ID: 1037

Impact of Layers' Thickness on the Thin-Film Photovoltaic Cells Based on CZTS

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ABSTRACT

The second generation of thin film solar cells uses semiconductor materials such as CZTS, CIS, GaAs, ZnO, etc. These materials have high absorption coefficients compared to crystalline silicon and possess excellent optical and electrical properties, which allow the realization of competitive photovoltaic devices. In our work, we simulate the performance of a thin-film solar cell based on CZTS semiconductors, by studying different solar parameters as: QE quantum efficiency, I-V characteristics, fill factor (FF), open circuit voltage (Voc), and short circuit current density (Jsc). In addition, we are interested in the thickness and doping of the CZTS and GaAs layers to study their influence on the output parameters. We used the "SCAPS1D" numerical simulation program to model our device and study thin-film solar cells. Our work is important because it contributes to understanding and improving the performance of thin-film solar cells, who get high potential to providing electricity by renewable sources.

Keywords: Thin film, Kesterite, CZTS, solar cells, BSF layer, GaAs SCAPS-1D.

1. Introduction

Thin-film solar cells are mainly based on the materials like CdTe, amorphous silicon, CIS, CIGS, CIGSe, GaAs and Cu2ZnSnS4 (CZTS). These cells based on GaAs and CdTe contain toxic elements (Cd, Te, As) and cells based on CIS that contain rare elements such as indium and gallium [1]. Therefore, and in the future, applications of large-area solar cells cannot be based on these two types of absorbers [2]. CZTS is a quaternary material compound of the I2-II-IV-VI4 group with a kesterit structure. Its bandgap is about 1.5eV, which is an optimal gap for solar energy conversion. This bandgap value is very close to the theoretical Shockley Queisser limit of the single p-n junction semiconductor solar cell (1.35 eV) [3]. CZTS is a direct bandgap semiconductor material with a high absorption coefficient [4]. CZTS for its environmental friendliness and non-toxicity is the best candidate for the next generation of thin-film solar cells. Recently, it has been announced that CZTS thin-film solar cells have already achieved more than 12.6% efficiency based on its associated sulfo-selenide material (CZTSSe) [5]. Although CZTS is considered a potential substitute for CIGSSe as an absorbent material, the formation of a p-n junction with appropriate electronic characteristics is very important to achieve a high-performance device, in particular the alignment of strips between CdS materials (type n) and CZTS (type p).

Our work will be devoted to simulation and discussion of the results obtained. Starting with the description of the SCAPS-1D program used for the simulation. Then, the study of the performance of two types of thin-film solar cells: the CZTS/CdS/ZnO structure and the GaAs/CZTS/CdS/ZnO structure. Also observe the effect of adding the BSF layer in GaAs on cell performance. Finally, the study is extended to the analysis of the effect of the variation of the thickness and the concentrations of the dopants of the different layers of the structure on the performances of the solar cell.

DOI: 10.21467/abstracts.169 ISBN: 978-81-970666-4-1 (eBook)

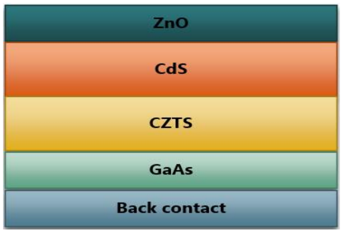

Figure 1:CZTS Solar cell based on GaAS as BSF layer

2. Results and Discussion

In order to optimize a specific design of a ZnO/CdS/CZTS heterojunction structure, we need to analyze and interpret the results to determine the influence of physical and technological parameters on device performance such as aBSF layer to obtain ZnO/CdS/CZTS/GaAs and thickness.

In the following work, we will study the effect of three CdS, CZTS and GaAs layers on the electrical conversion efficiency. For this, in our simulation, we varied the thickness parameters while keeping the other layer constant. Figure 2 shows the simulated current-voltage (I-V) characteristic of the reference CZTS/CdS/ZnO and heterojunction device.

Table 1: *parameter results obtained from the two structure devices.*

	Voc (V)	Jsc(mA/cm²)	FF (%)	η (%)
CZTS/CdS/ZnO	0.547	43.78	79.70	19.07
GaAS/CZTS/CdS/ZnO	0.754	47.26	85.32	30.39

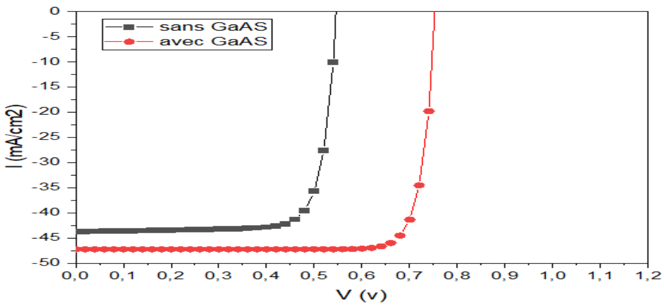

Figure 2:. J-V curves of CZTS solar cells with and without GaAs layer

It is evident from the representations that the GaAs layer is crucial to the performance of the solar cell. By simulating the cell with the GaAs/CZTS/CdS/ZnO structure, we obtain promising values for Voc (0.754 V) and Jsc (47.26 mon/cm²). In addition, this structure has a higher efficiency, reaching 30.39%. These results underline the importance of the GaAs layer in improving the overall performance of the solar cell.

3. Conclusions

In this work, we used numerical simulation to study the characteristics of these devices. We also optimized the physical and electrical parameters of a specific CZTS-based solar cell structure to achieve maximum electrical conversion efficiency. The results obtained for the final cell show encouraging performances, with a Jsc of 47.26 mA/cm2, a Voc of 0.753V, a FF of 85.31% and an energy conversion efficiency of 30.5%. In conclusion, this study paves the way for future improvements in the performance of thin-film solar cells.

4. References

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ISBN: 978-81-970666-4-1
Series: AIJR Abstracts
DOI: 10.21467/abstracts.169