AlInGaN laser diodes and micro LEDs with active regions shaped as micro ribbons and discs fabricated on corrugated substrates.

The III-N semiconductor emitters are the heart of many types of optoelectronic systems around us, including LED lightbulbs, car headlights etc. This material system offers a unique opportunity of fabricating emitters operating in the exceptionally broad spectral range – in principle from UV to even infrared. In reality, utilization of such a wide range is limited by technical difficulties related to the material properties. That is, the difference in lattice constants of the binary materials InN, GaN and AlN. As a consequence, the grown heterostructures are highly strained which leads to negative effects such as defect formation, cracks in the material or spatial segregation[1] of indium in InGaN layers (especially quantum wells, used as a heart of the light emitting system for most of the spectral range). Though, the dramatic improvement in the quality of green InGaN laser diodes was recently observed, their parameters still lag behind their shorter wavelength counterparts. The situation is even more difficult for high In content - InGaN red emitters.

The goal of this project lies in the development of InGaN/GaN active region for AlINGaN light emitters in a form of micro and sub-micro ribbons and discs (MRD). We create 3D pattern on the surface of the GaN substrate in a form of semicylinders and hemispheres. Next, during the epitaxial growth the shape of the surface evolves creating horizontal, flat plains – ribbons and discs, see Fig. 1. Depending on the details of the shape and size of the pattern, we can obtain significant increase of the indium content in InGaN quantum wells. Preliminary results are presented in Fig. 2. The main reason for this is reduction of the strain on the planes thanks to their small size and strain-relieving sidewalls. We also expect to improve the device work parameters thanks to improved carrier confinement (micro-LED, lasers) and light confinement (lasers).

We hope that our approach will be a step towards fabrication of AlInGaN quantum structures with high indium content (above 20%). These structures would be necessary for future red InGaN laser diodes and LEDs. In both cases such a devices would be a needed component of RGB displays (micro-LED or laser projection). Our experiments showed a possibility of fabricating on the same wafer lasers or μLEDs emitting e.g. in blue and green spectral range, so coming closer to realize the red component would be more than beneficial. Furthermore, we expect to be able to reduce the carrier leakage from the active region, this should improve the efficiency of the light emission and reduce the overall power consumption of the final device or system.

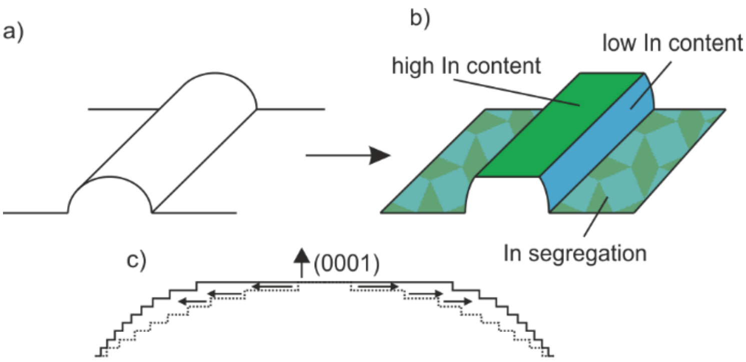

Fig. 1. a) Shapes of the structures obtained through photolithography. b) Schematic shape of the same structure after epitaxy: evolution of the (0001) flat areas and QW growth. c) Schematic presentation of expansion of (0001) crystallographic plane during the growth.

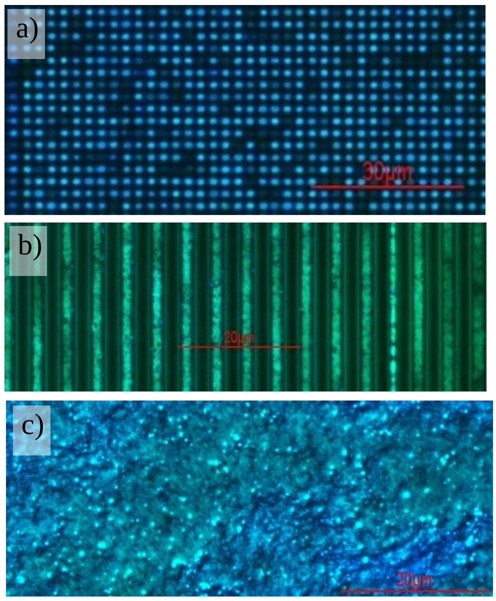

Fig. 2. Example fluorescence microscope images of the test samples with different patterns: a) discs, b) ribbons, and c) flat reference. All samples were fabricated together during the same growth run, flat reference is a separate, not-patterned crystal.