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ELECTRONIC PROCESSES IN INP AND RELATED COMPOUNDS.(U)

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ELECTRONIC PROCESSES IN InP AND RELATED COMPOUNDS

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January 1980

Contract No. N00019-79-C-0533
Quarterly Progress Report
13 August 1979 through 12 December 1979

Prepared for:
NAVAL AIR SYSTEMS COMMAND
Washington, DC 20361

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
ELECTRONIC PROCESSES IN InP AND RELATED COMPOUNDS

5. TYPE OF REPORT & PERIOD COVERED
Quarterly Progress Report I
13 Aug 1979 - 12 Dec 1979

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
K.V. Vaidyanathan, C.L. Anderson, H.L. Dunlap
D.E. Holmes, and G.S. Kamath

8. CONTRACT OR GRANT NUMBER(s)
N00019-79-C-0533

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Hughes Research Laboratories
3011 Malibu Canyon Road
Malibu, California 90265

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Department of the Navy
Naval Air Systems Command
Washington, D.C. 20361

12. REPORT DATE
January 1980

13. NUMBER OF PAGES

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)

15. SECURITY CLASS (of this report)
UNCLASSIFIED

15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)
[redacted]
APPROVED FOR PUBLIC RELEASE;
DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Liquid phase epitaxy of InP
Ionization coefficient measurements

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
An experimental system to measure ionization coefficients in InP and related compounds is described. The growth of high purity liquid phase epitaxial InP is described and the properties of such layers discussed.

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1. INTRODUCTION AND SUMMARY

The major purpose of this research program is to study the electronic processes in InP and related compounds,to develop device structures suitable for making photocurrent measurements, and to analyze the bias dependence of the photocurrent to obtain the ionization coefficients of electrons and holes in these materials. Such measurements will be useful in the optimal design of avalanche photodiodes for optical communications systems.

During this reporting period, primary emphasis was placed on two areas. The first was to assemble experimental equipment for photoresponse measurements and the analysis of the photoresponse data. The second was doping level and morphology control in the liquid phase epitaxial growth of InP.

The calculator-based experimental system has been assembled and is described in detail. We have successfully grown high purity epitaxial layers with excellent morphology. We are presently investigating the growth of silicon doped n^+ epitaxial layers.

2. IONIZATION COEFFICIENT MEASUREMENTS

The noise and gain-bandwidth product limitations of avalanche photodiodes are strongly dependent on the ionization coefficients of electrons (α) and holes (β) in the material. These coefficients are obtained from a study of photocurrents. To obtain this information, it is necessary to achieve photomultiplied currents from pure electron and pure hole injection into the high field region of the device structure. In addition, the electric field variation in the avalanche region must be known accurately.

In our experimental system, we hope to accomplish the pure electron and pure hole injection by the absorption of either 0.638 μm or 1.152 μm radiation. Two stable He-Ne lasers, one capable of operation at 0.638 μm and the other at 1.152 μm provide the necessary illumination. Chopped light from the two lasers is focused onto optical fibers, labeled 1 and 2 in Figure 1. The two fibers are fused together in the middle, allowing

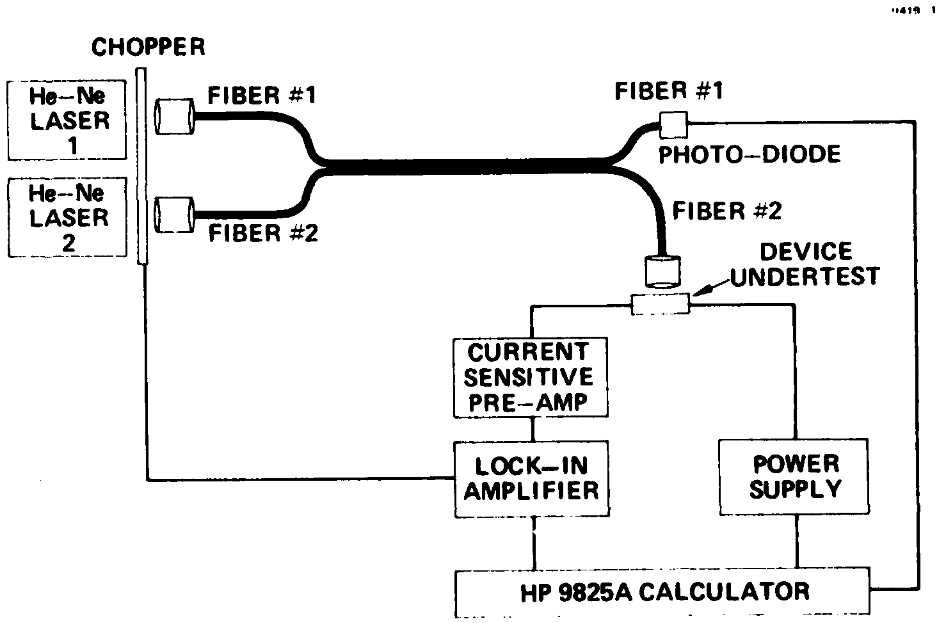

Figure 1. Schematic diagram of ionization coefficient measurement system.

coupling of radiation between the fibers. Approximately 50% of the radiation couples from fiber 1 to fiber 2 and vice versa. Radiation from fiber 1 is focused by a microscope objective onto the device structure, as shown in Figure 1. The radiation from fiber 2 is detected by a reference photodetector and provides a measure of the laser intensity incident on the test device at any given time. This feature will allow us to account for any fluctuations in the laser intensity during the time it takes to complete the measurement. The photo-induced currents will be measured by a current-sensitive preamplifier and a lock-in amplifier. The voltage applied to the device under test and the measurements will be controlled by a HP 9825A calculator. The system has been assembled and the interface between the calculator and the lock-in amplifier is being designed. The entire system will be available for measurements in early next quarter.

3. LIQUID PHASE EPITAXY OF InP

We have continued the growth of high purity InP epitaxial layers and have concentrated our efforts on achieving control over surface morphology. The high oxidation rate of InP at room temperature and the tendency toward thermal degradation of the material at the growth temperature make it necessary to carefully clean and prepare the substrate prior to growth. We have observed that by chemical/mechanical polishing the substrate in cold bromine-isopropyl alcohol, followed by an isopropyl alcohol quench, acceptable surfaces can be prepared. The epitaxial layers grown on such substrates exhibit acceptably smooth surfaces.

During the growth experiments, we have observed that by adding small quantities ($\sim$1 to 10 ppm) of water vapor to the growth ambient, the carrier concentration in the grown layers can be reduced to $\sim 2 \times 10^{15}$ cm^{-3}. Layers with reproducible electrical properties can be grown under these conditions. Typical layers exhibit room temperature mobilities of $\sim$4500 cm^2 V^{-1} s^{-1} and liquid nitrogen mobilities as high as $\sim$40,000 cm^2 V^{-1} s^{-1}. Low temperature photoluminescence analysis of the high purity samples show a narrow bandedge emission at $\sim$1.42 eV and absence of any donor-acceptor emission at $\sim$1.38 eV. The 1.38 eV emission band has been observed in samples which have carrier concentrations of $\sim 8 \times 10^{16}$ cm^{-3} grown from the same melt without water vapor addition.

During this quarter we have performed preliminary secondary ion mass spectrometry (SIMS) and Auger electron spectroscopy (AES) analyses of epitaxial layers grown with and without water vapor in the growth ambient. The data show that layers grown in the absence of water vapor exhibit considerable amounts of silicon in the grown layer ($\sim 1 \times 10^{17}$ cm^{03}). However, the samples grown in the presence of water vapor exhibit much lower silicon concentration ($< 2 \times 10^{16}$ cm^{-3}). The observations can be explained on the model that the quartz in the growth chamber is reduced by the hydrogen ambient, resulting in silicon doping of the solution. In the presence of small amounts of water vapor, the reduction of quartz is suppressed, thus resulting in a purer solution.

During this quarter, we have also investigated the growth of heavily doped InP layers. Several layers with donor concentration of $\sim 1 \times 10^{18}$ cm^{-3} have been grown with excellent morphological control.

4. PLANS FOR THE NEXT QUARTER

During the next quarter, we will investigate the growth of high purity layers and the growth of lightly doped p-type layers by adding Be to the solution. The interface between the lock-in amplifier and the HP9825A calculator will be completed early next quarter. Preliminary photoresponse measurements will be carried out on Schottky barrier structures on lightly doped p-type bulk InP.

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