Objective of the project

Semiconductor laser diodes have extremely wide and varied field of applications (optical data storage, projectors, detectors, spectroscopy etc.). In order to improve the quality of devices based on LDs, optimization of laser structure is necessary. The main objectives of this project are to increase the laser diode efficiency by modification of layer responsible for blocking the electrons escape from the active region, called EBL. We will design and fabricate a series of nitride laser diodes (LDs) with new structure of EBL to investigate its influence on dynamics of carriers transport mechanisms. Electron blocking layer is introduced close to the active region from the p-doped side of the structure, as shown in figure 1.

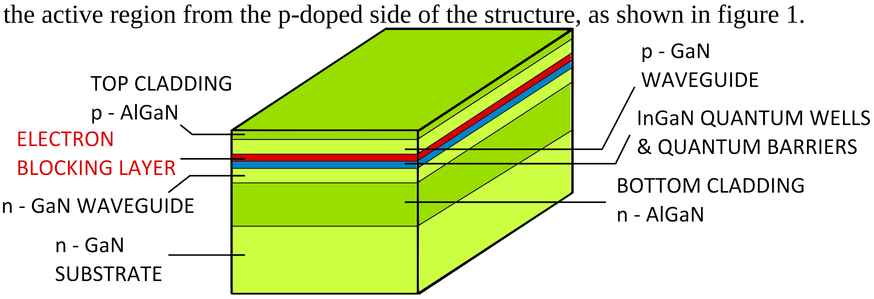

Fig. 1 Scheme of nitride laser diode epitaxial structure with an electron blocking layer.

In nitride devices there is a significant disproportion between free holes and electrons concentration, resulting from acceptors self-compensation, their high ionization energy and higher effective mass of holes, as well as their lower mobility. In consequence, we often face problems with insufficient amount of holes and their ineffective transport to the quantum wells. Together with electrons overflow and escape from the active region it causes the increase in the nonradiative recombination and decrease in optical power. The role of EBL is to reduce those negative effects and improve laser diode parameters.

Usually EBL has a form of thin AlGaN layer (fig. 2a). In this project we will compare the effectiveness of such structure with three other EBL's designs (fig. 2b, 2c, 2d):

b. Thin AlGaN layer with graded Al composition

c. Periodic AlGaN/GaN superlattice

d. Aperiodic AlGaN/GaN superlattice

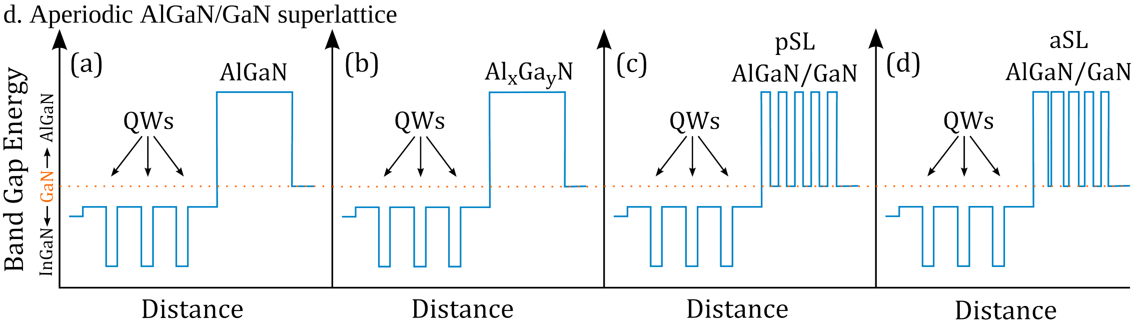

Fig. 2 Simplified schemes of band structures of proposed EBLs designs.

Basic research proposed in this project

In this project we propose basic research of:

- transport mechanisms of carriers in different nitride structures, especially:

a) the influence of strain and polarization charge resulting from lattice mismatch on holes transport

b) the influence of temperature on electrons overflow and escape from the active region in nitride LDs

c) the influence of band structure design of electron blocking layer on carriers transport (holes injection and electron blocking)

- the efficiency of p-type doping of different EBL structures

We propose a series of experiments to approach these issues. Carefully designed and fabricated laser diode structures will be characterized in two stages. In the first step, the quality of unprocessed structures will be investigated with different microscopic methods (TEM, EBIC-SEM) and p-type doping level will be determinated using SIMS technique.

In the second stage optical power versus current characteristics will be used to determine basic laser diodes parameters like threshold currents and differential efficiency of LDs. We will also investigate their thermal stability. Proposed experiments will allow to determine the injection efficiency of holes and thermal escape of electrons from quantum wells, thus to compare the effectiveness of different EBLs.

Reasons for choosing the research topic

Electron blocking layer is essential component of a laser diode, directly influencing the amount of radiative and nonradiative recombination in the structure. Nowadays EBL is well optimized only for electroluminescent diodes which operates in much lower current densities than laser diodes. Current densities necessary to obtain lasing action results in higher overflow current which requires much more effective electron blocking layer. Additional challenge is to design a structure that will not deteriorate the optical light confinement in the active region.

Attempts to optimize the electron blocking layer were made by many different research groups. To reduce the internal strain and improve the p-type doping efficiency, numerous EBL's designs were proposed. Quite efficient and popular became the electron blocking layer with graded or tapered Al profile. Quaternary AlInGaN EBL was found to provide better electrons confinement in the active region of laser diodes. Experiments with EBL in a form of multiquantum barriers showed that such devices, apart from better parameters, are also much more thermally stable.

However, there are still a lot of doubts about principle of EBLs' operation which reveals the need for better understanding of its influence on carriers transport mechanisms. According to different studies, small modification of layer's design and doping results in significant changes in device’s parameters. Still optimized nitride laser diode structures requires new approach to electron blocking layer design which can be realized in this project thanks to improving epitaxial techniques.