Modeling and simulation of heterojunction solar cell: determination of optimal values.

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Modelling and Simulation of Heterojunction Solar Cell; Determination of Optimal Values

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***Abstract* — A heterojunction solar cell of ZnSe/ZnO/CIGS/Si structure has been simulated in order to determine the optimal values. The performed modelling and Simulation is used to get an idea and identify the optimal values that can be use in the manufacturing process, and the values obtained in this simulation presented an electrical parameters using Solar Cell Capacitance Simulator (SCAPS). In this study, the influence of absorber or wafer thickness and doping concentration were varied on the solar cell device and the following optimal values were obtained; Current density (J_{sc}) = 35.08338 mA/cm^2, Open circuit voltage (V_{oc}) = 0.8339V, Fill Factor (FF) = 85.45%, and an efficiency (η) = 25%. The range of doping concentration (1x10^{12} to 1x10^{20} cm^{-3}). These variations lead to the achievement of 25% efficiency of the heterojunction solar cell and the optimal values shows a promising performance that the manufacturers can adopt.**

Keywords— Heterojunction, Solar Cell, Optimal Values, Simulation, Modelling

I. INTRODUCTION

Renewable and sustainable energy adoption has brought different explorations in the research community to find a cheaper, stable and more efficient way of generating electricity. Solar PV devices are part of the effective way towards a sustainable energy drive that can be used in converting sunlight into electrical energy through the photovoltaic effect[1] Thin-film solar cells are among the second generation solar cell devices[2]. They are highly promising due to their flexibility and weight, making them suitable for building integrated PV system[3]. Researchers are exploring different options of thin-film technologies with different combinations in order to get the optimal parameters for a cost-effective manufacturing model for thin-film. Copper Indium Gallium Selenide (CIGS) is an attractive option that can use to reduce the cost of materials while achieving high efficiency[4]. Also, CIGS have a high potential for conversion efficiency and stability [5]. Numerical modelling of CIGS in a Cu (In, Ga) Se_2-based solar cell that allowed one to identify different factors that can improve the performance of the photovoltaic devices[2], [6]. This paper presents an improved heterojunction ZnSe/ZnO/CIGS/Si structure using Solar Cell Capacitance Simulator (SCAPS).

It is a numerical software that allows the simulations of photovoltaic structures. The study, concentrated on varying different parameters of the heterojunction ZnSe/ZnO/CIGS/Si in the SCAPS such as doping concentration, thickness, temperature and area of the solar cell, for optimal performance[6]. In this heterojunction formation, the effect of the absorber layer with respect to its properties and the influence of other parameters are studied.

II. NUMERICAL MODELLING AND DEVICE ARRANGEMENT

The heterojunction architecture is based on CIGS solar cell structure. The solar cell consists of Electron Transport Layer (ETL), absorber layers and Hole Transport Layer (HTL) as shown in Fig 1. The structure arrangement is presented from back contact layer down to the front contact layer.

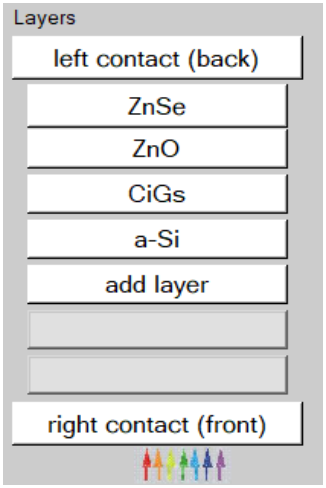

Fig. 1. Solar Cell Structure Defination[7]

In order to run a simulation using SCAPS, all the necessary heterojunction solar cell materials parameters must be inserted as illustrated in Fig. 2, such as the thickness of each layer, band gap E_g (eV), electron affinity (X_e), dielectric constant, conduction band density of states (N_c), valence band density of states (N_v), electron mobility (μ_n), hole mobility (μ_p), donor density (N_d), acceptor density (N_a) and defect density as shown in Table 1.

TABLE 1. Simulation Properties Used in the Solar Cell [3–8]

Parameters	**Layers**			
	ZnSe	**ZnO**	**CIGS**	**a-Si**
Layer Thickness (μm)	0.241	0.100	1.395	0.594
Bandgap E_g (eV)	2.470	2.500	1.159	1.120
Electronic Affinity X_e (eV)	4.100	4.400	4.500	4.150
Dielectric Constant	9.000	10.00	13.60	11.9
Electron Mobility (cm^2/V$_s$)	50.00	100.0	100.0	1450
Hole Mobility (cm^2/V$_s$)	20.00	25.00	25.00	500.0
Density at conduction band N_c (cm^{-3})	1.7 x 10^{18}	2.2 x 10^{18}	2.2 x 10^{18}	2.8 x 10^{18}
Density at valence band N_v (cm^{-3})	8 x 10^{16}	1.8 x 10^{19}	1.8 x 10^{19}	2.65 x 10^{20}
Doping, N_d (cm^{-3})	1 x 10^{18}	1.1 x 10^{18}	0	0
Doping, N_a (cm^{-3})	0	0	1.1 x 10^{19}	1 x 10^{20}
Defect Density (cm^{-3})	1 x 10^{14}	1 x 10^{14}	1 x 10^{14}	1 x 10^{14}

III. RESULTS AND DISCUSSIONS

The result is represented based on the influence of absorber or wafer thickness and doping concentration were varied on the solar cell device. Current density (J_{sc}) = 35.08338 mA/cm^2, Open circuit voltage (V_{oc}) = 0.8339V, Fill Factor (FF) = 85.45%, and an efficiency (η) = 25%, V_MPP = 0.740000V, J_MPP = 33.781620mA/cm^2 as shown in Fig. 3.

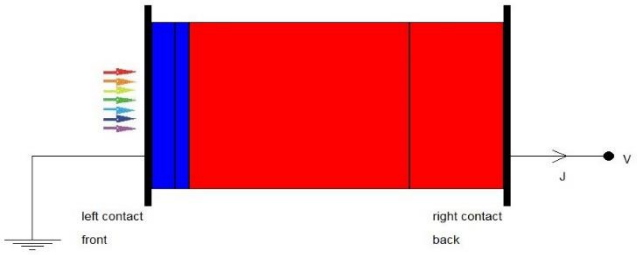

Fig. 2. The heterojunction Structure in SCAPS

The impact of the output simulation results makes it's easier, simpler, and faster in the design/fabrication consideration of solar cell performance.

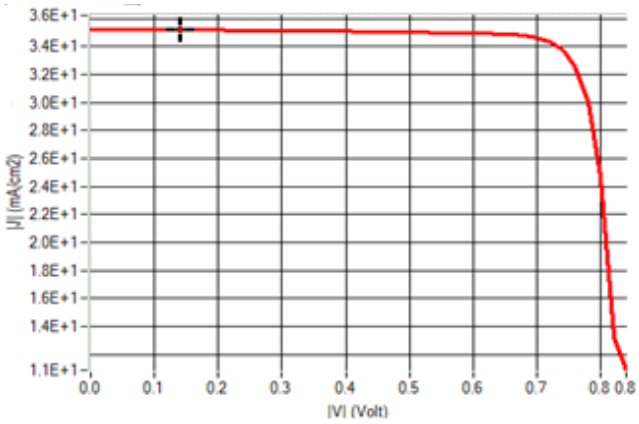

Fig. 3. Optimal J-V Characteristic from the solar cell

The influence of absorber thickness as shown in Fig. 4, absorber thickness must be carefully selected to reach the maximum current density of the heterojunction solar cell while the doping concentration is shown in Fig. 5 also must be selected between the lowest and heavy doping concentration value at both p-region and n-region for a maximum output current density of the solar cell[10].

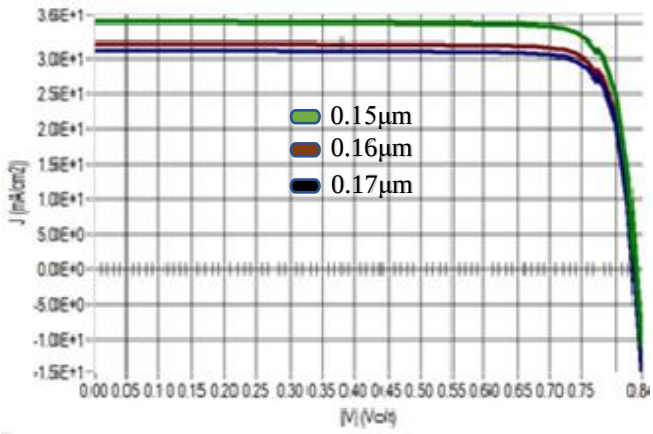

Fig. 4. Influence of absorber thickness on the J-V Characteristic

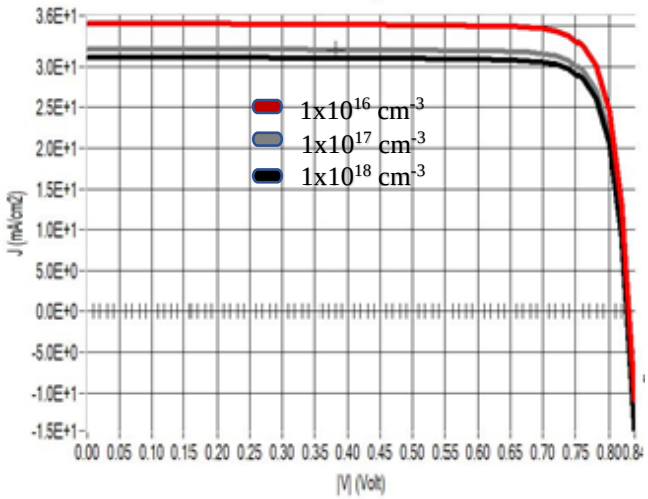

Fig. 5. Influence of doping concentration on the J-V Characteristic

IV. CONCLUSION

In the paper, we have investigated the effect of thickness absorber and doping concentration values on the heterojunction ZnSe/ZnO/CIGS/Si structure solar cell device in order to obtain optimal values for a better performance of the solar cell using the SCAPS software. The study has shown the influence of the absorber layer (CIGS) and supported transport layers, ZnSe with the contributions of the wafer layer. Variation of the layer thickness have influenced the obtained optimal values. Simulated results shows that the efficiency of this heterojunction solar cell is 25% at a temperature of 300K. These proposed values in the solar cell structure can be used or validated through the experimental/fabrication process.

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