FABRICATION AND CHARACTERIZATION TECHNIQUES TO STUDY FLEXIBLE MICRO LIGHT-EMITTING DIODES WITH A MILLIMETRIC RADIUS OF CURVATURE

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Keywords: flexible, micro light-emitting diode (µLED), van der Waals epitaxy

The interest in flexible micro light-emitting diodes (µLEDs) is growing in high-tech industries with foldable smartphones or unconventional surfaces (glasses, windshields, or e-papers), more specific applications can also be found in biomedical research. For example, in optogenetics stimulations by using µLEDs one could improve cochlear implants (CIs) since, contrary to electrical signals, there is no spreading of light in the ear, and the neurons responsible for hearing can be made sensible to blue light (~ 450 nm). GaN-based µLEDs are good candidates, however, inserting light-based CIs inside the cochlea of a mouse or human being, requires LEDs with reduced dimensions, and improved flexibility (typical dimensions < 50µm and radius of curvature (ROC) down to ~ 1 mm). Standard, relatively thick LEDs will be limited by their rigidity. In this work, we present the fabrication of flexible µLEDs and their opto-electronic characterization down to millimetric ROC.

Considering GaN-based LEDs generally grown on sapphire, the thinning of the substrate down to a thickness of ~ 100µm or less is challenging; moreover, such LEDs still too rigid to reach the required ROC. Thin-film LEDs with a ~ micrometric thickness are targeted, however, removing the native substrate represents a complex process. Some prototypes of optical-CIs (oCIs) were already demonstrated using laser lift off to decompose the GaN at the GaN-sapphire interface [1], which is a sequential, and costly process. To address this limitation, we aim at developing GaN µLEDs grown on sapphire using van der Waals epitaxy with h-BN. It has been recently demonstrated that a GaN LED structure grown on a few 2D layers of h-BN, grown on sapphire, could be easily removed "at will" from the sapphire wafer due to the weaker van der Waals bonds at the 2D layer interface [2]. Another possibility to fabricate the flexible µLEDs would be to start from a Si(111) growth substrate and then use silicon-processing techniques to remove the substrate after having reported the LEDs to a flexible host substrate.

As for the µLED flexibility assessment, the main challenge is to develop a set-up allowing the reproducible characterization of the LED opto-electronic properties with a variable ROC in the millimetric range. In the literature, two different methods were found: the sample is either stuck to a cylinder [3] or constrained laterally [4]. In one case, it is hard to change the ROC; in the other, obtaining the ROC at a fixed lateral constraint can be complicated. In both cases, the sample height may vary between ROC changes and measurements, if the sample is removed, making optical measurement difficult. We have developed a characterization bench to avoid these issues and to ensure a fixed height for variable ROCs down to 3 mm (fig. 1) With this, the IV characteristic of the LEDs, their electroluminescence (EL) spectrum, or optical power can be measured repeatably.

We will present the thin-film µLed fabrication and their first opto-electronic characterization down to millimetric ROC to assess their advantage compared to the standard "thick" LEDs.

Acknowledgment: Alexis POIZAT (C2N-CNRS) is gratefully acknowledged for his support in the characterization bench design and fabrication. This work was partially supported by LEDFLEX project in the FRAME of ANR Labex GaNext.

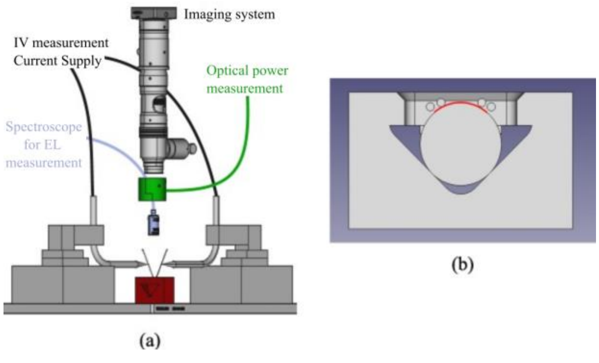

Figure 1. Representation of the measurement setup with (a) a side view of the setup to show the position of the different detectors while making measurements, all of them being removable at will and (b) the principle of bending system at the center of the setup, allowing a fixed height of the LED for variable ROC from 10-mm to 3-mm (the position of the sample shown in red).

[1] C. Goßler et al., J. Phys. D: Appl. Phys., 47, 205401 (2014).

[2] T. Ayari et al., Adv. Mater. Technol., 4, 1900164 (2019).

[3] G. Tabares et al., IEEE Photon. Technol. Lett., vol. 28, no. 15, pp. 1661-1664 (2016).

[4] H. -Y. Kuo et al., IEEE Photon. Technol. Lett., vol. 20, no. 7, pp. 523-525 (2008).