AlGaInN compounds are the second (after silicon) group of semiconductors with respect to the market size of devices based on these compunds. Current main applications of nitrides are white LEDs and BluRay lasers, and high-power, high-frequency transistors. In the nearest future, next multibilion markets will emerge: laser projectors and television, „last mile" communication via plastic waveguides installed in the buildings, cars, airplanes or ships. Probably, also LEDs will be replaced by laser diode arrays in lighting.

Poland is one of the world leaders in development of new nitride semiconductor technologies and there is a big chance that these technologies will very soon lead to a significant commercial production of laser diodes based on nitrides.

The Project proposed is the first step in developing new genereations of devices based on InGaN quantum wires, as well as should let us acquire a new knowledge on microscopic mechanisms of InGaN growth.

Nanosize objects are in electronics used not only because of possible miniaturisation, but also because of many physical properties unique only for the quantum objects. Most of the electronic devices (laser diodes, LEDs, photovoltaic cells, sensors, etc) are based on thin epitaxial layers which have the nanodimension only in the direction perpendicular to the surface. Future devices will also contain objects of nanodimensions also in directions parallel to the surface (quantum wires and quantum dots).

Fabrication of such nanoobjects is difficult because even the most advanced electronlithograpy offers resolution of a few tens of nanometers. Therefore, most of the nanowires are produced by spontaneous growth perpendicular to the surface.

In the Project proposed we are going to develop (for the very first time in the world) a method of growing InGaN quantum wires (parallel to the surface) in the GaN matrix using the MOVPE (metalorganic chemical vapour phase epitaxy) method. The wires will be formed by a sequential introducing In precursor in to the chamber during the atomic-step filling. The atomic steps will be formed due to the off-orientation of the GaN substrate. Idea of such growth was proposed by Petroff et al [1] for AlGaAs/GaAs, but has not been used for nitrides.

Fig. 1 shows and idea of Petroff for the growth of InGaN nanowires. The left-hand-side figure shows the growth of InGaN continuous layer (the growth is not interrupted and In precursor is all the time switched on). The growth is in the step-flow mode, when atoms are attached only to the step edges. The distance between the edges (the tarrace width) depends on the GaN substrate off-orientation. For example, for 1 deg off-orientation, it is 14.5 nm. The right-hand-side shows the idea of Petroff- the growth of InGaN is stopped at a certain moment, the tarrace is filled up with GaN, and then In-precursor is introduced again.

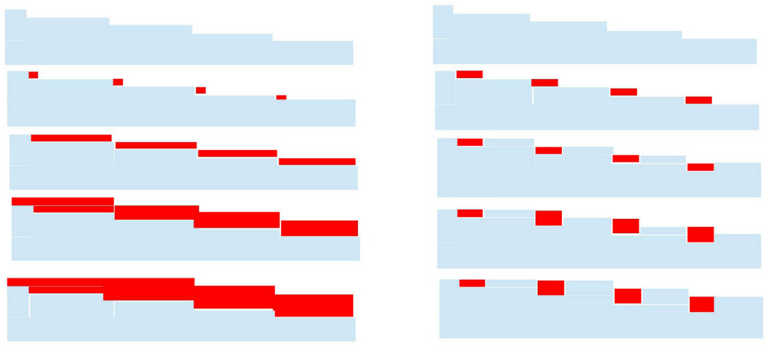

Fig. 1
Left: Step-flow growth mode of the epitaxial layer on the off-oriented substrate. Right: Step flow growth mode with laterally variable composition leading to the nanowire formation. Please note that in the figure, the sample edge was shown to illustrate the step-flow growth mode. Close to the edge, the quantum wires would be different than the others, but the number of them will be so small, that this problem is not relevant. Please also note that the step height is exeggareted- the ratio of the step height and the tarrace width is of an order of 100.

Such experiments are only possible using GaN substrates of an ultra-low defect density, otherwise the atomic steps are not straight. Our institute possess such unique, proprietary and patented technology. Moreover, in this technology, we are able to pattern the GaN substrate in such a way that on one wafer we have several off-orientations and asimuths, what makes the experiments quicker and cheaper.

The experiments planned should enable us to acquire a number of valuable information on the InGaN growth microscopic mechanisms, how the steps flow, what is an influence of pressure, temperature, hydrogen, total flow, etc.

To grow the quantum wires planned, we will have to optimize those growth parameters. For example, when we add just a few percent of hydrogen into the carrier gas, we will decrease significantly the amount of indium in InGaN, but we will, at the same time, smooth the atomic step, what is necessary to obtain the quantum wire. The amount of hydrogen in the carrier gas, the moment when it si switched-on and -off, all this depend on other parameters as temperature, pressure and total flow.

The second important research task will be a development of new techniques of the High Resolution X-ray Diffraction (HR XRD). It is a basic tool for evaluation of the crystallographic structure of semiconductors. In the case of nearly perfect material as AlGaAs on GaAs, we get a very good agreement of the experimental data and the simulated one based on the Theory of X-ray Diffraction Scattering. Unfortunately, for InGaN layers and quantum wires, which contain a large amount of crystallographic defects, the theory will have to be modified. In the Project, we would propose new experimental and simulation techniques. Our approach will be verified by the High Resolution Transmission Electron Microscopy), that is much more laborious.

Finally, in the Project, we are planning to construct laser diodes based on the InGaN nanowires. We expect that these devices will have better properties- lower threshold current, better slope efficiency.

The new technology will also pave the way to other devics: transistors, sensors and even integrated nanocircuits as the wires can be grown in various directions at the same time. Theintersections of such wires can form quantum dots.

[1] P. M. Petroff. A.C. Gossard, W. Wiegmann, Applied Physics Letters 45, 622 (1984).