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REPORT DOCUMENTATION PAGE

Form Approved OMB NO. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE March 1996

3. REPORT TYPE AND DATES COVERED 1/1/95-12/31/95

4. TITLE AND SUBTITLE
Wide Band-Gap II-VI Compound Semiconductor Grown by MOCVD and its Applications to Blue Laser Diodes

5. FUNDING NUMBERS
DAAH04-94-G-0353

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Office
P.O. Box 12211
Research Triangle Park, NC 27709-2211

10. SPONSORING / MONITORING AGENCY REPORT NUMBER
ARO 32884.5-EL

11. SUPPLEMENTARY NOTES
The views, opinions and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

12a. DISTRIBUTION / AVAILABILITY STATEMENT

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13. ABSTRACT
We have spent a great deal of effect in GaN as well as in ZnSe due to the rapid and more promising development of GaN recently. We have performed intensive material study on GaN, such as DLTS, TSC, photocurrent spectroscopy, and x-ray, to understand its defect nature. The major achievements of last year's work in our laboratory can be summarized as follows.
(1) We are the first group to observe the transferred-electron effect in GaN. We observed a negative differential resistivity (NDR) in GaN under high electric field. The threshold electrical field was found to be around 1.91×10^5 V/cm. The NDR of GaN can be used in the application of high-temperature Gunn diodes.
(2) We have performed a systematic studies on GaN M-S-M ultraviolet detectors made from GaN grown by MOCVD under different NH_3 flow rates. We have found that a 0.62 eV deep trap which was attributed to gallium antisites or nitrogen vacancy-related defects was responsible for the low responsivity and the slow response time in GaN UV detectors. In addition, this 0.62 eV level can be effectively reduced by increasing the NH_3 flow rate during the MOCVD growth. As a result, a high-performance UV detector was fabricated on GaN of the lowest 0.62 eV trap. This detector has a responsivity as high as 3200 A/W under 5 V at a wavelength of 365 nm and improved response times in the sub-milliseconds range.

14. SUBJECT TERMS.

15. NUMBER IF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OR REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

DTIC QUALITY INSPECTED 1

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18
298-102

Annual Report to ARO

by Dr. J. C. Chen, Dept.of EE, UMBC

Both GaN and ZnSe based materials are wide-band-gap compound semiconductors ideally suited for devices in the visible-to-ultraviolet region of the spectrum. Laser diodes and LEDs have been successfully demonstrated using both materials. Due to the rapid and more promising development of GaN recently [1], we also spent a great deal of effect in GaN besides in ZnSe.

In order to grow GaN, we have to modify our MOCVD system. Since the growth temperature of GaN is much higher than that of ZnSe, we have to use a RF heater instead of an IR heater to reach more than 1000° C. A 7.5 KW RF heater has been installed and tested up to 1200C. In addition, we also obtained the "highest purity" ammonia from Solktronic Chemicals, Inc., (SCI, a major supplier of high-purity semiconductor industry gas). In the last few years, SCI has spent tremendous efforts in improving the purity of ammonia. Recently, the so-called "blue-ammonia" was purified by a special process and tested with <u>all impurities less than 50 ppb</u>. It has been shown that the impurities (especially oxygen and moisture) in ammonia is one of the major obstacles in the growth of high-purity GaN [2]. Through the long term coorporation between SCI and UMBC, SCI agreed to provide the first blue-ammonia to us free of charge. The study using blue-ammonia is now underway. We believe that some breakthrough can be achieved soon by using high growth temperatures and high-purity ammonia.

Moreover, we have performed several characterization techniques, such as DLTS, TSC, photocurrent spectroscopy, and x-ray, on our previous GaN samples to understand its defect nature. Some important results are listed below and some of them have been published or submitted to Applied Physics Letters or other journals. We have received a lot of requsts of our reprints from companies and research institutes worldwide.

Key discovery:

The major results of last year's work in our laboratory can be summarized as follows.

(1) We are the first group to observe the transferred-electron effect in GaN [3]. Figure 1 shows a current-electric field (I-E) curve of GaN using a metal-semiconductor-metal (MSM) structure. It clearly shows a negative differential resistivity (NDR) in GaN under high electric field. The threshold electrical field was found to be around 1.91×10^5 V/cm. The NDR of GaN can be used in the application of high-temperature Gunn diodes.

(2) In collaboration with NASA and the Applied Physics Lab. of JHU,we have performed a systematic studies on GaN M-S-M ultraviolet detectors made from GaN grown by MOCVD under

Annual Report of Scientific Accomplishments

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(3) The defects in GaN characterized by thermally stimulated current (TSC) spectroscopy and photocurrent spectroscopy also show interesting behavior [5].

(4) Besides the study of GaN, several studies related to other wide-gap materials were also performed [6-7].

Summary and future plan:

We have achieved some in-depth understanding of the defect formation on GaN using various characterization techniques. We also upgraded our MOCVD system and source materials during the period of this project. Based on these achievements, we will continue to optimize our GaN growth and doping study in the next step.

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Research work published under the support of Army Research Office:

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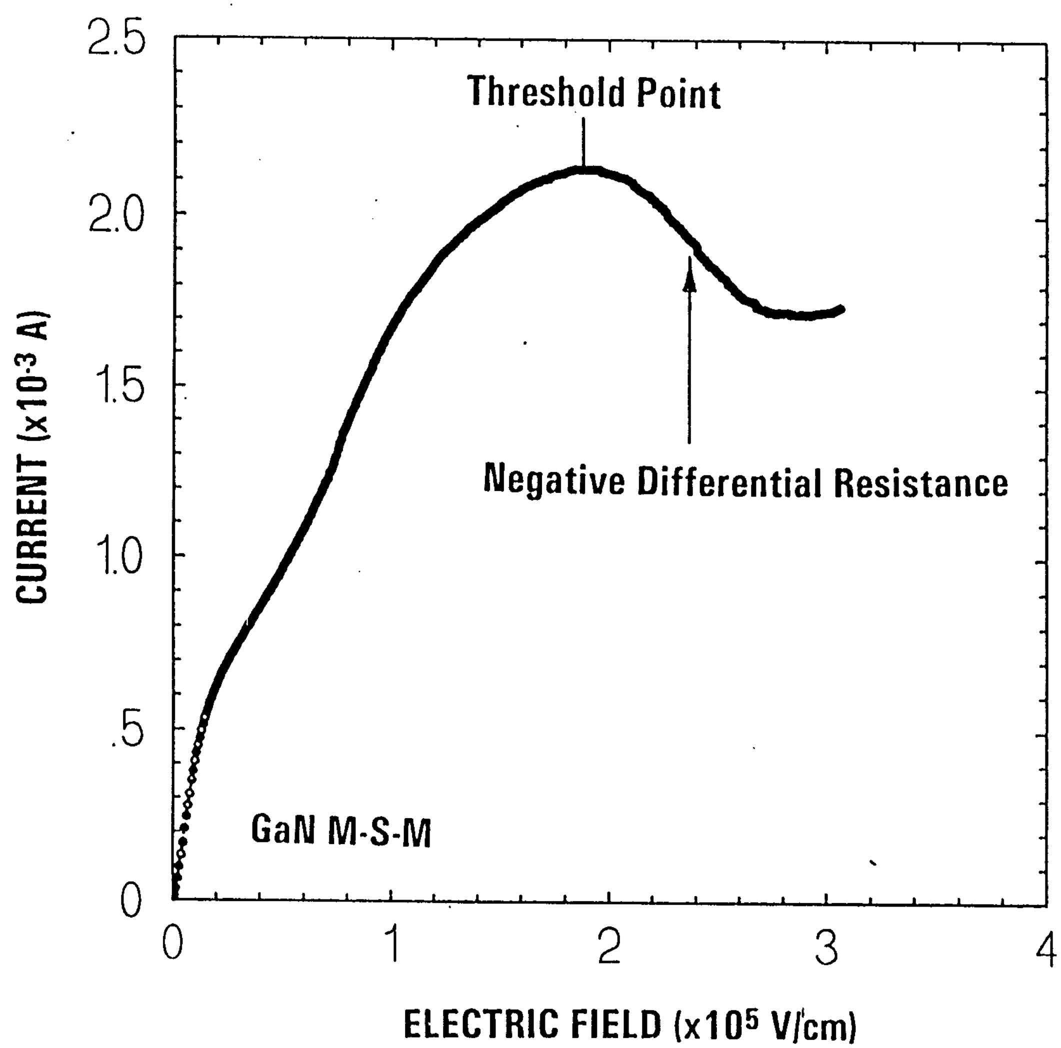

Figure 1. I-E curve at room temperature for GaN M-S-M system

Published in Appl. Phys. Lett. 67, pp. 2825 (1995)
by J. C. Chen et al. (support from ARO)

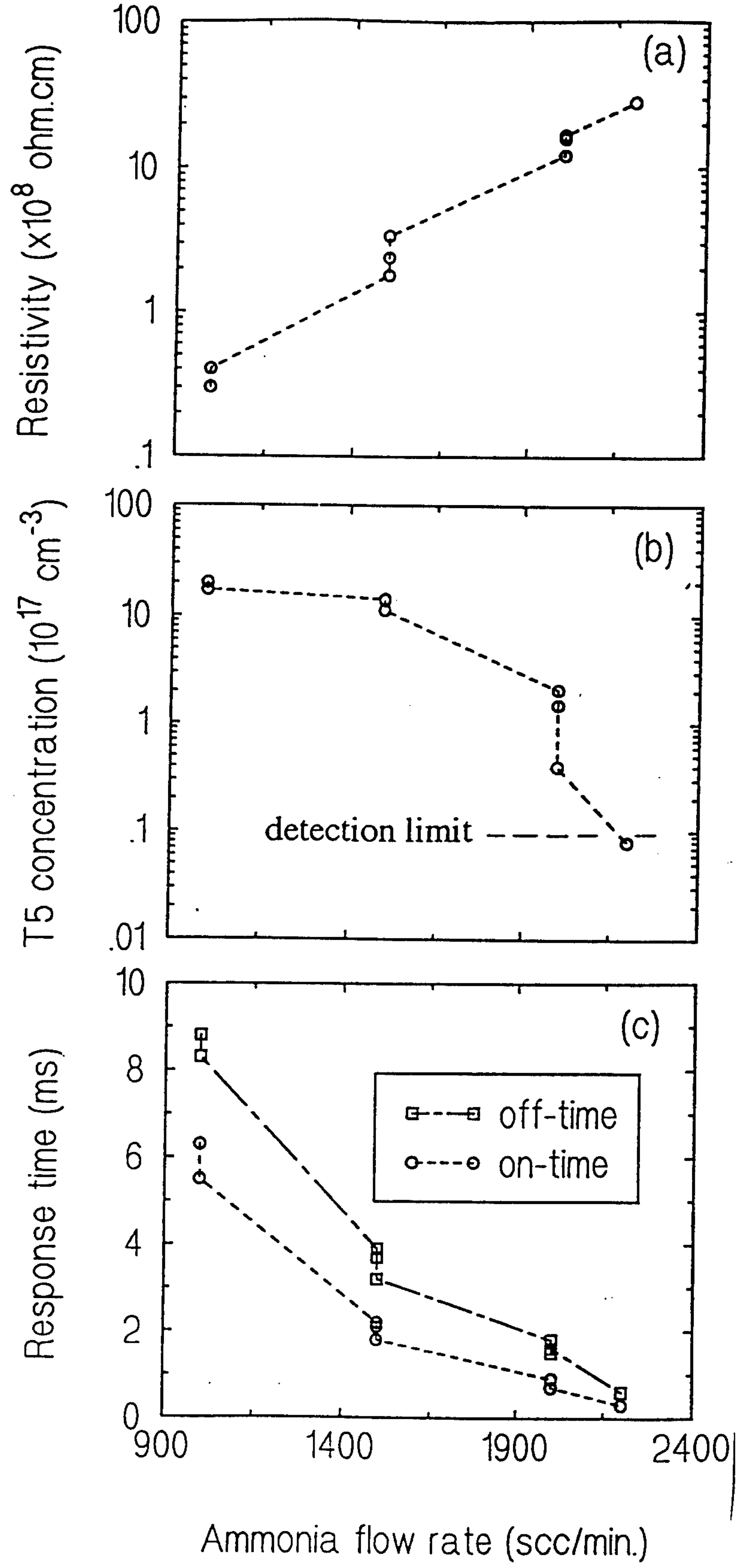

Figure 2. The measured resistivity, concentration of trap T5 and the response time as a function of NH_3 flow rate in GaN.

Submitted to Appl. Phys. Lett. (1996)
by J. C. Chen et al. (support from ARO)