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Parameters optimization of heterojunction ZnSe/CdS/CIGS/Si solar cells using SCAPS-1D software

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Abstract

It is required to simulate the performance of a photovoltaic solar cell performance to enhance it. Simulation optimization has the benefit of being inexpensive and straightforward, and it allows us to identify the optimum parameters that contribute to the enhancement of the cell. An alternative ZnSe/CdS/CIGS/Si structure has been presented using a solar cell capacitance simulator (SCAPS-1D). This paper aims to increase device efficiency by improving the physical characteristics of the many layers involved in cell realisation. We also tried to investigate the variation of electrical characteristics such as Voc, Jsc, η, and FF with the changes in material parameters, notably the absorber layer thickness (CIGS, p-Si) (CIGS, p-Si). On the other hand, the temperature dependency has been simulated to guide device manufacturers to attain higher efficiency in varied temperature circumstances. The calculation result shows that excellent performance can be reached by varying the parameters, and the highest efficiency (24,94 %) of the solar cell can be reached under certain conditions, where the thicknesses of ZnSe, CdS, CIGS, and Si are 0.2µm, 0.09µm, 1.4µm, and 0.6µm respectively and for the optimal value of temperature equal to 295K.

Keywords: CIGS Solar Cell; *J-V* characteristic; SCAPS-1D; Thickness.

1. Introduction

Solar cells are now the topic of many studies in order to obtain the optimal ratio between energy efficiency and price [1,2]. Indeed, thin-film solar cells based on Cu(In, Ga)Se_2 (CIGS) provide a very attractive option to minimize material costs while enabling to obtain high efficiency [3]. The numerical modelling of CIGS solar cells allows us to identify the most relevant factors on their photovoltaic performance.

The current study presents an improved ZnSe/CdS/CIGS/Si structure by employing SCAPS-1D. The solar cell capacitance simulator SCAPS-1D was established at Ghent University. It is quite practical to use, enabling the modelling of any photovoltaic structure by altering parameters (thickness, area, doping, etc.) [4].

The basic principle behind this study is the increase of the device efficiency by optimizing the physical characteristics of the several layers involved in the realisation of the cell, notably the absorber layer thickness (CIGS, p-Si) (CIGS, p-Si). On the other side, temperature dependency has also been tested.

2. Presentation of the structure

The schematic design of the CIGS solar cells structure utilized for this simulation is presented in Fig.1. The essential components of this cell are the ZnSe window layer, CdS buffer layer, and CIGS & p-Si absorbers layers.

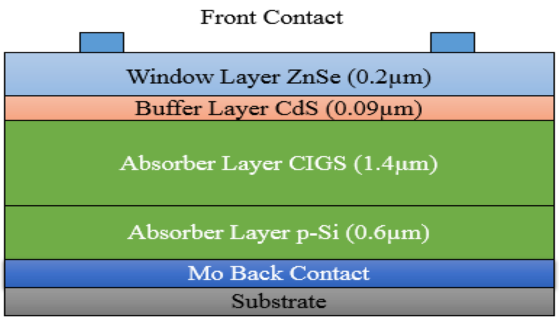

Fig 1. Schematic structure.

Fig. 2 shows the solar cell architecture employing SCAPS-1D.

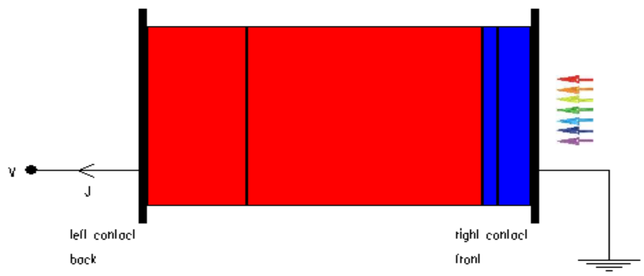

Fig 2. ZnSe/CdS/CIGS/Si structure using SCAPS-1D.

The semiconductors properties of each layer employed in the structure are presented in Table 1 [5-8].

Table 1. Layer's material properties.

Parameters	**Layers**			
	ZnSe	**Cds**	**CiGs**	**p-Si**
Bandgap, E_g (eV)	2.470	2.420	1.159	1.120
Electron affinity X_e (eV)	4.090	4.400	4.500	4.050
Dielectric constant	9	10	13.6	11.9
Electron mobility μ_n (Cm^2/Vs)	50	100	100	1450
Hole mobility μ_p (Cm^2/Vs)	20	25	25	500
Density at conduction band, N_c (Cm^{-3})	1.7×10^{18}	2.2×10^{18}	2.2×10^{18}	2.8×10^{18}
Density at valence band, N_v (Cm^{-3})	8×10^{16}	1.8×10^{19}	1.8×10^{19}	2.65×10^{19}
Doping, N_a (Cm^{-3})	0	0	1.1×10^{19}	1×10^{20}
Doping, N_d (Cm^{-3})	1×10^{18}	1.1×10^{18}	0	0

3. Results and discussion

3.1 Characteristic *J-V*

After simulation, we have the CIGS solar cell's current-voltage (*J-V*) characteristic shown in Fig. 3. She shows us that for low voltage values, the solar cell is a continuous current source with a current almost equal to the current of short-circuit *Jsc* [9]. As the tension increases, the current decreases exponentially until it reaches zero.

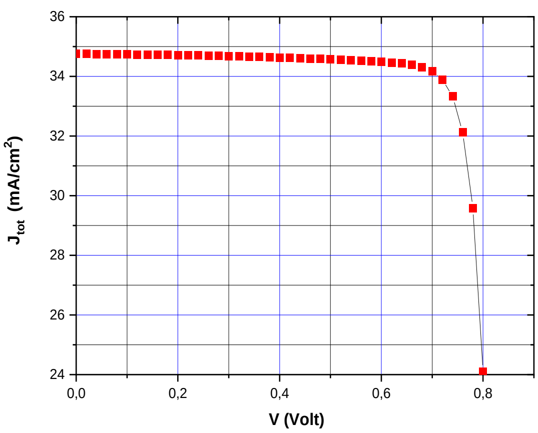

Fig 3. The simulated characteristic *J-V*.

Solar cell characteristics obtained from computed *J-V* curve (Fig.3): V_{oc} =0.930499 V;

J_{sc} = 34.75919892 mA/cm^2; *FF* = 77.1132 %; η = 24.9410 %; V_{MPP} = 0.750801 V; J_{MPP} = 33.21923666 mA/cm^2.

3.2 Influence of temperature

The performance of a solar cell is significantly affected by its temperature [10]. T=295K is the temperature at which the cell is most effective (Fig 4.). As the temperature rises, the gap band narrows, hastening electron-hole pair recombination between the conduction and valence bands. The solar cell's conversion efficiency decrease as Vco drops. Table 2 indicates the impact of temperature on the conversion efficiency of the solar cell.

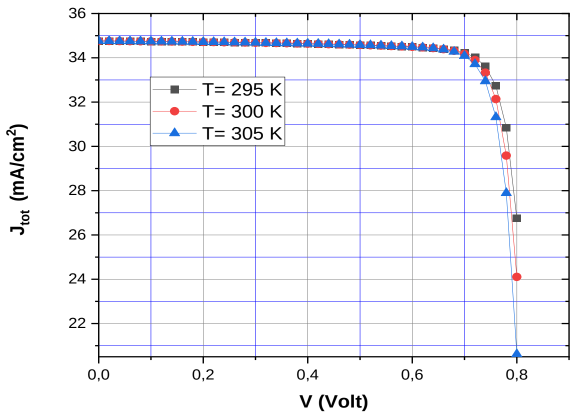

Fig 4. Effect of temperature on characteristic *J-V*.

Table 2. Effect of temperature on efficiency.

Temperature (K)	V_{oc} *(V)*	J_{sc} *(mA/cm^2)*	η %
295	0.9305	34.759199	**24.94**
300	0.8880	34.760887	24.67
305	0.8567	34.762680	24.40
310	0.8334	34.764550	24.12

3.3 Effect of thickness of absorber layer

The thickness of the CIGS absorber layer was changed from 1µm to 1.4µm (Fig 5.). We observe that if the thickness rises, only the short-circuit current Jsc increases since the absorption increases. However, Voc is minimally impacted by the thickness. This permits improving the efficiency towards a maximum value of roughly 24,94 %. Consequently, the ideal thickness for the CIGS absorber layer would be about 1.4 µm, a value from which the efficiency has no considerable improvement. By adding 0.6 µm of the layer Si of p-type [11], the efficiency has been enhanced from 19.71 percent for standard CIGS structure [12] to 24,94 percent for the suggested structure. Table 3 shows the effect of the thickness of the absorber layer on the solar cell's conversion efficiency.

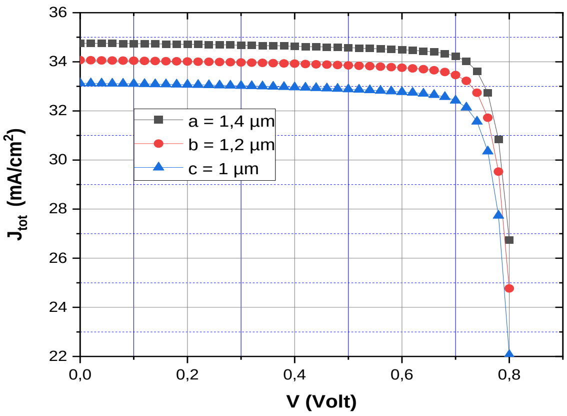

Fig 5. Effect of thickness of absorber layer on characteristic *J-V*.

Table 3. Effect of absorber layer thickness on efficiency.

Thickness absorber layer (µm)	V_{oc} *(V)*	J_{sc} *(mA/cm*^{2}*)*	*η %*
1.0	0.8778	33.129051	23.36
1.2	0.9041	34.065069	24.25
1.4	0.9305	34.760518	**24.94**

4. Conclusion

The calculation result shows that excellent performance can be attained by varying the parameters, and the best performance (24,94 %) of the solar cell can be obtained within certain conditions, where the thicknesses of ZnSe, CdS, CIGS, and Si are 0.2µm, 0.09µm, 1.4µm, and 0.6µm respectively and for the optimum value of temperature corresponding to 295K. The results above will play a guidance role in fabricating higher efficiency CIGS solar cells.

5. Acknowledgements

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6. References

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