Improving the Photovoltaic Parameters of a-Si/CZTS Solar Cells

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Research Article

Keywords: CZTS, a-Si, Solar cells, SCAPS, Doping

Posted Date: July 7th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-664671/v1

Abstract

Due to the high need for energy generation for today's electronic devices as well as with the natural disasters occurring at the increased frequency, intensity and duration, it becomes essential to explore this scientific area for the sustainability of the society. The benefit of a composite a-Si/CZTS photovoltaic devices for energy generation has not yet been investigated. Addressing the problem and providing a radical solution has been attempted in this research. This research reports the calculated parameters for the solar cell based on the new arrey of the layers, employing a-Si/CZTS. Adapted a-Si/CZTS configuration-based solar cell, debutant analysis of the parameters, and address the challenges that impeded the efficiency of the photovoltaic device are the chief novelty of this research work.

Introduction

Due to depleting energy resources [1], climate and safety concerns [2], demand for efficient and high-performance consumer electronics [2, 3], and rapid industrial growth [3], finding an innovative solution for energy generation becomes a significant concern and needs urgent attention at present. Solar cell technology could be one of the innovative solutions as an alternative to fossil fuels (oil and coal) and nuclear energy [1-4]. Generally, a solar cell is a cell that consists of layers of p and n-type materials to form a p-n junction and converts solar energy to electricity [5]. However, numerous challenges are involved in current solar cell technology that needs to address to increase efficiency. Currently, the 90% market share is occupied by silicon (Si) based solar cells. The theoretical efficiency of the different type of solar cells e.g. dye-sensitized solar cells, traditional Si-based solar cells and other types of the solar cells is limited to approximately 30% [6, 7] due to poor absorption of total incident light as a lack of completely transparent surface [5], inappropriate bandgap material [6], and low reflection within the device causing faster recombination of emitted electrons [6, 8]. As a result, a tandem cell is constructed from single-junction gallium arsenide (GaAs) and multi-junction (up to three p-n junctions) concentrators with different materials to absorb a larger spectrum of incident light [9]. However, the reported theoretical efficiency is 40.8% under concentrations of 326 suns which is not true for the practical condition [10]. In reality, the efficiency drops to 33.8% with one sun, and the process itself is not matured like Si-based technology [6, 9]. To increase the efficiency, the probability of succeeding in integrating a-Si/CZTS based solar cells as a prospective material for constructing the solar is promising and have a number of advantages in the race for large-scale solar module production [11-13]. The main objective of this chapter is to simulate and optimize the various physical and electrical parameters of a solar cell made from thin layers CZTS (Cu_2ZnSnS_4) by the one-dimensional software called SCAPS, in order to obtain good photovoltaic performance.

Description Of Simulation Parameters

In our study we simulated the physical and electrical parameters of solar cell structure based on CZTS by the SCAPS software [15-16]. The simplified representation of the solar cell is presente in Figure 1. Note that the solar cell was studied under AM1.5, with P = 100 mW/cm^2.

The main parameters that we used in our simulation of the CZTS-based solar cell were taken from the literature and are listed as a site in Table 1.

Table 1:Values of various material parameters used in the simulation

Sample parameter	CZTS	a-Si	SnO_2
thickness (µm)	variable	0.1	0.08
Gap energy E_g (eV)	1.5	1.8	3.6
Electronic affinity (eV)	4.21	3.9	4.55
Dielectric permittivity	10	11.9	10
Density of states BC, N_c (cm^{-3})	2.2×10^{18}	10^{20}	4×10^{18}
Density of states BV, N_v (cm^{-3})	1.8×10^{19}	10^{20}	9×10^{18}
Electron mobility (cm^2/V.s)	100	20	100
Holes mobility (cm^2/V.s)	20	5	25

Results And Discussion

The variation of the efficiency and short circuit current (J_{sc}) is presented in Figure 2. The short-circuit current (Jsc) also increases with increasing thickness of the absorbent layer CZTS from 0.2 µm to1 µm. The values reported in the literature [9] are lower that obtained in the present study. The value of other material parameters of different layers such as the doping of the absorbent layer, the thickness and the doping of the buffer layer (a-Si) were constant.

This study allowed us to find the optimum thickness of the CZTS absorbent layer which gives the best operating characteristics of our solar cell. In our case, this thickness is 1 µm. Figure 3 illustrates the current-voltage characteristic for these two. It is observed that the photovoltaic parameters of the SnO_2/a-Si/CZTS. The improvement is mainly recorded in short-circuit current density (Jsc) and the solar radiation conversion efficiency (η) of the solar cell. In comparison to the values obtained in the present study, the values given in the literature are lower owing to the geomatrical arrangement of the layers.

Table 2 summarizes the photovoltaic parameters of the two configurations of the solar cell calculated from the current-voltage characteristics.

Table 2. Current Voltage characterisitics comparison between two solar cell configuration

	SnO_2/a-Si/CZTS
V_{oc} (Volt)	0.94
J_{sc} (mA/cm^2)	26.85
FF (%)	84.14
η (%)	21.39

As shown in figure 4, There is a decrease in the values of short-circuit current density (Jsc) and efficiency (η) of the solar cell with increasing temperature. The variation of open circuit voltage and efficiency with temperature is compared with the values given in the literature. The variation of efficiency follows the same tred but have significantly low values where as the open circuit voltage reported in the literature is higher with similar decrease in the values with the temperature. It is observed that initially the efficiency decreases slowly till 300 K and sharply at the higher temperature. There is almost linear decrease in the open circuit voltage and short circuit current as a function of the temperature.

To see the influence of the doping of the a-Si buffer layer, the concentration of donor carriers (N_D) donors is varied from 10^{18} to 10^{21} cm^{-3}, as illustrated in Figure 5. It is observed that and the efficiency increases with the density of donor carriers (N_D). This increase is due to the enlargement of the load area of space which increases the collection of generated carriers and subsequently increases the current.

The effect of change of doping concentration in the absorbent layer on efficiency is presented in Figure 6. It can be seen that the efficiency increases when the doping of the CZTS layer is increased. The main reason behind is that with the rise in the concentration of acceptors (N_A), the process of recombination and will decrease the probability of collecting electrons generated by photons.

Conclusion

In this chapter, we have simulated CZTS based solar cells with two structures using the SCAPS simulator, with a study of the effect of changing the buffer layer, temperature, doping, series resistance, shunt resistance and of thickness of absorbent layer on the electrical characteristics of solar cell which are: the open circuit voltage (Vco), the short-circuit current density (Jcc), the form factor (FF), the conversion efficiency (η).

Declarations

Acknowledgements

The authors would like to express their sincere gratitude to Marc Burgelman and his team at the University of Ghent for providing access of SCAPS-1D.

Authors Contribution All of the authors contributed to the idea, simulation of the research, the analysis of the results, and the writing of the manuscript.

Funding No funding.

Data Availability Not applicable.

Conflict of Interest Authors declare no conflict of interest that are directly or indirectly related to the work submitted for publication.

Research Involving Human Participants or Animals Not applicable.

Informed Consent Not applicable.

Consent to Participate Not applicable.

Consent for Publication Not applicable.

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Figures

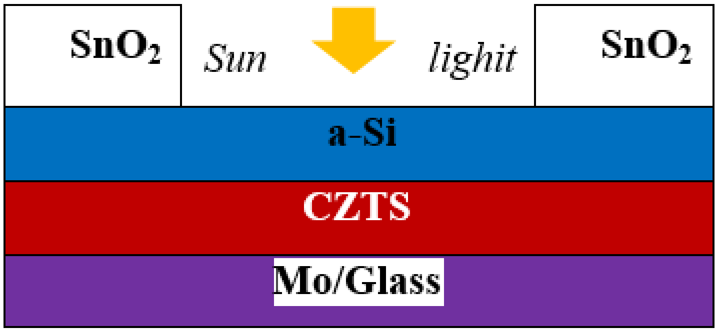

Figure 1

strucure of solar cell studied

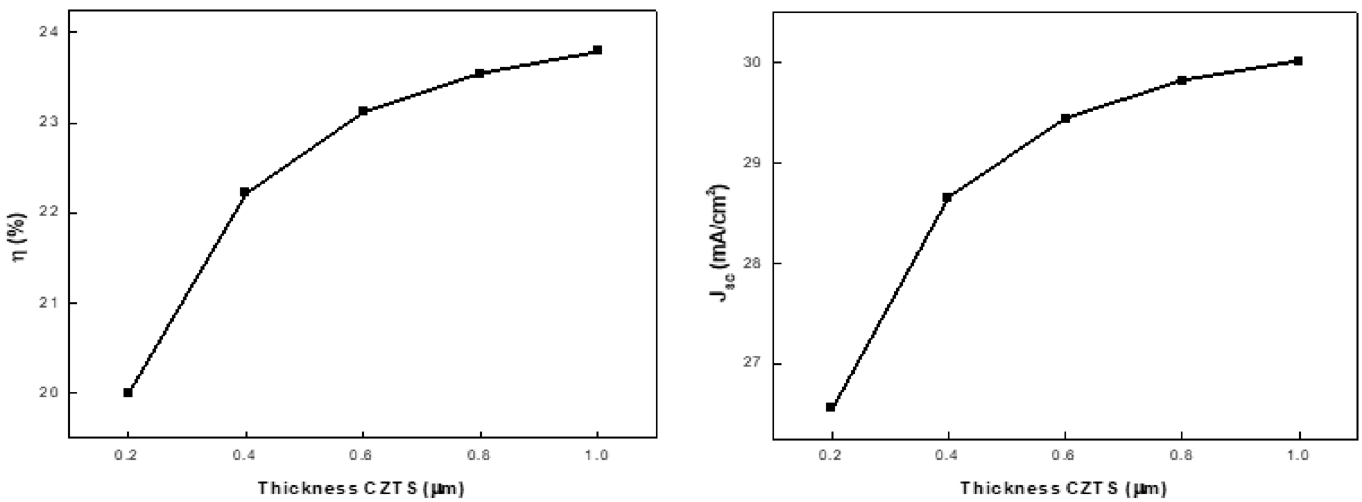

Figure 2

The variation of the efficiency and open circuit current as a function of thickness of the absorbent layer of CZTS.

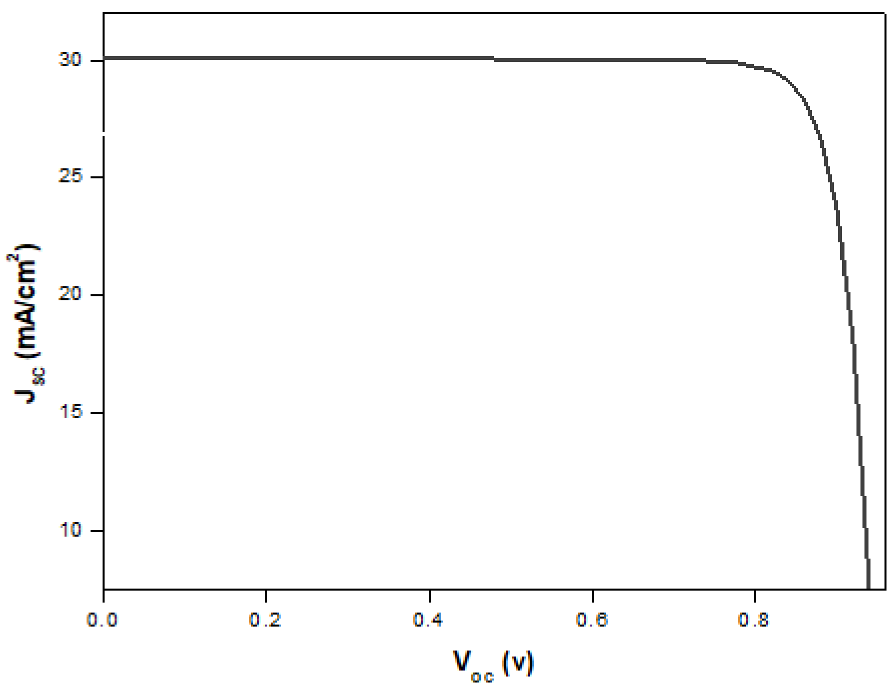

Figure 3

(I-V) curve of SnO2/a-Si/CZTS solar cells.

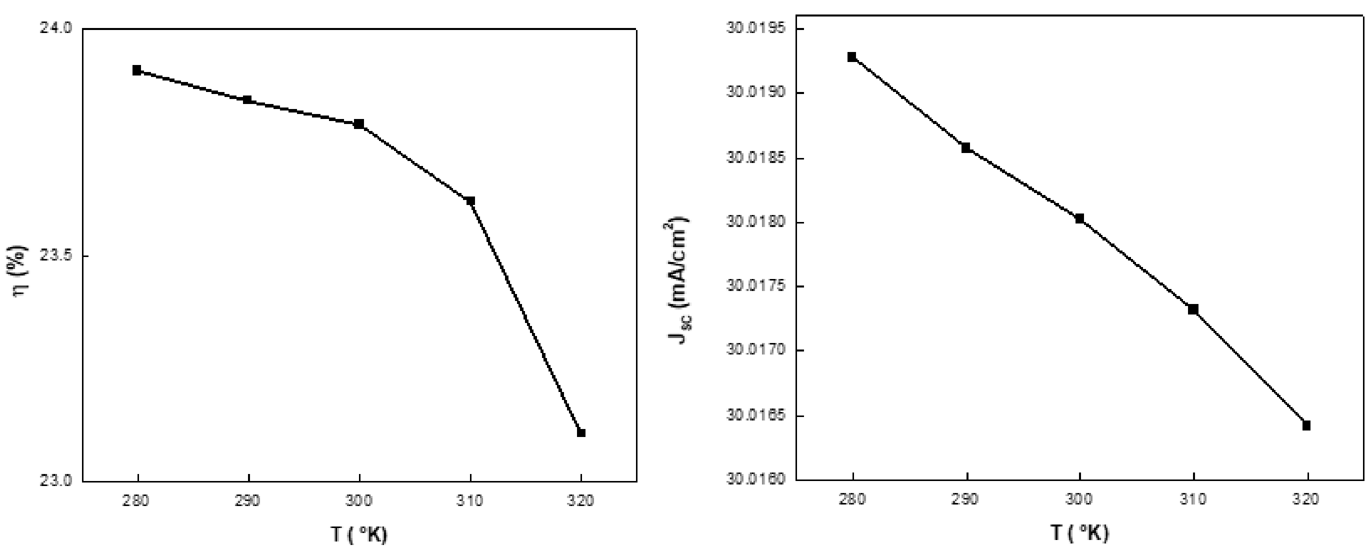

Figure 4

effect of temperature on the of short-circuit current density (Jsc) and efficiency (η)

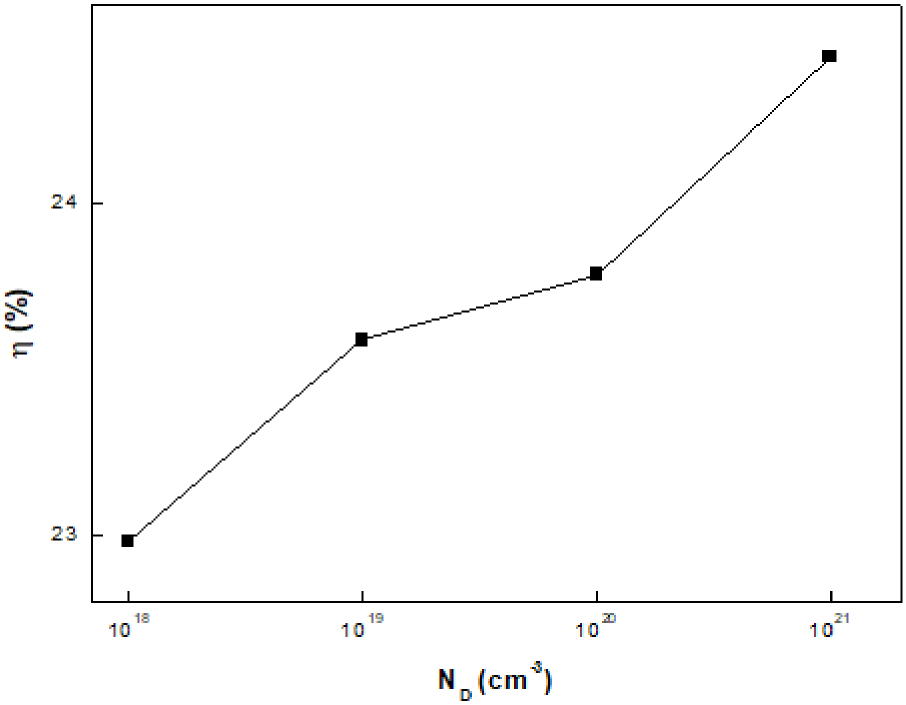

Figure 5

Influence of donor concentration on efficiency

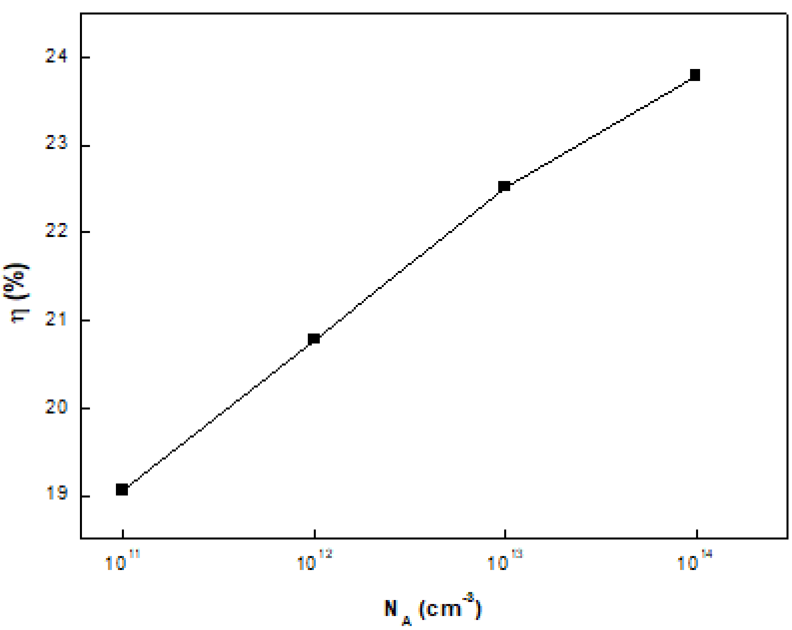

Figure 6

Effect of acceptor concentration on efficiency.