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Performance Enhancement of Kesterite $Cu_2ZnSn(S,Se)_4$ Thin Film Solar Cell

1st Satyendra Kumar

Department of Electronics Engineering,
Swami Keshwanand Institute of Technology, Management & Gramothan, Jaipur, India-302017
rajeshwar.satyendra@gmail.com,

2nd Swati Arora

Department of Electronics Engineering,
Swami Keshwanand Institute of Technology, Management & Gramothan, Jaipur, India-302017
aroraswati14@gmail.com

Abstract –Work presented in this paper is based on findings of SCAPS simulation of Kesterite CZTSSe thin film solar cell. The main objective of this work is to investigate and improve overall performance of nanostructured $Cu_2ZnSn(S_{1-x},Se_x)_4$/CdS/ZnO solar cell through optimization of thickness, band gap and doping concentration in absorption layer. These are major parameters which determine performance of the cell on large extent. The highest efficiency (simulation) reported for CZTSSe/CdS/ZnO before is 13%. Materials with large absorption coefficient in visible spectrum of solar irradiance, regular crystal structure and optimum band gap are being searched by researchers and industrialists for solar applications. There are less number of material compositions used for solar cell thin film application with concerns of cell-efficiency, device flexibility, manufacturing cost and availability of source materials in nature. Because extracting elements from its ores and then making a compound for the required applications raised manufacturing cost significantly. Adequacy of Kesterites in nature, less toxic, easy extraction of CZTS as compared to chalcogenide CIGS make it competent for the application. Removal of toxic elements introduced additional challenges which can be future objective of this work. The proposed optimizations have increased the cell-efficiency by 22.76% w.r.t. the reference work.

Keywords– Solar Cell Capacitance Simulator, Kesterite, Cell-Efficiency, Solar Irradiance, Optimisation

1. INTRODUCTION

The reference work on CZTSSe thin film single junction solar cell was based on optimization of thickness of transparent conducting oxide layer. It reported that cell efficiency of optimized thickness TCO Kesterite thin film solar cell can be improved up to 13% [1]. However the percentage enhancement in efficiency published with similar treatment of TCO layer does not hold the same result. After simulating multiple iterations with different possible configurations it has been found that maximum 0.2% absolute increment in efficiency is possible with optimization of thickness of TCO layer. Therefore, wide gap in SQ limit ≈ 30% and observed efficiency motivated to study effect of variation in other parameters contributing to the overall performance. To model the cell $Cu_2ZnSn(S_{1-x},Se_x)_4$ is used as p-type active layer as shown in figure 1. Aluminium doped ZnO of thickness 0.050µm is used as trans-conducting oxide for front contact. It behaves as transparent medium for solar irradiance with transmittance greater than 90% for photons of wavelength λ greater than 350nm [2]. An n-type buffer layer of Cadmium Sulphide of thickness 0.050µm with band gap 2.4eV [3] is modelled. Series resistance $R_s = 0.36\Omega.cm^2$ and parallel resistance $R_{sh} = 1000\ \Omega.cm^2$ are used. Optical and electrical properties of CdS as well as ZnO are directly used from the 1D- SCAPS [4, 5] library files.

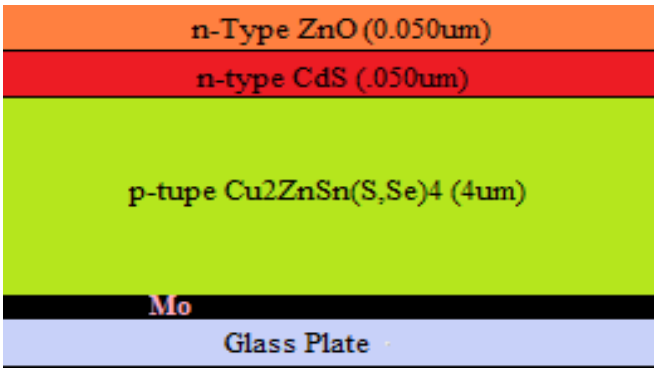

Fig. 1 Structure of Thin Film Solar Cell

2. LITERATURE REVIEW

There are number of research work and publications referenced to propose this work. A few of them, works on kesterite thin film solar cell are introduced here in brief.

Meriem Chadel et al. – improved the cell simulation efficiency upto 13% at band gap of active layer 1.13eV through optimised trans-conducting oxide layer. [1]

J. Kim et al. - achieve efficiency upto 12.4% by using double emitter structure with deficit of 593 mV in open circuited voltage at band gap of active layer 1.13 eV [6].