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TEMPERATURE EFFECT OF ELECTRICAL PROPERTIES OF CIGS SOLAR CELL

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ABSTRACT

In this paper we are interested in studying the copper–indium–gallium–selenium (CIGS) solar cells sandwiched between cadmium sulfide (CdS) and ZnO as buffer layers, and Molybdenum (Mo). Thus, we report our simulation results using the capacitance simulator (SCAPS) in terms of layer thickness, absorber layer band gap and operating temperature to find out the optimum choice. An efficiency of 20.61% (with V_{oc} of 635.2mV, J_{sc} of 44.08 mA/cm^2 and fill factor of 0.73) has been achieved with CdS used as buffer layer as the reference case. It is also found that the high efficiency CIGS cells with the low temperature were a very high efficiency conversion.

Key words: Thin film solar cells, SCAPS, CIGS, temperature, effiency energetic.

1. INTRODUCTION

A solar cell converts radiant energy into electrical energy. One such thin-_lm technology is based on a compound of the elements copper, indium, gallium and selenium, abbreviated Cu(In; Ga)Se2 or CIGS. Two advantages of this thin-_lm technology are the low material consumption and the high efficiency that has been demonstrated, which both make it economically competitive [1].

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A CIGS solar cell is built up of a substrate of soda-lime glass, a back contact of molybdenum (Mo), a light absorbing layer consisting of copper indium gallium diselenide (Cu(In;Ga)Se2), a buffer layer of cadmium sulphide (CdS) or zinc oxy sulphide (Zn(O; S)), a thin layer of high resistive zinc oxide (ZnO) and a transparent front contact of aluminium doped zinc oxide (ZnO:Al). Figure 1 shows the cross section of a CIGS solar cell with typical thicknesses of the different layers indicated.

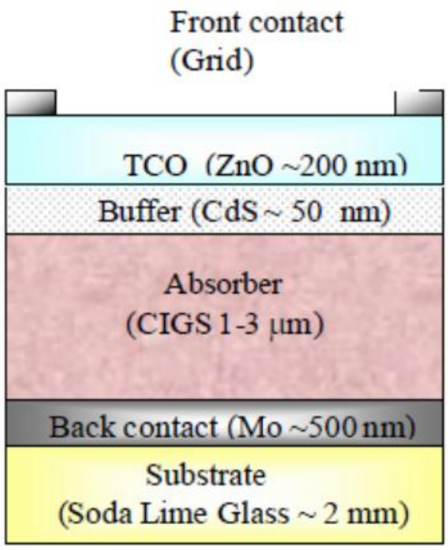

Fig.1. A schematic of a typical CIGS solar cell

2. SOLAR CELL OUTPUT PARAMETERS

J-V measurements are performed to characterize solar cells. Figure 4 shows a typical J-V curve with some of the following solar cell output parameters indicated [2]:

*Short-circuit current, J_{sc}, is the maximum current at zero voltage. The short-circuit current density, J_{sc},

*Open-circuit voltage, V_{oc}, is the maximum voltage at zero current.

*Maximum power point, P_{mp}, is the maximum power output at optimal operating condition,i.e. $P_{mp} = V_{mp} J_{mp}$.

*Fill factor, FF, is a measure of how square the J-V curve is. It is defined As

$$FF = \frac{J_{mp}V_{mp}}{J_{sc}V_{co}} = \frac{p_{mp}}{V_{oc}J_{sc}} \qquad (1).$$

*Efficiency, ¦ , is the energy-conversion efficiency. It is given by (1)

$$¦ = \frac{P_{mp}}{P_{in}} = \frac{J_{sc}V_{oc}}{P_{in}} \qquad (2).$$

where P_{in} is the total power of the incident light.

QE measurements are another method for characterization of solar cells:

*Quantum efficiency, QE, is the number of generated electron-hole pairs per incident photon in the solar cell. When measured with an external circuit this quantity is also referred to as the external quantum efficiency, EQE. It is often measured for wavelengths, ª , in the range from 200nm to 1200nm.The short-circuit current density can be calculated from the measurement

As.

$$J_{sc} = \int_0^\infty EQE(ª)\Phi(ª)dª \qquad (3).$$

Where Φ is the photon flux at the AM 1:5 spectrum

The model of a CIGS solar cell module has to take into account electrical, optical

and geometrical parameters [3]. The CIGS layer provides a shunting path between the front contact and the back contact, indicated in Figure 2.

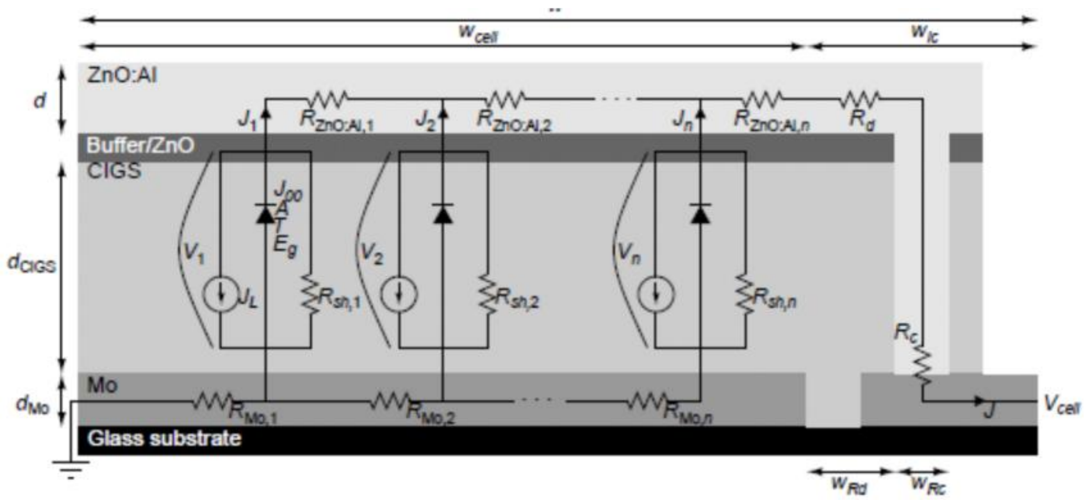

Fig.2. Equivalent electrical circuit of a CIGS solar cell. The one-diode model, shunt resistances and series resistances are shown. Voltages, currents and dimensions are defined. After Ref. [4] and [3].

3. SIMULATIONS, RESULTS AND DISCUSSIONS

Solar cells. It is developed especially for CdTe and CIGS solar cells.SCAPS is used to replicate and investigate all the available research-level CIGS solar cells with various buffer layers. From the solution provided by an **SCAPS** [5] simulation, output such as current voltage characteristics in the dark and under illumination can be obtained. These may be computed as a function of temperature. For solar cell and detector structures, collection efficiencies as a function of voltage, light bias, and temperature can also be obtained. By incorporating the various material parameters into **SCAPS** for all of the analysis aspects, changes in the values for **efficiency**, **Voc**, **Jsc** and **FF** as well as the effect of operating temperature are observed. Tables 1 and 2 shows the description of the parameters in the simulation and the base parameters that have been used in this study [5]. **SCAPS** is a one dimensional computer software to simulate the **AC** and **DC** electrical characteristics of thin film.

Table 1. Overall electronic properties.

EPS Relative permittivity, er
MDN Electron band mobility, ln (cm2/V s)
MDP Hole band mobility, lp (cm2/V s)
NA Acceptor concentration (1/cm3)
ND Donor concentration (1/cm3)
EG Electrical band gap (eV)
NC Effective density of states in conduction band (1/cm3)
NV Effective density of states in valence band (1/cm3)
CHI Electron affinity, xe (eV)

Table 2. Base parameters for ZnO/CdS/CIGS.

Quantity	ZnO	CdS	CIGS
Layer thickness (nm)	80	50	3000
EPS	9	10	13.6
CHI [eV]	4	3.8	4.1
Eg [eV]	3.3	2.4	1.15
MUN [cm2/Vs]	100	100	100
MUP [cm2/Vs]	25	25	25
Nc [1/cm-3]	2.22E18	2.22E18	2.22E18
Nv [1/cm-3]	1.78E19	1.7E19	1.78E19
NA [1/cm-3]	0	0	3.5E16
ND [1/cm-3]	1E5	3.5E17	0
ve [cm/s]	1E7	1E7	1E7
vh [cm/s]	1E7	1E7	1E7

The obtained results in figure.3 demonstrate an optimum current density at very low bias and an optimum power at 0.5 volt at 300 K temperature.

We have remarked also in figure.4 a more stability of current-density curves for temperatures less then 320K and an instability of the curves for temperatures >340K. As soon as power is more optimum with low temperatures (<320K).

From figures 5. A,B,C and D the Voc is more optimized at 300K, the J_{sc} is stable at the range of temperatures 300-400K, the FF is optimized for <350K and minimized for temperatures > 360K and finally the effiency of our solar cells is optimized for a temperature of work of 300K.

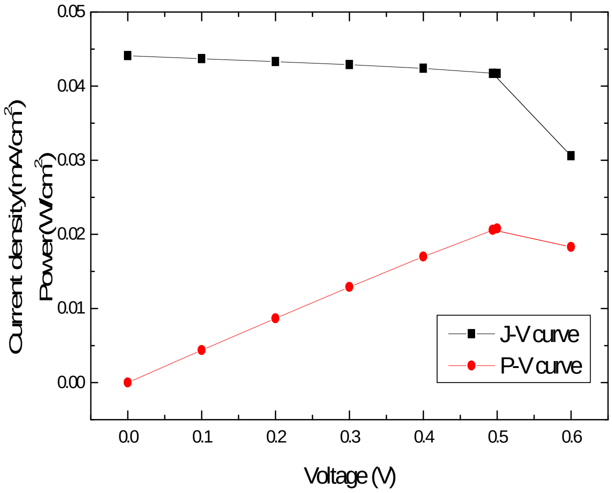

Fig.3. J–V and the power characteristics of CIGS solar cell at 300K

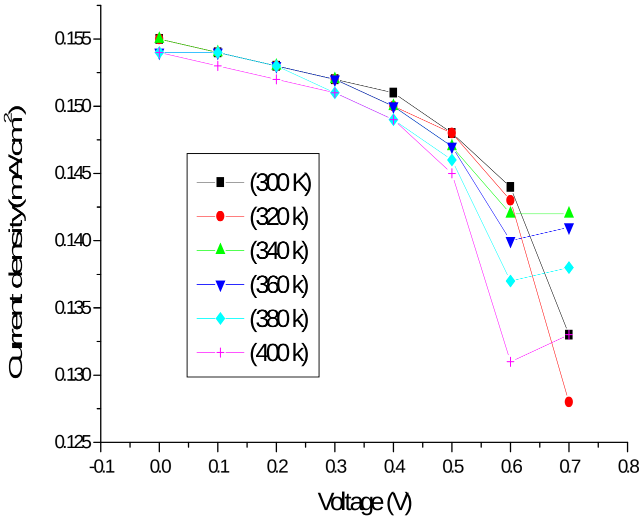

Fig.4. J–V characteristics of solar cell with variable the temperature of CIGS

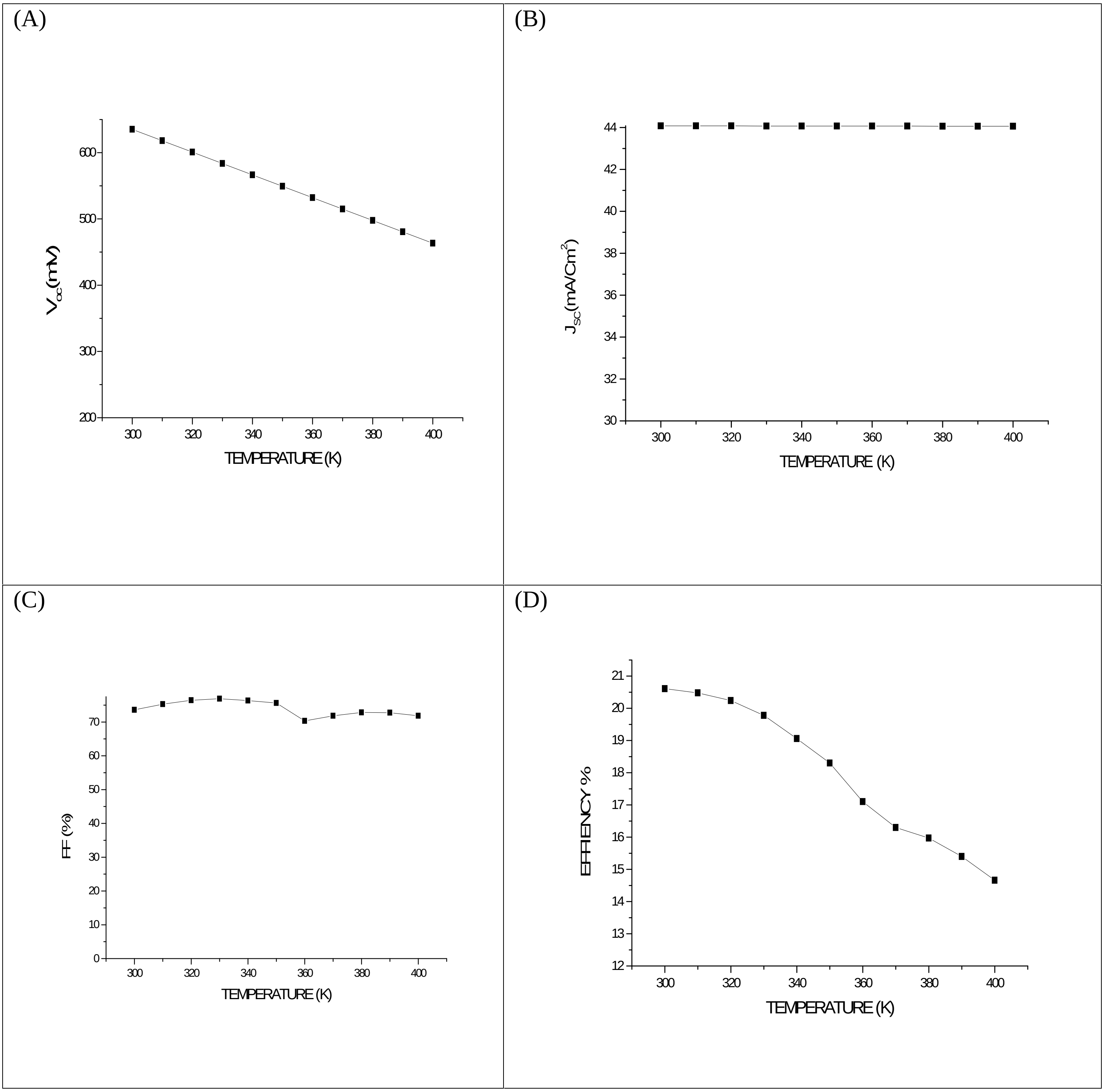

Fig.5. Solar cell performance of the CIGS cells with different buffer layers.

4. CONCLUSION

Various temperature for a possible study of electrical parameters of CIGS solar cells have been investigated in terms overall cell performance at thickness of CIGS layer. For an optimum thickness of around 3 µm of high-efficiency CIGS absorber, the optimum thickness of buffer layers is found to be 50 nm.

Simulation results show that the solar cell performances are affected by the increase in operating temperature for all CIGS semiconductor with differences in the temperature gradients. The gradient of temperature has no effect on the short-circuit current, the V_{co} decrease with increasing temperature, the FF is medal affected and the essential result is that the energetic effiency is optimum for ambient temperature at 300K.

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