Point light sources based on pinhole InGaN/GaN microLED arrays for lensless cell monitoring systems

Shinta Mariana[1,*], Gregor Scholz[1], Feng Yu[1], Agus Budi Dharmawan[1,2], Iqbal Syamsu[1,3], Joan Daniel Prades[4], Andreas Waag[1], Hutomo Suryo Wasisto[1,*]

[1]*Institute of Semiconductor Technology (IHT) and Laboratory for Emerging Nanometrology (LENA), Technische Universität Braunschweig, 38106 Braunschweig, Germany.*

[2] *Faculty of Information Technology, Tarumanagara University, 11440 Jakarta, Indonesia.*

[3] *Research Center for Electronics and Telecommunication, Indonesian Institute of Sciences (LIPI), 40135 Bandung, Indonesia.*

[4] *MIND, Department of Electronic and Biomedical Engineering, Universitat de Barcelona, 08028 Barcelona, Spain.*

*E-mail: s.mariana@tu-braunschweig.de ; h.wasisto@tu-braunschweig.de

For evolving applications in life sciences (e.g., cell counting and imaging), a compact system based on digital inline holographic microscopy provides a lightweight and cost-effective platform, which can be integrated in an incubator set-up enabling a real-time, in-situ and continuous biological cell monitoring. Although commercial surface mounted device (SMD) -packaged LEDs can be employed, they still have limitations in terms of size, integration flexibility, spatial illumination coherency and therefore achievable image resolution, especially when extension to 3D imaging and capabilities of pixel super-resolution are required. Therefore, smaller point light sources arrays, which can be specifically designed and fully integrated into a miniaturized imaging system, would offer tremendous advantages.

In this work, pinhole-shaped microLED arrays with openings ranging from 100 µm down to 5 µm have been designed and fabricated from planar InGaN/GaN LED wafers using processing flow steps shown in Fig. 1. Firstly, an insulating SiO_2 layer is deposited on the *p*-GaN, which is followed by sequential photolithography and etching processes to realize openings for transparent *p*-contacts and larger *n*-contact areas. Different thin metal layers, such as Ti/Au and Pd/Au, are deposited and subsequently annealed to produce the contacts. Finally, metallization defines both electrical connection and dimensions of the pinhole LEDs (Fig. 2).

Prior to integration into lensless holographic microscope, the LED devices are characterized by electroluminescence (EL) measurements at room temperature. The I-V curves (Fig. 3) indicate that the LED devices can be operated under normal bias of ~3 V. To test their capability as an enhanced point light source, a single 90 µm pinhole LED is assembled into a lensless holographic microscope to image polystyrene microbeads with diameters of 5 µm. From the captured images, we have observed that the interference and diffraction effects from the dense microbead clusters can be reduced by using the pinhole LED instead of a large area LED with a size of 230 × 230 µm². This results in images with better resolution and quality (based on their focus value) than those obtained by commercial blue SMD LEDs (Fig. 4).

Supplementary information

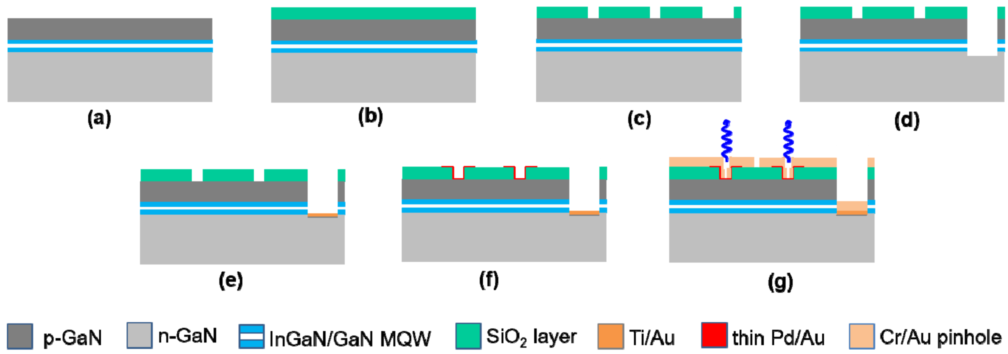

Figure 1. Fabrication process of pinhole LEDs, consisting of: (**a**) Preparation and cleaning of GaN-based LED sample with InGaN/GaN multiquantum well (MQW). (**b**) Deposition of SiO_2 as insulating layer. (**c**) Opening of holes and contacts on SiO_2 layer. (**d**) Dry etching down to *n*-GaN layer. (**e**) Deposition of Ti/Au as *n*-contact. (**f**) Deposition of thin and transparent Pd/Au as *p*-contact. (**g**) Metallization using Cr/Au to subsequently define pinhole openings, which emit blue light after contacting.

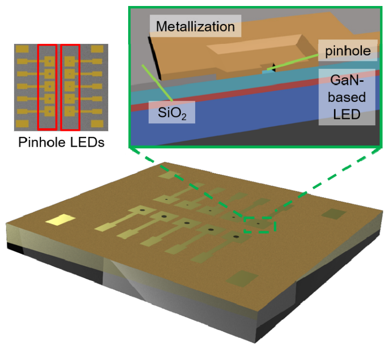

Figure 2. Schematic of the pinhole LED arrays.

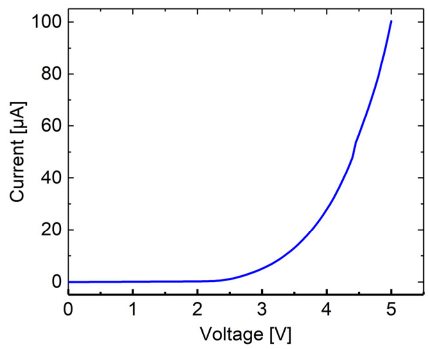

Figure 3. Measured I-V curve of a single pinhole LED having a diameter of 90 µm.

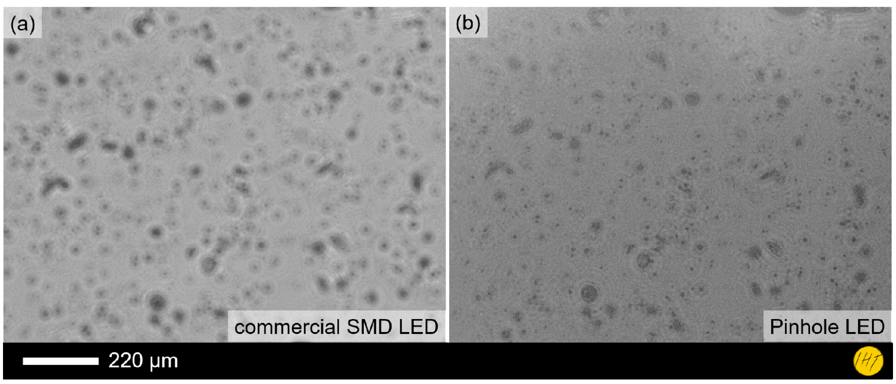

Figure 4. Side-by-side comparison of the reconstructed images of 5 µm microbeads embedded in transparent polydimethylsiloxane (PDMS) using illuminations of (a) a commercial blue SMD LED with a size of 230 × 230 µm² and (b) a single pinhole LED with diameter of 90 µm both at a wavelength of 465 nm. In contrast to (a), clear diffraction patterns can be seen in (b) due to the larger spatial coherence length of the microLEDs.