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Research Article

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SCAPS-1D Simulation of CIGS-based Solar Cells with CdS as Buffer layer

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Abstract

This paper uses SCAPS-1D software to simulate a film solar cell with the highly efficient Cu(InGa)Se_2 (CIGS). For large-scale solar applications, CIGS is a suitable material. Thin film solar cells made of Mo/CIGS/CdS/SnO_2 has better implementation. The performance of this structure was enhanced by utilizing the window layer (SnO_2) bandgap's effects on the characteristics of the solar cells, including the short circuit current density (J_{SC}), open voltage (V_{OC}), fill factor (FF), and CIGS solar cell efficiency. According to the findings of the structure simulation, the efficiency is improved by 20.43%, while the J_{SC}, V_{OC}, and FF values are 37.208720 mA/cm, 0.6622 V, and 82.91%, respectively.

Keywords

CIGS, CdS, SnO_2, SCAPS-1D

Introduction

Gallium Indium Copper Selenide, sometimes referred to as CIGS, is a compound consisting of selenium, gallium, copper, and indium. It effectively absorbs light because of its straight band gap [1-3]. Its long-term stability and this characteristic make it a desirable material for solar cells used in terrestrial applications [4, 5]. In this study, the window layer was made using the tin oxide semiconductor SnO_2:F to increase transparency. In comparison to undoped films, F-doped SnO_2 films exhibit increased conductivity, transmissivity, and infrared reflectance. The structure of CIGS-based solar cells uses the p-type broad band gap absorber layer of CIGS [6-8].

In this investigation, a glass substrate that had previously been covered with molybdenum (Mo) received a CdS coating. The semiconductor CdS, which belongs to the II-VI group and has a band gap (BG) of 2.45 eV, is renowned for its distinctive optoelectronic characteristics. Because of its outstanding qualities, it is frequently employed as a buffer layer in solar cells. High and low absorbance light can be captured by thin films composed of CdS, with the ultraviolet region (0.36 - 0.45 microns) having the highest absorbance and the infrared and visible spectrums having the lowest absorbance.

Experimentation

Simulation

By adjusting all device and material attributes, SCAPS is a tool that can replicate the characteristics of one-dimensional solar cells. We can examine current-voltage (J-V) or quantum efficiency (QE) data and spot trends by modifying the model's input parameters. Other software for modeling solar cells, such as AMPS-1D, ASA, PC-1D, and AFORS-HET, is also available. However, SCAPS-1D is preferred because of its high agreement with experimental results for thin film solar cells. As a result, SCAPS-1D is employed in our study.

The SCAPS-1D programme is used in this study to model a CIGS-based thin film solar cell and determine the ideal BG for a high efficiency. Various electrical metrics, such as J-V, C-V, QE, efficiency, and others, are calculated by the program under various lighting situations and AM solar spectrum values. The electrical shunt impedance, carrier current density, V_{OC}, J_{SC}, FF, QE, generation, recombination profile, capacitance frequency spectroscopy, and capacitance voltage spectroscopy are also all variables that may be determined using SCAPS.

The CIGS, n-In_3S_3, and SnO_2:F were utilized as the absorption layer, n-type buffer layer, and window layer, respectively, to characterize the solar cells using the AM1.5 sun spectrum. According to estimates, the optical band gaps of CIGS sheets range between 1.4 and 1.5 eV, making the buffer layer's (In_2S_3) characteristics essential for the development of solar cells. Due to its strong electrical resistance properties, In_2S_3 is a fantastic candidate for a buffer layer in solar cells.

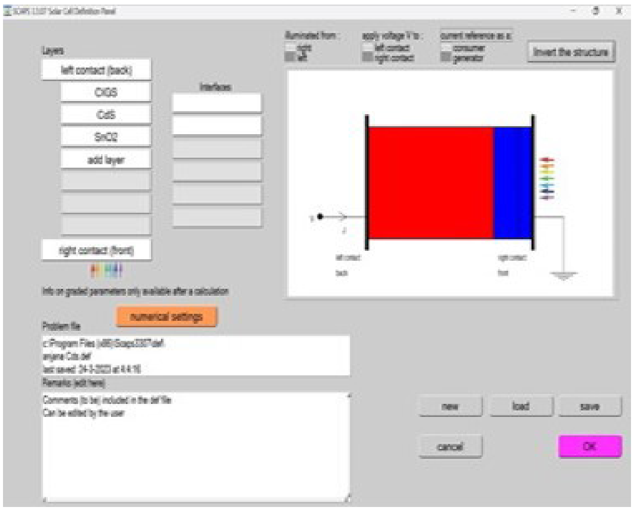
Structure

In this paper, CIGS, CdS, and SnO_2 as the absorber layer, buffer layer, and window layer, respectively, in this experiment. as depicted in figure 1. With a sun-like illumination capacity of 1000 W/m^2 and AM 1.5 global spectrums, light has been illuminated from the front contact. Using the SCAPS-1D package, all layer parameters, including BG, thickness, electron and hole mobility, and dielectric permittivity values, were entered. The CIGS material characteristics used to make this solar cell are displayed in table 1.

Results and Discussion

Effect of the BG on the performance of CIGS-based thin film solar cells

Any semiconductor's material characteristic is called electron BG. The minimal energy needed to excite an electron from its valence band into its conduction band (CB) is known as the semiconductor's BG. The value of the BG is determined by the energy differential between the CB, which is filled with holes, and the valence band (VB), which is filled with electrons. The effect of CIGS film BG on solar cell efficiency is demonstrated in this study. In the CIGS absorber layer, the BG values ranged from 1.1 to 1.5 eV. QE and J-V characteristics (Figure 2) at 300 K. The values of solar characteristic parameters like V_{OC}, J_{SC}, FF, and are shown in table 2 for various BGs. The variation of these V_{OC}, J_{SC}, and FF (Figure 3).



Info on graded parameters only available after a calculation

Problem file
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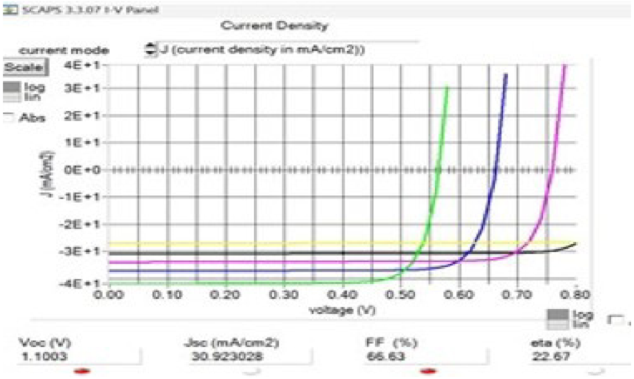
Figure 1: Schematic of a CIGS thin film solar cell based on SnO_2.

Table 1: Material parameters used for CIGS solar cells simulation.

Material properties	Absorber layer (CIGS)	Buffer layer (CdS)	Window layer (SnO_2)
Thickness	2.0 (µm)	400 (nm)	0.2 (µm)
Energy BG (eV)	1.2	2.4	3.8
Electron affinity (eV)	4.5	4.18	4.5
Dielectric permittivity	13.6	10	9
CB effective density of state (cm^{-3})	2.2 x 10^{19}	2.2 x 10^{18}	2.2 x 10^{18}
VB effective density of state (cm^{-3})	1.8 x 10^{19}	1.8 x 10^{19}	1.8 x 10^{19}
Electron thermal velocity (cm/s)	1.0 x 10^{7}	1.0 x 10^{7}	1.0 x 10^{7}
Hole thermal velocity (cm/s)	1.0 x 10^{7}	1.0 x 10^{7}	1.0 x 10^{7}
Electron mobility (cm^2/Vs)	100	100	20
Hole mobility (cm^2/Vs)	25	25	10
N_D	0	1.0 x 10^{18}	1.0 x 10^{18}
N_A	2.0 x 10^{18}	2.0 x 10^{15}	0



Voc (V) 1.1003
Jsc (mA/cm2) 30.923028
FF (%) 66.63
eta (%) 22.67

Figure 2: J-V characteristic and how it relates to CIGS's BG (eV) values.

Conclusion

In the current study, CIGS thin films were designed and analyzed using the SCAPS-1D software. For improved performance, the CIGS film's window layer (SnO_2) has been researched. Mo/CIGS/CdS/SnO_2 thin films' effectiveness and performance have been taken into account when optimizing. We have different BGs of SnO_2 layer here. Based on CIGS layer simulation findings, it was determined that BG of 1.4 eV exhibits the highest FF and efficiency. As a result, we draw the conclusion that 1.4 eV should be the ideal number of BG for

Table 2: Characteristics values.

BG	V_{OC}	J_{SC}	FF	Eta
eV	V	mA/cm²	%	%
1.1	0.5651	41.89	81.17	19.22
1.2	0.6622	37.211	82.98	20.45
1.3	0.7600	33.94	84.38	21.77
1.4	1.1003	30.92	66.63	22.67
1.5	1.2001	29.00	64.41	21.31

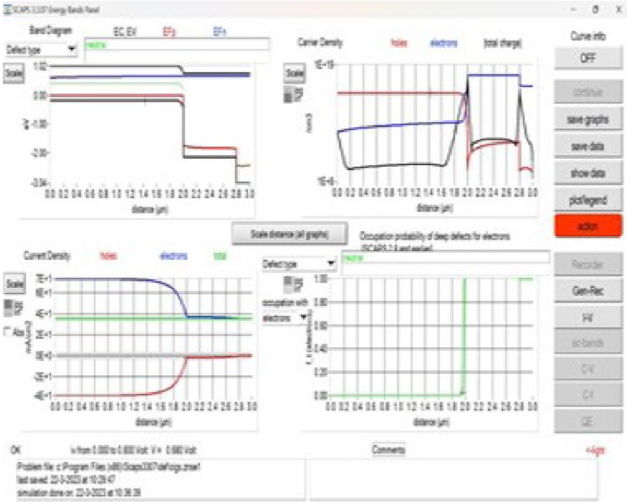


Figure 3: Output characteristics.

CIGS layer using SnO_2 as the window layer. Recombination and photon generation peaked at a location of two meters. All of these models will provide crucial guidelines for the viability of creating CIGS solar cells with a SnO_2 absorber layer.

Acknowledgements

None.

Conflict of Interest

None.

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