DESIGN AND DEVELOPMENT OF HIGH-EFFICIENCY CdS/CdTe THIN-FILM SOLAR CELLS BY ENHANCING ABSORPTION AND MINIMIZING RECOMBINATION

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DECLARATION

I declare that this is my own work, and this thesis/dissertation does not incorporate without acknowledgement any material previously submitted for a degree or diploma in any other University or Institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text. I retain the right to use this content in whole or part in future works (such as articles or books).

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Name of Supervisor: ………………………………….. Date: 03/09/2024

Dr. R.M. Thushara Damayanthi

Name of Supervisor: ………………………………….. Date: 03/09/2024

Prof. Indika De Silva

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ABSTRACT

Second-generation solar cells, known as thin-film solar cells, have emerged as promising alternatives to traditional silicon-based first-generation photovoltaic cells. As the solar cell arrangement, superstrate configuration is the widely used structure for constructing thin-film solar cells. Nevertheless, less broadband light absorption due to light reflection from the front cover glass surface and carrier recombination at absorber layer back surface mainly contributes to less performance in thin-film solar cells. Herein, ZnO anti-reflection (AR) coating was introduced using spin coating technique on glass/FTO/CdS/CdTe/Cu/Au substrate to enhance the power conversion efficiency of the solar cell through reduction of front surface reflectance. The ZnO layer deposited at 3000 rpm in 15 s showed the minimum reflectance and higher transmittance over the 500-900 nm wavelength region. Further, the thickness of the optimal condition film was 63.32 nm, which was compatible with the ideal theoretical AR coating thickness of 65 nm. Comparing the device performances of the CdS/CdTe solar cell with AR coating and without AR coating, all tested devices have shown an average short circuit current density improvement of 6.7%, and the overall power conversion efficiency enhancement of 9%. Furthermore, a simulation study for CdTe solar cells was conducted using parameters of laboratory-developed solar cells. The variation between simulated and experimental data was discussed. Subsequently, to mitigate recombination at the back surface, the study suggested a solution: the introduction of a SnS back surface field (BSF) layer between the absorber layer and the back contact layer. This investigation was carried out using the SCAPS-1D simulation platform. According to the results obtained, the average power conversion efficiency was improved by 38%. Moreover, the simulation suggested that this approach could reduce the thickness of the CdTe layer, subsequently lowering manufacturing costs.

Keywords: AR coating, BSF layer, CdS/CdTe solar cell, SCAPS-1D, Spin coating

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LIST OF ABBREVIATIONS

Abbreviation	Description
AFM	Atomic Force Microscope
AM	Air Mass
AMPS-1D	Analysis of Microelectronic and Photonic Structures in 1 Dimension
AR	Anti-Reflection
a-Si:H	Amorphous Silicon
BSF	Back Surface Field
CBD	Chemical Bath Deposition
CdS	Cadmium Sulfide
CdTe	Cadmium Telluride
CEB	Ceylon Electricity Board
CIGS	Copper Indium Gallium Selenide
CVD	Chemical Vapor Deposition
DSSC	Dye-sensitized Solar Cell
EDX	Energy dispersive X-ray
EQE	External Quantum Efficiency
ETL	Electron Transparent Layer
FF	Fill Factor
GHG	Greenhouse Gas
IEA	International Energy Agency
I_{MP}	Current at Maximum Power Point
IQE	Internal Quantum Efficiency
I_{SC}	Short Circuit Current
I-V	Current-Voltage
J_{SC}	Short Circuit Current Density
LECO	Lanka Electricity Company (Private) Limited
LED	Light Emitting Diodes
LPD	Liquid Phase Deposition
MPM	Molecular Precursor Method

NDC	Nationally Determined Contributions
NSSP	Numerical Solar Cell Simulation
NZE	Net Zero Emissions by 2050 Scenario
PC1D	Personal Computer One-dimensional
PCE	Power Conversion Efficiency
PECVD	Plasma-Enhanced Chemical Vapor Deposition
P_{MP}	Power at Maximum Power Point
PSC	Perovskite Solar Cell
PV	Photovoltaic
PVD	Physical Vapor Deposition
QE	Quantum Efficiency
QDSSC	Quantum Dot Solar Cell
RF	Radiofrequency
RMS	Root Mean Square
RPM	Round Per Minute
R_s	Series Resistance
R_{sh}	Shunt Resistance
SEM	Scanning Electron Microscopy
SCAPS-1D	Solar Cell Capacitance Simulator in One-dimension
SnS	Tin Sulfide
SLSEA	Sri Lanka Sustainable Energy Authority
TSC	Tandem Solar Cell
UV	Ultraviolet
V_{OC}	Open Circuit Voltage
V_{MP}	Voltage at Maximum Power Point
XRD	X-ray Diffraction
XPS	X-ray Photoelectron Spectroscopy
ZnO	Zinc Oxide