Contents

		page
Abstr		i
	owledgements	iii
Conte		. v
	f Figures	İX
	f Tables f Sumbols	xi xii
	rf Symbols if Abbreviations	xiii
LISU		XIII
Char	oter 1: Introduction	
1.1	Photovoltaic Process and Photovoltaic Cell	1
1.2	Evolution of Photovoltaic Cells	1
1.3	Conventional Photovoltaic Cells and Excitonic Solar Cells	2
1.4	Quantum Dot Sensitized Solar Cells	3
1.5	Carrier Multiplication in Semiconductor Quantum Dots	4
1.6	Objective	5
1.7	Outline of Thesis	6
Chap	oter 2: Review of Literature	
2.1	Evolution of Solar Cells in Generations	8
2.2	Building Blocks of a Quantum Dot Sensitized Solar Cells	11
	2.2.1 Excitonic Absorber	11
	2.2.2 Electron Transport Material	13
	2.2.3 Sensitization Schemes	14
	2.2.4 Hole Transport Material	15
	2.2.5 Counter Electrode	16
2.3 2.4	Theoretical Efficiency of Quantum Dot Sensitized Solar Cells Summary	17 17
Char	ntor 2: Adopted Methodology	
-	o ter 3: Adopted Methodology Sensitization of Mesoporous Electrode	10
3.1 3.2	Transition Metal Doping in Cadmium Sulfide Quantum Dots in QDSSCs	19 21
3.3	Photoelectrode Material for Efficient QDSSCs	22
3.4	Detailed Balance Efficiency Calculation for QDSSCs	23
Chap	oter 4: Experimental details	
4.1 •	Fabrication and Synthesis Techniques	25
	4.1.1 Fluorine Doped Tin Oxide (FTO) Substrate Preparation for Photoelectrode Material	25
	Deposition	
	4.1.1.1 FTO Cleaning	25
	4.1.1.2 Titanium Chloride Treatment of FTO	25
	4.1.2 Photoelectrode Material Preparation and Deposition over Treated FTO Substrate	25
	4.1.2.1 Zinc Titanate Photoelectrode Material Preparation	25
	4.1.2.2 Photoelectrode Material Paste Preparation for Deposition over Treated FTO 4.1.2.3 Photoelectrode Paste Deposition over FTO and Mesoporous Electrode Preparation	26 26
	4.1.3 QDs Synthesis Techniques, Sensitization of Mesoporous Electrode and Surface Treatment	20
	4.1.3 QDs Synthesis rechinques, Sensitization of Mesoporous Electrode and Surface Treatment 4.1.3.1 Hydrothermal Synthesis of QDs and In-Situ Sensitization	26
	4.1.3.2 Successive Ionic Layer Adsorption and Reaction Sensitization	20
	4.1.3.3 ZnS Surface Treatment for Sensitized Mesoporous Electrode	28
	4.1.4 Polysulfide Electrolyte Preparation	29
	4.1.5 Counter Electrode Preparation	29
	4.1.5.1 PbS/Pb Counter Electrode Preparation	29
	4.1.5.1 Cu2S/Brass Counter Electrode Preparation	29
	4.1.6 Assembling of Quantum Dot Sensitized Solar Cell (QDSSC)	29
4.2	Characterization techniques	29
	4.2.1 Structural Characterization and microstructural characterization techniques	29

4.2.1.1 X-ray Diffraction Characterization Technique	30
4.2.1.2 Scanning Electron Microscopy	31
4.2.1.3 Atomic Force Microscopy	32
4.2.2 Optical Characterization	33
4.2.2.1 Ultraviolet Visible Spectrometer	33
4.2.2.2 Fourier Transform Infrared Spectrometer	34
4.2.2.3 Fluorescence Spectrometer	35
4.2.2.3 High Resolution Transmission Electron Spectroscopy	35
4.2.3 Electrical Characterization	36
4.2.3.1 Photovoltaic Performance Characterization	36
4.2.3.2 Impedance Spectroscopy Characterization	36

Chapter 5: In-situ Hydrothermal Sensitization of Mesoporous Electrode

5.1	Introduction	39
5.2	Experimental Procedure	40
	5.2.1 Mesoporous Electrode Preparation	40
	5.2.2 Mesoporous Electrode sensitization and surface treatment	41
	5.2.3 Quantum Dot Sensitized Solar Cell Preparation	41
	2.2.4 Mesoporous Electrode and sensitized mesoporous electrode characterization	41
5.3 R	5.3 Results and Discussion	
	5.3.1 X-ray Diffraction Analysis	42
	5.3.2 Microstructure and Surface roughness analysis	42
	5.3.3 HR-TEM analysis of sensitized mesoporous electrode	44
	5.3.4 Optical characterization	45
	5.3.5 Photovoltaic characterization	46
5.4 C	oncluding Remarks	49

Chapter 6: Transition Metal Doping Investigation in TiO2/CdS

6.1	Introduction	51
6.2	Experimental Procedure	53
	6.2.1 Mesoporous TiO2/CdS Photoelectrode Preparation	53
	6.2.2 QDSSC Preparation and Characterization	53
6.3 Results and Discussion		53
	6.3.1 X-ray Diffraction Analysis	53
	6.3.2 Microstructure and Surface Roughness Analysis	54
	6.3.3 Optical Properties Analysis	56
	5.3.4 Photovoltaic Characterization of QDSSCs	56
6.4 (Concluding Remarks	60

Chapter 7: Zinc Titanate as a Photoelectrode Material for Quantum Dot Sensitized Solar Cells

		<i>.</i>
7.1	Introduction	61
7.2	Experimental Procedure	62
7.3	Results and Discussion	62
	2.2.1 X-Ray Diffraction Analysis	62
	2.2.2 Investigation of Electronic Properties of Zinc Titanate Nano Powder	64
	2.2.3 Investigation of Microstructural Properties of Zinc Titanate Electrode	65
	2.2.4 Investigation of Optical Properties of CdS Sensitized ZTO Electrode	66
	2.2.5 Investigation of Photovoltaic Properties of CdS/ZnS Sensitized ZTO Electrode	67
7.4	Concluding Remarks	69

Chapter 8: Limiting Efficiency of Quantum Dot Sensitized Solar Cells: A Detailed Balance Study

8.1	Introduction	71
8.2	Calculation of Ultimate Efficiency	72
8.3	Calculation of Ultimate Efficiency with Carrier Multiplication	73
8.4	Calculation of Detailed Balance Efficiency for QDSSCs	75
8.5	Calculation of Detailed Balance Efficiency for QDSSCs with Carrier Multiplication	77
7.4	Concluding Remarks	79

	Chapter 9: Conclusion	81
	Annexure A : MATLAB code for detailed balance study	
A.1	MATLAB Code to Generate Ultimate Efficiency in Ideal Case and Limited Ediff Case	83
A.2	MATLAB Code to Generate Staircase Internal Quantum Efficiency	84
	A.2.1 MATLAB Code for Unit Step Function	85
A.3	MATLAB Code to Generate Finite Slope Internal Quantum Efficiency	85
A.4	MATLAB Code to Generate Ultimate Efficiency with Ideal Voc and Finite Voc	86
	Approximation with Staircase Carrier Multiplication	
A.5	MATLAB Code to Generate Ultimate Efficiency with Ideal Voc and Finite Voc Approximation with Finite Slope Carrier Multiplication	88
A.6	MATLAB Code to Generate Photovoltaic Performance Parameter with Detailed Balance Consideration with Ideal Voc and Limited Voc Case	90
A.7	MATLAB Code to Generate Photovoltaic Performance Parameter with Detailed Balance Consideration with Ideal Voc and Limited Voc Case with Carrier Multiplication	92
-		

References