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<p>The work constituted an initial part of a 3 year program on "Defect Engineering in GaAs.". This part realized at the Massachusetts Institute of Technology was terminated on October 14, 1989. The work was focused on the role of the EL2 defect and native shallow acceptors in the engineering of GaAs resistivity and thermal conversion characteristics. The program was interrupted by a transfer of the principal investigator (J.L.) to EE Department of the University of South Florida (USF)</p>			
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**Fundamental and Applied Aspects of Defect
Engineering in G2As; EL2 and Other
Nonstoichiometric Defects**

FINAL REPORT

Jacek Lagowski

January 24, 1990

U.S. Army Research Office

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Massachusetts Institute of Technology

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1. Forward

The work constituted an initial part of a 3 year program on "Defect Engineering in GaAs.". This part realized at the Massachusetts Institute of Technology was terminated on October 14, 1989. The work was focused on the role of the EL2 defect and native shallow acceptors in the engineering of GaAs resistivity and thermal conversion characteristics. The program was interrupted by a transfer of the principal investigator (J.L.) to EE Department of the University of South Florida (USF)

2. Results:

The project was initiated on February 15, 1989. In accord with the Statement of Work, our research was focused on the engineering of the EL2 defect in GaAs employing nonstoichiometric crystal growth and annealing rapid cooling treatments. We have completed a series of very high temperature annealing of Ga-rich samples at temperatures only about 10⁰C below the GaAs melting point. Prior to annealing, Ga-rich samples contained virtually no EL2 (below 10¹⁵ cm⁻³) and our experiments were designed to answer the question of whether EL2 can be formed via annealing in As-rich ambient.

Samples were characterized using the near infrared optical absorption in the range 2 to 0.8 mm (whereby characteristic optical transitions via the EL2 defect take place). Very high sensitivity measurements which included optical bleaching and thermal recovery cycling between 4K and 140K showed no EL2 absorption in (0); (1+) and (2+) states at a level exceeding 10¹⁵ centers/cm³. DLTS measurements of O/(1+) EL2 level (electron, trap) and 1+/2+ level (hole trap) yielded similar results. Therefore we conclude that EL2 is not formed in Ga-rich crystals even during 100 hours long annealing at 1300⁰C in As overpressure.

We have completed a detailed theoretical analysis of the engineering of GaAs resistivity. In the approach we used our refined empirical relationships between the concentration of a native EL2 double donor and the concentrations of native acceptors determined as a function of engineering parameters, namely, the growth melt stoichiometry and the crystal cooling rate. Residual carbon acceptors were also introduced in our model. The results show that all essential GaAs parameters, i.e., the resistivity value, the semiconducting-semi-insulating transition point, and the margin for heavy metal contaminants, could be controlled by controlling the arsenic atom fraction in the melt and/or the rate of crystal colling between 1000⁰C and 700⁰C. The results were presented at the Electronic Materials Conference in Boston, June 19-24, 1989, and they are under preparation for publication in the Journal of Applied Physics. Representative theoretical data are shown in the enclosed figure 1. They are an excellent agreement with experimental data.

Our experimental study indicated very important role of the native acceptor located at 68meV above the valence band. This single acceptor center becomes dominant under Ga-rich crystals. However the presence of 68 meV acceptor has not been documented by previous measurements. Accordingly we prepared a series of samples suitable for electronic Raman spectroscopy measurements. The measurements were performed by Dr. Wagner at the Fraunhofer Institute in Freiburg, Germany. Results confirmed the presence of 68 meV via observation of new 505 cm^{-1} Raman line corresponding to 1s-2s excitation. The strength of the line correlates with the acceptor concentration determined by us from DLTS measurements. Binding energies estimated from both measurements are also in good agreement. The results are being prepared for publication.

In addition to basic research involvement we have also performed service type tasks supplying unique ITC GaAs samples to other laboratories. A series of samples were prepared, and characterized for the Forth Momuth Laboratory researchers namely Mr. Burk (optical switching) and Dr. Poindexter (paramagnetic resonance study).

3. List of manuscripts submitted or published under ARO sponsorship during this reporting period, including journal references:

J. Lagowski, "GaAs vs. Si--Hopes, Challenges and Defect Engineering," presented at Int'l. Conference on the Physics of Semiconductor Compounds, April 25-29, 1989, Jaszowiec, Poland, to be published in Acta Physical Polonica.

K. H. Ko and J. Lagowski, "Reassessment of Native Compensation Mechanism in SI GaAs--The Role of Defect Engineering" presented at Electronic Materials Conference, June 19-24, 1989, Boston, Mass.

4. Scientific Personnel supported by this project and degrees awarded during this reporting period:

J. Lagowski--Principal Investigator
K.H. Ko--Postdoctoral Fellow
J. Di Maria--Engineering Assistant

NATIVE DEFECTS

DEFECT ENGINEERING OF SI-GaAs

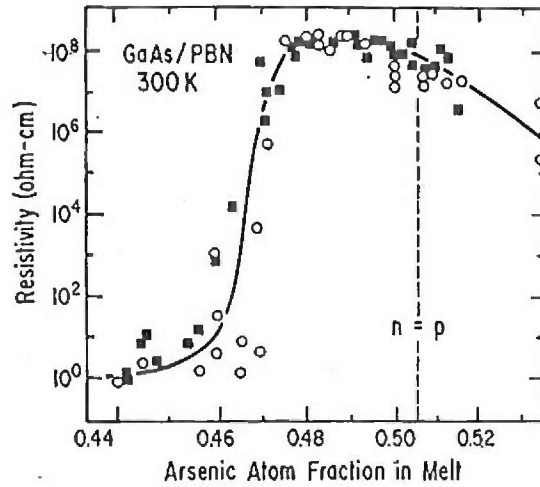
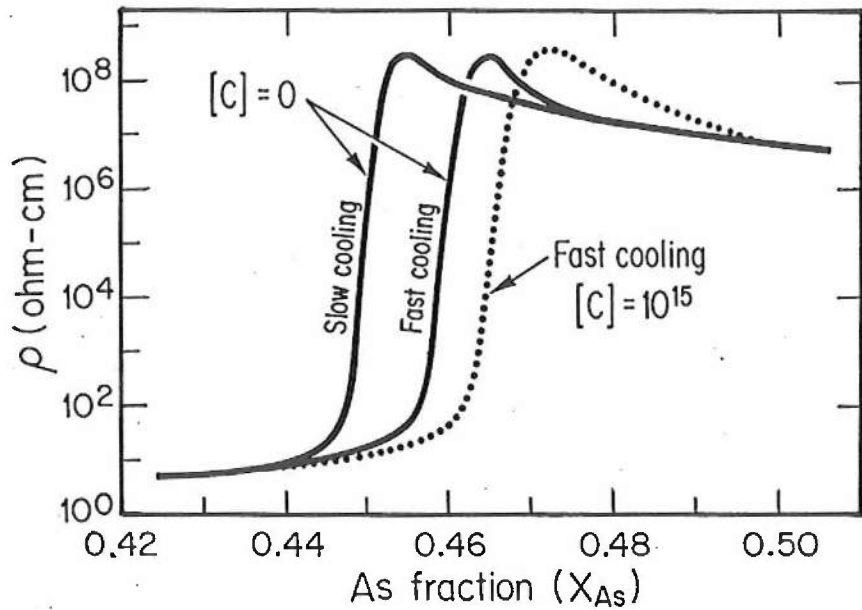


Fig. 1. Resistivity of undoped GaAs grown by the LEC method vs. Arsenic atom fraction in melt.: \blacksquare - results of Westinghouse group ; \circ - results of Rockwell group.



QUANTITATIVE MODEL FOR MELT GROWN
CRYSTALS INCLUDING: COOLING RATE AND
MELT STOICHIOMETRY

Fig. 1.