

MBE Growth of Quaternary AlGaAsSb/InGaAsSb Heterostructures for Tunable Lasers with 2.2-2.6µm Emission Wavelength



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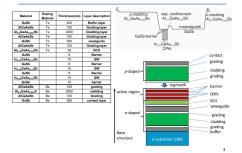
Overview

This poster details the development of growth of the III-V semiconductor materials to be used for realization of the multiple quantum well lases designed to emit between 2.2-2.6 μ m. Thin films and heterostructures from the 'quaternary' In $_{x}$ Ga $_{[1:x]}$ As $_{y}$ Sb $_{[1:y]}$ and Al $_{x}$ Ga $_{[1:x]}$ As $_{y}$ Sb $_{[1:y]}$ material systems were grown by molecular beam epitaxy (MBE) at UCSB and characterized by reflection high energy electron diffraction (RHEED), optical microscopy, atomic force microscopy (AFM), X-ray diffraction (XRD), and photoluminescence (PL). Once satisfactory results were obtained from calibration growths and test structures, full p-n diode laser structures were grown according to the designs outlined below. These preliminary results are the first step towards development of sampled grading DBR lasers which to our knowledge have not been demonstrated using this material system.

Objective

- The objective of this project is to fabricate sampled grading DBR lasers with full tenability between 2.2-2.6μm
- ➤ Three different laser structures are to be used to accomplish this
- The 2.6 μm emitting design shown makes use of InGaAsSb QWs with GaSb barriers
- Designs centered at 2.2 μm and 2.4 μm make use of InGaAsSb QWs with AlGaAsSb barriers

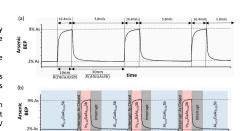
2.6 µm laser structure



Methods: Materials Growth and Characterization

1. Materials Growth

- ➤ Molecular beam epitaxy (MBE) was used to grow binary and quaternary compounds such as those listed in the laser structure shown above
- Typical III-V MBE of arsenides and antimonides makes use of a so called growth window
- In the growth window, excess group V material is desorbed from the sample surface and growth rate is determined by the group III flux
- Obtaining the desired composition in compounds with both arsenic and antimony is difficult due to the different vapor pressures and sticking coefficients of the group V elements
- Obtaining abrupt interfaces and uniform composition in heterostructures with varying Sb and As composition is difficult due to the 'memory effect' of As in the MBE chamber (see image to the right)



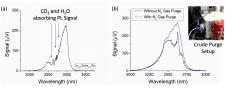
(a) Arsenic beam equivalent pressure (BEP) vs. time as the As shutter is opened and closed during growth of a MQW structure. The finite response time is due to the arsenic 'memory effect' through the valved cracker source. (b) shuttering sequence used for growth of MQW somples showing compensation of the memory effect.

2. Materials Characterization

- > X-Ray Diffraction (XRD) was used to obtain lattice constants and information about crystal quality and abruptness of interfaces
- > Photoluminescence (PL) was used to obtain emission wavelength. Material is optimized for narrow and bright PL.
- Atomic force microscopy (AFM) was used to obtain topographic images of material surfaces.



A photoluminescence setup was constructed in Chris Palmstrøm's lab at UCSB. This setup utilizes all fluoride optics and an InAs detector. Either a 532nm or a 980nm pump laser is used. This setup works well for PL signals from 1-3µm and samples can be cooled to 20K

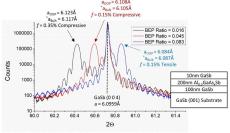


Strong atmospheric absorption is present near 2.6 μ m wavelength due to both water vapor and CO₂. (a) shows this effect clearly in the PL signal of a thick inGaAsSb calibration sample. (b) shows improvement with the use of a crude purge setup. A more sophisticated purge source was later

Results: Structural Characterization and Photoluminesence

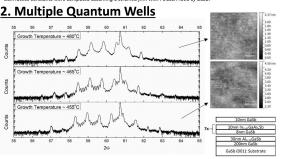
1. Lattice matching

- > The proposed laser designs make use of thick (2μm) Al_xGaAsSb cladding layers
- > The cladding layers need to be closely lattice matched (below 0.1%) to the GaSb substrates in order to reduce defects
- > Lattice matching is accomplished by adding a small amount of arsenic (2-7%) to 'quasi-ternary' AlGaAsSb compounds

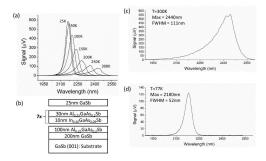


A calibration series was grown in order to determine the desired amount of aresenic for lattice matching of $A_{\rm las}$ GoASsb to the GoSs bustrate at the optimized growth temperature. The figure above shows ω -20 XRD measurement of films grown with varying arsenic concentration. Increasing the arsenic to antimony ratio decreases the lattice constant. "Bulk lattice routants were community ansumina a trained film with Poisson ratio of GoSh

(a) A lattice matched p-n junction structure was grown using the calibration series shown to the left for transport measurements. Lattice matching is near perfect, (b) First attempt at lattice matching for higher aluminum concentration cladding layers. The estimated flux required was extrapolated from the calibration series shown at the left resultion in lattice mismatch below 0.1%.



Earlier attempts (not shown) suggested that thick In_{0.46}GaASSb films grew best at substrate temperatures around or below 45°C. However, it was found that heterostructure (MQVI) growth at this temperature resulted in unfavorable surface morphology. The figure above shows a-20 KRB of a MQVB veries grown with varying substrate temperatures. Growth at 465°C gives the sharpest thickness fringes indicating high quality films with abrupt interfaces. The AFM images at the right show a transition from stee flow to island like condwit with decreasing arowth temperature.



(a) Temperature dependent PL of a MQW calibration sample designed to emit at 2400nm at 300K. (b) layer structure of the PL calibration sample. (c) Room temperature PL. (d) PL at 77K showing FWHM of 52nm indicating high quality material

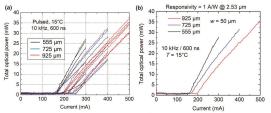
Broad Area Laser Characterization: Preliminary Results

> Broad area lasers were fabricated using contact lithography and dry etching

After dry etching laser bars, samples are thinned, metal is deposited on the backside, and sample is cleaved before mounting on an AIN carrier for pulsed measurements

Lapping Backside metallization Cleaving Mountin





(a) L-I curves of broad area lasers cleaved to different lengths (b) 'Best' characteristics for each laser length

Conclusions

- The desired composition was obtained in MBE grown films for all quaternary compounds in 2.2, 2.4 and 2.6 μm laser designs
- > The growth temperature of heterostructures and multiple quantum wells was optimized using XRD, AFM, and PL
- > Unoptimized laser structures were grown and successfully fabricated into broad area lasers
- > These results pave the way for MBE regrowth and processing efforts to realize widely tunable SGDBR lasers emitting between 2.2-2.6 μm