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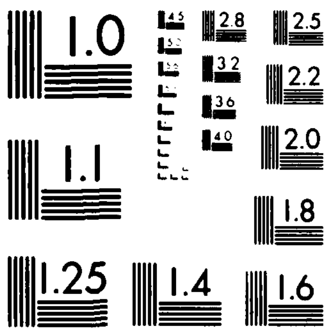

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Experimental work this past year was primarily directed toward enhancing the growth and characterization capabilities of the PI's laboratory. Significant improvements were completed on the MBE system and the in-situ ellipsometry apparatus was demonstrated in a bread board setup. Theoretical work consisted of preliminary Monte-Carlo investigation of the MBE growth III-V compounds. Extensive progress was made on modeling the phase separation occurring during growth of Al(x)Ga(1-x)As on (110) GaAs. A mismatch induced, strain dependent exchange reaction between Al and Ga was shown to give long period variations in the Al concentration. The specific predictions of the theory will be tested in a collaborative effort with JPL.

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Status Report

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Some Investigations of Molecular Beam Epitaxial Growth of III-V Semiconductor Films via Monte-Carlo Computer Simulations, Carrier Tunnelling and Spectroscopic Ellipsometry

AFOSR Contract #F49620-83-C-0074

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Date: Feb. 15, 1984

Introduction

The research sponsored under AFOSR contract #F49620-83-C-0074 began on April 15, 1983. The anticipated plan of the work during the first budget year involved primarily

(a) Spectroscopic Ellipsometry studies of MBE grown GaAs/$Al_xGa_{1-x}As$(100) and GaAs/$In_xGa_{1-x}As$(100) structures in the visible to UV range.

(b) Extending the ellipsometry wave length region from 8000Å to 2.2 μm (i.e. covering the visible to near IR range).

(c) Carrying out C-V and tunnelling measurements on the GaAs/$Al_xGa_{1-x}As$/GaAs structures at the JPL Electrical Measurements Laboratory while establishing the same capabilities at USC.

(d) Studying the phenomena of surface orientation induced "miscibility gap" in the MBE growth of $Al_xGa_{1-x}As$ alloys on GaAs(110).

(e) Carrying out Monte-Carlo computer simulations of GaAs/$Al_xGa_{1-x}As$(100) and (110) MBE growth.

The GaAs/$Al_xGa_{1-x}As$ MBE samples, appropriate for the experimental investigations noted under (a), (c) and (d) were to be grown under the supervision of Prof. M. Gershenzon. The GaAs/$In_xGa_{1-x}As$(100) systems were to be grown at the JPL MBE facility as a collaboration between the principal investigator (A. Madhukar) and Dr. F. J. Grunthaner of JPL.

Progress

(I) MBE Growth of GaAs/$Al_xGa_{1-x}As$

From the time of the inception of this work, it became clear at a relatively early stage that the USC MBE facility required major effort and investment to be able to grow reliable samples. In an effort to achieve this aim, the principal investigator (A. Madhukar) was forced to take responsibility of the MBE growth as well - a situation not originally anticipated. Accordingly, from July, 1983 until December 1983, major effort was spent making the USC MBE machine operational and putting in place basic support facilities (such as substrate cleaning and preparation). The situation with regard to the MBE machine thus, unfortunately, deprived us of appropriate GaAs/$Al_xGa_{1-x}As$ samples to be able to proceed with the experiments noted under (a), (c) and (d). We did, however, grow a few $GaAs/Al_xGa_{1-x}As/GaAs$ tunnelling structures around April/May 1983, had them fabricated into actual tunnel structures, and carried out Fowler-Nordheim resonance tunnelling experiments at JPL. The results indicated that the interfacial quality of these structures were rather poor. Indeed, these findings were at the base of the principal investigator taking on the additional responsibility of implementing the MBE growth program as well.

The following major items have to-date been accomplished on the MBE machine:

1. Detecting and fixing leaks.

2. Fixing cryopump, quadrupole mass analyzer, RHEED gun and screen.

3. Redesigning source-oven thermocouple arrangement to achieve stable temperature control and the attendant control on flux.

4. Redesign the pumping system and configuration on the growth chamber. Implementation of the design to be effected over the next few months.

We have, during the past month, grown GaAs samples with a view towards calibration of fluxes, substrate temperature (via usage of eutectic alloys and IR pyrometer) and to obtain an idea of the unintentional background doping type and level. Hall measurements indicate the samples to be p-type GaAs with doping levels between $1 - 5 \times 10^{15}/cm^3$.

We are now preparing to begin growth of $Al_xGa_{1-x}As$ single interface structures on both GaAs(100) and GaAs(110) surfaces so as to begin the experimental studies noted under (a), (c) and (d).

(2) Spectroscopic Ellipsometry

(a) Preliminary investigations of $GaAs/In_xGa_{1-x}As$ single alloy layers, grown on the JPL MBE system, have been carried out. some results have also been obtained on GaAs/InAs strained layer superlattices with individual layer thicknesses corresponding to 4 and 8 atomic layers each. Systematic investigations of the comparison of the alloy and superlattice optical behaviour are in progress.

(b) The ellipsometry instrumentation was extended into the near IR regime and testing of the system begun.

(3) Surface Orientation Induced Miscibility Gap: The $GaAs/Al_xGa_{1-x}As(110)$ System

In the absence of reliable MBE samples we spent time fruitfully developing a theoretical model which postulates a possible mechanism for the reported quasi-periodic fluctuations in the Al concentration along the growth direction. The basic physical idea is that a lattice-mismatch induced strain dependent exchange reaction between Al and Ga, coupled with the strain-memory effect, can give rise to long range periodic variations in the Al concentration. This is a totally kinetic and new mechanism which does not involve bulk diffusion - the process responsible for the spinodal decomposition mechanism of phase-separation. Our theory makes specific predictions for the behaviour of the alloy as a function of concentration, etc. which can be tested by the planned experiments.

(4) Electrical Measurements

Setting up C-V and tunnelling measurements capability at USC is underway and expected to be finished in the next few months. The Hall mobility measurements facility has been in operation and several measurements as a function of temperature down to 4.2K have been made.

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