CANDIDATE'S DECLARATION

I hereby declare that the work presented in the dissertation entitled ***"Design, fabrication and characterization of some advanced semiconductor solar cells"*** is an authentic record of my own work carried out at the Department of Electronics Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi as the requirement for the award of the degree of Doctor of philosophy in Electronics Engineering, submitted in the Indian Institute of Technology (Banaras Hindu University), Varanasi for the session 2021-22 under the supervision of **Prof. P. Chakrabarti (Supervisor),** Department of Electronics Engineering and **Dr. Santanu Das (Co-Supervisor),** Department of Ceramic Engineering, Indian Institute of Technology (Banaras Hindu University), Varanasi.

It does not contain any part of the work, which has been submitted for the award of any degree either in this university or in the other university/Deemed University without proper citation.

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This is to certify that the thesis *entitled* ***"Design, fabrication and characterization of some advanced semiconductor solar cells"*** being submitted by **Ashutosh Kumar Dikshit (Roll No- 17090025)** to the Indian Institute of Technology (Banaras Hindu University) Varanasi, for the award of the Degree of Doctor of Philosophy in Engineering is a record of bonafide research work carried out absolutely by him under our supervision and guidance. The thesis has reached the standard; fulfilling the requirements of the regulations relating to the nature of the degree. The results embodied in this thesis have not been submitted to any other university or institute for the award of any degree or diploma.

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Dedicated to…

My beloved Parents

&

New Family Members

Geo & Deo

Chapter wise Figure Index

Chapter 2

Optimization of back ITO layer as the sandwiched reflector for exploiting longer wavelength lights in thin and flexible (30 μm) single junction c-Si solar cells

Chapter 3

SHJ solar cells on adequately thin (~30 µm) c-Si wafer with unique dome like front and double layer of ITO nanoparticles as back light trapping arrangements

Chapter 4

SHJ solar cells on adequately thin (~30 µm) c-Si wafer with unique dome like front and double layer of ITO nanoparticles as back light trapping arrangements

Chapter 5

Hybrid inorganic-organic inverted solar cells with ZnO/ZnMgO barrier layer and effective organic active layer for low leakage current, enhanced efficiency, and reliability

Abbreviations and Symbols (In order of their appearance)

S. No	Abbreviations and Symbols	Full Name
1.	TW	Tera Watt
2.	GW	Giga Watt
3.	PV	Photo Voltaics
4.	IEA PVPS	International Energy Agency Of Photovoltaics Power System
5.	a-Si	Amorphous Silicon
6.	CdTe	Cadmium Telluride
7.	CdS	Cadmium Sulphide
8.	GaInP	Gallium Indium Phosphide
9.	S/V	Surface/Volume Ratio
10.	c-Si	Crystalline Silicon
11.	μm	Micro-Meter
12.	ITRPV	International Technology Roadmap For Photovoltaic
13.	SiO_2	Silicon Dioxide
14.	HfO_2	Hafnium Oxide
15.	Al_2O_3	Aluminium Oxide
16.	ITO	Indium Tin Oxide
17.	SiN_x	Silicon Nitride
18.	UV	Ultra-Violet

19.	D_{it}	Interface Charge Density
20.	S_{eff}	Surface Recombination Velocity
21.	N_2	Nitrogen Gas
22.	H	Hydrogen Gas
23.	FEM	Finite Element Method
24.	SHJ	Silicon Heterojunction
25.	CIGS	Copper Indium Gallium Selenide
26.	QD	Quantum Dot
27.	PCBM	Fullerene Derivative [6,6]-Phenyl-C_{61}-Butyric Acid Methyl Ester
28.	P3HT	Poly(3-Hexylthiophene)
29.	PbS	Lead Sulphide
30.	CdTe	Cadmium Telluride
31.	$CH_3NH_3P\ X_3$	Methyl Ammonium Lead Trihalide
32.	J_{sc}	Short Circuit Current
33.	V_{oc}	Open Circuit Current
34.	FF	Fill Factor
35.	IQE	Internal Quantum Efficiency
36.	EQE	External Quantum Efficiency
37.	VB	Valance Band
38.	CB	Conduction Band
39.	λ	Wavelength
40.	E_g	Band-Gap

41.	N_t	Number Of Photons At Given Time
42.	N_0	Number Of Photons Before Incident
43.	x	Path Length
44.	τ	Carrier Lifetime
45.	L_d	Diffusion Length
46.	μ	Mobility
47.	SC	Semiconductor
48.	q	Charge
49.	I_L	Load Current
50.	I_0	Recombination Current
51.	η	Efficiency
52.	PERL	Passivated Emitter Rear Locally Diffused
53.	EHP	Electron-Hole Pair
54.	$\varphi(\lambda)$.	Photon Density
55.	R_{bi}	Integrated Reflectance
56.	BSi	Black Silicon
57.	RIE	Reactive Ion Etching
58.	SF6	Sulphur Hexafluoride
59.	C_4F_8	Octafluorocyclobutane
60.	Cu	Copper
61.	Ag	Silver
62.	HF	Hydrofluoric Acid

63.	SEM	Scanning-Electron Microscope
64.	n	Refractive Index
65.	ARC	Anti-Reflection Coating
66.	Si_3N_4	Silicon Nitride
67.	NP	Nanoparticles
68.	SPP	Surface Plasmon Polarization
69.	TCO	Transparent Conductive Oxide
70.	WGM	Whispering Gallery Modes
71.	TIR	Total Internal Reflection
72.	Q	Quality Factor
73.	RCA	Radio Corporation Of America
74.	SC-1	Standard Clean-1
75.	NH_4OH	Ammonium Hydroxide
76.	PECVD	Plasma Enhanced Chemical Vapour Deposition
77.	HHV	Hind High Vacuum
78.	MFCs	Mass Flow Controllers
79.	PLC	Programmable Logic Circuit
80.	XRD	X-Ray Diffraction
81	W	Tungsten
82.	LaB6	LanthanunHexaboride
83.	LID	Light Induced Degradation
84.	HIT	Heterojunction With Intrinsic Thin Layer

85.	IBC	Interdigited Back Contact
86.	PERC	Passivated Emitter Rear Cell
87.	RPCVD	Reduced Pressure Chemical Vapor Deposition
88.	IMEC	Interuniversity Microelectronics Centre
89.	NaOH	Sodium Hydroxide
90.	AFM	Atomic Force Microscopic
91.	FWHM	Full Width At Half Maximum
92.	BSF	Back Surface Field
93.	KOH	Potassium Hydroxide
94.	IPA	Isopropyl Alcohol
95.	HNO_3	Nitric Acid
96.	CH_3COOH	Acetic Acid
97.	SHJ	Silicon Heterojunction
98.	DBR	Dielectric Bragg Reflectors
99.	MAPD	Maximum Achievable Photocurrent Density
100.	TMO	Transition Metal Oxide
101.	TIR	Total Internal Reflection
102.	EWFD	Electromagnetic Wave Frequency Domain
103.	OSCs	Organic Solar Cells
104.	OPVs	Organic Photovoltaics
105.	BHJ	Bulk-Heterojunction
106.	HPD	Hybrid Photovoltaic Devices

107.	IOSCs	Inverted Organic Solar Cells
108.	PEDOT:PSS	Poly(3,4-Ethylene Dioxythiophene):Poly(Styrenesulfonate)

Contents

Chapter 1: Introduction & Literature review with Experimental techniques

PART-A: Review and Scope of work

Part-B: Experimental and Characterization techniques