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Design and Simulation of Multi-Junction Solar Cells

A Thesis
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Statement

This thesis "Design and Simulation of Multi-Junction Solar Cells" is submitted to Faculty of Engineering, Ain Shams University for the degree of master in Electronics and Communication Engineering.

The work included in this thesis was carried out by the author. No part of this thesis has been submitted for a degree or a qualification at any other University or Institution.

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I_o:	Ideal Reverse saturation current
I_{SC}:	Short circuit current
k:	Boltzmann constant
q:	Electron charge
T:	Temperature
n:	Ideality factor
V_{OC}:	Open circuit voltage
P_{max}:	Maximum power point
V_{max}:	Voltage at maximum power
I_{max}:	Current at maximum power
FF:	Fill Factor
η:	Conversion efficiency
P_{inc}:	Incident power
$h\nu$:	Photon energy
conc:	Doping concentration
NC300:	Density of conduction states at 300K
NV300:	Density of valence states at 300K
EG300:	Energy gap at 300K
ε:	Permittivity “dielectric constant”
χ_e:	Electron affinity

List of Abbreviations

ARC:	Antireflection Coating
ASTM:	American Society for Testing and Measurement
BSF:	Back Surface Field
CONMOB:	Concentration-Dependent Low Field Mobility
CPE:	Chemical Phase Epitaxy
DJ:	Dual Junction
DOE:	Design of Experiment.
E_g:	Energy bandgap
EHP:	Electron-Hole Pairs
EQE:	External Quantum Efficiency
IMM:	Inverted Metamorphic
MBE:	Molecular Beam Epitaxy
MJSC:	Multi-Junction Solar Cell
MM:	Metamorphic
MOCVD:	Metal Organic Chemical Vapor Deposition
MUN (μ_n):	Electrons Mobility
MUP (μ_p):	Holes Mobility
NREL:	National Renewable Energy Laboratory
OPTR:	Optical recombination
PV:	Photovoltaic
SRH:	Shockely-Read-Hall recombination
TJ:	Triple Junction
TW:	Tera-Watt

Abstract

The window and back surface field (BSF) layers are two important layers in the design of multi-junction solar cells. In this study, the focus is on selecting suitable materials for the top window layer as well as the top and bottom BSF layers of an InGaP/GaAs Dual-Junction (DJ) solar cell with introducing the effect of thickness variation of these layers. Furthermore, the doping concentration of the top and bottom BSF layers is optimized.

Another interest in this study is to present an optimization procedure for the design parameters of InGaP/GaAs/ InGaAs Triple-Junction (TJ) solar cell. The optimization technique is performed on InGaP/GaAs/Ge. The Ge sub-cell is then replaced by an InGaAs sub-cell and a comparison between the performance parameters of InGaP/GaAs/Ge and InGaP/GaAs/InGaAs TJ solar cells is investigated.

The simulations of DJ and TJ solar cells are carried out using advanced Silvaco TCAD tools. For each design, the solar cell performance parameters like open-circuit-voltage *(V_{OC})*, short-circuit-current density *(J_{SC})*, Fill Factor *(FF)* and the conversion efficiency *(η)* are extracted and compared with previously published results to ascertain the results of the present work.