Light Extraction Improvement of Transfer Printable GaN LEDs on Si with Backside Roughening

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Transfer printing is an emerging technology that allows devices to be released from native substrates and placed onto new targets, which makes higher-level heterogeneous assembly/integration possible [1]. Combining such technology with GaN-based light-emitting diodes (LEDs) grown on Si, many applications such as inorganic-LED displays and bio-integrated optoelectronics have been demonstrated and awaiting commercialization [2]. However, one of the key issues inhibiting further development is to make transfer printable LEDs with high performance, which requires improvement on material quality as well as light extraction efficiency. Although many approaches via surface roughening or photonic crystalshave been well developed for traditional LEDs to enhance the light extraction, to apply these methods to releasable LEDs in a practical way is still under investigation.

In this work, an approach that can roughen the backside of transfer printable GaN-based LEDs is proposed using wet etch. The roughened surface where high density of GaN pyramids are formed, as shown in Fig. 1(b), is expected to improve the light extraction efficiency significantly. The release of devices with sidewalls covered by SiN_x is realised by anisotropic undercut etching using TMAH. Surface roughening on the LED backside is then performedafter the sidewall protection layer is removed as shown in Fig. 1(a). The surface roughness,e.g. the size of pyramids, could be also controlled by varying the undercut etching time after SiN_x removal.

Initial measurementswith fluorescence microscope after devices transfer-printed on a transparent target substrate show that, light intensity of devices with rough backside is ~3 times higher than those with smooth surface. Further detailed characterization such as light output-current-voltage (L-I-V) measurements are also performed and analysed on devices with different size of pyramids. Light extraction simulation based on similar structures is also carried out and made comparison with experimental results. This work was performed in the MICROPRINCE project funded under the ECSEL Joint Undertaking - grant agreement No 737465.

References:

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[2] H.-S. Kim, E. Brueckner, J. Song, Y. Li, S. Kim, C. Lu, J. Sulkin, K. Choquette, Y. Huang, R. G. Nuzzo and J. A. Rogers, Proc. Natl. Acad. Sci. 108, 10072 (2011).

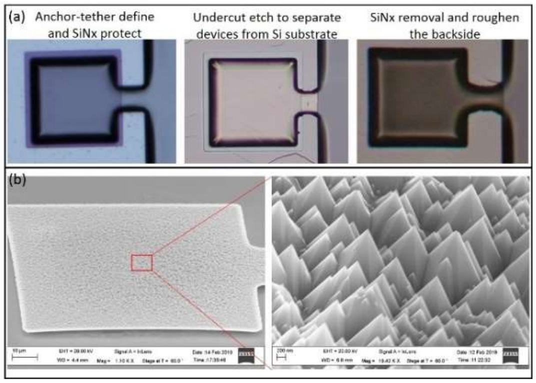

Figure 1 (a) Undercut and backside roughening of LED dummies (without metal pads for better view purpose). (b) LED backside with high density of GaN pyramids. The device is released by and sitting on a PDMS stamp.

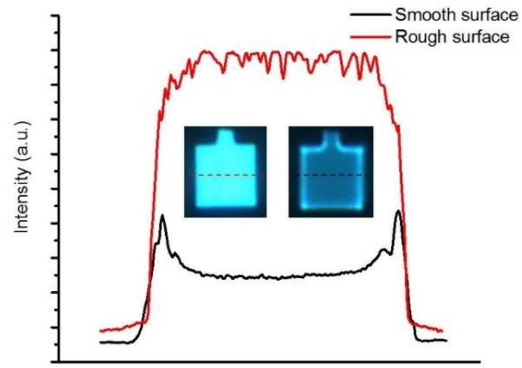

Figure 2 Intensity plot across the devices with smooth or rough surface. The inset is the emission images for printed devices taken with a fluorescence microscope.