III-nitride light emitting diode modelling in the ultraviolet spectral range

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A multi scale transport simulation model for III-nitride light emitting diodes is presented. The simulation approach couples semiclassical transport with a $\mathbf{k}\cdot\mathbf{p}$-Schrödinger solver for the quantum wells in a self consistent way. Studies on the effect of p-side design and the inhomogeneous broadening in deep ultraviolet light emitting diodes will be presented.
Deep ultraviolet (DUV) light emitting diodes (LED) made of Aluminium Gallium Nitride (AlGaN) are in high demand for medical, environmental, and technical applications. Recent research concentrates on the enhancement of the efficiency which is still below 10 [1]. One obstacle is the low free hole density in p-doped high band gap AlGaN seen through a low hole injection efficiency. Another issue is the low extraction efficiency and high re-absorption of the dominant transversal magnetic polarized emission from the quantum wells (QW) with high Al content [5]. In addition, the thin and lattice mismatched QWs are susceptible to inhomogeneous broadening (IHB) so that the spectral width of the DUV LED emission may be as large as $\sigma \approx 100$meV. We propose calibrated physical modelling of large band gap III-nitride LEDs to support the efficiency improvement because it enables an investigation of the opaque active region physics and potential bottlenecks there through the macroscopic characteristics. Our physics based transport simulator for III-nitride LEDs is based on a multi scale and multi population approach [3]. As a numerical example we analyze the impact of the acceptor doping profile, the p-side electron barrier, and the active region design on the quantum efficiency. We introduce a statistical model for the IHB [2] which enters on the microscopic level [4] and is fully integrated into the self consistent transport simulation scheme. With this model we investigate how the IHB affects the macroscopic characteristics. We demonstrate that the IHB generally increases the ideality factor and interacts with the internal quantum efficiency by mitigating electron leakage. Simulations show that the enhanced transversal electric polarized emission observed in some DUV LEDs can be related to the IHB.

References

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