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Thickness optimization of various layers of CZTS solar cell

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Abstract

Thin film solar cells based on Cu_2ZnSnS_4 (CZTS) absorbers are proposed with the structure glass/Mo/CZTS/buffer/ZnO. In this work we have simulated CZTS thin film solar cell using solar cell capacitance simulator (SCAPS). The influences of thickness of (CZTS) absorber, thickness of (CdS) buffer layer and Zinc oxide window Layer (ZnO) on the photovoltaic cell parameters are studied. It can be seen after reviewing the results, that for high conversion efficiency, the cell should have a thin buffer layer and a thick absorber layer. In addition, the effect of operating temperature on the cell performance shows that the efficiency will be strongly affected by the increased temperature.

Keywords: CZTS; solar cell; SCAPS.

1. Introduction

Recently, $Cu_2ZnSn(S/Se)_4$ (CZTS) has also been considered as a possible candidate for photovoltaic applications since it only consists of abundant elements [1]. However, potentially other p-type semiconductors with fewer elements and perhaps reduced complexity than CZTS are also available such as the ternary Cu–Sn–S system or SnS [2].

CZTS is an quaternary semiconducting compound which has received increasing interest as an absorber layer in a thin film solar cell because of a suitable band-gap energy of 1.4-1.5 eV and of a large absorption coefficient over $10^4 cm^{-1}$ [3, 4]. Carrier concentrations and absorption coefficient of CZTS are similar to CIGS. Other properties such as carrier lifetime (and related diffusion length) are low (below 9 ns) for CZTS.

This low carrier lifetime may be due to high density of active defects or recombination at grain boundaries. However, chalcopyrite solar cells employing alternative buffers can reach the same efficiency as those with CdS buffers. Moreover, in some cases it is observed though that these alternative buffers, are mine prone to metastable effets like hight soaking and show less stability in damp heat testing [5].

In the present contribution, a numerical study has been realized in order to show the effect of thickness and doping of a window ,buffer and absorbent layers in the photovoltaic cell parametres CZTS baser solar cells. The calculs have been performed using a numerical model with the solar cell capacitance simulation (SCAPS) program.

2. Device modelling

Numerical simulation is now almost indispensable for the understanding and design of solar cells based on crystalline, polycrystalline and amorphous materials [4]. SCAPS is a numerical device simulator for thin film solar cells, It is developed especially for CdTe and CIGS solar cells and Other such as CZTS [5].

In the model the CZTS the absorber is P-type, with a gap of 1. 5 eV and the junction is made between the CZTS P-type and N-type CdS which has a gap of 2.45 eV. The window layer is formed of ZnO with a gap equal to 3.3 eV.

In the present work, numerical modeling of CZTS thin film solar cell has been performed SCAPS computer software program [6]. So as to investigate the effects of thickness and doping of layers such window layers , buffer layer and absorber layer on the photovoltaic cell paramtres grading on the overall CZTS solar cell device performance . Note that version SCAPS 2.8 car handle graded cell structures [7].

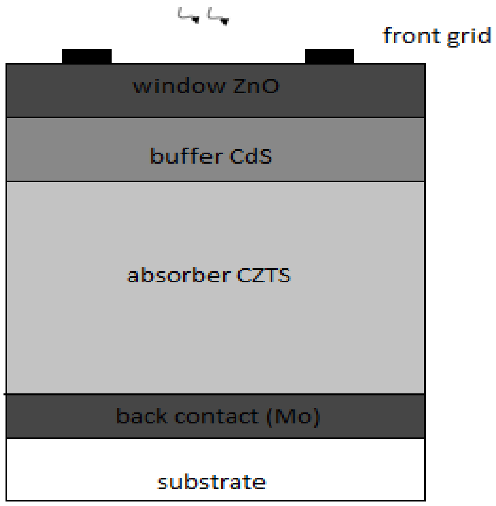

Fig1. Schematic view of CZTS solar cells.

3. Results and discussion

The structure has been studied under solar spectrum AM 1.5 with p=1000W/m2 and at a temperature T=300°K .The measurement of the photovoltaïc parameters has been made in the case of a nul serie resistance and shunt resistance infinitely large. In What follows, we will present our result regarding the influence of the three layers, namely window layer ZnO, buffer layer CdS and absorber layer CZTS on the efficiency of the electric conversion .For that purpose, we have varied the thickness of one layer and kept unchanged the optimal value of the other two reaming layer.

3. 1. Influence of absorbent layer thickness on conversion efficiency

The cell photovoltaïc paramtres for various thicknesses of CZTS ranging from 1 to 4 µm are given in Fig 2.We observe that as the thickness of CZTS is increased both V_{oc} and J_{sc} of CZTS solar cells increased as will. In fact this allows the collection of lighten wave lengths which contribute to the generation of the electron- trou pairs [8], and result in the increases of the V_{oc} and J_{sc}.

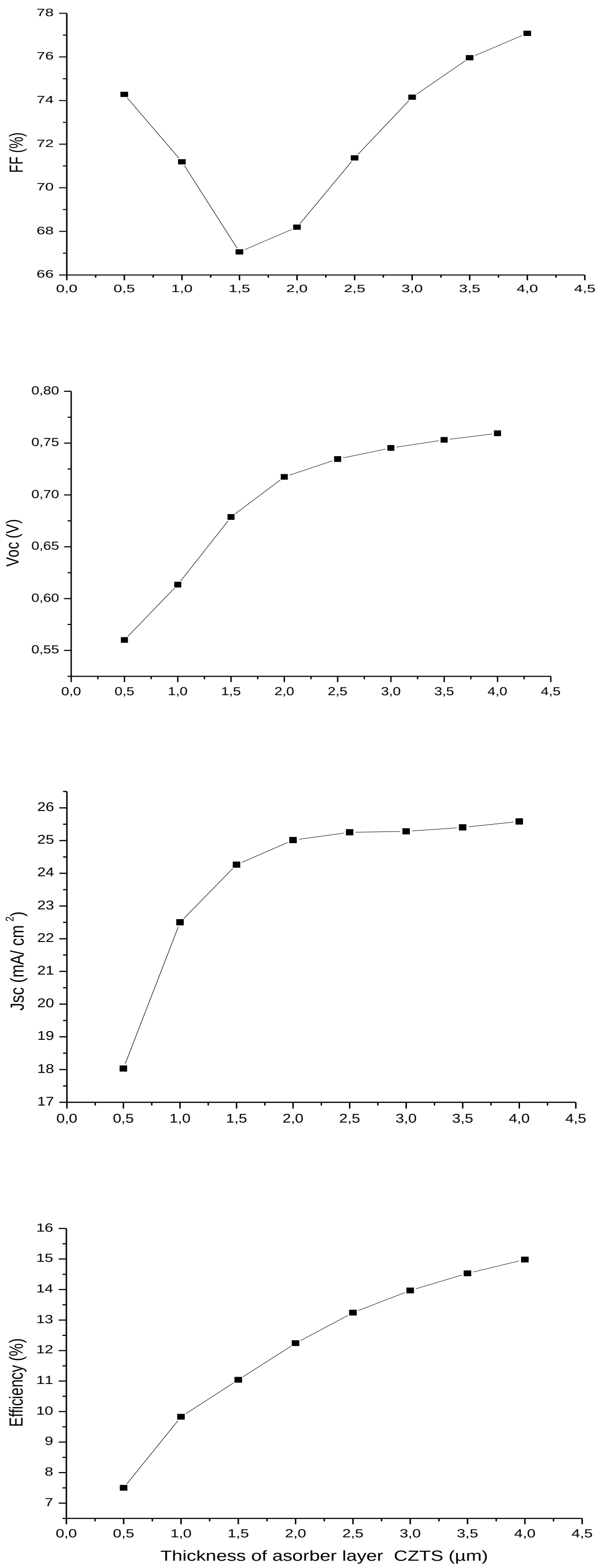

Fig.2. Variation of efficiency versus absorber layer thickness for CZTS.

It is generally agreed that values of V_{oc} and J_{sc} will be reduced of the thickness of the absorber layer is reduced. This may be caused by the recombination process at the contact back of the solar cell.

Note that as the thickness of CZTS increases the effciency increases and linearly. On the other hand, the fill factor of the solar cell as well with the increases of the thickness of the absorber layer (see Fig.2). This is in good. Moreover for Fig.2, we can notice that four a thickness of CZTS of 4µm. an imported electric efficiency of 14.98% can be reached for the solar cell of interest.

3.2. Influence of window layer thickness on conversion efficiency

For the thickness of ZnO we have proceeded from 0.02 µm to 0.1 µm. with regarding the cell photovoltaïc parametres for various thickness of ZnO. we notice that as the thickness of the window layer of ZnO from 0.02 to 0.1 µm, the fill factor decreases significantly. The same trend can be observed from Fig.3 for the efficiency which decreases from 14.76% to 14.98 %.

This means that the increases of the thickness of the window layer will affect efficiency. Besides, when the window layer thickness is very thin, the cell performance degrades. The reason could be to on the are hard the increases of series resistance (increases of losses) [9], and on the other hard to the thickness of the layer. As for as the thickness decreases, the absorption increases (for longer wave lengths). Consequently, on optimal thickness of ZnO layer necessary for best performance of solar battery.

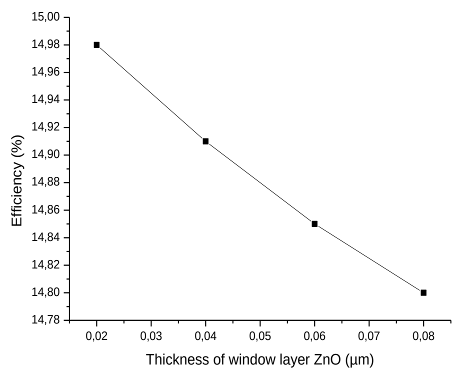

Fig.3. Variation of efficiency versus window layer thickness for ZnO.

3. 3. Influence of buffer layer thickness on conversion efficiency

Let as now turn our attention to the influence of thickness of buffer layer on the solar cell efficiency. For that purpose, we now show the influence of the thickness of CdS buffer layer on the solar cell efficiency. In this respect, we present in Fig.3 the cell photovoltaïc parametres for various thicknesses of CdS of ranging from 0.005 to 0.05 µm. we observe that except for the parameter V_{oc} which remain constant, cell remaining paramtres of interest increases with varying the thickness of CdS layer. Fig.4 shows the variation of the efficiency as a fraction of the thickness of CdS buffer layer. Note that the efficiency increases momently with increase the thickness of CdS.

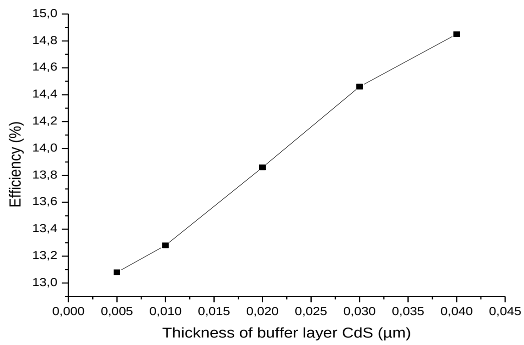

Fig.4. Variation of efficiency versus buffer layer thickness for CdS.

4. Conclusion

In the present study, the effect of thickness of the different layers of interest on the parameters of the photovoltaic cell has been investigated. We have determined the optimal parameters for each layers which constitute the solar structure (ZnO, CdS and CZTS) and which give the best efficiency. After that we have obtained the optimal structure of the solar cell of interest. By combining the optimal parameters of each layer. On study solved that the best structure must have a window layer (ZnO) of thickness of 0.02 µm, a biffer layer (CdS) of thickness of 0.05 µm and an absorbent layer (CZTS) of thickness of 4 µm. These characteristics show the best transport of carriers by reducing their recombinations at the back contact level. The solar cells with these parameters give an electric efficiency of 14.98% with a fill factor of 77.08%, current density of 25.58 mA/ cm^2 and voltage of open circuit of 0.7595 Volt. The obtained efficiency in the present study is better than those reputed so for in the literature for CZTS based solar cells.

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