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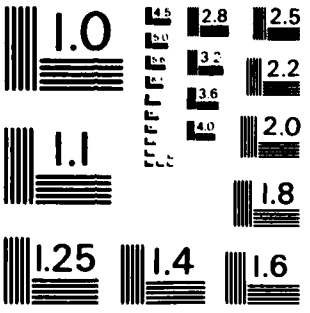

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ANNUAL TECHNICAL REPORT FOR THE GRANT NO. AFOSR-77-3426

For the Period

August 1981 - October 1982

Rensselaer Polytechnic Institute
Troy, New York 12181

by

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An alternative to Capacitance-Voltage (C-V) measurement is experimentally demonstrated. This technique measures the Transverse Acoustoelectric Voltage (TAV) as a function of applied D.C. voltage across the semiconductor. The technique is nondestructive and is applied to uniformly doped Si samples. Surface properties such as the flat band voltage, oxide charge and the zero bias surface condition are determined.

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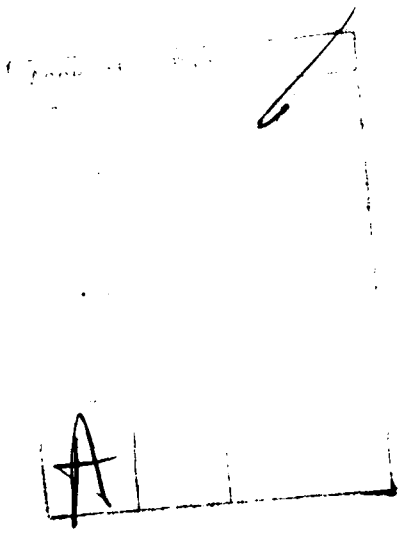
P.S. An annual interim report is being accepted as the Final report for AFOSR-77-3426. The technical effort is being continued for one year under AFOSR-82-0281. The Final report for this continuation will contain more overall detail and should be considered as the final report for the entire technical effort.



ABSTRACT

A surface acoustic wave (SAW) device has been developed under AFOSR Grant No. 77-3426 for use in the nondestructive determination of the electronic properties of semiconductors. The properties that can be determined by this technique include the bulk and surface conductivity, the location in the energy gap of traps, surface states, and interface states, trap emission and absorption times and storage times in the depletion layer. This characterization of the semiconductor could be performed at progressive stages of device fabrication thereby improving yield by identifying faulty processing steps. Preliminary investigations have been conducted on silicon, ion-implanted silicon, gallium arsenide, indium arsenide, gallium phosphide and cadmium sulfide. These are well documented by 20 papers and 14 meeting presentations as listed in the report. The technique uses surface acoustic waves on a piezoelectric substrate. The electric field associated with the SAW interacts with free carriers of a semiconductor placed near the piezoelectric surface. The interaction generates detectable currents in the semiconductor and attenuates the SAW. By observing these effects while varying external parameters such as temperature, applied acoustic power, SAW frequency, semiconductor surface irradiation and bias voltage, the desired information is obtained.

This report discusses the progress made in the last year.

1. INTRODUCTION

The research being carried out under this grant is directed toward the development of a technique for nondestructive determination of electrical properties of semiconductors using surface acoustic waves.

Recent developments in the field of semiconductor devices demand highly reliable material processing techniques. This, in turn, requires increased sophistication in monitoring the properties of the semiconductor during processing. For example, the diminishing size and increasing packing density necessary for silicon VLSI circuits places great importance on detection of impurities and defects in order to maintain high yield. As a second example, consider the high speed GaAs devices which are approaching the production stage. The high electron mobility in GaAs offers a significant improvement in operational speed for digital signal processing with anticipated clock rates of 10 GHz or more. Since GaAs is a direct gap semiconductor, laser diodes can be fabricated on it opening the way to single chip integration of signal processing and light source for optical transmission systems. But before these devices can be reliably produced with high yield, several material and processing obstacles must be overcome. Some of these problems may not be best solved by the conventional techniques employed for silicon.

It is projected that the use of the surface acoustic wave (SAW) technique can provide the energy location, concentration, capture and emission rates, and spatial distribution of energy levels within the bandgap of various semiconductors. Investigations have been performed on silicon, gallium arsenide, gallium phosphide, indium arsenide and cadmium sulfide. Because of the importance of GaAs, special emphasis is being given to anodically oxidized GaAs. The SAW technique can also be effective in

characterizing ion implanted semiconductors. Measurements can be performed which will detect the presence of the ion implanted layer near the semiconductor surface and its effective dose, lifetime, and conductivity. The effectiveness of annealing also can be monitored nondestructively.

Semiconductor testing using surface acoustic waves has the unique advantage of being contactless; there is no need to form a junction or apply a metal to the surface. It is possible to test the same sample after each processing step without disturbing the electrical or physical properties of the sample.

Significant progress has been made in the development of this nondestructive semiconductor evaluation technique using SAW in the last few years. In the last reporting year significant results have been obtained in the general area of contactless C-V measurements using SAW-semiconductor interaction. This is discussed in papers nos. 18 and 19 listed in the next section. As the papers 18, 19 and 20 are not yet published, they are included in this report.

LIST OF PUBLICATIONS RESULTING FROM THIS AFOSR GRANT

1. P. Das, R. T. Webster, H. Estrada-Vazquez and W. C. Wang, "Contactless Semiconductor Surface Characterization Using Surface Acoustic Waves", Surface Science 86, pp. 848-857, 1979.

2. R. T. Webster, H. Estrada-Vazquez, P. Das and R. Bharat, "Study of the Surface Properties of Thermally Oxidized Silicon Using Surface Acoustic Wave Attenuation", Solid State Electronics, Vol. 22, pp. 541-548, 1979.

3. P. Das, H. Estrada-Vazquez and R. Webster, "Transverse Acoustoelectric Voltage (TAV) Spectroscopy of High Resistivity GaAs", J. Appl. Phys., Vol. 50, pp. 4942-4950, 1979.

4. R. Bharat, P. Das, R. T. Webster and H. Estrada-Vazquez, "Contactless Measurement of Carrier Generation Rate in Semiconductors", Proceedings of the Topical Conference on Characterization Techniques for Semiconductor Materials and Science, pp. 93-105, 1978.

5. F. M. Mohammed Ayub and P. Das, "Spectroscopy of InAs Using SAW Generated Transverse Acoustoelectric Voltage", J. Appl. Phys., Vol. 51, pp. 433-436, 1980.

6. P. Das, "Transverse Acoustoelectric Voltage (TAV) Spectroscopy of Gallium Phosphide, Indium Arsenide and Cadmium Sulphide-Nickel Chloride", J. Vac. Sc. and Tech., Vol. 16, pp. 1379-1382, 1979.

7. P. Das, M. K. Roy, R. T. Webster and K. Varahramyan, "Nondestructive Evaluation of Si Wafers Using SAW", 1979 Ultrasonics Symposium Proceedings, IEEE Publication No. 79 CH 1482-9, pp. 278-283, 1979.

8. K. Varahramyan, R. T. Webster and P. Das, "Contactless Monitoring of Impurity Activation in Ion-Implanted Silicon by Surface Acoustic Wave Techniques", J. Appl. Physics, Vol. 51, pp. 1234-1237, 1980.

9. P. Das, H. Gilboa, K. Varahramyan and R. T. Webster, "Nondestructive Evaluation of Semiconductor Surfaces Using the Surface Acoustic Wave Convolver", Proceedings of the 14th Electrical Electronics Insulation Conference, IEEE Publication No. 79 CH 1510-7-EI, pp. 284-289, 1979.

10. P. Das, R. T. Webster and B. Davari, "SAW Characterization of Photo-Voltaic Solar Cell", Electrochemical Society Extended Abstracts, Vol. 79-1, Spring Meeting, Boston, MA, May 6-11, 1979.

11. B. Davari and P. Das, "The Study of the Effect of Growth Parameters on the Electrical Properties of the GaAs Oxide Layer Grown by Anodic Oxidation", Electrochemical Scoiety Extended Abstracts, Vol. 81-2, Fall Meeting, Denver, CO, October 11-16, 1981.

12. P. Das, S. N. Chakravarti and K. N. Bhat, "Characteristics of GaAs-Anodic Oxide Metal-Oxide-Semiconductor Solar Cells", J. Applied Phys., 52(3), 1605-1607, 1981.

13. S. N. Chakravarti, P. Das, R. T. Webster and K. N. Bhat, "CW Argon Laser Annealing of Anodic Oxide", J. Appl. Phys., 52(2), 1132-1133, 1981.

*14. B. Davari and P. Das, "A Study of the High Resistivity GaAs Surface and the GaAs/oxide Interface Using Two Beam Transverse Acousto-electric Voltage Spectroscopy", J. Appl. Phys. 3(5), May 1982, pp. 3668-3672.

*15. K. Varahramyan and P. Das, "Electrical Surface Properties of Semi-insulating and Ion-implanted GaAs Revealed by Thermo-optical Acousto-electric Voltage Method", Solid State Electronics, Vol. 25, No. 6, pp. 517-524, 1982.

*16. K. Varahramyan and P. Das, "Nondestructive Evaluation of GaAs by AEV Measurements", 1981 Ultrasonics Symposium Proceedings, IEEE Catalog No. 81-CH-1689-9, pp. 755-760, 1981.

*17. B. Davari and P. Das, "Quenching and Enhancement of the Exciton and Subbandgap Absorption in GaAs:CR Using the Two-beam Tranverse Acousto-electric Voltage Spectroscopy", Applied Physics Letters, 49(9) pp. 807-809, 1982.

**18. B. Davari, P. Das and R. Bharat, "Semiconductor Surface Characterization Using Transverse Acoustoelectric Voltage Versus Voltage Measurements", J. Appl. Physics, Jan. 1983, to be published.

**19. B. Davari and P. Das, "Profiling the Implanted Region in Si, Using Nondestructive Transverse Acoustoelectric Voltage vs. Voltage Technique", Proceedings of the 1982 Ultrasonics Symposium, to be published.

**20. M. Tabib-Azar, B. Davari and P. Das, "Study of the Effect of Anodic Oxidation on High Resistivity GaAs Surface States Using Two Beam Acoustoelectric Voltage Spectroscopy", to be published.

*Previously listed as to be published

**New papers in the last reporting period.

LIST OF PRESENTATIONS IN MEETING RESULTING FROM THIS AFOSR GRANT

1. P. Das, R. T. Webster, H. Estrada-Vazquez and W. C. Wang, "Contactless Semiconductor Characterization using Surface Acoustic Waves", presented at the International Conference on Solid Films and Surfaces, Tokyo, Japan, July 5-8, 1978.

2. P. Das, H. Estrada-Vazquez and R. T. Webster, "GaAs Surface Spectroscopy Using Surface Acoustic Waves", American Physical Society March meeting, Washington, May 21-26, 1978.

3. R. Bharat, P. Das, R. T. Webster and H. Estrada-Vazquez, "Contactless Measurement of Carrier Generation Rate in Semiconductors", presented at the 153rd Meeting of the Electrochemical Society, Seattle, Washington, May 21-26, 1978.

4. P. Das and R. T. Webster, "Transverse Acoustoelectric Voltage (TAV) Spectroscopy of Gallium Phosphide and Indium Arsenide", presented at the American Physical Society Meeting, March 19-23, 1979, Chicago, Illinois.

5. R. Bharat and P. Das, "Nondestructive Monitoring of Impurity Activation in Ion-implanted Silicon by Surface Acoustic Waves", presented at the Electrochemical Society Meeting, May 6-11, 1979, Boston, Massachusetts.

6. P. Das, M. K. Roy, R. T. Webster and K. Varahramyan, "Nondestructive Evaluation of Si Wafers Using SAW", presented at the Ultrasonics Symposium, New Orleans, Sept. 26-28, 1979.

7. P. Das, H. Gilboa, K. Varahramyan and R. T. Webster, "Nondestructive Evaluation of Semiconductor Surfaces Using the Surface Acoustic Wave Convolver", presented at the 14th Electrical/Electronics Insulation Conference, Boston, MA, October 8-11, 1979.

8. P. Das, "Transverse Acoustoelectric Voltage (TAV) Spectroscopy of Gallium Phosphide, Indium Arsenide and Cadmium Sulphide-Nickel Chloride", presented at the Conference on Physics of Compound Semiconductor Interfaces, Monterrey, California, Jan. 30-Feb. 2, 1979.

9. K. Varahramyan and P. Das, "Study of Electrical Activation in Ion-Implanted GaAs", presented at the American Physical Society Meeting, March 16-20, 1981.

10. B. Davari and P. Das, "The Effect of Growth Parameters on the Properties of the GaAs Oxide Layer, Grown by Anodic Oxidation", presented at the Electrochemical Society Meeting, Denver, Colorado, October 11-16, 1981.

11. K. Varahramyan and P. Das, "Nondestructive Evaluation of GaAs by AEV Measurements" presented at the IEEE Ultrasonics Symposium, Chicago, Illinois, October 14-16, 1981.

12. B. Davari and P. Das, "Evaluation of GaAs Interface States Using Two Beam TAV Spectroscopy, presented at the APS March Meeting, Dallas, TX, March 8-12, 1982.

13. B. Davari and P. Das, "Profiling the Implanted Region in Si Using Nondestructive Transverse Acoustoelectric Voltage Versus Voltage Technique", presented at the IEEE Ultrasonics Symposium, San Diego, CA, October 27-29, 1982.

14. M. Tabib-Azar, B. Davari and P. Das, "Study of the Effect of Anodic Oxidation on High Resistivity GaAs Surface States Using Two Beam Acousto-Electric Voltage Spectroscopy", to be presented at the New York Meeting of APS, 24-27, Jan. 1983.

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