



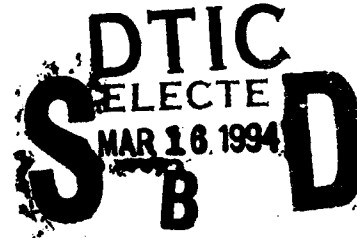
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Novel Optoelectronic Devices based on combining
GaAs and InP on Si

project DAJA45-90-C-0003

Final Technical Report

by P. Demeester



1. Abstract

This work has concentrated on basic technologies for the fabrication of devices which can be used in optical interconnect and optical computing applications.

One of the most important issues is the technology for integration of different devices on the same substrate. Three different possibilities were investigated : heteroepitaxial growth, epitaxial lift-off and patterned epitaxy. The heteroepitaxial technique and the epitaxial lift-off can be used to integrate optoelectronic and electronic devices on the same substrate (resulting in optoelectronic integrated circuits or OEICs). In terms of device performance and material quality, very good results were obtained with the epitaxial lift-off. This was reflected in the realisation of a number of interesting devices and optoelectronic integrated circuits. The heteroepitaxial growth still suffers from the large defect density and although clear improvements were obtained, no good device results could be obtained. As an alternative the bonding by atomic rearrangement was also successfully investigated. The patterned growth technique has a different application field and has important advantages in the fabrication of photonic integrated circuits (PIC) where two (or more) optoelectronic devices are integrated and coupled optically (e.g. laser and waveguide). Much work was devoted to the shadow masked growth technique which has been applied to a number of interesting applications (e.g. multi wavelength laser arrays).

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A second important issue is the fabrication of free space optical modulators. These can be used in both optical interconnection and optical computing applications where an essential function is the modulation of the intensity of light propagated in free space. The work was concentrated on the fabrication of InGaAs/AlGaAs multi quantum well modulators on GaAs.

The project was finished successfully with 43 publications (in which the project was acknowledged) and with 3 PhD degrees (which were considerably supported by the project).

2. Statement of problem

The aim of this project was to investigate some basic technological steps for the fabrication of novel optoelectronic devices for optical interconnection and computing. The basic technologies were split into four major research areas : (1) heteroepitaxial growth, (2) patterned growth, (3) MQW modulators and (4) Epitaxial Lift-Off.

3. Summary of the most important results

In this report we will briefly summarize the most important results obtained during the whole projects. Detailed information can be found in the interim reports and the publications.

3.1 Heteroepitaxial growth

Heteroepitaxial growth is important to combine different materials monolithically on a single substrate. Typical examples are the growth of GaAs on InP or GaAs on Si.

This part has mainly concentrated on the growth of InP on GaAs and InP on GaAs on Si. State of the art material quality was obtained by the use of selective growth and temperature cycling techniques. This work has resulted in a number of publications [3, 11, 12, 18, 21, 22, 26] which deal mainly with the fundamental problems of the growth process (MOVPE based). In the second part of the project we have also investigated the Bonding by Atomic Rearrangement (BAR) technique for InP on GaAs and

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InP on Si, as an alternative to direct epitaxial growth. This has resulted in good material quality and low loss InP waveguides on GaAs.

3.2. Patterned growth

Patterned growth is a techniques where epitaxial layers are grown on a patterned substrate in order to change the normal growth behaviour observed during non-patterned growth. This finds interesting applications in photonic integrated circuits, advanced devices etc.

Three different patterning techniques have been investigated : non-planar growth, selective growth and shadow masked growth. Most work has been devoted to the in house developed Shadow Masked Growth (SMG) technique [5, 9, 14, 17, 19, 23, 25, 27, 28, 31, 32, 33, 36, 40, 43,] although good results were also obtained with the two other techniques [2, 28] . Besides the basic characterization, some interesting device results have been obtained (using SMG). These include : multiwavelength laser arrays (wavelength span of 130 nm, both on GaAs and InP), extended cavity lasers, lasers with tapered facets resulting in more symmetric farfield, tapered waveguides with improved coupling to fibres, broad spectrum LEDs. A number of the above mentioned papers were invited papers [19, 25, 36, 43].

3.3. MQW modulators

The use of free space optical modulators opens interesting perspectives for optical interconnection and computing. One of the important problems is the fabrication of high quality modulators on transparant substrates.

This work has concentrated on the developement of InGaAs/AlGaAs MQW structures for optical modulators (both transmission and reflection). Very good material quality was obtained resulting in good device results (e.g. Asymmetric Fabry-Perot Modulators). Different publications resulted from the research on modulators [6, 8, 16, 20, 24, 29, 30].

3.4. Epitaxial Lift-Off (ELO)

An interesting alternative to the heteroepitaxial growth is the transplantation of epitaxial films (as developed by Bellcore in 1987). This technique has the advantage that the layers can be grown lattice matched without introducing defects (as is the case with heteroepitaxial growth). It also allows the combination of GaAs with other materials (glass, LiNbO₃)

The basic technology for epitaxial lift-off has been developed to a stage where good device results can be obtained. One of the major breakthroughs was the use of under water transplantation, which reduced the defect density by two orders of magnitude! Numerous device results were obtained : GaAs LEDs and lasers on Si, GaAs MESFETs on Si and InP, GaAs optical modulator on glass, optoelectronic integrated circuits (GaAs-LED + GaAs-FET , GaAs FET + LiNbO₃ switch, etc.). This resulted also in a large number of publications [1, 4, 7, 13, 15, 20, 35, 37, 39, 41, 42] including a number of invited papers [10, 34, 38].

4. List of publications

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5. Participation of scientific personnel

P. Demeester as group leader

I. Pollentier was involved in the ELO work and he received a PhD degree in 1993

G. Coudenys was involved in the heteroepitaxial growth and the SMG and he received a PhD degree in 1993

L. Buydens was involved in the modulator work and he received a PhD degree in 1993

Gent, nov. 1993