Nanorod structures have the potential to overcome several performance limiting issues in today’s LED technology. The small lateral dimensions of nanorods lead to strain relaxation which allow for higher Indium-contents in the active layers, leading to longer wavelengths, while a very high material quality is maintained. Furthermore, the significantly enlarged active areas of core-shell geometries increase the total light output and improve the luminous efficacy via reduction of current densities compared to planar structures at the same operation point. Additionally, the nanorod dimensions in the order of the emission wavelength result in unique optical properties. Periodic arrays of nanorods enable improved light extraction and beam shaping if the position of the nanorods can be controlled precisely.

A comprehensive study on InGaN/GaN nanorods is presented supported by simulation results of their optical properties. Two different types of nanorods have been analyzed: i.) MOVPE-grown core-shell nanorods, which consist of InGaN multi quantum wells wrapped around an entire GaN nanorod. ii.) Nanorods with disc shaped InGaN MQWs fabricated in a top-down approach from conventional 2D LEDs by a dry etch process. The position of individual nanorods within the entire array was determined by openings in the growth- or etch-mask, respectively. Both were manufactured by nanoimprint lithography (NIL). The structural quality and defect progression within nanorods were determined by transmission electron microscopy. Different emission energies for InGaN quantum wells could be assigned to different side facets by room temperature cathodoluminescence measurements. Electro-optical characterization proves the LED operation of nanorod structures. Further optical studies, such as photoluminescence and angular-resolved reflection measurements were performed to obtain quantitative input for the simulation studies.

Theoretical investigations and numerical simulations were performed to determine the optical properties of nanorods and nanorod arrays having realistic geometries. In periodic arrays of nanorods, both vertical waveguiding within individual nanorods as well as resonant scattering on neighbouring nanorods is present. Furthermore, simulations on the internal and external quantum efficiency for arrays of core shell nanorods were performed to determine optimum geometries of nanorods and of arrays of nanorods in novel 3D LED structures. A comparison of theoretical predictions and experimental findings is presented and compared to state of the art 2D LEDs.

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