Optimization of Some Parameter In Solar Cells With SCAPS-1D Software

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September 22, 2020

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***Abstract*—This Work represents the influence of some parameters (Temperature, existance/note existance of Zinc Sulfied (ZnS) and thickness of ZnS buffer layer), using a Numerical simulation of thin film solar cells, named SCAPS (which is a one-dimensional solar cell capacitance simulator) in modeling of the high efficiency CIGS-based solar cells (with efficiency of η=10.84%).In each case, the photovoltaic parameters have been calculated.It has been concluded that,the efficiency of CIGS-based solar cells is decreasing with increasing of the temperature and the thickness of Zinc Sulfied buffer layer.However, when the buffer layer doesn't exist in solar cells photovoltaic, we noticed that the efficiency of solar cells is increasing to (η=12.04%) under the AM1.5 spectrum, one sun and at room temperature, with increasing of the short-circuit current density (Jsc), and decreasing of open-circuit voltage (Vco).**

***Keywords*—ZnS, open circuit voltage Vco , short circuit-current density.**

I. INTRODUCTION

The Solar cell thin film based on CIGS is a 1-II-V2 semiconductor material composed of copper, indium, gallium, and selenium. It had proved him role on terrestrial applications thanks to their high efficiency, long-term stable performance and potential for low-cost production. In fact, this typical solar cells polycrystalline provide a good alternative to wafer based crystalline silicon solar cells, which currently constitute the major share of photovoltaics installed and used worldwide. [5-6] (in our case, we will study the CIGS-based solar cells wich the efficiency is 10.84%). Normaly, the band gap of these semi-conductor is direct which minimize the requirement for long minority carrier diffusion lengths [2-5-6].However, Cadmium is a metal that can cause severe toxicity in humans and the environment [3]. For this reason, we decide to replace this dangerous material by Zinc (Zn) and we present a numerical study of the thin film CIGS-based solar cells with SCAPS, wich is used to calculate the photovoltaic parameters at sunder standard illumination (AM1.5G, 100 mW/cm2,300K). We studied also the influence of: Temperature, existance/note existance of ZnS, thickness of ZnS as a buffer layer on the performance of the CIGS-based solar cells. The J-V characteristic has been calculated to get the optimal value of efficiency, without using CdS.

II. EASE Numerical Modeling of SCAPS-1D Software:

The structure of the CIGS forms a complex junction made of materials of different types (heterojunction) of CIGS (p) / CdS (n) / ZnO (n) type in the higher efficiency devices. In this structure, CIGS is a p-type wide-band gap absorber layer, wich is deposited on the molybdenum coated back glass substrate. he other members of this junction is a buffer layer n-type (Zinc Sulfied thin films) and a window layer n-type (ZnO) (figure 1).

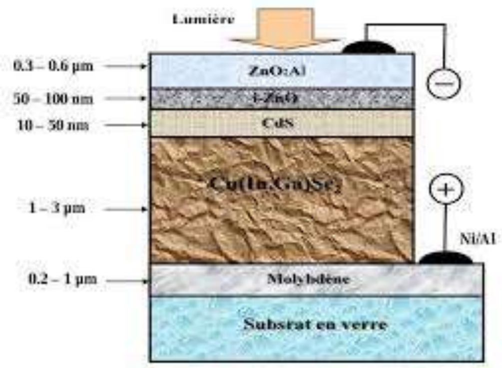


Figure **1:** The CIGS Structure of solar cells Thin Films.

In this paper, we will study some parameter optimization of solar cells, using SCAPS-1d software.

The principle of SCAPS software is based on four equations namely:

2.1The poisson equation:

$$\frac{d^2\psi(x)}{dx^2} = \frac{e}{\varepsilon_0\varepsilon_r}\left(p(x) - n(x) + N_D - N_A + \rho_p - \rho_n\right)$$

Where Ψ(x) is electrostatic potential, P(x) and n(x) are respectively electron and hole density; ε0 and εr are

respectively vacuum and relative permittivity, ND and NA are respectively charged impurities of donor and acceptor, ρn and ρp are respectively electron and hole distribution;

2.2 The continuity equations of electrons and holes :

$$\frac{dj_n}{dx} = G - R \quad and \quad \frac{dj_p}{dx} = G - R$$

Where Jn and Jp are respectivly electron and hole current densities, R is the recombination rate, and G is the generation rate.

2.3 The equations of carrier transport in semiconductors occurs by drift and diffusion :

$$J_{p=D_p\frac{dp}{dx}+\mu_p\frac{d\emptyset}{dx}} \quad \text{and} \quad J_{n=D_n\frac{dn}{dx}+\mu_n\frac{d\emptyset}{dx}}$$

Where:
μn and μp are respectively electron and hole mobility.

In this work, we studied some parameter optimization of solar cells thin films used in photovoltaic applications, with efficiency of η=10.84%, wich the parameters used for simulations are summarized in table 1:

TABLE I: PARAMETERS SET FOR CIGS SOLAR BASICS CELLS AT ROOM TEMPERATURE (300 K) AND AT A.M 1,5 G

Parameters	**i-ZnO**	**OVC**	**CdS**	**CIGS**
Thickness (μm)	0.080	0.015	0.100	1.000
Band Gap (eV)	3.400	1.450	2.450	1.200
Electron affinity (eV)	4.550	4.500	4.450	4.500
Dielectric permittivity (relative)	10.000	10.000	10.000	10.000
CB effective density of stattes (cm^{-3})	4.000E+18	2.000E+18	2.000E+18	2.000E+18
VB effective density of states (cm^{-3})	9.000E+18	2.000E+18	1.500E+18	2.000E+18
Electron thermal velocity (cm/S)	1.000E+7	1.000E+7	1.000E+7	1.000E+7
Hole thermal velocity (cm/S)	1.000E+7	1.000E+7	1.000E+7	1.000E+7
eLectron mobility (cm^2/V.S)	5.000E+1	1.000E+0	5.000E+1	5.000E+1
Hole mobility (cm^2/V.S)	2.000E+1	1.000E+0	2.000E+1	2.000E+1

III. Results and Discussion:

A. *Impact of buffer layer thin film:*

The buffer layer is a thin film located between the absorbent layer and the layer transparent conductive oxide (TCO). Its role is to be as much transparent as possible, allowing a maximum sunlight absorption in the absorber layer while maintaining a low interface recombination rate [7]. When the transparent conductive oxide layer (TCO) and the absorbent layer (CIGS) are directly putting in contact, we may get in this case a photovoltaic junction, but its performance will be limited by:

B. +the unsuitability of bandgaps;

C. +existence of short-circuits density.

TABLE II. IMPACT OF BUFFER LAYER THIN FILM ON CIGS SOLAR CELLS

Parameters	**Voc**	**Jsc (mA/cm^2)**	**FF (%)**	**Efficiency(%)**
With buffer layer	0.5587	31.68649	61.40	10.87
Without buffer layer	0.55420	33.30812	65.24	12.04

It has benne proved that without buffer layer thin films in CIGS based solar cells, the efficiency is increasing (from 10.84% to 12.04%) with increasing of density short circuit (from 31.68649 mA/cm2 to 33.30812 mA/cm2) and with decreasing of open circuit voltage (from 0.5587 v to 0.5542 v). In fact, Buffer layer optimizes the alignment of the bands between the CIGS and the window layer and to limit the recombination carriers at the interface of these two layers.It also assures, the protection of the surface absorber during sputter deposition of the ZnO layer, wich can be caused the formation of defects on the CIGS surface layer.

B Impact of buffer layer thickness:

In this part of the simulation, we started by choosing the thickness of CIGS layer set to 1 µm, and we changed the thickness of Zinc Sulfied (ZnS) buffer layer, from 0.3 µm to 0.002 µm. We noticed, that the high efficiency is decreasing with the increasing of the thickness of ZnS buffer layer. We noticed also, that the high efficiency of CIGS film solar cells is decreasing with the increasing of Zinc Sulfied buffer layer thickness (from 11.88% for 0.002 µm to 5.13% for 0.3 µm). As we can see, all solar cells performance are decreasing with increasing of buffer layer thickness, except open circuit voltage. Although, the ZnS buffer layer or thickness emitter is responsible for some of the absorption losses in the solar cells, wich can explain the profil of this result. Figure shows the variation of buffer layer thickness (ZnS) on the performance of CIGS based solar cells:

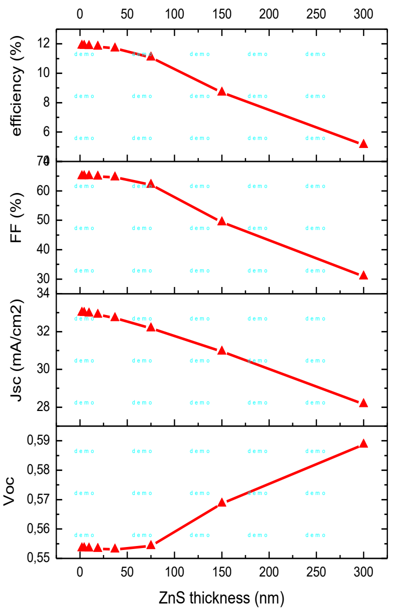


Figure 4: Effect of ZnS buffer layer thickness on the CIGS films solar cells performance.

C. mpact of temperature, on the CIGS-based solar cells, using CdS as buffer layer :

One of the most parameter optimization in solar cells thin films is the operating temperature, wich acts an important role in the examination of the performance of solar cells thin films. As we can see, the performance of the solar cells thin films is decreasing with the increasing of the higher operating temperature.

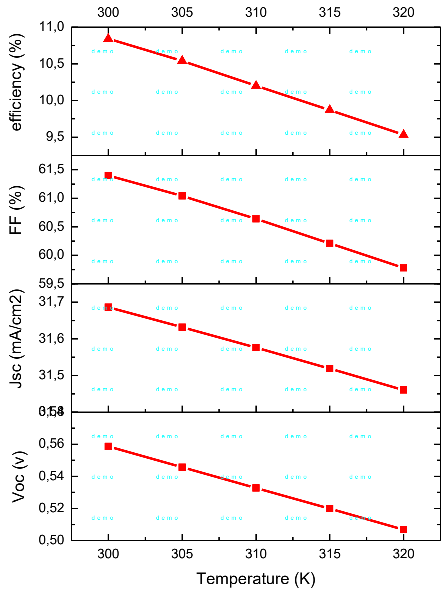


Figure 5: The dependence of solar cell performance, using CdS buffer layer and the high temperature.

D. Impact of temperature, on the CIGS-based solar cells, using ZnS as buffer layer :

The Goal of replacing of the CdS Buffer layer by ZnS buffer layer, here, is optimizing the variation of all solar cells properties, to see, wich material would be the performant one, that can be explained mathematically, by the values of variation of these characteristics. In first, we study the influence of the temperature on CIGS-based solar cells, using ZnS as Buffer layer. It can be see, thar the profile of CIGS based solar cells using CdS as buffer layer, and other using ZnS as buffer layer have numerically, the salme variation of performance properties, with the increasing operationg temperature. This explains that ZnS would be a good alternatif material to replace CdS in photovoltaic applications.The figure 6 shows the influence of operating temperature on CISG based solar cells, using ZnS as buffer layer.

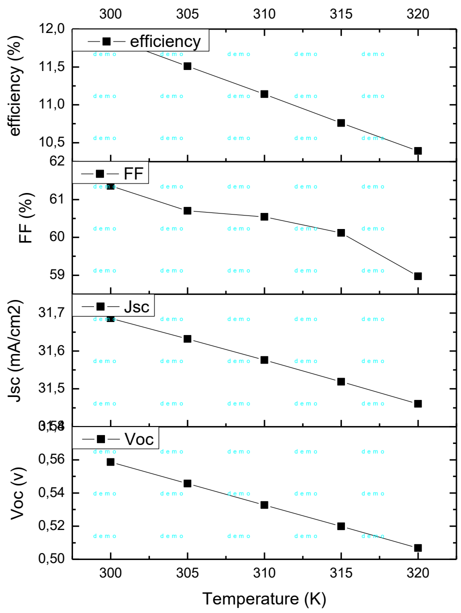


Figure 6: Effect of the Temperature on performance of solar cells, using ZnS as Buffer layer.

E. Comparaison between the efficiency of solar cells using ZnS and CdS as buffer layers:

We notice, that the performance of CIGS-Based solar cells (Efficiency, Open circuit Voltage, Short current density and fill form), is decreasing with increasing of the Temperature. Xe made in this part of the paper a comparaison, in order to optimize the rate of variation of the solar cells efficiency, to make sure if our material (ZnS) is challenger to Sulfied Cadmium (CdS):

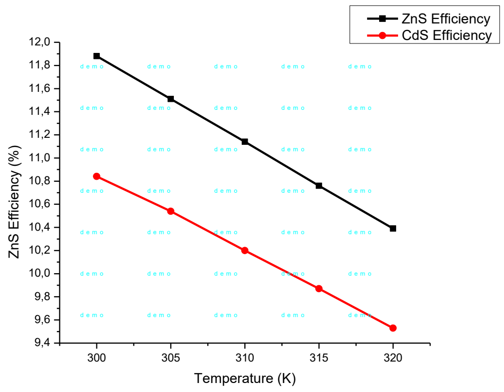
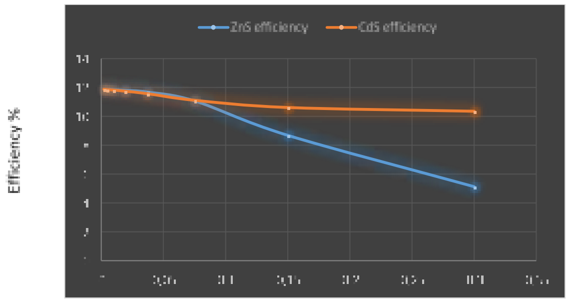


Figure 8: The effect of temperature in the efficiency of Zinc Sulfied and Cadmium Sulfied buffer Buffer layer.

From this graph, we can notice that the Zinc Sulfied buffer layer thin film and Cadmium Sulfied buffer layer thin films have the same curve, it tells as that with the presence of high temperature, Zinc Sulfied buffer layer can replace the Cadmium sulfide.



Thickness (μm)

Figure 8: The effect of thickness in the efficiency of Zinc Sulfied and Cadmium Sulfied buffer Buffer layer.

In this graph, and for small thickness (between 23 nm and 75 nm) of these materials, we can notice that the efficiency of CIGS-based solar cells, using ZnS as buffer layer, is relatively more much than the efficiency of solar cells using CdS as buffer layer, for smallest thickness.

CONCLUSIONS

-The performance of CIGS-Based SOLAR cells, has been examinated. The highest power conversion efficiency is achieved 11.88% (Voc=0.5535v, Jsc=33.00085 mA/cm2, FF=0.6503) for 1 μm thickness of absorber layer in the proposed material.

-It can be seen that the buffer layer affects the efficiency and performance of photovoltaic solar cells, when it is subjected to changes in temperature and the thickness of said layer.

ACKNOWLEDGMENT

-The authors would like to thank the department of Sciences physics of university Ibn Tofail Kenitra, and the laboratory of physics of condensed material (LPMC), for funding this research.

-we gratefully acknowledge to Professor M.Burgelman department of electronics and information systems (ELIS), of the university gent, Belgium, for providing the SCAPS simulation software.

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