Quantum wells for long wavelength laser diodes grown by plasma-assisted MBE

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For long wavelength nitride laser diodes (LDs) high In content InGaN layers are still a challenging issue. The poor quality of InGaN quantum wells (QWs) and deterioration of QWs during growth of upper part of LDs are the limiting factors of performance of green LDs grown by metal organic vapour phase epitaxy (MOVPE) either on polar, semipolar and nonpolar substrate orientations [1,2].

The alternative growth technique used for nitride LDs, plasma-assisted molecular beam epitaxy (PAMBE), proved that it is possible to grow high quality InGaN at growth temperatures as low as 650°C. Nevertheless, the low temperature growth of InGaN still requires further studies and better understanding. Recently we demonstrated the important role that high nitrogen flux plays in the growth of high quality InGaN layers and QWs [3]. The increase of the nitrogen flux allows to grow high In content InGaN at higher growth temperatures. Such growth strategy led to the demonstration of efficient AlGaN cladding free true-blue (460nm) and cyan (482nm) LDs [4,5].

In this work we report on the role of active nitrogen flux in the growth of high indium content InGaN. We study the influence of the growth temperature, gallium and nitrogen fluxes and substrate miscut on quality of InGaN layers and QWs. Clear improvement of crystal quality for the InGaN layers grown using higher nitrogen was confirmed by X-ray diffraction scans**.** Pronounced triangular shape of atomic step edges for the sample grown using higher growth rate was observed by atomic force microscopy. Improvement of structural quality was also seen in dependency of full width at half maximum (FWHM) of photoluminescence (PL) lines for series of QWs grown using different atomic fluxes. Samples grown using higher nitrogen flux exhibit narrower emission for the same wavelength or sustain the same FWHM emitting at longer wavelength. Time decay of PL for samples grown using different gallium and nitrogen fluxes will be presented. The experimental results will be analyzed using phenomenological model of InGaN growth by PAMBE taking into account nonequivalent atomic steps in wurtzite crystals [6].

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[1] M. Funato et al. *Appl. Phys. Express* **6** 122704 (2013)
[2] Y. S. Kim et al. *Appl. Phys. Express* **4** 052103 (2011).
[3] M. Siekacz et al. *J. Appl. Phys.* **110**, 063110 (2011).
[4] C. Skierbiszewski et al., *Appl. Phys. Express* **5**, 112103 (2012).
[5] H. Turski et al., *Appl. Phys. Lett.* **104**, 023503 (2014).
[6] H. Turski et al., *J. Cryst. Growth* **367** 115 (2013)