Short Communication

Junction Configuration Effect on the Performance of In_2S_3/CZTS Solar Cells

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This research work presents a numerical simulation of CZTS based solar cell by using one dimensional solar cell simulation program called solar cell capacitance simulator (SCAPS). In this work, the influence of In_2S_3 buffer layer thickness and natural defect density on the performance and the J-V characteristics of CZTS based solar cells has been studied. The simulation results illustrate that the optimal In_2S_3 buffer layer thickness is 50 nm. We observed that the defect density is perfect from10^{15} to 10^{17} cm^{-3}. The optimal photovoltaic parameters have been achieved with an efficiency of 20.95 % with J_{SC} = 26.85 mA/cm^2 and V_{OC} = 0.78 V.

Keywords: In_2S_3, Solar cells, CZTS, SCAPS-1D.

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1. INTRODUCTION

Harnessing the abundantly available solar energy carried out by employing solar cell which works on the principle of photovoltaic effect has been emphasized to be one of the best methods [1, 2]. Currently, silicon based materials are the most widely used semiconductor materials for solar cells [3-5]. The multijunction solar cells based on $CuInGaSe_2$ (CIGS) consist of CIGS layer, a p-type semiconductor material, which absorbs incoming photons [6-9]. The Cu_2ZnSnS_4 (CZTS) based solar cells have been reported to have the largest efficiency on the laboratory scale as well as for large-area modules [10]. Cu_2ZnSnS_4 is a quaternary semiconductor with excellent photovoltaic properties such as high absorption coefficient over 10^4 cm^{-1} and a direct band gap value of about 1.4-1.5 eV, which is very close to the optimum band gap value of the single-junction solar cells [11, 12].

The goal of this work is to study the effect of In_2S_3 buffer layer thickness and the natural defect density on photovoltaic performance of SnO_2:Al/In_2S_3/CZTS solar cell employed by SCAPS-1D simulation software.

2. DEVICE MODELLING

The solar cell capacitance simulator structures (SCAPS-1D) [13] software has been employed to analyze the CZTS based solar cells. This simulation program was developed by the Department of Electronics and Information Systems (ELIS), the University of Gent, Belgium [14, 15].

The cell structure consists of a p-CZTS which is deposited on the molybdenum (Mo) coated back glass substrate. An n-type buffer layer is made of n-In_2S_3 and a window layer is made of n-SnO_2:Al. The structure of the solar cell is illustrated schematically in Fig. 1.

The numerical values of various material parameters that are used in a solar cell layer for the simulation are presented in Table 1.

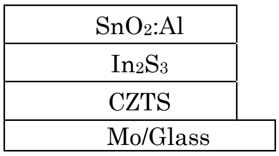

Fig. 1 – Structure of SnO_2:Al/In_2S_3/CZTS solar cell

Table 1 – Parameters used for the simulation

Parameters	n-SnO_2:Al	n-In_2S_3	p-CZTS
Thickness (nm)	80	50-125	1000
E_g (eV)	3.6	2.8	1.54
N_a (cm^{-3})	10^{10}	10^{10}	10^{19}
N_d (cm^{-3})	10^{19}	10^{19}	10^7

3. RESULTS AND DISCUSSION

At the beginning of the simulation, the thickness of In_2S_3 layer is changed from 50 nm to 125 nm to investigate the impact of the buffer layer on thickness in the cell performance, while other material parameters of different layers are kept unchanged [16]. The cell performance output by varying In_2S_3 buffer layer thickness is shown in Fig. 2. It can be observed from Fig. 2 that the efficiency of the solar cell with the layer configuration as presented in Fig. 1 decreases with the increase in the In_2S_3 buffer layer thickness.

The variation of the current density (J) as a function of the voltage (V) for different In_2S_3 buffer thickness of CZTS based solar cell is presented in Fig. 3 for the AM 1.5 illumination conditions (100 mW/cm^2) and T = 300 K.

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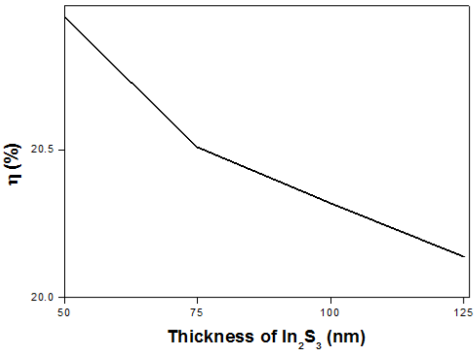

Fig. 2 – Influence of the thickness of n-In_2S_3 on the efficiency

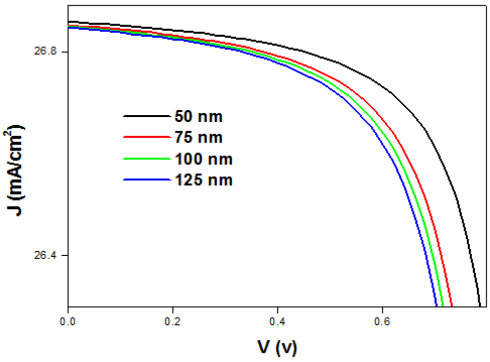

Fig. 3 – Effect of n-In_2S_3 thickness on J-V characteristic

The parameters extracted from J-V characteristics give the following values for In_2S_3 buffer layer thickness of 50 nm: short-circuit photocurrent $J_{SC} = 26.85$ mA/cm^2, open-circuit voltage $V_{OC} = 0.78$ V, efficiency $\eta = 20.95$ %.

Fig. 4 shows the effect of natural defect density in n-In_2S_3 buffer layer with 50 nm thick on the performance of CZTS based solar cell. The defect states can introduce additional carrier recombination centers [17].

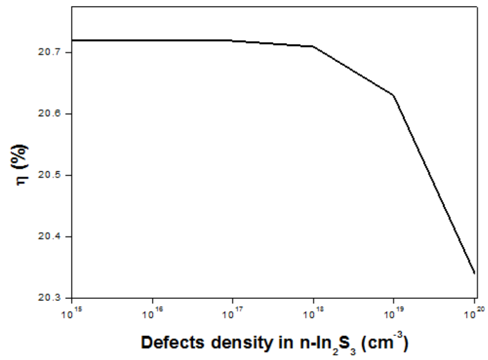

Fig. 4 – Variation of efficiency as a function of natural defect density in n-In_2S_3 layer

It was observed that the defect density is perfect from 10^{15} to 10^{17} cm^{-3}.

4. CONCLUSIONS

In conclusion, the SnO_2:Al/In_2S_3/CZTS solar cell performance is numerically simulated by using SCAPS-1D to improve the solar cell performance significantly. The numerical simulations have been done on the In_2S_3 buffer layer thickness and natural defect density in order to see their effects on the J-V characteristics and the cell performance. The simulations show that the optimized thickness for the In_2S_3 buffer layer should be 50 nm and the defect density is perfect from 10^{15} to 10^{17} cm^{-3}. The simulation results show that the optimal photovoltaic parameters with an efficiency of 20.95 % with $J_{SC} = 26.85$ mA/cm^2 and $V_{OC} = 0.78$ V can be achieved.

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Вплив конфігурації переходу на продуктивність сонячних елементів In_2S_3/CZTS

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У роботі представлено чисельне моделювання сонячних елементів на основі CZTS з використанням одновимірної програми моделювання сонячних елементів, яка називається симулятором ємності сонячного елементу (SCAPS). Було вивчено вплив товщини буферного шару In_2S_3 та густини природних дефектів на продуктивність та характеристики *J-V* сонячних елементів на основі CZTS. Результати моделювання показують, що оптимальна товщина буферного шару In_2S_3 становить 50 нм. Було виявлено, що густина дефектів ідеальна від 10^{15} до 10^{17} см$^{-3}$. Оптимальні фотоелектричні параметри були досягнуті з ефективністю 20,95 % при J_{SC} = 26,85 мА/см^2 та V_{OC} = 0,78 В.

Ключові слова: In_2S_3, Сонячні елементи, CZTS, SCAPS-1D.