (Jsc) is 27.512886 (mA/cm^2), FF is 72.37% and efficiency is 28.66% has been observed.

V. CONCLUSION

The cell performance has been analyzed and simulated by the variation of buffer layer and absorber layer thickness using SCAPS-1D software as well as demonstrated the effect of absorber thickness and buffer layer thickness on the solar cell parameters like open-circuit voltage (Voc), short-circuit current density (Jsc), Fill Factor (FF), conversion efficiency (η%). The optimum thickness of absorber layer and buffer layer of a CIGS thin film solar cell with ZnS buffer layer has been found in the range of (4 – 4.5) µm and between (0.04 - .05) µm respectively. The conversion efficiency increased until the absorber layer thickness reached at around 4000 nm. Further increase in the thickness of the film does not show any improvement in the efficiency. The optimum conversion efficiency is 28.66% has been observed. This type of proposed CIGS solar cell can be fabricated in the laboratory in order to comprise with simulation result and for better performance. These observation leads to the conclusion that for the optimum performance of the solar cell device the thickness of the absorber layer and buffer layer plays an important role.

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