Material and Process Optimization in Dye Sensitized Solar Cell for Efficiency Enhancement

Thesis submitted in partial fulfillment

for the Award of Degree

DOCTOR OF PHILOSOPHY

by

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"Education does not consist merely of book- learning and the time has come when India needs something more. The development of the intellect and the building up of character must proceed hand in hand and at a time of the student's life when he is most susceptible to influences. We want men of constructive genius who will build up the edifice of India's moral and material well-being.Character, Industry and integrity-these are the cards to win the game of life"

-Bharat Ratna Pandit Madan Mohan Malaviya Ji

Dedication

I have dedicated this Ph.D. thesis to **Lord Shiva** and **Lord Krishna** who taught me everything and guided me in my life. I am greatly indebted to my **family membe**r who has supported me in every situation of life. And, I have also dedicated my Ph.D. to **Mr. Mukesh Solanki** whose immense efforts helped me in completing this degree.

CERTIFICATE

It is certified that the work contained in the thesis titled **"Material and Process Optimization in Dye Sensitized Solar Cell for Efficiency Enhancement"** by **Juhi Singh** has been carried under my supervision and that this work has not been submitted elsewhere for a degree.

It is further certified that the student has fulfilled all the requirements of Comprehensive Examination, Candidacy, and SOTA for the award of Ph.D. Degree.

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DECLARATION BY THE CANDIDATE

I, **Juhi Singh**, certify that the work embodied in this Ph.D. thesis is my bonafide work carried out by me under the supervision of **Dr. Ravi P. Jaiswal** for a period of 6 years from July 2017 to June 2023 at the Department of Chemical Engineering & Technology, Indian Institute of Technology (BHU), Varanasi, India. The matter embodied in this Ph.D. thesis has not been submitted for the award of any other degree/diploma.

I declare that I have faithfully acknowledged, given credit to, and referred to the research workers wherever their works have been cited in the text and the body of the thesis. I further certify that I have not willfully lifted some other's work, paragraph, text, data, results, etc. reported in the journals, books, magazines, reports, dissertations, theses, etc., or available on websites and included them in this Ph. D. thesis and cited as my work.

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This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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LIST OF ABBREVIATIONS AND SYMBOLS

Abbreviation	Nomenclature
DSSCs	Dye-Sensitized Solar Cells
PV	Photovoltaic
PCE	Power Conversion Efficiency
LHE	Light Harvesting Efficiency
IPCE	Incident Photon to Current Conversion Efficiency
DC	Direct Current
TCO	Transparent Conducting Oxide
FTO	Fluorine Doped Tin Oxide
ITO	Indium Doped Tin Oxide
NREL	National Renewable Energy Laboratory
Si	Silicon
WEs	Working Electrodes
CEs	Counter Electrodes
NIR	Near Infrared Regions
HOMO	Highest Occupied Molecular Orbital
LUMO	Lowest Unoccupied Molecular Orbital
BIPV	Building Integrated Photovoltaic
Jsc	Short Circuit Current Density
Voc	Open Circuit Voltage
FF	Fill Factor
P_{in}	Incident Power
P_{max}	Maximum Power
CVD	Chemical Vapour Deposition
RGO	Reduced Graphene Oxide
GOS	Graphene Oxide Sponge
NFs	Nanofillers
GNs	Graphene Nanosheets
S^+/S^*	Dye in Excited State
Pt	Platinum

V	Voltage
I	Current
eV	Electron Volt
2D	Two Dimension
€	Molar Extinction Coefficient
A	Amount of light sample absorbs for a particular wavelength
L’	Distance that light travels through the dye solution
C	Concentration of Dye Solution
η	Efficiency
CdTe	Cadmium Telluride
CIGS	Copper Indium Gallium Diselenide
RPM	Revolution Per Minute
GO	Graphite Oxide
Rs	Equivalent Series Resistance
Rct	Charge-Transfer Resistance
TTIP	Titanium Isopropoxide
TTIB	Titanium Isobutoxide
PDI	Polydispersity Index
PSD	Particle Size Distribution
EVA	Ethylene Vinyl Acetate
d	Interlayer Spacing
D	Average Crystallite Width
n	Number of layers per domain
k	constant, which depends on crystallite shape
β	Full Width Half Maximum
λ	X-ray wavelength
θ	Half of Diffraction Angle
λ_{max}	Wavelength at Maximum Absorbance
L	In-Plane Crystallite Size