Research Article

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Impact of a Zinc Sulfide Insulation Layer on CIGS Solar Cell Efficiency

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Abstract

In this paper, we present a simulation of a CIGS solar cell with a ZnS buffer layer, performed using the Silvaco-Atlas simulator. However, we obtained an efficiency of 24.13%,short-circuitcurrent of 37.81 mA/cm², an open circuit voltage of 740 mV, and a fill factor of 78.78% at was around 1.41 eV, corresponding to an x ratio of 0.5 for the CIGS solar cell using a ZnS buffer layer. We optimized the performance of the ZnS/CIGS solar cell with the improved effects of layer parameters such as thickness and acceptor densities ZnS buffer layers.

Keywords: Buffer Layer (ZnS),CIGS, Solar Cell, Optimization, Silvaco-Atlas.

Introduction

In the visible solar spectrum, the CIGS compound semiconductor offers captivating features, such as a directly controllable bandgap from(1.0to1.7eV) to maximize irradiance , Anda absorption factor of 106cm-1. CIGS and CDs solar cells are the most popular thin-film photovoltaic technology, with an energy conversion efficiency of 22.6%. When the 2.4e V bandgaps unsuitable f or solar cells, the CDs buffer layer shows optical absorption losses, particularly in the short-wave range [1-4]. In addition, because of the hazardous cadmium (Cd) waste produced during deposition, the CDs buffer layer can pose risk to human health and the environment. Given these factors, the CIGS absorption layer is compatible with other wide-bandgap buffer layers [5-7]. Zinc sulfide (ZnS) prepared using chemical bath deposition (CBD) offers an attractive alternative to CDs in collaboration with CIGS absorbers due to its wide bandgap round 3.68eVanditsnon-toxicity to the environment [8, 9]. Cell efficiency is enhanced by ZnS/CIGS, Zn1-xSnxOy and CIGS, InxSy/CIGS, with rates of 21.0%, 18.2% and 18.1% respectively. The energy of zinc sulfide (ZnS) is much higher than that of CDs in the bandgap. The ZnS buffer layer used in CIGS solar cells improves current generation at shorter wave lengths. CIGS solar cells with a ZnS buffer layer perform almost identically to CDs/CIGS solar cells [10, 11]. The use of solar cell simulation has become an essential tool for studying their operation and improving the design of high- performance solar cells. In this research, we Performa simulation of both CIGS and ZnO/ZnS/CIGS solar cells to evaluate their performance [12-16], where ZnS/CIGS solar cells are more promising than CDs/CIGS solar cells [17].

The main parameters of ZnS/CIGS cells have been identified by several numerical studies, such as thickness, bandgap, gradient of the CIGS absorber layer and thickness of the ZnS buffer layer [18-21].

Structure Simulated

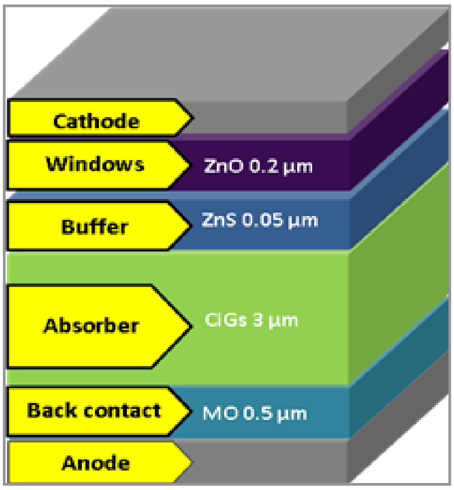


Figure1: Structure of CIGS Solar Cell.

Physical Models

Table1 Shows the parameters for each layer of the solar cell, which serve as input data for the Atlas- Silvaco numerical simulation [22].

Table 1: Material parameters used in the simulation.

Layerproperties	ZnO	ZnS	CIGS
Eg(ev)	3.3	3.68	Varied
ε_r	4.1	4.5	4.8
χe(ev)	9	8.32	13.9
$\mu(cm^2/Vs)n$	100	250	100
$\mu(cm^2/Vs)$	25	40	25
$N(cm^{-3})$ cNcm	2.2x1018	1.5x1018	2.2x1018
Gaussiandefectstates V–3	1.8x1019	1.8x1019	1.8x1019
N ,N (1/ cm^3)DGVG	D:1017	A:1015	D:1015
EA,ED(eV)	Midgap	Midgap	Midgap
WG(eV)	0.1	0.1	0.1
$\sigma cm^2 e$	10^{-12}	10^{-17}	10^{-13}
h_2	10^{-15}	10^{-13}	10^{-15}

In this simulation, we use the illumination conditions of theAM1.5G solar spectrum at one sun, with an incident power density of 100m W/cm2 and an ambient temperature of 300°K.

Simulation Results and Discussion

Optimal Cigs Absorbing Layer Bandgap

We set the thickness of the CIGS absorber layer at 3µm and varied the bandgap by changing the x ratio from 0 to 1. The characteristics of the CIGS cell for different band gaps as a function of efficiency are shown in Figure2. It can be seen that an increase in the bandgap of the CIGS absorber layer, and therefore an increase in the x-ratio, leads to a proportional increase in efficiency. In Figure 4(d), we can see that an increase in efficiency from 16.75% to 24.13%, and then a decrease to ratio x=1. The excellent efficiency obtained for the CIGS solar cell was 24.13%. The optimum efficiency of the CIGS cell was achieved when the optical bandgap was around 1.27 eV, corresponding to an x ratio of 0.3.

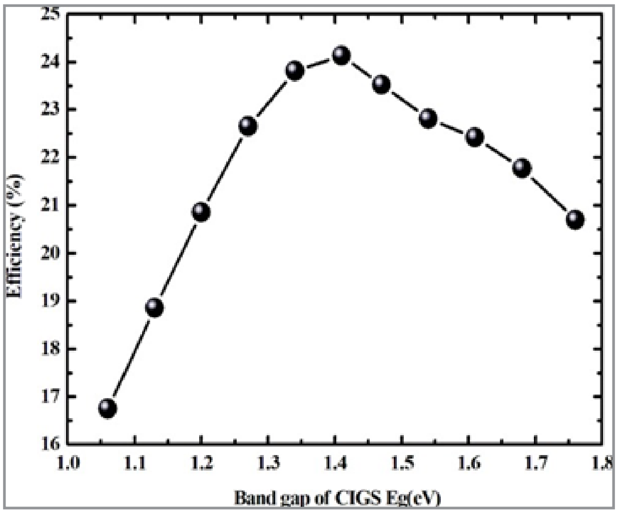


Figure 2: The Variation Band Gap Energy of CIG Sas Function of Efficiency.

Influence of Absorber Layer Thickness

The CIGS solar cell structure, obtained using Silvaco-Atlas, is shown in Figure 3.

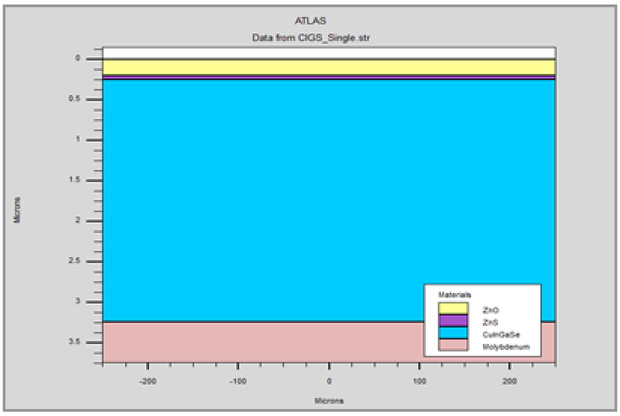
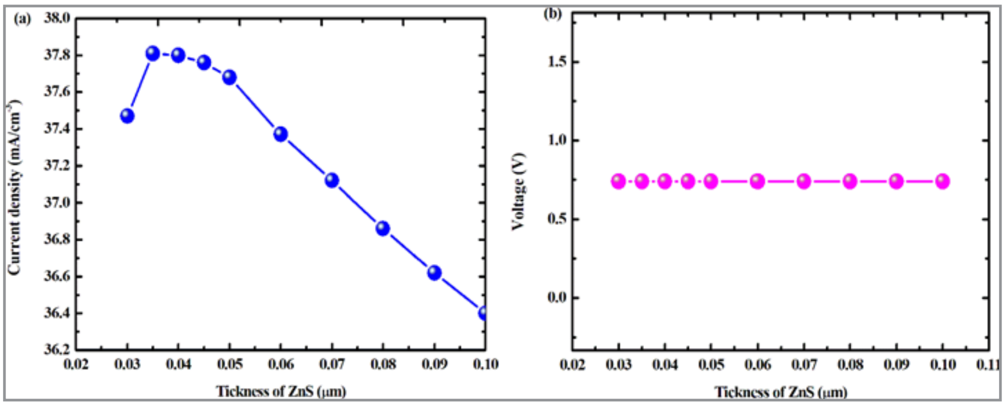


Figure 3: Silvaco-Atlas Structure File of the CIGS Solar Cell

In this section of the simulation, we first opted for a CIGS layer thickness of 2µm, then adjusted the thickness of the zinc sulfide (ZnS) buffer layer from 0.1µm to 0.03µm. We observed that the efficiency increases and then decreases with increasing ZnS buffer layer thickness. We also found that the high efficiency of CIGS thin-film solar cells decreases as the thickness of the zinc sulfide buffer layer increases (from 22.45% for 0.035µm to 20.91% for 0.1µm). Asis obvious, the performance fall solar cells decreases as the buffer layer thickness increases, with the exception of open-circuit voltage , which remains constant. Even if some absorption losses in solar cells are caused by the ZnS buffer layer or emitter thickness, this may explain the profile of this result. The ZnS layer has a thickness ranging from 10 nm to 30 nm, while the CIGS layer varies from 1µm to 4µm. Figures 4 (a, b, c and d) shows the impact of ZnS layer thickness on the performance of CIGS-based solar cells. The short-circuit current density increases from30.69 to 35.70 mA/cm2 as the thickness of the ZnS buffer layer increases from10 to 35 nm. The increase lead stories in the solar cell's conversion rate. In physical terms, a very thin absorber layer indicates that the back contact and the depletion zone are very close, which favors electron capture by this contact. Cell performance is affected by this form of recombination process, as it has an impact on conversion efficiency.



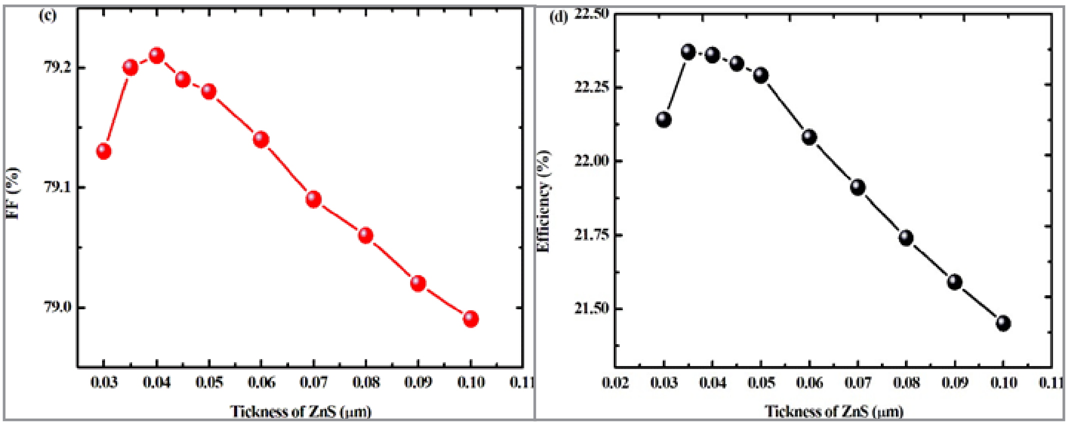


Figure 4: Impact of ZnS thickness CIGS solar cell sona)current density, b) the voltage, c) the factor form, d) the efficiency η(%).

Conclusion

In this work, we have presented and discussed the results of a numerical simulation study of the electrical characteristics of a CIGS-based thin-film hetero-junction solar cell. We studied the electrical stimulation of the CIGS cell with the ZnS cell, proving that the ZnS cell is better than the other cells. Then we studied the impact of ZnS buffer layer with the aim of designing an optimal ZnO/ZnS/CIGS hetero- junction structure that gives the best electrical performance.

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