

بسم الله الرحمن الرحيم



HOSSAM MAGHRABY



شبكة المعلومات الجامعية

التوثيق الالكتروني والميكرو فيلم



HOSSAM MAGHRABY

جامعة عين شمس

التوثيق الإلكتروني والميكروفيلم

قسم

نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها
على هذه الأقراص المدمجة قد أعدت دون أية تغيرات



يجب أن

تحفظ هذه الأقراص المدمجة بعيدا عن الغبار

HOSSAM MAGHRABY



بعض الوثائق الأصلية تالفة



HOSSAM MAGHRABY



بالرسالة صفحات

لم ترد بالأصل



HOSSAM MAGHRABY

**THE EFFECT OF PREPARATION
PARAMETERS ON THE PROPERTIES
OF CdTe FILMS**

B/0400

THESIS
SUBMITTED IN PARTIAL FULFILLMENT
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
MATERIALS SCIENCE



BY
Eng. ABD EL-HADY BASHIR KASHYOUT
M.Sc. IN ELECTRICAL ENGINEERING

MATERIALS SCIENCE DEPARTMENT
INSTITUTE OF GRADUATE STUDIES AND RESEARCH
UNIVERSITY OF ALEXANDRIA

E.A. Nasser

M. Shalaby

2001

A handwritten signature, likely of the supervisor or a reviewer, located to the right of the student's name.

A handwritten signature, likely of the student, located at the bottom left of the page.

Supervised By:

Prof. Dr. Mahmoud Mohamed Shabana

Electrical Engineering Department

Faculty of Engineering

Alexandria University

Prof. Dr. Mohamed Abd Allah El-Gamal

Materials Science Department

Institute of Graduate Studies and Research

Alexandria University

Dr. Moataz Bellah Mohamed Soliman

Materials Science Department

Institute of Graduate Studies and Research

Alexandria University

ACKNOWLEDGEMENT

I kneel humbly to **ALLAH** thanking **HIM** for showing me the right path and helping me in my effort to achieve this work.

I wish to express my deep gratitude and thanks to **Prof. Dr. Mahmoud M. Shabana** for his valuable advises and keen guidance.

Deep thanks and sincere gratitude are extended to **Prof. Dr. Mohamed A. El-Gamal** who has devoted much of his precious time for supervising this work and careful reviewing of the thesis.

Sincere thanks to **Dr. Moataz M. Soliman**, for suggesting this research work, patient guidance and continuous encouragement. His help was invaluable in the fulfillment of this dissertation

Special thanks are due to **Ms. Manal Abdel Razek** and **Eng. Thana Khalid** for their technical help.

Finally, I wish to thank my wife for her patience and support.

List of Contents

	Page
List of Figures -----	VI
List of Tables -----	XIV
List of Symbols -----	XVI
Summary -----	XIX

CHAPTER I INTRODUCTION

1.1 General -----	1
1.2 CdS/CdTe Heterojunction Thin Film Solar Cells -----	2
Aim of the Work -----	6

CHAPTER II THEORETICAL ASPECTS OF CdS/CdTe HETEROJUNCTION SOLAR CELLS

2.1 Introduction -----	7
2.2 Heterojunction Energy Band Diagram -----	7
2.3 The Dark Current transport Mechanisms -----	11
2.3.1 Anderson Model -----	12
2.3.2 Modifications to Anderson Model -----	13
2.4 The Photogenerated Current Mechanism and Current Voltage Characteristics of Heterojunction Solar Cells -----	19
2.5 Calculation of Solar Efficiency -----	24
2.6 Junction Capacitance -----	27
2.7 Losses in CdS/CdTe Heterojunction Solar Cells -----	29

CHAPTER III LITERATURE REVIEW

3.1 Introduction -----	32
3.2 Electrodeposition of CdS/CdTe Solar Cells -----	32
3.2.1 Monosolar Inc. and University of California Experience -----	33

	page
3.2.2 AMETEK Experience -----	41
3.2.3 Australian Experience -----	42
3.2.4 The Czech Experience -----	45
3.2.5 CdTe Thin Films from Non-Aqueous Solvents	46
3.2.6 Theoretical Model for CdTe by Electrochemical Deposition -----	47
3.2.7 General Problems Concerning the Application of Electrodeposition Technique -----	52
3.3 Screen- Printing of CdTe/CdS Solar Cells -----	53
3.3.1 Introduction -----	53
3.3.2 Cell Fabrication -----	53
3.4 Close-Spaced Sublimation (CSS) of CdTe/CdS Solar Cells	55
3.4.1 Introduction -----	55
3.4.2 Cell Fabrication -----	57
3.5 Spraying Technique for CdS/CdTe Solar Cells -----	58
3.5.1 Introduction -----	58
3.5.2 Cell Fabrication -----	58
3.6 R.F. Sputtering for CdS/CdTe Solar Cells -----	60
3.6.1 Introduction -----	60
3.7 General Overview for CdS/CdTe Solar Cells -----	62

CHAPTER IV/ EXPERIMENTAL TECHNIQUES AND MEASUREMENTS

4.1 Introduction -----	65
4.2 Substrate Cleaning -----	65
4.3 Electrodeposition of CdS Thin Films from Organic Solvent -----	66
4.4 Electrodeposition of CdS Thin Films from Aqueous Solution -----	68

	Page
4.5 Electrodeposition of CdTe Thin Films -----	68
4.5.1 Cyclic Voltammetry Analysis of CdTe Thin Films -----	70
4.5.1.1 General -----	70
4.5.1.2 Reduction and Oxidation of Tellurium	71
4.5.1.3 Reduction and Oxidation of Cadmium	71
4.5.1.4 Reduction and Oxidation of CdTe	74
4.5.1.5 Effect of Bath Temperature on the Redox Process -----	76
4.5.1.6 Effect of Cd Concentration -----	79
4.5.2 Electrodeposition of CdTe Thin Films -----	79
4.6 Electrodeposition of ZnTe:Cu Thin Films -----	79
4.7 CdTe/CdS Solar Cell Fabrication Procedure -----	82
4.8 Characterization Techniques -----	82
4.8.1 Materials Characterization -----	82
4.8.1.1 X-Ray Structural Analysis -----	82
4.8.1.2 Composition and Morphology Analyses	83
4.8.1.3 Optical Measurements and Band Gap Calculations -----	83
4.8.2 Junction Characterization -----	85
4.8.2.1 Capacitance-Voltage-Frequency Measurements -----	85
4.8.2.2 Dark Current-Voltage Characteristics	85
4.8.2.3 Light Current-Voltage Measurements	87

CHAPTER V RESULTS AND DISCUSSION

5.1 Introduction -----	90
5.2 Materials Characterization -----	91
5.2.1 Characterization of CdS Thin Films Prepared	

	Page
Using an Aqueous Solution -----	91
5.2.1.1 Structural Analysis -----	91
5.2.1.2 Morphology and Composition Analyses	94
5.2.1.3 Optical Measurements -----	98
5.2.2 Characterization of CdS Thin Films Prepared	
Using an Organic Solvent -----	103
5.2.2.1 Structural Analysis -----	105
5.2.2.2 Morphology and Composition Analyses	105
5.2.2.3 Optical Measurements -----	109
5.2.3 Characterization of CdTe Thin Films Prepared	
by Electrodeposition -----	113
5.2.3.1 Structural Analysis -----	113
5.2.3.2 Morphology and Composition Analyses	124
5.2.3.3 Optical Measurements -----	132
5.2.4 ZnTe Thin Films by Electrodeposition ----	132
5.2.4.1 X-Ray Analysis -----	136
5.3 Device Characterization -----	136
5.3.1 The light Current-Voltage Characteristics	136
5.3.1.1 Effects of Cd&Te Ion Concentrations on	
Cell Performance -----	139
5.3.1.2 Effect of Heat Treatment on Cell	
Performance -----	139
5.3.1.3 Effect of CdCl ₂ Heat Treatment	142
5.3.1.4 Effect of Device Structure on Cell	
Performance -----	145
5.3.1.5 Effect of CdS Thin Films on	
Cell Performance -----	148
5.3.2 Junction Capacitance -----	151
5.3.3 Dark Current-Voltage Measurements ---	156

	Page
CONCLUSIONS -----	158
APPENDICES -----	161
REFERENCES -----	165

<u>List of Figures</u>	<u>Page</u>
Figure 2.1 Cross Section of n-Window/p-Absorber Heterojunction Solar Cell -----	8
Figure 2.2 Energy Band Diagram for a n/p Heterojunction; (a) Before and (b) After the Formation of an Abrupt Junction -----	9
Figure 2.3 Energy Band Profile of a n/p Heterojunction According to a) Anderson Model and b) Including Charged Interface States -----	15
Figure 2.4 Dolega Model of Junction Transport for n/p Junction ----	15
Figure 2.5 The Possible Loss Mechanisms in Real Devices -----	18
Figure 2.6 Schematic Representation of n/p Heterojunction Solar Cell under Illumination Condition -----	20
Figure 2.7 The Equivalent Circuit of the Solar Cell -----	26
Figure 2.8 Maximum Power, Current Density and Voltage for CdTe Cells and Estimated Magnitude of Primary Loss Mechanisms -----	30
Figure 3.1 Cathode Plating System for CdTe Thin Films -----	34
Figure 3.2 Current Density Vs. Cathode Voltage of Deposition to Control the Stoichiometric Condition -----	36

	Page
Figure 3.3 Structure of the Heterojunction Electrodeposited CdS/CdTe Photovoltaic Cell -----	38
Figure 3.4 Spectral Response of a Glass/ITO/CdS/CdTe/Au Device -----	40
Figure 3.5 Plots of Total Current Density Vs. Deposition with Cadmium Ion Activity as a Parameter -----	50
Figure 3.6 Potential-pH Diagram of CdTe in Aqueous Solution --	51
Figure 3.7 Schematic Representation of Screen Printing Process	54
Figure 3.8 Screen-Printed CdTe Cell Typical Structure -----	54
Figure 3.9 Schematic Diagram of the CSS Reactor -----	56
Figure 3.10 Schematic Diagram of R.F. Sputtering Process -----	61
Figure 4.1 Schematic Representation of the Circuit Used for Galvanostatic Deposition -----	67
Figure 4.2 Block Diagram of Typical Potentiostat System -----	69
Figure 4.3 Cyclic Voltammograms of Electrodeposition Bath of an Aqueous Solution (pH 1.6) Containing 2.5×10^{-4} M TeO_2 and Reversed at Different Potentials. -----	72