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Amorphous Silicon Semiconductors—Pure and Hydrogenated

Editors: A. Madan, M. Thompson, D. Adler and Y. Hamakawa

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These Proceedings are dedicated to the late

Professor David Adler

An outstanding Physicist, Colleague, Friend and

Symposium Co-chairman

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Preface

These proceedings contain the papers presented at the very successful symposium on Amorphous Silicon Semiconductors--Pure and Hydrogenated, held as part of the 1987 MRS Spring Meeting in Anaheim, Ca. The four day symposium focused on key issues in the science and technology of novel amorphous tetrahedrally bonded materials. The sessions were packed with attendees from early morning to late night.

In the opening remarks of the symposium, a short appreciation was given for Professor David Adler who unfortunately passed away on March 30, 1987. An outstanding scientist in this field, he served as one of the organizers of this symposium as well as previous symposia since 1985. We all appreciate the leadership and dedication that he provided in making this symposia series a success. He was loved and respected by us all. He will be truly missed in the field of physics and technology of amorphous semiconductors. We express our sincere sympathy to his family.

These proceedings contain detailed papers on the electronic structure of a-Si:H and related alloys. Electronic and optoelectronic properties in a-Si material are characterized by the existence of a large density mid gap states originating from unpassivated dangling bonds or defects in the amorphous network. Researchers are currently clarifying knowledge of electronic and optical processes of the mid gap states. With the help of various characterization techniques, such as DLTS (Deep Level Transient Spectroscopy), CPM (Constant Photocurrent Method), CTS (Current Transient Spectroscopy), MPS (Modulated Photocurrent Spectroscopy, etc.), they are investigating not only the energy locations of D_1 , D_2 and D^* states (or D^+ , D^0 , D^- and U_{eff}), but also their distributions. To proceed to the next step, however, researchers must address new questions on the microstructure and source of the dangling bond states related to the hydrogen diffusion, Si-Si bond breaking mechanism under the photo-stress, and thermal-energy perturbations. Also under investigation are hydrogen diffusion, the effect of annealing in the a-Si system, and carrier dynamics correlated with localized gap states in undoped and doped a-Si:H.

In the panel discussion, which was an innovative event for this symposium, present knowledge for various features of the DOS spectra was discussed by four panelists who reviewed "Microstructure and Hydrogen Diffusion," "Gap States Spectroscopies and Characterizations," "Impurity Related Processes," and "Stability on Photon Irradiation and Other Energy Perturbation."

It is evident from the many papers presented at the symposium and included in these proceedings that there are still many unresolved issues on film growth kinetics and atomic structure of a-Si alloys with regard to electronic and optical properties. Film quality improvement and growth rate are key elements in terms of commercialization. Plasma chemistry in gas phase reactions, effect of hydrogen dilution, and related surface reaction correlation of hydrogen with dopants were among topical issues. Reports included studies of local structure in hydrogenated amorphous silicon network with and without substitutional impurities conducted by NMR, ENDOR and Coherent Anti-Stokes Raman Spectroscopy, along with updates on new

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deposition techniques such as HR-CVD (Hydrogen Radical Enhanced CVD), ECR-CVD (Electron Cyclotron Resonance CVD) and CTL-CVD (Catalytic CVD).

In recent years, noticeable progress has been made in the development of the amorphous mixed alloys such as a-SiC, a-SiN, a-SiGe, and a-SiN as well as microcrystalline materials. All of these materials have considerably good valency electron controllability by doping with a substitutional impurity. Regarding a-Si-Ge alloys, the effect of hydrogen contents and the role of fluorine on the film quality were among highlight topics. Reports of comparative studies of structure and hydrogen incorporations in a-SiC were also included. The a-SiC alloy holds greatest promise in solar cell, photoreceptor and other optoelectronic functional device applications.

Current topics on the interface, heterojunctions and superlattices are included in this proceedings. Many issues on interface states, the mid gap states and also Schottky barrier contact in metal/a-Si alloy system are still unresolved. Heterojunctions in a-SiC/a-Si, a-Si/a-SiGe and a-Si/a-SiN are of great interest and importance in device applications. A remarkable recent trend in this field is that the superlattices in a-Si alloy system are becoming useful functional elements in device applications such as efficient wide gap window in solar cells, carrier injection electrode, and a new type of Schottky contact. A new fabrication technique of a-SiC/a-Si superlattice by PP & P (Pulsed Plasma and Photo-) CVD is postulated in this session.

Many papers in Parts VII and VIII are devoted to amorphous silicon solar cells which is one of the largest application device areas, already representing over one-third of the world photovoltaic market. Because of their potential impact on the module efficiency improvement for power application, R&D efforts have been centered on stacked solar cells utilizing various band gap materials such as a-Si alloys and polycrystalline thin films. Device physics considerations, optimum design concepts, material options for multijunction stacks, cell fabrication technologies and also photovoltaic system operation conditioning on two terminal and four terminal stacked solar cells were discussed. Speakers also reported on some new technologies for efficiency enhancements such as rough TCO contact, a bottom side barrier layer, and buffer layer in the stacked interfaces.

Light induced effects in a-Si and stability of a-Si solar cells are key issues in the development of photovoltaics. In the past few years an increased understanding of the electronic processes by light soaking and thermal annealing treatment has occurred. However, these effects involve the creation of deep metastable defects D* states after carrier recombination. Moreover, D* are very sensitive to the quality of i-layer film, which is basically related to the hydrogen content as well as the nature of the amorphous network. Some new results on changes in IR vibrational absorption by light soaking, light induced changes in the carrier drift mobility in a-Si:H and also its thermal annealing behaviors were presented.

Thin film transistors (TFT) are another extremely active field using a-Si technology devices. An advantage of uniform thin film deposition on large area substrates in a-Si:H is fully utilized on the development of integrated TFT and TFD (Thin Film Diodes). A series of technical issues, from device fabrication technologies and dynamic characteristics to application systems, are contained in Part VI. The key topical issues in material

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processing are plasma deposited a-Si:H, a-SiN, low temperature thermal oxidation of silicon dioxide, and contact metallization effects on metallization technologies. A new type of linear imaging sensor with 2560 picture elements in 8.5 inches in length (300 bits/inch) has been developed by an integration of PD (photodiode), TFT with multiplex circuit on a glass substrate. As regards the LC display devices, a full color TV picture quality comparable to CRT was realized by using integrated TFTs having 408X640X3 pixel elements with adequate uniformity and stability.

Papers on photoreceptors and other optoelectronic device applications are contained in Parts IX and X. Progress has been made in the development of electrophotographic receptors and other optoelectronic devices utilizing the wide area uniform deposition capability and carrier blocking layers. While our understanding of these photoreceptor structures has improved, several important issues remain to be clarified. Much attention and discussions were focussed on material combinations of back blocking layer, by p/i, n/i and heavily boron doped microcrystalline Si, etc. A high deposition rate technology of thick a-Si:H films for the photoreceptor production purpose was also demonstrated and its photoconductive properties with response time were discussed.

Researchers have proposed a wide variety of new functional device elements, such as an artificial neural network using binary synaptic connection of a-Si memory switching devices, a quantum device utilizing metal-nonmetal transition, etc. The successful emissions of visible light in a-SiC p-i-n junction and its improved brightness by an efficient carrier injector with heterojunction have attracted much attention. Scientists anticipate an innovative application field in OE-IC (optoelectronic Integrated Circuit) combined with a-Si alloy photosensors. Development of a high speed a-Si p-i-n diode is also of great interest for practical applications.

Finally, we the organizers, are grateful to all the sponsoring companies for their financial assistance to this symposium. All of the topical sessions proceeded in a stimulating atmosphere. The organizers were pleasantly surprised with the enthusiastic and positive response. We sincerely hope that the result of this symposium will contribute to the promotion of the science and technologies in this field. A similar symposium on amorphous silicon is scheduled for the 1988 MRS Spring Meeting.

Yoshiro Hamakawa
Arun Madan
Malcolm J. Thompson