Numerical Investigation on Laboratory-developed CdS/ CdTe Thin Film Solar Cell

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I. INTRODUCTION

Sri Lanka is aiming to make its electricity sector more environmentally friendly by 2050 by achieving carbon neutrality in the electricity industry. As a result, electricity generation is being planned to reach 70% of it by Renewable Energy (RE) sources [1]. According to the latest Long Term Generation Expansion Plan 2023-2042, our country will have 31% of its energy share from solar power [2]. However, the low efficiency and high cost of solar panels are currently a barrier to achieving this goal.

The purpose of this study is to propose a method to increase the efficiency of the glass/FTO/CdS/CdTe/Cu/Au solar cell which was developed under laboratory conditions. CdTe solar cells are second-generation thin film solar cells that are more economical and can increase efficiency subsequently than the first-generation Si solar cells [3]. Solar Cell Capacitance Simulator (SCAPS 1D) software is used for the simulations and the software is validated using practically measured cell output parameters and simulation results to ensure its suitability for the study.

II. LITERATURE REVIEW

Thin-film cells are leading in today's PV industry. At present thin-film solar cells (TFSC) are a promising choice in terms of device design, fabrication, and cost-effectiveness. Amorphous silicon and most TFSCs are second-generation (2G) solar cells. Second-generation solar cells offer better electrical performance. Production of these 2G solar cells is more profitable as compared to the first-generation wafer-based silicon solar cells. Leading TFSCs can be categorized as: a-Si: H (Hydrogenated Amorphous Silicon), CdTe (Cadmium Telluride), and CIGS (Copper Indium Gallium di-Selenide) [3].

Cadmium Telluride (CdTe) as thin-film polycrystalline solar cells is one of the most hopeful candidates for photovoltaic energy conversion [4]. The polycrystalline CdS is the best-suited hetero-junction n-type partner with a p-type CdTe absorber for CdS/CdTe solar cells[5]. Therefore, the glass/FTO/CdS/CdTe/Cu/Au solar cell has a good performance.

Numerical simulation is crucial for understanding and optimizing solar cell designs. The SCAPS simulator, compatible with Windows and Linux, is a valuable tool for analyzing and improving CdS/CdTe solar cell performance [6-8]. SCAPS 1D, a free simulation tool, is well-suited for thin-film modeling and offers flexibility for modifying parameters like thickness and doping in various solar cell structures [9, 10]. It was used to simulate the J-V characteristics of the CdS/CdTe solar cell.

III. MATERIALS AND METHODS

The thickness of each layer of the aforementioned solar cell was measured using Scanning transmission electron microscopy with energy-dispersive X-ray (STEM-EDX) analysis as shown in Fig. 1. The average of those thicknesses was taken as inputs in SCAPS 1D. The average thickness of the CdTe is 5.95 µm and the thickness of CdS is 0.294 µm. Other material parameters are extracted from [11, 12, 13].

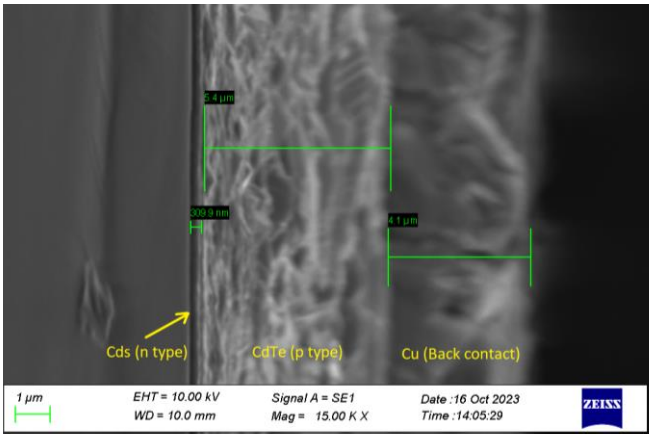

Fig. 1: Thicknesses of each layer of CdS/ CdTe solar cell, from STEM-EDX Analysis

Practical measurements for open circuit voltage (Voc), short circuit current density (Jsc), fill factor (FF), and power conversion efficiency (η) of the solar cell are needed to validate the software. Those parameters were measured using the solar simulator (PEC-L12).

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IV. Results and Discussion

Results of electrical parameters with the variation of Thickness of the CdTe layer

In the simulation, the thickness of this layer varied from 0 µm to 10 µm, while other parameters remained constant. According to Fig. 2, Voc and Jsc are increased with the thickness of CdTe, while FF is decreased. As the thickness of the absorber layer increases, it can absorb more photons and enhance Jsc and Voc. Moreover, the increase in the absorber layer thickness can also increase the series resistance, which leads to reducing the FF. Since, the efficiency is determined by the Voc, Jsc, and FF, any change in Voc, Jsc, or FF can also lead to a change in Efficiency. Red lines refer to the reference solar cell.

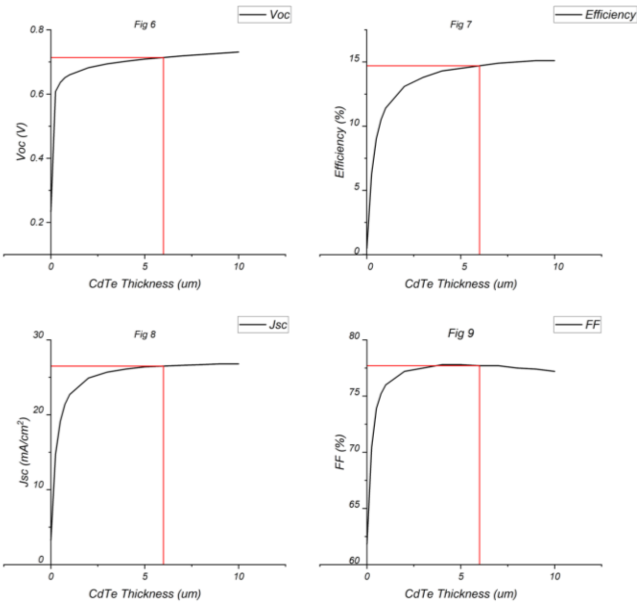

Fig. 2: Behavior of Electrical parameters with the thickness variation of the CdTe layer

Solar cells that exhibit a greater FF are considered more efficient and are preferred for practical applications. Therefore, a CdTe layer thickness of 4.85 µm was chosen, as it yielded the highest FF (according to Fig. 2).

Results of electrical parameters with the variation of Thickness of the CdS layer

From the simulations, the thickness of the CdS layer was selected as 20nm where height efficiency was obtained. From the results obtained, The highest efficiency of 15.5% was achieved for the simulated structure containing the CdS window layer (thickness 20 nm) on the CdTe absorber layer (thickness 4.85 µm). Moreover, Voc, Jsc, and FF were recorded as 0.7193V, 27.95 mA/cm2, and 77.775%, respectively. Therefore, setting the CdTe layer thickness at the same value of 4.85 µm, and reducing the CdS layer thickness to 20 nm can be proposed as a method to increase the cell efficiency.

V. Conclusion

Based on the analysis, it is suggested that the actual measured thickness of the CdS layer (2.94 µm) and the CdTe layer (5.95 µm) can be adjusted to 20 nm and 4.85 µm to achieve the highest efficiency of 15.28 % for Sri Lankan laboratory developed glass/FTO/CdS/CdTe/Cu/Au solar cell according to the simulation. For further enhancement of efficiency, the essence of the Back surface field layer can be identified as previously mentioned.

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