Effect of PECVD process parameters on structural transition of a-Si/µc-Si thin-film solar cell and its operational parameters

By
Heba Ragab Abd El-aaty Mohamed

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Metallurgical Engineering

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Effect of PECVD process parameters on structural transition of a-Si/µc-Si thin-film solar cell and its operational parameters

By
Heba Ragab Abd El-aaty Mohamed

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Metallurgical Engineering

Under the Supervision of

Prof. Dr.: Iman Salah El-din El-Mahallawi
Head of Mining, Petroleum, and
Metallurgical Engineering department Faculty
of Engineering
Cairo University

Prof. Dr. Madiha Ahmed Shoeib
Professor at surface treatment corrosion
Central Metallurgical Research and
Development Institute CMRDI

Dr: Osama Fouad Tobail
Researcher at Zewail City, Cairo

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Effect of PECVD process parameters on structural transition of a-Si/µc-Si thin-film solar cell and its operational parameters

By
Heba Ragab Abd El-aaty Mohamed

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
DOCTOR OF PHILOSOPHY
in
Metallurgical Engineering

Approved by the
Examining Committee

1. Prof. Dr.: Iman Salah El-din El-Mahallawi (Thesis Main Advisor)
Head of Mining, Petroleum, and Metallurgical Engineering department,
Faculty of Engineering,
Cairo University.

2. Prof. Dr. Madiha Ahmed Shoeib (Advisor)
Professor at Surface treatment corrosion Lab,
Central Metallurgical Research and Development Institute CMRDI.

3. Prof. Dr. Nadia Hussein Rafat (Internal Examiner)
Professor of Engineering Physics,
Faculty of Engineering,
Cairo University.

4. Dr. Yehia Mourad Mohamed Abdallah (External Examiner)
Head of Development Sector,
National Organization for Military Production

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer's Name: Heba Regab Abd El-aaty Mohamed
Date of Birth: 04/08/1984
Nationality: Egyptian
E-mail: eng_heba_ragab@yahoo.com
Phone: 01155109118
Address: 1st settlement, New Cairo

Registration Date: 01/10/2012
Awarding Date: …./…./2018
Degree: Doctor of Philosophy
Department: Mining, Petroleum, and Metallurgical Engineering
Supervisors:

Prof. Dr. Iman Salah El-din El-Mahallawi
Prof. Dr. Madiha Ahmed Shoeib
(Central Metallurgical R&D Institute (CMRDI))
Dr. Osama Fouad Tobail (Zewail City)

Examiners:

Prof. Dr. Iman Salah El-din El-Mahallawi
(Thesis Main Advisor)
Prof. Dr. Madiha Ahmed Shoeib (Advisor)
(Central Metallurgical R&D Institute (CMRDI))
Prof. Dr. Nadia Hussein Rafat (Internal Examiner)
Prof. Dr. Yehia Mourad Mohamed Abdallah (External Examiner) National Organization for Military Production

Title of Thesis:
Effect of PECVD process parameters on structural transition of a-Si/µc-Si thin-film solar cell and its operational parameters

Key Words:
a-Si/µc-Si thin-film solar cell; Silver nanoparticles; light trapping; structural transition from a-Si to µc-Si.

Summary:
In the first part of this work the Plasma Enhanced Chemical Vapor Deposition PECVD process parameters; namely dilution ratios and substrate temperature, were controlled to build i-layer at low dilution ratios with moderate substrate temperatures. An intrinsic layer was deposited on Indium Tin Oxide glass by PECVD technique, with different dilution ratios of silane in hydrogen and different substrate temperatures to study the transition from amorphous to microcrystalline phase. The Si:H thin film was evaluated by field emission scanning electron microscopy, x-ray diffraction and atomic force microscopy. The structural transition between a-Si:H to µc-Si:H was achieved at dilution ratio 13.3 and substrate temperature 250°C with surface roughness 22.5 nm. This condition was used to build a p-i-n junction. The second part of the work included using the p-i-n junction as a substrate and applying a silver nanoparticles layer by Physical Vapor Deposition (PVD) technique at different substrate temperatures. The microstructure and the morphology of the entire silver deposited a-Si:H/µc-Si:H p-i-n junction was studied by FESEM and atomic force microscope AFM. The performance of the a-Si:H/µc-Si:H solar cell was evaluated by current-voltage measurements and optical absorption. It was observed that PVD silver nanoparticles layer deposited at 200°C had a surface roughness of 88nm, which resulted an increase in the optical absorbance to 74% at 300nm wavelength with a cell efficiency of 7.38%.

ACKNOWLEDGMENT

My deep thanks to Allah who supported, guided and still supporting and guiding me to the right way.

Grateful acknowledgment is due to **Prof. Dr. Iman El-mahallawi** professor of Metallurgy Faculty of Engineering Cairo University suggesting the topic of this thesis and for much valuable guidance, useful advice, helpful suggestions, and discussion throughout the whole work.

I would like to express my gratitude to **Prof. Dr. Madihha Shoeib** head of Corrosion Control and Surface Protection Dept. at Central Metallurgical Research and Development Institute for her efforts, supervision, and valuable guidance throughout the whole work particularly during the experimental program and continuing encouragement.

I would also like to express my gratitude to **Dr. Osama Tobail** Lecturer, Faculty of Engineering, Zewail City, Cairo, Egypt- currently, and visiting researcher, Institute of photovoltaic for his efforts, supervision, and guidance throughout the experimental work.

I am very grateful to **Eng. Engy El-shazly** Renewable Energy Laboratory at **BUE** for supporting me during PV efficiency tests.

I wish to present, special word of gratitude and thank my family, especially to my parents, my father in law, brothers (**Mustafa, Walid**), sister (**Yasmin**) and my kids (**Nada, Adham**) for encouraging and pushing to complete this work.

Finally, my big thanks must be presented to my husband (**Eng. Ahmed**) for helpful suggestions, helping me in computer works, continuous encouraging and pushing to complete this work.

DEDICATION

I would like to thank and dedicate this thesis to my husband, Eng. Ahmed M. Fouad, and to my parents, who all have always supported me in my scientific work and whole life.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES