Nanoscale insights into structure size and surface effects in InGaN/GaN nanoLEDs

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III-nitride-based light-emitting diodes (LEDs) have emerged over the last two decades as highly energy-efficient, cost-effective, compact, and robust light sources. While general purpose lighting has been the dominant application so far, a set of other applications can be further explored from the advantageous LED properties, including optical communication, structured illumination, and display technologies. Especially, GaN LEDs in a micron range (µLEDs) offer a competing technology for self-emissive, high-brightness microdisplays, in which the size and pitch of these µLEDs determine the resolution of such displays [1].

As the LED pixel dimensions are scaled further down to a sub-micron range, the relationship between the nanoscale size and performance of an LED is of great interest [2]. In this work, micro-/nanoLED arrays with pixel dimensions ranging from 1.4 µm down to 200 nm were designed and fabricated by a series of top-down manufacturing steps. Technical details of the challenging 3D processing of these structures, based on a combination of inductively coupled plasma reactive ion etching (ICP-RIE) and wet etching, will be presented.

Opto-electrical analysis of these micro-/nanoLEDs based on nanoneedle probing tips inside a scanning electron microscope (Fig. 1(a)) will be reported. Spatially resolved I-V- measurements could be conducted and simultaneously electroluminescence (EL) characteristics of these tiny light sources with dimensions of < 1 µm were extracted. Moreover, the quality of contacts, multi quantum well (MQW), and p-n-junction after top-down etching were evaluated via cathodoluminescence (CL) and electron-beam-induced-current (EBIC) measurements (Figs. 1(b) and (c)). The properties of µLEDs in comparison to their conventional large area counterparts will be discussed in detail, with a particular emphasis on size dependent efficiency and droop behavior (Fig. 2).

References:

[1] Jiang, H. X., & Lin, J. Y. (2013). Nitride micro-LEDs and beyond - a decade progress review. *Optics Express*, 21(S3), A475-A484.

[2] Olivier, F., Tirano, S., Dupré, L., Aventurier, B., Largeron, C., & Templier, F. (2017). Influence of size-reduction on the performances of GaN-based micro-LEDs for display application. *Journal of Luminescence*, 191, 112–116.

Supplementary information

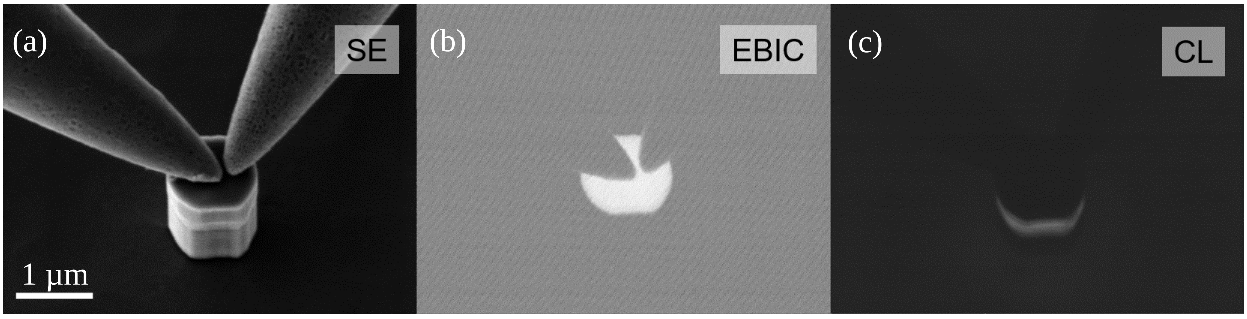

Figure 1 - Contacted µLED with a diameter of 1 µm. Three different imaging methods show

(a) the topography via secondary electrons (SE),

(b) the p-n-junction via electron-beam-induced-current, and

(c) the emission of the MQW via monochromatic cathodoluminescence.

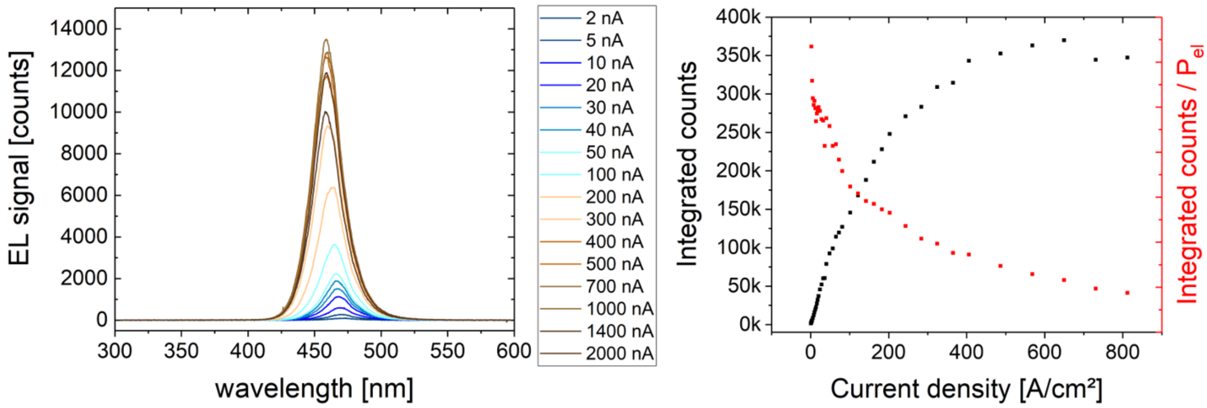

Figure 2 - Electroluminescence (EL) spectra for different biasing currents (left) and the efficiency analysis (right) of a single µLED.