InGa(N)As/GaAs Quantum Well Laser Structures Grown by MOVPE

A. Mereuta, S. Bouchoule, I. Sagnes, F. Alexandre, G. Le Roux, H. Sik, J. Decobert, and A. Ougazzaden

1Laboratoire de Photonique et de Nanostructures (LPN-CNRS), 196 av. H. Ravaera, 92222 Bagneux Cedex France
2OPTO+, Route de Nozay, 91460 Marcoussis France
3Now with Lucent Technologies, 9999 Hamilton Blvd, Briengsville, PA 18103, USA

ABSTRACT

The MOVPE growth of (InGa)(N)As/GaAs structures with room temperature photoluminescence in 1– 1.59 µm range is presented. Infinite threshold current densities of 0.095, 1.22 and 2.3 kA/cm² at 1.18, 1.22 and 1.24 µm emission wavelengths, for In₀.₃₅Ga₀.₆₅NyAs₁₋ₚ/GaAs Quantum Well (QW) laser diodes with 0, 0.4 and 0.5% of nitrogen, respectively, were obtained. Characteristic temperature (T₀) values of 82, 117 and 102K were determined for as-cleaved lasers in the 20-80°C temperature range.

Keywords: InGaNAs, GaNAs, MOVPE, DMHy

1. INTRODUCTION

Thermal performances of conventional InGaAsP/InP lasers are limited due to the weak electron confinement resulting from a small conduction band offset between the active and the confinement layers. In the InP-based material system it is also difficult to obtain distributed Bragg reflectors for vertical cavity surface emitting lasers (VCSELs). New InGaNAs/GaAs structures have been presented as an alternative, due to the possibility to realize 1.3 and 1.55 µm emission wavelengths on GaAs substrate and to get a strong electron confinement at the interfaces between InGaNAs active layer and AlGaAs or InGaP cladding layers [1].

Laser emission at room temperature in the range of 1.1-1.38 µm for both strained QW [2-4] and bulk matched InGaNAs [5-6] laser diodes has already been reported. A 1.18 µm VCSEL has been demonstrated [7]. In the same way, highly strained InGaAs/GaAs QWs were also shown to be potential laser sources for single mode data link [8]. However, there have been some remaining difficulties in obtaining high-quality InGaNAs alloys and the threshold current densities of InGaAsN laser diodes remain relatively high compared with InGaAsP/InP and InGaAs/GaAs lasers.

In this work, the MOVPE growth study of InGaNAs structures on GaAs substrate and their room temperature photoluminescence (RTPL) and laser diode characteristics are presented.

2. EXPERIMENTAL

The growth was performed by atmospheric pressure MOVPE on (100)-oriented n-GaAs substrates using TMIn, TMGa, AsH₃, PH₃, and DMHy as precursors. A 0.5 µm thick n-GaAs buffer, 1.5µm thick n-InGaP cladding, the 150 nm GaAs-waveguides and InₓGa₁₋ₓNyAs₁₋ₚ (x=0; 35%, y~0-7%) active layer structures were grown and studied in a first step. The typical growth rate was ~1.2µm/h for GaNAs and ~1.8µm/h for InGaNAs, V/III flux ratio ~ 50 - 100 and the ratio of DMHy in gas phase fDMHy/(fDMHy+fAsH3) has been explored in the range ~ 0.65 - 0.98. The structural and optical properties of the QW structures have been studied using transmission electron microscopy (TEM), high-resolution X-
Ray-diffraction (HR-XRD) and by room temperature photoluminescence (RTPL) measurements. An 1.5 µm thick $p$-InGaP and 0.1 µm thick $p^+$-GaAs layers were then regrown in a second step to form the cladding and contact layers and broad area laser diodes with 50 µm stripe width were processed from this structures.

3. RESULTS AND DISCUSSION

In Fig. 1 the nitrogen incorporation (a) and growth rate dependence (b) with the DMHy ratio in gas phase for strained InGaNAs QWs and for GaNAs alloy are presented. The nitrogen composition in InGaNAs alloy was estimated by comparing XRD peaks between InGaAsN and a reference InGaAs well, assuming that the DMHy presence at the growing surface does not influence In incorporation. At high composition of indium the incorporation level of nitrogen in InGaAsN layers is much lower compared with GaNAs at the same ratio of DMHy in reactor. The highest nitrogen compositions, which have been obtained, are 6.7% for GaNAs and 2.9% for InGaNAs.

![Fig. 1. Nitrogen incorporation (a) and growth rate dependence (b) with the DMHy ratio in gas phase for strained InGaNAs QWs and for GaNAs alloy.](image)

It was also found that the growth rate of GaNAs and InGaNAs decreases about 10-20% at high DMHy gas phase composition (in excess of 0.9) as compared to GaAs and InGaAs.

For the GaNAs layers a RTPL in the 1-1.3 µm range was obtained, but the PL is much lower than for strained InGaNAs QWs. Fig. 2a shows the relationship between the nitrogen solid composition (y) in InGaAsN quantum wells and their RTPL wavelengths. A RT photoluminescence in 1.18-1.59 µm range was obtained for as-grown samples. In order to improve the PL intensity, InGaNAs structures were annealed at 650°C during 20 min, leading to a PL intensity increase by a factor of 10 combined with a 20-50 nm blue-shift of the PL peak wavelength [9] (Fig.2a).

The typical RTPL spectra of In$_{0.35}$Ga$_{0.65}$As$_{1-y}$N$_y$ QW structures after annealing are presented in Fig. 2b. With increasing N composition from 0.5% to 2.9%, the PL intensity decreases by a factor of 20, while full width at half maximum (FWHM) increases by a factor of 2.
Fig. 2: Room temperature PL wavelengths as function of nitrogen incorporation in as-grown (triangles) and annealed (squares) InGaAsN QW structures (a) and RTPL spectra for the annealed InGaAsN/GaAs QW structures with 0.5, 1.2 and 2.9% of nitrogen composition (b).

Broad area laser diodes with 50 µm stripe were processed and laser effect is presently obtained for the structures with 0.4 and 0.5% nitrogen compositions. For comparison, N-free InGaAs/GaAs QW laser structure was processed and characterized. InGaAs laser has a 9-nm-thick In0.35Ga0.65As compressively strained active layer. InGaAsN structures contain a ~8-nm-thick compressively strained well sandwiched between 150-nm-thick GaAs waveguide layers.

Laser wavelengths of 1.18, 1.22 and 1.24 µm are measured at room temperature for the InGaAs and InGaAsN QW lasers, respectively. The threshold current density (J\text{th}) measured under pulsed operation as a function of the inverse cavity length (1/L) is shown in Fig.3a. A very low value of 0.095 kA/cm² can be deduced for the infinite threshold current density (J\text{∝}) of InGaAs QW structure. By comparison, threshold current densities of InGaAsN lasers are higher by a factor of ten, leading to a J\text{∝} ~ 1.22 and 2.3 kA/cm², respectively. This significant increase might be due to the large miscibility gap and the incorporation of carbon and hydrogen in InGaAsN layer during the growth.

Approximately 900 µm long lasers with as-cleaved facets were soldered on submounts and tested. Figure 3b shows for InGaAs/GaAs and InGaAsN/GaAs (y~0.4 and 0.5%) structures the threshold current density as a function of the laser temperature. As can be seen from Fig. 3b, a perfectly linear evolution in logarithmic scale is obtained for both laser structures in the 20-80°C temperature range. Thus, characteristic temperature values (T_0) of 82, 117 and 103K can be deduced in the whole temperature range for InGaAs and InGaAsN laser diodes, respectively.

The room temperature slope external efficiencies are 0.25, 0.15 and 0.1 W/A for lasers with 0, 0.4 and 0.5% of nitrogen, respectively. Furthermore, in the 20-80°C range, no significant decreases of external efficiency were observed. The lasing wavelength at 80°C is 1.20 µm for InGaAs diode and 1.24 µm for InGaAsN (0.4% N). The highest lasing wavelength was obtained at 65°C with the third InGaAsN (0.5%) structure with a 1.257 µm wavelength.

4. SUMMARY

In summary, (InGa)(NAs)/GaAs structures with increased nitrogen incorporation have been grown. We have achieved room temperature PL emission in the 1 - 1.59 µm and broad area QW laser diodes in the 1.18 - 1.24 µm wavelength ranges. Infinite threshold current densities of 0.095, 1.22 and
2.30 kA/cm² were obtained and the characteristic temperatures of 82, 117 and 103K were determined for InGaAs and InGaNAs lasers, respectively, in the 20-80°C temperature range.

Fig. 3. Threshold current density (J_{th}) versus the inverse of the laser cavity length (1/L) (a) and evolution of J_{th} with temperature (b) for InGaAs and InGaNAs QW lasers under pulsed operation.

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REFERENCES