Nanoscale GaN LED arrays for chip-based optical nanoscope

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Since the invention of high-power gallium nitride (GaN) light-emitting diodes (LEDs), enormous investigations have been carried out in the last decade, not only to improve the material quality and device performance but also to extend their applications. InGaN/GaN LEDs have been broadly employed in general illumination and backlight units because of their higher luminous efficacy and longer lifetime compared to conventional light sources. Furthermore, several innovative optoelectronic devices have been introduced into industrial markets (e.g., high-brightness display and optical sensors in smartphones). By integrating LEDs with CMOS control electronics, matrix-addressed and individually controlled 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]. However, their spatial resolution was still low, which resulted from the LED dimensions with pixel and pitch sizes of several micrometers. Thus, in this work, nanoscale InGaN/GaN LED arrays with individual pixel control were designed and fabricated to be integrated as a novel illumination source in a chip-based lensless microscope (i.e., ChipScope) for real-time monitoring of biological cells. The challenging 3D processing steps of the high-aspect-ratio nano-/microLED arrays have been optimized to create tiny optoelectronic modules. To fabricate the well-ordered high-aspect-ratio nano-/microstructures, a top-down approach comprising nanophotolithography and hybrid etching was employed [2]. In this case, GaN LED fins with smooth sidewalls could be realized from the sequential processes of SF_6/H_2-based ICP-RIE and KOH-based wet chemical etching (Figures 1(a) and (b)). As top and bottom surfaces of the structures are distantly separated by about 3.5 – 5 µm, device planarization plays a critical role for the feasibility of top metal contact deposition. Thus, different polymer filling materials have been carefully investigated (e.g., photoresist, spin-on-glass, and benzocyclobutene (BCB)). Along with the device fabrication, simulations of the light emission patterns have been conducted with different conditions of the integrated materials to optimize the nanoLED designs (Figure 1(c)).

References

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Supplementary information

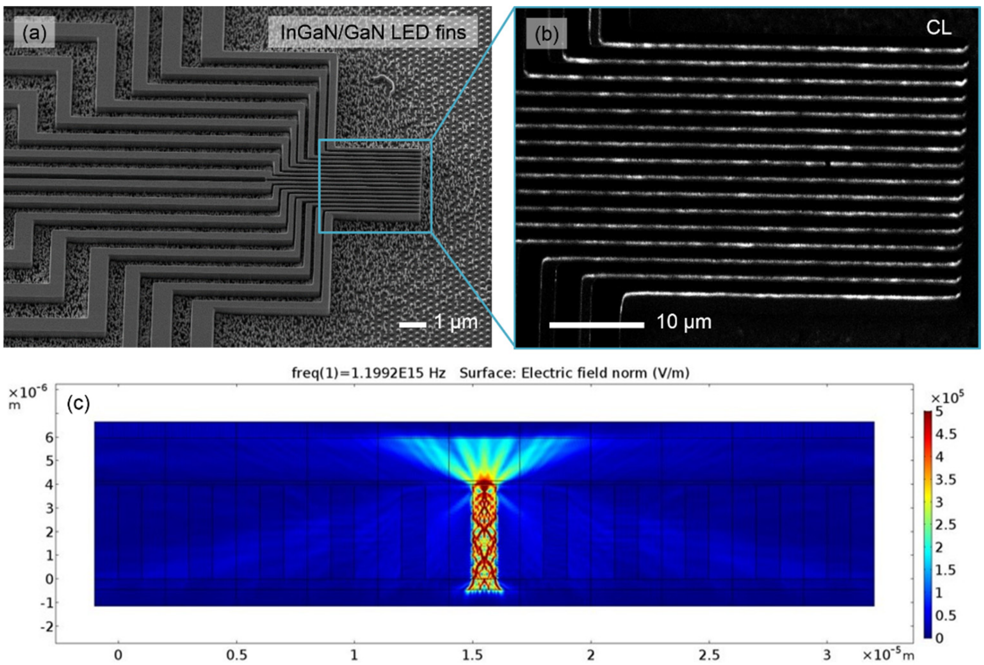

Figure 1. (a) SEM image of 1 µm InGaN/GaN LED fin array after ICP-DRIE and (b) its corresponding cathodoluminescence (CL) result showing the monochromatic emission at the peak wavelength of 465 nm. This nanoLED array is used in chip-based lensless microscope (ChipScope). (c) 2D simulation results of the light emission pattern from a nanofin LED.