

CONTENTS

Acknowledgement	V
Abstract	VII
Chapter 1	
Introduction	
	1
1.0 Motivation, Objectives and Abstract	1
1.1 Renewable resources – An Imperative Energy!	2
1.2 Solar Radiation Distribution	3
1.3 Photovoltaic – Generations and Performance	5
1.4 Fundamentals of Photovoltaic Device	7
1.5 Profile of Chalcopyrite CIGS Solar Cell Module	11
1.5.1 Substrate	12
1.5.2 Back contact layer	14
1.5.3 Absorber layer	15
1.5.4 Buffer layer	17
1.5.5 Window layer	17
1.5.6 Monolithic Integration: Cell to Module	18
1.6 Stabilities, Band-alignment, and Degradation	19
1.7 Organization of the Thesis	26
References	29
Chapter 2	
Technical Aspects: Deposition And Characterization of Photovoltaic Device	
	33
2.0 Motivation, Objectives and Abstract	33
2.1 Deposition Techniques	34
2.1.1 DC Magnetron Sputtering	34
2.1.2 RF Magnetron Sputtering	35
2.1.3 Substrate Cleaning Process	36
2.2 Process Steps Involved: CIGS Solar Cell Module	39
2.3 Characterization Techniques	39
2.3.1 X-ray Diffraction	39
2.3.2 Scanning Electron Microscopy	43
2.3.3 Elemental Dispersive X-Ray Analysis	44
2.3.4 X-Ray Fluorescence	46
2.3.5 Atomic Force Microscopy	46
2.3.6 Raman Spectroscopy	48
2.3.7 Photoluminescence	49

2.3.8	Hall effect measurements	50
2.3.9	Current-Voltage and Spectral Response	53
2.3.10	Ultraviolet-Visible-Near Infrared Spectroscopy	55
	References	56
Chapter 3		
	Molybdenum: A Rear Gateway of CIGS Solar Cell Module	59
3.0	Motivation, Objectives and Abstract	59
3.1	An Essential Ohmic Back-Contact: Molybdenum layer	60
3.2	Experimental Details	61
3.3	Influence of Sputtering Power	62
3.3.1	X-Ray Diffraction Analysis	62
3.3.2	Optical Reflectivity Analysis	66
3.3.3	Electrical Resistivity Analysis	69
3.3.4	Atomic Force Microscopy Analysis	70
3.3.5	Scanning Electron Microscopy Analysis	72
3.4	Influence of Substrate temperature	74
3.4.1	X-Ray Diffraction Analysis	75
3.4.2	Optical Reflectivity Analysis	77
3.4.3	Electrical Resistivity Analysis	79
3.4.4	Atomic Force Microscopy Analysis	80
3.4.5	Scanning Electron Microscopy Analysis	81
3.5	Bilayer Molybdenum Thin Film at Different Thickness	84
3.5.1	X-Ray Diffraction Analysis	84
3.5.2	Optical Reflectivity Analysis	85
3.5.3	Electrical Resistivity Analysis	85
3.5.4	Scanning Electron Microscopy Analysis	86
3.6	Nanosecond Laser Scribing	88
3.6.1	YAG Focusing Lens	95
3.6.1.1	Pulse Repetition Rate	95
3.6.1.2	Laser Scribing Speed	97
3.6.1.3	Different Laser Pass Delay	99
3.6.1.4	Different Laser Power	101
3.6.1.5	Depth of Focus	102
3.6.2	YAG F-Theta Lens	103
3.6.2.1	Laser Power	103
3.6.2.2	Pulse Repetition Rate	105

3.6.2.3	Galvo-Speed	106
3.6.2.4	Depth of Focus	108
3.7	Adhesion Test	109
	Conclusions	111
	References	112
Chapter 4		
	Copper Indium Gallium Diselenide: Photocarrier Generator	116
4.0	Motivation, Objectives and Abstract	116
4.1	Chalcopyrite Absorber: CIGS Layer	117
4.2	Experimental Details	118
4.3	Results and Discussion	120
4.3.1	X-Ray Diffraction Analysis	120
4.3.2	X-Ray Fluorescence Analysis	123
4.3.3	Raman Spectroscopic Analysis	124
4.3.4	Atomic Force Microscopic Analysis	128
4.3.5	Microstructural Analysis	132
4.3.6	Optical Transmittance And Urbach Energy	134
4.4	Consequences of Eclectic CIGS Annealing Profiles	137
4.4.1	X-Ray Diffraction Analysis	138
4.4.2	Optical Reflectivity and Bandgap Analysis	139
4.4.3	Energy Dispersive X-ray Analysis	141
4.4.4	Raman Spectroscopic Analysis	142
	Conclusions	143
	References	143
Chapter 5		
	Cadmium Sulphide: n-Junction and Barrier Partner	146
5.0	Motivation, Objectives and Abstract	146
5.1	A Protective Buffer: Cadmium Sulphide Layer	147
5.2	Experimental Details	147
5.3	Results and Discussion	148
5.3.1	Structural Characterization	148
5.3.2	Optical Analysis	151
5.3.3	Electrical Characterization	153
5.3.4	Photoluminescence Analysis	154
5.3.5	Scanning Electron Microscopic Analysis	157
5.3	P2 Patterning: Laser and Mechanical Scribing	159
	Conclusions	161
	References	161

Chapter 6		
Intrinsic and Aluminum Doped Zinc Oxide: Passivator and		
Charge collector		164
6.0	Motivation, Objectives and Abstract	164
6.1	High Resistive and Top Conductive: i-ZnO and AZO	165
6.2	Experimental Details	166
6.3	Results and Discussion	167
6.3.1	Structural Analysis	167
6.3.2	Optical Analysis	174
6.3.3	Urbach Energy and Electrical Measurements	183
6.3.4	Atomic Force Microscopy Analysis	186
6.3.5	Scanning Electron Microscopy Analysis	192
6.3.6	Photoluminescence Analysis	193
6.3.7	Raman Spectroscopic Analysis	197
	Conclusions	200
	References	201
Chapter 7		
Fabrication and Performance: CIGS Solar Cell Module		205
7.0	Motivation, Objectives and Abstract	205
7.1	Fabrication Process of CIGS solar cell Module	206
7.2	Results and Discussion	213
	Conclusions	221
	References	222
	Summary and Future Recommendations	224
	List of Symbols	227
	Abbreviations	230
	List of Publications	232