ELLIPSOMETRIC STUDIES OF SOME STRUCTURAL ASPECTS OF AMORPHOUS Si, Ge AND Ge-Se FILMS

By

SATYENDRA KUMAR

Department of Physics

Thesis submitted in fulfilment
of the requirements of the degree of

DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

OCTOBER, 1986

DEDICATED TO MY PARENTS

CERTIFICATE

I am satisfied that the Thesis entitled "Ellipsometric Studies of Some Structural Aspects of Amorphous Si, Ge and Ge-Se Films" presented by Satyendra Kumar is worthy of consideration for the award of the Degree of Doctor of Philosophy and is a record of the original bonafide research work carried out by him under my guidance and supervision and that the results contained in it have not been submitted in part or full to any other university or institute for award of any degree/diploma.

(Professor K.L. Chopra)
Head, Thin Film-Solid State
Technology Laboratory

DKPandya
27/10/81
(Dr. D.K. Pandya)
Assistant Professor

Department of Physics
Indian Institute of Technology, Delhi
New Delhi-110016 (India)

ACKNOWLEDGEMENTS

I take this opportunity to express my sincere gratitude to Professor K.L. Chopra and Dr. D.K. Pandya for their inspiring guidance, critical evaluation and continuous encouragement, which have greatly contributed towards the completion of this work. Their knowledge and experience have helped me to understand various aspects of thin films and amorphous semiconductors.

It is a pleasure to thank Professor I. Solomon and Professor J.P.M. Schmitt of Ecole Polytechnique, France, for the excellent environment and hospitality they provided during my stay in their Laboratory. Their counsel and encouragement have been invaluable. I also wish to record my gratitude to Dr. B. Drevillon for introducing me to the field of ellipsometry. The work on in-situ ellipsometry has been carried out with his advice and support.

This work has benefited immensely from the cooperation of all members of Thin Film Laboratory. In particular, I wish to thank Dr. L.K. Malhotra and Dr. G.L. Sharma for their availability and help on the glow discharge system. It has been a pleasure to be associated with Drs. R.C. Budhani, O.S. Panwar, K.S. Harshvardhan, K. Chidambaram, B.R. Mehta, G.B. Reddy, S. Major, A.N. Tiwari, P.K. Srivastava and Ms. Vandna Agarwal, and their help in various forms is gratefully acknowledged. I am thankful to my colleagues Mr. P.K. Gupta, Mrs. A. Uma, Ajay Agarwal, Ravi Rastogi, Sunil Kumar, B.M. Gupta, Mukesh Bhatnagar and Dr. R.D. Tarey for providing a pleasant company and extending their full cooperation whenever needed. The technical staff of our Laboratory has been very cooperative and I thank them for their help and support.

The members of Equipe Solaire, LPNHE and PMC Lab. of Ecole Polytechnique have been very helpful and supportive. I wish to acknowledge my association with Professor Gilles de Rosny, Drs. Antoni Lloret, Jean Huc and R. Vanderhaghen, and thank them for their cooperation. Dr. Jérome Perrin has been very helpful scientifically and personally. In particular, discussions with him on effective medium theories and plasma deposition have been very helpful. I thank Jérome and his wife Marie-Claude for their hospitality. Jean-Marie Siefert, R. Benfehrat, Anne Antoine, Pere Roca and C. Godet are thanked for providing a pleasant company and ready help.

I acknowledge with pleasure the helpful discussions with Professor M.L. Thèye of University of Paris and Dr. K. Vedam of Pennsylvania State University on optical properties and ellipsometry. Dr. O.P. Sharma of Centre for Atmospheric Sciences is thanked for useful discussions on statistical analysis.

Financial assistance of IIT Delhi and Department of Non-Conventional Energy Sources, and the French Foreign Ministry Scholarship under the Indo-French Scientific Collaboration are gratefully acknowledged.

I am also grateful to my parents and family members for their encouragement and support throughout my studies.

Finally, in the preparation of this manuscript, I am grateful to Mr. V.N. Sharma for his meticulous typing, Mr. N.S. Gupta for drafting the figures and my colleague, Sunil, for his help in compilation of this Thesis.

Kumar

(SATYENDRA KUMAR)

ABSTRACT

Spectroscopic Ellipsometry (SE) has been effectively used to study the microstructure and optical properties of non-crystalline Si, Ge and Ge-Se films deposited by different techniques. Computer programmes have been developed to analyze the SE data for a multilayer system and the real time ellipsometric data using nucleation and growth models. Linear regression analysis (LRA) and effective medium approximations (EMA) have been incorporated in this programme to study the microstructure (in terms of thicknesses of various layers and volume fractions of constituent phases) of a multilayer-multiphase system.

The growth process of glow discharge deposited hydrogenated amorphous silicon (a-Si:H) and microcrystalline silicon (μc-Si) has been studied using real time and spectroscopic ellipsometry. With increasing rf power and silane dilution in hydrogen, a gradual transition from good (dense) a-Si:H to a spongy material with large density deficit to a microcrystalline Si film is observed. The growth of μc-Si is found to be inhomogeneous and anisotropic in thickness. In-situ ellipsometry suggests the presence of crystallinity in the films from the beginning of μc-Si film growth. The results are explained in terms of a nucleation and growth model. The μc-Si is found to be a mixture of crystalline and amorphous silicon, and voids. The volume fraction of each phase has been determined using LRA-EMA analysis.

SE studies have yielded significant information on the microstructure and dielectric properties of evaporated amorphous Ge and Ge-Se films. It is shown that the SE can be used to characterize the obliquely deposited films. SE data analysis provided a quantitative determination of the density of obliquely deposited films. Biaxial anisotropy due to tilted columnar microstructure has been directly observed using SE.

In contrast to a single peak behaviour of tetrahedrally bonded amorphous semiconductors, the ε_2 spectra of amorphous Ge-Se films show a two peak structure which is a signature of the presence of a lone pair band in the electronic band structure of these materials. The dielectric function spectra of a-Ge-Se films in the interband transition region are found to be sensitive to photoexposure. The SE data suggest the presence of a Se rich surface layer on the photoexposed a-Ge-Se films.

CONTENTS