Journal of New Technology and Materials
JNTM
Vol. 04, N°01 (2014)73-76

OEB Univ. Publish. Co.

Effect of a buffer layer on the Performance of Thin-film $Cu(In,Ga)Se_2$ Solar Cells

M. Mostefaoui[1, 2], H. Mazari[2], S.Khelifi[1], R.Dabou[1]

[1] *Unité de Recherche en Energies Renouvelables en Milieu Saharien d'Adrar, Algérie*

[2] *Laboratoire de Microélectronique Appliquée, Département d'électronique, Université Djillali Liabès de Sidi Bel-Abbes, Algérie*

Received: 30 April 2014, accepted 26 May 2014

Abstract

Copper indium gallium diselenide ($CuIn_{1-x}Ga_xSe2$ or CIGSe) solar cells has been considered to be one of the most promising thin-film solar cells and is important for terrestrial applications because of their high efficiency, long-term stable performance and potential for low-cost production. In this work, the CIGS heterojunction solar cell has been numerically simulated using SCAPS-1D tool. We study the influence of a buffer layer on the performance of the CIGSe solar cells. Quantum efficiency, Jsc ,Voc and efficiency has been calculated in different buffer layer materials (CdS, ZnS, ZnSe, InS).The solar cell optimized shows an efficiency of > 18% under the AM1.5G spectrum and one sun.

Keywords :CIGSe solar cells, buffer layer, simulation, SCAPS-1D.
PACS:

1. Introduction

Solar or photovoltaic cells represent one of the best possible technologies for providing an absolutely clean and virtually inexhaustible source of electricity. Thin film solar-cells with polycrystalline $Cu(In,Ga)Se_2$ (CIGSe) absorber layers provide a good alternative to wafer based crystalline silicon solar cells, which currently constitute the major share of photovoltaics installed and used worldwide. These compounds are direct bandgap semiconductors which minimize the requirement for long minority carrier diffusion lengths. Such p-type semiconductors with high absorption coefficient are the promising absorbing materials for thin film photovoltaic technology [1].

Buffer layer is an intermediate layer film between the absorber and window layers with two main objectives, to provide structural stability to the device and to fix the electrostatic conditions inside the absorber layer [2].

Cadmium sulphide (CdS) is a prominent candidate to be used a buffer layer in $Cu(In,Ga)Se_2$ based solar cell. Note that Cadmium (Cd) is a metal that can cause severe toxicity in humans and the environment.

In this work, we present a numerical study of the thin film CIGSe solar cells with SCAPS, is used to calculate PV parameter sunder standard illumination (AM1.5G, 100 mW/cm^2, 300K).

We study the influence of a buffer layer on the performance of the CIGSe solar cells. Quantum efficiency, Jsc, Voc and efficiency has been calculated in different buffer layer materials (CdS, ZnS, ZnSe, InS). The purpose is to replace the CdS by Other materials like Zinc Sulphide (ZnS), Zinc Selenide (ZnSe) and Indium Sulphide (InS).

2. Simulation details

2.1. Program Description

SCAPS is a one-dimensional solar cell device simulator, developed at ELIS, University of Gent, which is freely available to the PV research community [3]. The user can define a solar cell as a series of layers with different properties, such as thickness, doping densities and defect distribution. It is then possible to simulate a number of common measurements: I–V, QE, C–f, and C–V. Several modeling tools such as AMPS-1D, PC1D specific to PV devices have been developed.

SCAPS is used to simulate the J–V characteristics of the CIGSe solar cell under the global spectra AM1.5. We demonstrate the effect of buffer layer on the photovoltaic parameters (J_{sc}, η, V_{oc} and FF).

2.2. Cell Structure

Solar cell structure used in the device simulation is consists of an p-CIGSe absorber layer, the buffer layer and a window layer made of n-ZnO:Al. Aluminum (Al) is used as the front contact and Molybdenum (Mo) back contact layers. The cell is illustrated schematically in Fig. 1.

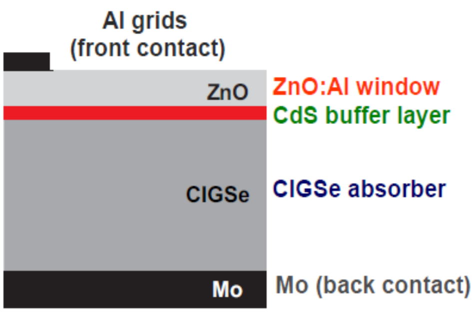

Fig.1: Schematic structure of a CIGS solar cell.

From its earliest development, CIGSe was considered promising for solar cells because of its favorable electronic and optical properties including its direct band gap with high absorption coefficient and inherent p-type conductivity [4].

2.3. Input parameters

Before simulating any device, we have to describe the materials that are used to build the structure. The parameters used for simulations of a standard CIGSe solar cell are summarized in the following table1.

Table 1. The parameters for the CIGSe solar cell at 300K[5].

parameters	CIGSe	CdS	ZnO :Al
Eg(eV)	1.5	2.4	3.5
ε_r	13.6	10	9
χ(eV)	4.5	4.2	4.65
μ_n ($cm^2V^{-1}s^{-1}$)	100	100	100
μ_p ($cm^2V^{-1}s^{-1}$)	25	25	25
Nc (cm^{-3})	$2.2.10^{18}$	$1.5.10^{18}$	$2.2.10^{18}$
Nc (cm^{-3})	$1.8\ .10^{19}$	$1.8.10^{19}$	$1.8\ .10^{19}$
Vt(cm/s)	1.10^7	1.10^7	1.10^7
Vt (cm/s)	1.10^7	1.10^7	1.10^7

Other materials such as ZnS, ZnSe, InS were tested with CdS are used for the simulation (Table 2).

Table 2. The parameters for the CIGSe solar cell at 300K.

parameters	ZnS	ZnSe	InS
Eg(eV)	0.06	0.08	0.05
ε_r	10	10	13.5
χ(eV)	3.5	2.9	2.8
μ_n ($cm^2V^{-1}s^{-1}$)	50	50	400
μ_p ($cm^2V^{-1}s^{-1}$)	20	20	210
Nc (cm^{-3})	$1.5.10^{18}$	$1.5.10^{18}$	$1.8.10^{19}$
Nc (cm^{-3})	$1.8.10^{18}$	$1.8.10^{18}$	$4.0.10^{19}$
Vt(cm/s)	1.10^7	1.10^7	1.10^7
Vt (cm/s)	1.10^7	1.10^7	1.10^7

3. Simulation results and discussion

The simulation has been carried out by using SCAPS dedicated thin films solar cells. The J-V characteristics are represented in the figure below for CdS buffer layer.

3.1. Current-voltage simulation

Figure 2 shows the simulated characteristics J (V), with the AM1.5 illumination conditions (100mW/cm^2), for different buffer layer. The table 3 includes all the photovoltaic parameters (I_{sc}, η, V_{oc} and FF) of the CIGSe solar cell with different buffer layer.

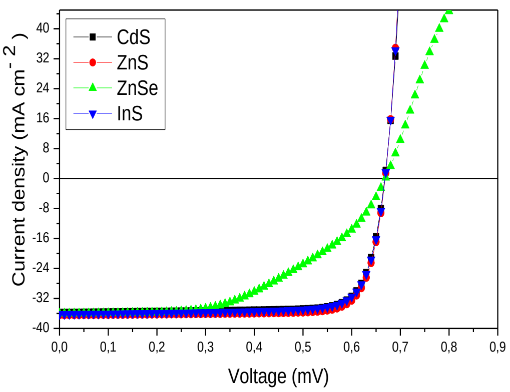

Fig.2: Current-voltage characteristics under AM1.5 illumination for the CIGSe solar cell.

	CdS	ZnS	ZnSe	InS
Vco(V)	0.668	0.668	0.669	0.668
Jsc(mA /Cm^2)	35.76	36.42	36.02	36.16
FF %	80.48	81.30	50.33	79.58
η %	19.23	19.80	12.13	19.23

Table2. The photovoltaic parameters for the CIGSe solar cell.

From these figures, one can notice that solar cells with CdS, ZnS and InS as buffer layer gives high conversion efficiency. As for the solar cell buffer With ZnSe layer had the least conversion efficiency.

3.2. Spectral response simulation

The quantum efficiency *QE* is the number of carriers collected by the solar cell to the number of photons incident on the solar cell. The short circuit current density can be predicted from the wavelength dependency of quantum efficiency *QE*(λ) and the solar spectrum .

$$J_{sc} = q\int_{\lambda} \phi(\lambda) QE(\lambda) d\lambda \qquad (1)$$

Where ϕ *(λ)* is the incident photon flux density per unit wavelength band width.
The choice of the buffer layer can also be explained by the drawing of the quantum efficiency which is shown in Figure 3.

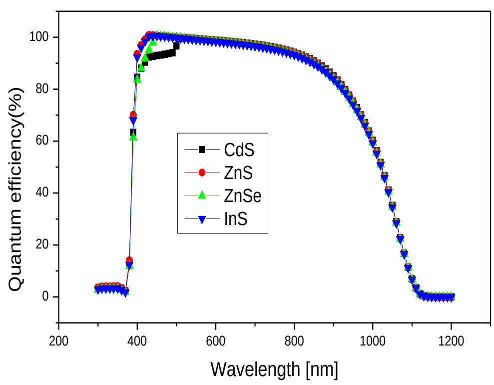

Fig.3: Simulated QE spectrum for different buffer layer.

From Fig. 3, we note that the QE with CdS buffer layer is lower with respect to the ZnS (ZnSe and InS) buffer layer in the wavelength regime of 350nm-900nm.

The solar cell with ZnS, ZnSe and InS buffer shows the increasing spectral response reaches a maximum 100% from the wavelength 370 nm to 900 nm. The steeper slope for shorter wavelength between 400 nm and 500 nm is occurred in CdS buffer of 90% and exhibit a higher response of 98% at the wavelengths larger than 800 nm.

4. Conclusion

In this investigation, we study the performance of the CIGSe solar cells. The CdS buffer layer is replaced by other materials like Zinc Sulphide (ZnS), Zinc Selenide (ZnSe) and Indium Sulphide (InS).

The analysis of all the results shows that the best photovoltaic parameters (J_{sc}, η, V_{oc} and FF) are obtained with ZnSe and ZnS as buffer materials can be compared to CdS buffer.

We concluded that InS and ZnS can be used as alternative material to CdS. As the later presents serious environmental problems.

References

[1] Byung Tae Ahn, Liudmila Larina, Ki Hwan Kim, and Soong Ji Ahn , Development of new buffer layers for Cu(In,Ga)Se2 solar cells, Pure Appl. Chem., Vol. 80(200).

[2] Nawfal Y. Jamil, Suha N. Abdulla, Abid A.K. Muhammed, Design and Fabrication Heterojunction Solarcell of Si-CdS-ZnO Thin Film, proceedings of the international conference nanomaterials: applications and properties, Vol. 1 No 4,(2012)

[3] Koen Decock , Samira Khelifi, Marc Burgelman, Modelling multivalent defects in thin film solar cells Thin Solid Films 519 (2011) 7481–7484.

[4] Rocheleau R, Meakin J, Birkmire R, *Proc.* 19th IEEE Photovoltaic Specialist Conf., 972–976(1987).

[5] Thèse de doctorat, Zacharie Jehl Li Kao, Elaboration of ultrathin Copper Indium Gallium Di-Selenide based Solar Cells,2012.