InGaN/GaN nanoLED arrays for bioimaging applications

Jan Gülink[1,2,*], Steffen Bornemann[1,2], Hendrik Spende[1,2], Shinta Mariana[1,2], Muhammad Fahlesa Fatahilah[1,2], Matthias Auf der Maur[3], Aldo Di Carlo[3], Joan Daniel Prades[4], Hutomo Suryo Wasisto[1,2], Andreas Waag[1,2]

1) Institute of Semiconductor Technology (IHT), Technische Universität Braunschweig, Hans-Sommer-Str. 66, D-38106 Braunschweig, Germany
2) Laboratory for Emerging Nanometrology (LENA), Technische Universität Braunschweig, Langer Kamp 6a, D-38106 Braunschweig, Germany
3) Department of Electronic Engineering, Universitá degli Studi di Roma "Tor Vergata", Via del Politecnico 1, I-00133 Rome, Italy
4) MIND-IN²UB, Department of Engineering: Electronics, University of Barcelona, C. de Martí i Franquès, 1, E-80124 Barcelona, Spain
**Corresponding author; tel.: +49 531 391 3814; e-mail: j.guelink@tu-bs.de*

In recent years, gallium nitride-based light-emitting diodes (GaN LEDs) have been continuously developed and employed in not only solid state lighting but also high-brightness display and optical sensor applications. By integrating them with CMOS controlling electronics, matrix-addressed and individually controlled blue GaN microLED arrays could be realized with a display luminance of 10^6 cd/m^2 (12 W/cm^2), which is a factor of 10^3 higher than normal commercial displays [1]. Although those optoelectronic devices exhibited promising results and could subsequently be used for illumination sources and manipulation tools in the life sciences, their spatial resolution was still low, which was resulted from the LED pixel and pitch sizes of 80 × 80 µm^2 and 100 µm, respectively. Therefore, as for the biologists, the imaging at nanometer resolution has become more exciting to gain insights of live-cell dynamics and nanostructure at the single-molecule level (e.g., for intracellular fluorescent proteins and activity-dependent plasticity of axon morphology), several efforts have been made to realize super-resolution microscopy [2].

In this work, InGaN/GaN nanoLED arrays had been designed and fabricated to be used as a nanoillumination source for live-cell imaging inside on-chip microscope. As the LED pixel dimension had been scaled down to submicrometer range, the comprehension of the relationship between the nanoscale size and performance of an LED was therefore investigated, involving its extensive optical and electrical simulations. For quick but reliable opto-electrical measurements of nanoLEDs, nanoneedle probing tips inside a scanning electron microscope were utilized (Fig. 1(a)). Hence, I-V and electroluminescence characteristics of small light sources with dimensions of < 1 µm could be extracted (Figs. 1(b,c)). Moreover, very challenging 3D processing of these high-aspect-ratio top-down nanoLED arrays had been tackled to create nanoLED-based optoelectronic nanodevices, in which its results will be presented.

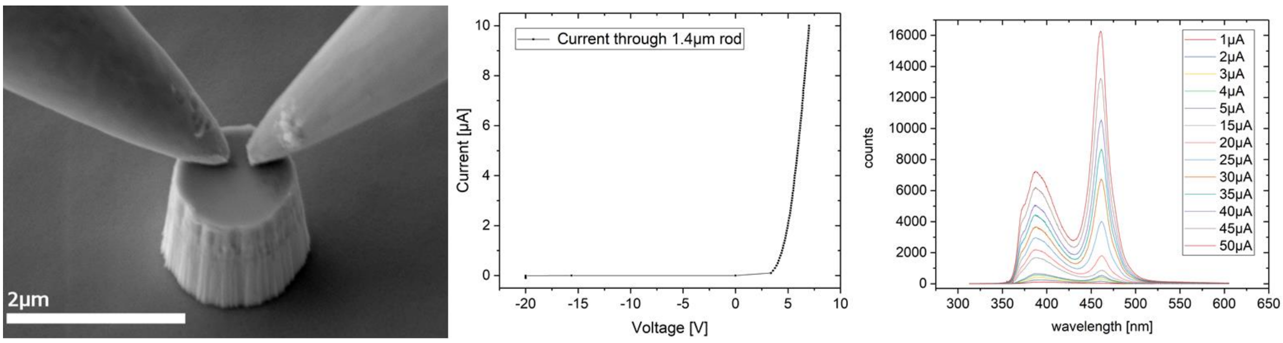

Figure 1. Nanoneedle probing tips inside an SEM for opto-electrical characterization of nanoLED array (left). I-V and electroluminescence characteristics of single nanoLED with high current densities (middle, right).

References:
[1] J. Herrnsdorf et al., Active-matrix GaN micro light-emitting diode display with unprecedented brightness. *IEEE Transactions on Electron Devices*, 62(6), 1918-1925 (2015).
[2] F. Balzarotti et al., Nanometer resolution imaging and tracking of fluorescent molecules with minimal photon fluxes. *Science*, 355(6325), 606-612 (2017).