Optimization of device parameters for CIGS based solar cell using SnO_2 as window layer

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Abstract— **In this study, the performance of CIGS based thin film solar cell is evaluated using SCAPS-1D device simulator. Unlike the conventional CdS/CIGS solar cell, we attempted an alternate buffer layer ZnS which has wider band gap, environment friendly and toxic free material. Further, we have used wide band gap SnO_2 as window layer to achieve low losses from solar spectrum. The solar cell device parameters (Jsc, Voc, FF and η) are analyzed with variation of doping thickness and band gap of absorber layer. In order to investigate the performance of proposed structure, we have optimized band gap, thickness and doping of the absorber layer. Best efficiency of 23.88% is obtained for the optimized device structure.**

Keywords— CIGS, absorber layer, fill factor and efficiency.

I. INTRODUCTION

In the category of chalcopyrite based thin film solar cell, I-II-VI based CIGS solar cell is one of the promising materials for generating clean energy. This is due to its direct band gap (1 to 1.7 ev), high absorption coefficient (10^6 cm^{-1}) and low cost. Efficiencies upto 23% have been reported for CdS/CIGS solar cells [1]. In [2], cd free buffer layer has been explored with zinc chalcogenide-based materials to improve efficiency further. Cadmium is known to be hazardous material for human health as well as environment. Zinc Sulphide (ZnS) has much wider band gap of 3.68 eV, in comparison to CdS thus enabling better current generation. Efficiencies upto 22.16% has been reported with ZnS as the buffer layer [2].

II. SIMULATION METHOD

In this paper, we have designed SnO_2, ZnS and CIGS as window layer, buffer layer and absorber layer respectively. Usually, ZnO is the preferred choice of material for window layer in CIGS based solar cell. In this work, we have proposed SnO_2 instead of ZnO due to its high transparency. Similar approach has been done in [3], but the maximum efficiency values reported is just around 13.8 %. Also, we have optimized the band gap, thickness, and doping of the absorber layer with respect to solar cell parameters (Jsc, Voc, FF and η). In this work we have used SCAPS 1D tool for the simulation of CIGS based solar cell. Typical illumination conditions include AM 1.5G spectrum (1000 W/m^2) form the front contact.

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III. SIMULATION RESULTS

The proposed device structure is shown in Fig.1. It consists of mainly three layers. The wide band gap transparent conducting oxide (SnO_2) on top providing transparency to the maximum part of solar spectrum. Followed by buffer layer (ZnS), main absorbent layer (CIGS) and a back contact. Since the band gap of CIGS can be controlled within the range of 1.1 to 1.7 eV, we started with optimizing the band gap of absorber layer by keeping all the parameters fixed. Figure 2 shows the efficiency values obtained with respect to variation in band gap. At band gap of 1.4 eV, we obtained the efficiency of 22.61 %. With increase in band gap further, the efficiency is marginally improved, but the fill factor reduced considerably. With fixing band gap at 1.4 eV, we proceeded further with the variation of thickness of CIGS layer to analyze the variation of efficiency. The efficiency started to increase with thickness, and kind of saturated for thickness greater than 2.5 µm. From Figure 3, even though we increased the thickness upto 6µm, it can be observed that the efficiency could not exceed beyond 24%. At 1.4 eV and 2.5 µm thickness, we next started to optimize the doping of the absorbent buffer layer. For the results shown in Figure 2 and 3, the doping of the absorbent layer was fixed at 1E15 cm^{-3}. Figure 4 shows the variation of doping density with respect to efficiency. Increase in efficiency was observed with increase in doping density, and for the doping values beyond 1E16 cm-3, the efficiency reached saturation and did not increase further. Finally, the optimized parameter values from Figure 2, 3 and 4 are bandgap of 1.4 eV, thickness of 2.5µm and doping of 1E16 cm^{-3} respectively. With the optimized parameters, we have plotted Quantum efficiency as shown in Figure 5. Good range of response intensity for wavelengths up to 850 nm can be seen from Fig.5.

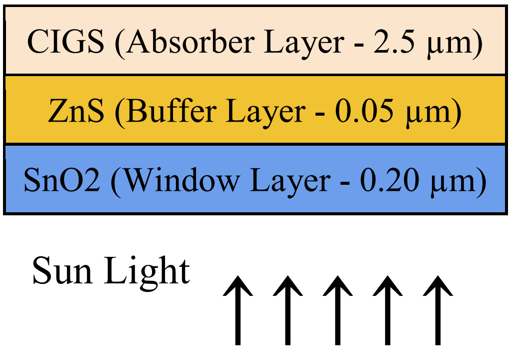

Fig (1) : Basic Solar Cell Structure

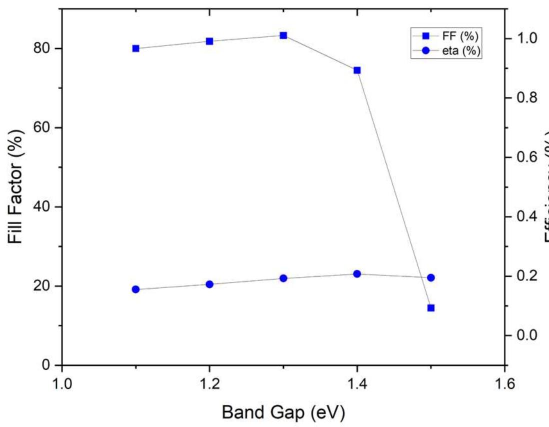

Fig (2) : Comparison of Fill Factor and Efficiency for different Bandgap (eV) of absorber layer

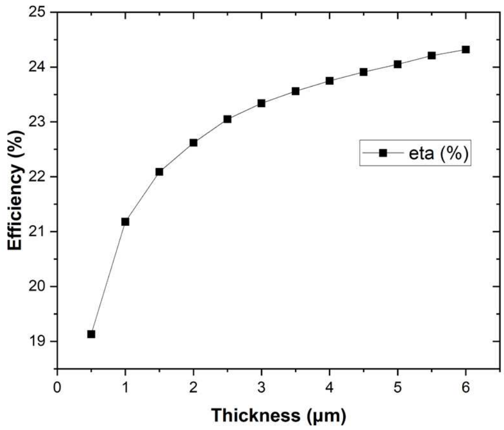

Fig (3) : Efficiency curve for varying thickness of absorber layer

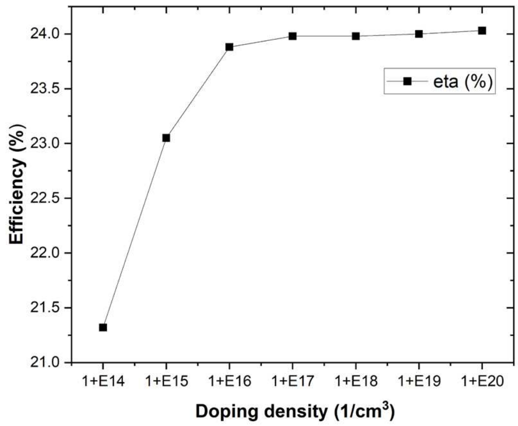

Fig (4) : Effect of absorber layer doping density on cell efficiency

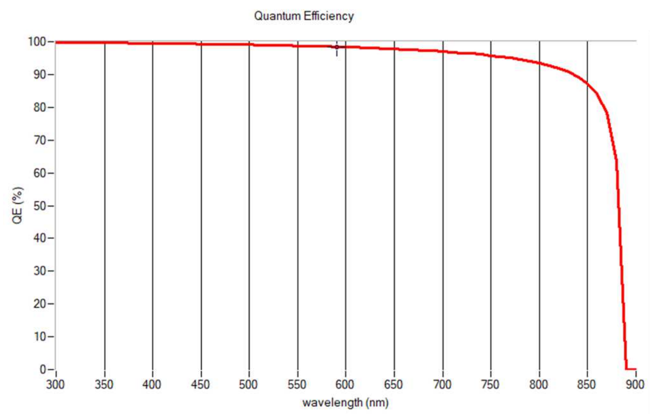

Fig (5) : The Quantum Efficiency (%) response of CIGS solar cell with respect to wavelength (nm)

References

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