Nano-LEDs Based on Micron-Sized III-Nitride Platelets

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There is a significant interest in fabricating displays that emit the three basic colours (red, green and blue) directly (self-emissive displays), rather than using the conventional filtering out of the individual colours from white back lighting. Micron-sized light-emitting diodes (μ-LEDs) are typically used in self-emissive displays for virtual and augmented reality (VR/AR), where pixel sizes in the micron range are needed. The blue and green μ-LEDs in displays are currently based on III-nitrides (InGaN) and the red ones on AlGaInP. We present a study of the optical properties of various steps in the process of fabricating LEDs based on quantum wells (QWs) in submicron-sized InGaN platelets [1]. Due to their sub-micron size, they are referred to as nano-LEDs. In this study, we focus on structures for red emission, but the technology is equally suitable for the less technologically challenged blue and green emitting nano-LEDs.

The platelets are seeded by selective area growth of short GaN nanowires from a regular array of submicron sized holes in a SiN mask. The small hole size blocks most of the threading dislocations in the GaN-on-sapphire substrate and the nanowires are virtually defect free. Each nanowire is the starting point for the growth of an InGaN pyramid with a sub-micron sized hexagonal base. The pyramids are also free from dislocations, and they are flattened using chemical mechanical polishing. The resulting platelets have a top c-facet and are used as templates to grow low-strain, single QWs in both heterostructures and full LEDs including n- and p-barriers on either side of the QW. The structures are investigated in terms of homogeneity in emission energy and intensity using hyperspectral cathodoluminescence (CL) imaging. The main contribution to the inhomogeneity is the growth of the initial pyramid, showing facet driven variations in the indium incorporation. When imaging the QW emission in top view, we observe a number of dark lines when imaging the QW emission. The number of dark lines increases with indium content. Green-emitting QWs show almost no dark lines, whereas the red-emitting QWs show a number of dark lines, FIG 1. These dark lines can also be observed when imaging the barrier emission, leading us to identify these as stacking mismatch boundaries [2]. This was confirmed by a preliminary TEM study.

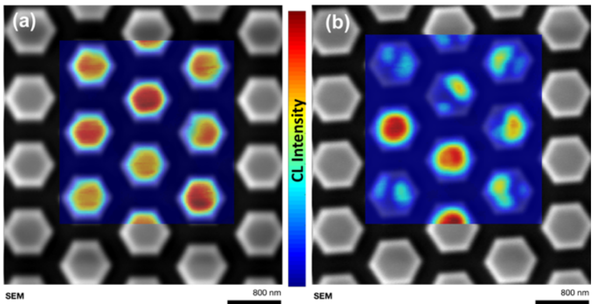

FIG 1. *Top view CL images of the QW emission in false colour overlaid on a normal SEM image in grey scale. a) is the green QW and b) is the red QW. The green QWs show a nearly ideal hexagonal emission pattern. Only a few of the red QWs are homogenous and hexagonal, the rest exhibit dark areas.*

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