

R .

PERPUSTAKAAN UNIVERSITI MALAYA

ACI-1176
INVC. ms 19/11/99

**STRUCTURAL, ELECTRICAL AND OPTICAL
CHARACTERISATION OF CRYSTALLINE AND
AMORPHOUS SEMICONDUCTORS**

BY

VENGADAESVARAN S/O V.BALAKRISHNAN, B.Sc. (Hons)

**A dissertation submitted in partial fulfilment of the requirement for the
Degree of Master of Technology (Material Science)**

INSTITUTE OF POSTGRADUATE STUDIES AND RESEARCH

UNIVERSITY OF MALAYA

KUALA LUMPUR

MALAYSIA

1999

Perpustakaan Universiti Malaya



A509083718

Dimikrofiskan pada... 28.09.2000
No. Mikrofis... 14913
Jumlah Mikrofis... 3

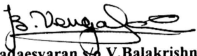
HAMSI AH BT. MOHAMAD ZAHARI

UPR
UNIT REPROGRAFI
PERPUSTAKAAN UTAMA
UNIVERSITI MALAYA

DECLARATION

I hereby declare that the work reported in this dissertation is my own
unless specified and duly acknowledged by quotation.

26 May 1999


Vengadaesvaran s/o V. Balakrishnan

ACKNOWLEDGEMENTS

First and foremost, my most sincere and profound appreciation to my supervisor, Dr. D.K. Roy and co-supervisor, Associate Professor Dr. Saadah Abdul Rahman for their instrumental role in assisting me to complete this dissertation. Their valuable guidance was an essential factor in the progress of my work.

A special word of thanks to Associate Professor Dr. Abdul Kariem Arof for his permission in allowing me to use the instruments in 'Pusat Asasi Sains'. My sincere thanks also goes to Professor Muhammad Rasat Muhammad for permitting me to use the Solid State Laboratory at the Physics Department. To my laboratory mates, Jacob, Mathi, Ramesh, Lim, Rajan, Anand, Shamim, Baharam, Sundar, Amin, Vicky, Bouzid and Sufian, I take great pleasure in extending my profound gratitude for all their assistance and I will treasure the moments we spent together working on our individual as well as common objectives. My gratitude also goes out to IRPA for the valuable financial aid provided which greatly contributed towards the successful completion of my dissertation.

I would also like to take this opportunity to thank my fellow friends and housemates, namely Raman, Terence Raj, Nantha, Stephen, Kapar, Selva, Gandhi, Prakash, Murali, Raghu, Rotu, Sivam, Mano, Rajesh, Mani, Jesu, Dass, Sashi, Shankar and others who had, in more ways than one, pitched in to assist me in my endeavour to complete this work.

My heartfelt thanks also goes out to Ms. Sagayamary and my sister, who have, in their own way, been instrumental in providing moral encouragement for my success.

Last but certainly not least, I owe a great deal to my parents who have toiled all these years to provide me with the right ingredients in making my life a successful one. I wish to take this opportunity to express my most heartfelt gratitude to them for all that they have done for me.

My final acknowledgement goes out to the One who has no finality. He has answered my prayers in many ways and blessed me with the faculties that has enabled me to achieve this success.

ABSTRACT

The objective of this project is to study the structural, optical and electrical properties of crystalline and amorphous semiconductors. The crystalline semiconductors studied in this work are Germanium and Silicon while thin film hydrogenated amorphous Silicon (a-Si:H) is the amorphous semiconductor studied. The crystalline Germanium and Silicon are grown commercially while the hydrogenated amorphous Silicon was prepared using a home-built horizontal d.c. plasma glow discharge system from a pure silane discharge. For the a-Si:H samples, two sets of samples prepared using different silane flow-rates are studied. These samples are also annealed at temperatures of 300⁰C and 500⁰C to study the effects of annealing on these properties.

The x-ray diffraction technique is used to confirm the crystallinity and amorphous nature of these samples. Fourier Transform Infra-Red Spectroscopy technique is used as a tool to determine the bonding configurations present in the a-Si:H film. The hydrogen content in the film is also determined from the infra-red spectrum of the a-Si:H film. The optical transmission spectrum in the ultra-violet to near infra-red wavelength region is used to determine the energy gap of the crystalline silicon while for the a-Si:H film, this spectrum is used to determine various parameters namely refractive index, film thickness, hydrogen content, optical energy gap and the Urbach tail band width. Alternating and direct-current conductivity measurements are carried out on both the crystalline and amorphous semiconductors studied. For the d.c. conductivity measurement the Four Point Probe technique is used on the crystalline Germanium while the normal current-voltage measurement technique is used on the crystalline Silicon and the a-Si:H samples. Variation

of capacitance and conductance with frequency measurement is used in the a.c. conductivity studies of these materials. The conductivity and the activation energy of the crystalline Silicon and a-Si:H are obtained from the d.c. conductivity measurements. The density of states of the a-Si:H film at the Fermi Level is determined from the a.c. conductivity measurement. The resistivity, the carrier density, the energy gap, the hole mobility and the activation energy of the crystalline Silicon and Germanium are determined from the d.c. conductivity and the Hall effect measurements.

The results of the characterisations done on the crystalline semiconductors show that the magnitudes of the above parameters determined are close to the standard values for these materials as reported in the literature. As for the a-Si:H samples studied, the results show that hydrogen plays an important role in the structural, optical and electrical properties of the film. However, it is not the hydrogen content in the film that determines these properties but the manner in which the hydrogen atoms are incorporated is the more dominant factor.

CONTENTS

Chapter I Introduction

1.1	Introduction.....	1
-----	-------------------	---

Chapter II Crystalline and Amorphous Semiconductors

2.1	Introduction	4
2.2	Crystalline Semiconductors.....	6
2.2.1	Band Structure of Crystalline Semiconductor.....	7
2.2.2	Electrical Properties.....	12
2.2.3	Optical Properties.....	20
2.2.4	Structural Properties.....	22
2.3	Amorphous Semiconductors.....	22
2.3.1	Band Structure of Amorphous Semiconductors.....	24
2.3.2	Electrical Transport Properties.....	27
2.3.3	Optical Properties.....	34
2.3.4	Structural Properties.....	38
2.3.5	The Role of Hydrogen Content and Dangling Bonds in Hydrogenated Amorphous Silicon.....	39

Chapter III Experimental and Calculation Techniques

3.1	Introduction.....	43
3.2	Characterisation of Crystalline Semiconductor.....	44
3.2.1	Electrical Characterisation of Crystalline Germanium.....	44
3.2.2	Electrical Characterisation of Crystalline Silicon.....	63
3.2.3	Optical Characterisation of Crystalline Silicon.....	68
3.3	Preparation of Hydrogenated Amorphous Silicon.....	70
3.3.1	Sample Preparation.....	70
3.3.2	Preparation of a-Si:H Sample.....	71
3.3.3	Optical Characterisation of a-SiH.....	72
3.3.4	Electrical Characterisation.....	79

3.4	Structural Investigation for Crystalline and Amorphous Semiconductor.....	87
3.5	Fourier Transform Infra-Red Spectroscopy for a-Si:H	90
3.6	Annealing Process.....	93

Chapter IV Experimental Results and Discussion

4.1	Introduction.....	95
4.2	Characterisation Results for The Crystalline Materials.....	96
4.2.1	Structural Characterisation Results for Crystalline Silicon	96
4.2.2	Optical Characterisation Results for Crystalline Silicon.....	97
4.2.3	Electrical Characterisation Results for Crystalline Germanium and Crystalline Silicon.....	98
4.3	Hydrogenated Amorphous Silicon.....	108
4.3.1	Preparation Condition of a-Si:H.....	108
4.3.2	FTIR Characterisation Results of a-Si:H.....	109
4.3.3	X-Ray Diffraction Results.....	116
4.3.4	Optical Spectroscopy Results.....	122
4.3.5	Conductivity Measurement on a-Si:H.....	134

Chapter V Analysis of Experimental Results

5.1	Introduction.....	143
5.2	Analysis of Crystalline Semiconductor.....	144
5.2.1	Analysis of Structural Characterisation Results.....	144
5.2.2	Analysis of Optical Characterisation Results for Crystalline Semiconductors.....	144
5.2.3	Analysis of Electrical Characterisation Results for Crystalline Semiconductors.....	145
5.3	Analysis on The Growth Rate of a-Si:H.....	149

5.4	The Effect of Annealing Temperature to the Thickness of a-Si:H.....	151
5.5	Analysis of Refractive Index Values.....	152
5.6	The Effect of Annealing Temperature on Polycrystalline Grain Size.....	154
5.7	Analysis of the Fourier Transform Infra-Red Spectroscopy Results.....	156
5.8	The Effect of Annealing Temperature on the R Parameter.....	159
5.9	The Effect of Annealing Temperature on the Density of States at the Fermi Level.....	160
5.10	Analysis of Activation Energy Results and the DC Conductivity.....	162
5.11	Analysis of Hydrogen Content in the a-Si:H.....	163
5.12	Optical Gap of a-Si:H.....	165
5.13	Analysis of the Urbach Tail Band Width.....	166
Chapter VI	Conclusion.....	168
Appendix A	Reference.....	173
Appendix B	Error Calculations.....	181
Appendix C	189