7th Int. Symp. "Nanostructures: Physics and Technology"
St Petersburg, Russia, June 14–18, 1999

Optical and structural properties of InGaAsN/GaAs heterostructures

A. Yu. Egorov†, D. Bernklau, M. Schuster, Yu. Sherniakov†, V. M. Ustinov† and H. Riechert
Siemens Corporate Technology, D-81 730 München, Germany
† Ioffe Physico-Technical Institute, St Petersburg, Russia

Semiconductor lasers emitting at 1.3 and 1.5 μm have found wide applications in systems for long-range, high-speed fiber-optical communications. At present, such lasers are fabricated from the InGaAsP heterostructures grown on InP substrates. However, the performance of these devices is limited due to fundamental physical properties of the materials used, i.e. poor temperature stability and weak variation of refraction index leading to problems in the formation of distributed Bragg reflectors for VCSELs. A novel material, InGaAsN lattice matched to GaAs, has been recently proposed to solve this problem [1]. The incorporation of the InGaAsN should be feasible and should lead to GaAs-based lasers emitting at 1.3 μm or longer wavelengths.

We have grown strained and lattice matched GaInAsN/GaAs heterostructures with the N composition of 1–2.3% on GaAs substrates by molecular beam epitaxy. A RF-coupled plasma source was used to incorporate N into layers. The intensity of photoluminescence (PL) observed in the 1.0–1.4 μm spectral range at room temperature was comparable with the PL intensity for GaAs/InGaAs/GaAs quantum wells. The dependences of the PL intensity and the transition energy of the ground state versus quantum well thickness for the GaAs/GaInAsN/GaAs structures with various nitrogen content are presented in Fig. 1. One can see that the increase in nitrogen content or increase in the quantum well thickness leads to the decrease in the photoluminescence intensity. 1.3 μm room temperature photoluminescence was achieved for 8 nm quantum well with the nitrogen content of 1.9% and In content 38%.

We investigated the effect of growth conditions on the crystal quality of the layers and present the results of optical and structural characterization of the grown layers and quantum well structures. We have found that the FWHM of luminescence line is mainly due to nonuniformity of the grown layers. The PL intensity and FWHM as a function of the growth temperature is shown in Fig. 2. The growth of GaInAsN in optimal temperature range significantly improves the uniformity and crystal quality of the structures which results in the decrease in the FWHM of the luminescence line and increase in the intensity.

Post-growth annealing of the structures at elevated temperatures results in more than one order of magnitude increase in PL intensity. The increase in the PL intensity for the annealed sample is accompanied by about 60 nm blue shift of the PL line and decrease in the full width at half maximum to 40 nm. The high resolution XRD measurements have shown that the nitrogen content for the sample after annealing was little higher than before. This fact indicates that there is no diffusion of nitrogen from the quantum well region to the barrier layer. More likely, the reason of the blue shift of the PL maximum with annealing is the decomposition of nitrogen clusters which form nitrogen-rich areas and shift the maximum of the PL line to the longer wavelength.

As the result of the optimization of the growth regimes and post-growth treatment the bright 1.3 μm PL and EL was achieved for the GaAs based heterostructures with InGaAsN active region at room temperature. Fig. 3 shows the electroluminescence spectra

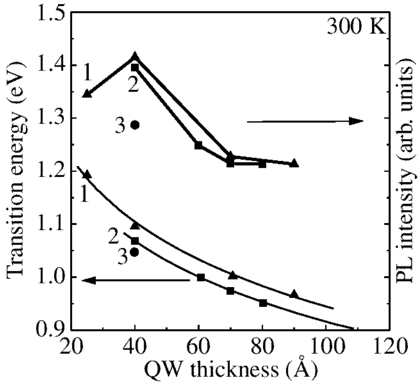

Fig. 1. Photoluminescence characteristics of the heterostructures with quantum wells: (1) $In_{0.38}GaAsN_{0.015}$ (2) $In_{0.38}GaAsN_{0.019}$ (3) $In_{0.38}GaAsN_{0.023}$.

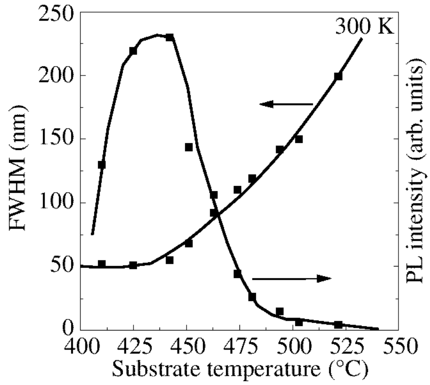

Fig. 2. PL characteristics vs growth temperature for MQW structure $In_{0.3}Ga_{0.7}As_{0.985}N_{0.015}$/GaAs.

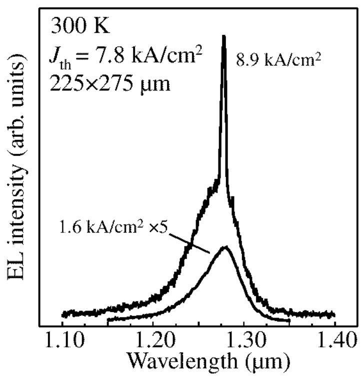

Fig. 3. EL spectrum of InGaAsN based laser diode at 300 K.

of GaAs/InGaAsN heterostructures at 300 K. The lasing with the thershold curent density of 7.8 kA/cm^2 was achieved for the laser based on three InGaAsN quantum wells in the active region and GaAs cladding layers.

This work was supported by the Program "Physics of Solid State Nanostructures" of the Ministry of Science of Russia.

References

[1] M. Kondow, K. Uomi, A. Niwa *et al.*, *Jpn. J. Appl. Phys.*, **35** (1), 1273 (1996).