Study of the Properties of GaAsSbN/GaAs Quantum Wells Heterostructures for Opto Electric Device Application

Principal Investigator
Prof. Shanthi Iyer
North Carolina A&T State University, Greensboro

W911NF0410025

11/01/03 to 10/31/05
Research Proposal

This proposal will address a continuation of work on GaAsSbN system. As this system contains three anions the incorporation of these three elements is highly interdependent. This dependence is not well known. Hence we propose to carry out a detailed and systematic study of the growth conditions of GaAsSbN/GaAs and accurate determination of the growth alloy composition in the strained QW to determine the exact dependence of the band gap reduction on N composition as a function of the host alloy composition. The other focus of the study will be the determination of the physical parameters such as the mass parameters of the valence and condition band from magneto-luminescence spectroscopic studies. During the second year our emphasis will be on fabricating a suitable optoelectronic device structure using this system. In the following we briefly our plan of study.

A. Detailed and systematic study of the growth conditions

• An accurate determination of the alloy composition will be carried out using various characterization and techniques, namely simulation of the high resolution x-ray diffraction (HRXRD), PL and RBS (SIMS blue ). PBS(SIMS blue ) will provide independent measurements of Sb which then can be used to determine the N composition form the x-ray and PL data. ←Completed→

• Variation of band gap reduction with N composition for two host alloy composition namely for Sb composition of ~10% and ~33%. ←Completed→
Research Proposal (Continued)

• Annealing studies of growth chamber under As overpressures, and ex-situ nitrogen will be carried out. Annealing temperature in the 600-800°C will be investigated. ←Completed→

B. Determination of the mass parameters of the condition and valence bands of the carrier using magneto optical PL techniques. ←In Progress→

• Development of appropriate theoretical models to interpret the experimental data. ←In Progress→

• Transmission electronic microscope will be used to determine the quality of the interfaces in GaAsSbN/GaAs and evidence of any clustering at higher N concentration. ←In Progress→

• Atomic force microscopy for surface morphology, and infrared absorption measurement for the band gap. (At this point no plan of completion)

• Photo-reflectance measurements will be carried out to determine the band offset. (No plan of completion)

• X-Ray Photo electron Spectroscopy (XPS) will be performed to demonstrate the successful incorporation and bonding configuration of nitrogen. ←In Progress→
Research Proposal (Continued)

C. Fabrication of the broad area edge emitting laser structure LED and following characterization is carried out. In Progress and will be the major focus of the current year.

• Lasing wavelength as a function of temperature
  ➢ Characteristic temperature of the laser
  ➢ Threshold current density as a function of temperature
  ➢ Output power/facet as a function of drive current
  ➢ Peak threshold modal gain as a function of threshold current density.

• Internal efficiency losses measured from inverse slope efficiency as a function of resonant length.
# Schedule and Milestones

## Project Period # 1

<table>
<thead>
<tr>
<th>First Half of the period</th>
<th>Second Half of the period</th>
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<tbody>
<tr>
<td>Continuation of the current project: systematic and detailed investigation of N incorporation in GaAsSb epilayers on GaAs, optimization of growth conditions. ←<strong>Completed</strong>→</td>
<td>Magneto PL and photoreflectance studies. ←<strong>Completed</strong>→</td>
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<tr>
<td>Variation of the band gap with N concentration and accurate determination of the alloy composition. ←<strong>Completed</strong>→ Annealing studies ←<strong>Completed</strong>→</td>
<td>Detailed and systematic in-situ and ex-situ characterization of the heterostructures. ←<strong>Completed</strong>→</td>
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<tr>
<td>Necessary theoretical modeling ←<strong>In Progress</strong>→</td>
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## Schedule and Milestones Continued

### Project Period #2

<table>
<thead>
<tr>
<th>First Half of the period</th>
<th>Second Half of the period</th>
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<tr>
<td>Growth of the strained QW structure for the devices fabrication of the device.  (\text{←In Progress→})</td>
<td>Continued fabrication of the device.</td>
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<tr>
<td>Necessary theoretical modeling.</td>
<td>Device characterization.</td>
</tr>
<tr>
<td></td>
<td>Necessary theoretical modeling.</td>
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Publications & Presentations

Paper Published:

Paper Presented at Meeting:

Jia Li, Sudhakar Bharatan, Kalyan Nunna, Liangjin Wu, Shanthi Iyer, K. Bajaj, “Carrier localization in GaAsSbN/GaAs Quantum Wells” Presented at MRS Fall Meeting 2003, Boston. Ma


From the Previous Grant


Liangjin Wu, David Jones, Jia Li, Sreenivasa Kothamasu and Shanthi Iyer “A study of low melting temperature interlayers for strain relaxation”,” APS March Meeting, Austin, TX, March 3, 2003
Publications and Presentations (Continued)

Manuscripts submitted:

Jia Li, Shanthi Iyer, Sudhakar Bharatan, Liangjin Wu, Kalyan Nunna, Ward Collis, K. Bajaj, Kevin Matney, and Greg Duscher
“Annealing Effects on the Temperature Dependence of the Photoluminescence of GaAsSbN Single Quantum Wells”- has been return from J. Appl. Phys. to provide a better explanation of the observed experimental data. Will be submitted 2nd week of December.

Gradsuates Undergraduates and Collaborators

Name of Graduate Students:
Liangjin Wu (Ph. D. candidate) “MBE Growth and Properties of GaAsSbN/GaAs Single Quantum Wells”
Kalyan Nunna (Ph. D. candidate) “Effects of N incorporation in GaAsSbN/GaAs Single Quantum Wells and their Application in LED”
Sudhakar Bharatan (Ph. D. candidate) “Study of GaAsSbN Alloys For Solar Cell Application”

Names of Student receiving Masters:
Sreenivasa Kothamasu, “X-Ray Diffraction Study of GaAsSb/GaAs and GaAsSbN/GaAs Quantum Well Hestrostucture”, November 2003

Names of Post Doctorates:
Dr. Jia Li
Names of Undergraduates Students:

Travis Chambers
Erin Woolridge
Renee Styron
Paul Stan
David Jones (Winner of NC Space Grant Consortium Scholarship) ← Under Previous Grant →
David LeClair (Winner of MRS – Undergraduate Materials Research Initiative) ← Under Previous Grant →

Collaborators:

Dr. William Mitchel (Air Force Laboratory) – Provided additional $25,000 for this grant
Dr. Ward Collis, North Carolina A&T State University
Dr. Kevin Matney, Bede Scientific Inc
Dr. K. Bajaj, Emory University
Dr. X. Wei, National High Magnetic Field Laboratory, Tallahassee
Dr. John Muth, NCSU
Mr. Fred Stevie, NCSU
Dr. Ralph Dawson, University of New Mexico

Technical Review Meeting Dec. 2, 2004
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Undergraduate Students

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http://www.ece.ncat.edu/research/mbe
Financial Status

Funding anticipated for this project
$3,25,000.00

Funding granted for this project
$1,60,000.00

Current balance
$34,000.00

Funding starts in mid semester
Cannot be used for students and Faculty
Problems with MBE for the last five months

- Replenished the sources in June
- Replaced the flux monitor filaments
- Beryllium fell out of the crucible
- Replaced the Be again
- Substrate temperature reading was erratic - recalibrated the pyrometer sensitivity after cleaning the window
- Gallium shutter was broken - replaced
- Arsenic flux was not appropriate - leak was detected in the water cooling jacket of the As bulk.
Current commercial display technology:
• Manufactured on glass substrates
• *Problem:* significant protection from damage
  ➔ adds weight and cost to the electronic components.

Alternative technology:
• OLED-based displays on flexible substrates
• *Problem:* highly impaired by the environmental sensitivity of the organic materials
  ➔ do not perform well when exposed to air and moisture.

Innovative Flexible Display Technology:
• Novel hybrid light-emitting device (HLED)
  ➔ combine the benefits of organic and inorganic materials.

Application: To enable a superior display technology for mobile electronics, vehicle-based communications and weapons systems required by Future Force Warrior (FFW) for U.S. Army.