Towards Near-UV Laser Diodes Grown by Molecular Beam Epitaxy on Bulk Ammono-GaN Substrates

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The technology of violet, blue and green InGaN-based laser diodes (LDs) has matured over the past two decades and finds numerous applications. The current research is devoted to extend the operating wavelength towards two opposite directions: near-UV and yellow color. In this paper we will focus on near-UV LDs with applications such as gas detection, laser lithography, polymer curing, material processing to disinfection. Interestingly, despite the abundance of potential applications and significant resources devoted to development of near-UV LDs, their commercial success is yet to come. Several important obstacles are responsible for this situation with the three main being: i) lack of proper substrates – devices grown on standard GaN substrates suffer from large band-to-band light absorption, ii) lattice mismatch between AlGaN claddings and GaN substrates – significant strain leads to relaxation through generation of extended defects, and iii) increased degradation rate for short-wavelength LDs.

Recently, we have developed technology of nano-porosification of GaN by means of electrochemical etching and used it as cladding layers in blue LDs [1]. Nanoporous GaN layers offer a significant refractive index contrast to GaN, which enables confinement of light without the need of thick, high Al-content AlGaN layers.

In this work, we will show results of utilization of nanoporous claddings to near-UV LDs. We will investigate, by means of simulations, the influence of porosity and design of laser structure on confinement of light. We will discuss simulation results showing that, instead of nanoporous-GaN, which absorbs near-UV light, we need to use nanoporous-AlGaN layers. Importantly, low Al-content is sufficient to prevent band-to-band absorption, and porosification allows to use even very thin layers. This solves the two main challenges in the demonstration of near-UV LDs.

In this study we use molecular beam epitaxy to grow the near-UV laser structures. Interestingly, visible optoelectronic devices grown with this technique have a different degradation mechanism than the devices grown by the conventionally used metalorganic vapor phase epitaxy [2], probably due to lack of hydrogen species during the growth. Exploration of degradation mechanism in near-UV emitters grown by MBE is of crucial importance to obtain reliable devices. Furthermore, we will utilize wide AlGaN/GaN quantum wells (QWs), which serve two purposes. Firstly, the increase in thickness of the QW enhances the optical confinement factor. Secondly, as we have shown, wide polar QWs can have, contrary to common intuition, a high oscillator strength despite the extreme polarization field [3]. We will study, both by means of simulations and experiment, the influence of thickness of the QWs on both light confinement and optical transitions.

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