AlGaN Quantum Well Heterostructures for Mid-Ultraviolet Emitters with Improved Room Temperature Quantum Efficiency

E. A. Shevchenko[1], A. A. Toropov[1], D. V. Nechaev[1], V. N. Jmerik[1], T. V. Shubina[1], S. V. Ivanov[1], M. A. Yagovkina[1], G. Pozina[2], J. P. Bergman[2] and B. Monemar[2]

[1] *Ioffe Physical-Technical Institute, Russian Academy of Sciences, Polytekhnicheskaya 26, 194021 St.Petersburg, Russia*
[2] *Department of Physics, Chemistry and Biology, Linköping University, S-581 83 Linköping, Sweden*

Compact and efficient light emitters in a middle ultraviolet (MUV) spectral range (λ<300 nm) are required for numerous applications involving medicine, telecom, lightning, etc. AlGaN-based semiconductor compounds are to be most suitable materials for manufacturing the MUV optoelectronic devices. However, AlGaN heterostructures exhibit a large density of defects (especially in the case of *c*-sapphire substrates) and strong electric fields induced by spontaneous and piezoelectric polarizations in AlGaN quantum wells (QWs), causing the quantum-confined Stark effect (QCSE). Both factors harmfully affect radiative properties of the AlGaN based heterostructures emitting below ~300 nm. The figure of merit of the required QW structures is the internal quantum efficiency at room temperature, which can be characterized by the amount of reduction of photoluminescence (PL) intensity with increasing temperature from a cryogenic range (~4 K) up to 300 K.

In our recent paper [1] dedicated to suppression of the QCSE in a corrugated 6-nm-thick $Al_{0.31}Ga_{0.69}N/Al_{0.45}Ga_{0.55}N$ QW we demonstrated that three-dimensional QW morphology can significantly improve the room temperature quantum efficiency. However, corrugated layers can hardly be used for fabricating planar laser heterostructures, which makes development of AlGaN-based QWs with plane morphology and high quantum efficiency of particular interest. In this work we report on comparative optical studies of a series of single 2.2-nm-thick $Al_xGa_{1-x}N/Al_{x+0.1}Ga_{0.9-x}N$ QW structures ($x \geq 0.45$) with planar interfaces, grown by plasma-assisted molecular beam epitaxy (PA MBE) on a thick Al(Ga)N multilayer buffer deposited atop of a *c*-sapphire substrate. The structures differing mainly in the growth regimes and, hence, in the density of extended defects were studied by both *cw* and time-resolved PL spectroscopy and spatially resolved cathodoluminescence in the whole range of temperatures between 2 and 300 K. To evaluate composition, strain, and defect density in the structure layers X-ray diffraction measurements were carried out as well. As a result, temperature-dependent kinetics of exciton localization and recombination has been evaluated as dependent on density of extended defects in planar AlGaN QWs. The sample with the lowest total defect density (~4.5×10^9 cm^{-2}), emitting at ~280 nm, demonstrates only three-fold reduction of the integrated PL intensity at 300 K as compared to 4.5 K, that implies the room temperature internal quantum efficiency as high as ~30%. At present, this result is one of the best known for AlGaN/*c*-Al_2O_3 heterostructures that makes PA MBE very promising for fabrication of efficient mid-UV lasers.

[1] A. A. Toropov, E. A. Shevchenko, T. V. Shubina, V. N. Jmerik, D. V. Nechaev, M. A. Yagovkina, A. A. Sitnikova, S. V. Ivanov, G. Pozina, J. P. Bergman, and B. Monemar, *J. Appl. Phys.* **114**, 124306 (2013).