Technische Universität Braunschweig

CHIPSCOPE

epitaxy competence center ec^2

LENA Laboratory for Emerging Nanometrology

Institut für Halbleitertechnik

InGaN/GaN nanoLED arrays for bioimaging applications

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

[1]Institute of Semiconductor Technology (IHT) and Laboratory for Emerging Nanometrology (LENA), Technische Universität Braunschweig, D-38092 Braunschweig, Germany

[2]Department of Electronic Engineering, Universitá degli Studi di Roma "Tor Vergata", Via del Politecnico 1, I-00133 Rome, Italy

[3] MIND-IN[2]UB, Department of Engineering: Electronics, University of Barcelona, C. de Martí i Franquès, 1, E-80124 Barcelona, Spain

What is the purpose of nanoLED arrays?

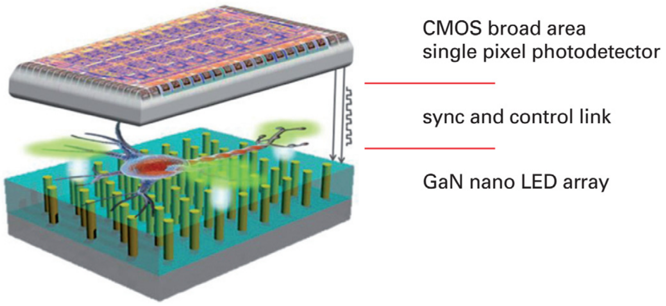
Physical laws of diffraction limit the spatial resolution of optical systems

→ A new approach to optical super-resolution by nanoLED arrays is investigated

Core idea: spatially resolved illumination instead of spatially resolved detection for microscopy functionality

Advantages:
+ chip-sized
+ affordable and ubiquitously available
+ robust since no lenses are needed

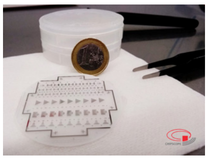
Requirements: very small light sources with individiual pixel control



Fabrication

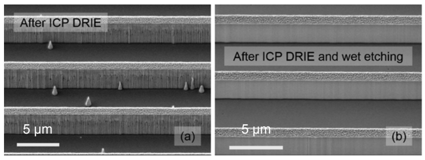
Top-down approach is more versatile and reproducible than bottom-up:
- free choice of material → wavelength selection for biocompatibility
- Different geometries and leads can easily be employed

Processing steps include:
- MOVPE growth of the LED wafer
- Optical lithography
- Hybrid etching (dry etching + wet etching)
- Planarization
- TCO and contact deposition



Principle of hybrid etching

- DRIE ICP etching forms initial truncated structure
- Wet etching (KOH-based) removes ion-damaged parts and forms a smooth sidewall, thus reducing surface defect channels

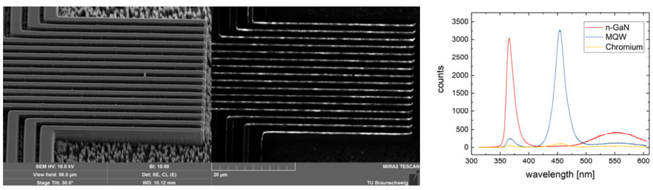


Hybrid etching allows well controlled widths and heights of fin and rod structures

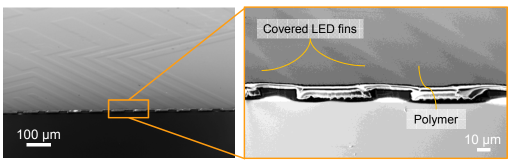
Processing results

Sequential iterations of optical lithography and hybrid etching lead to determined fin structures in the LED wafer. The fins will be connected by orthogonal TCO-lines on top to establish a passive matrix control

- High-aspect ratio fins with 1 µm width and 2 µm pitch with smooth sidewalls Monochromatic CL emission shows the position of the MQW and its uniformity



- Filling of fin structures with a low-k polymer

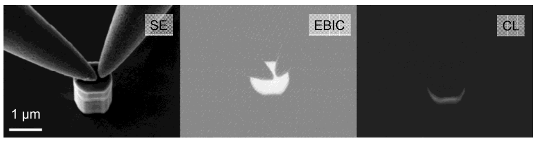


Filling enables top contact

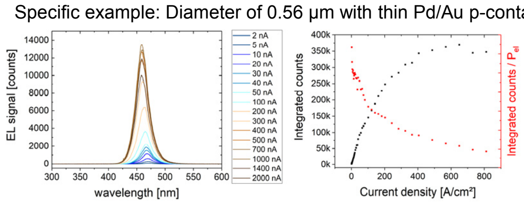
Opto-electrical investigation

Measuring setup:
Tescan Mira 3 FEG-SEM
with micro manipulators enabling (three-point) I-V, EL, CL and EBIC measurements

Test sample:
Micropillars with different sizes (1.4 µm to 100 nm) etched in an LED wafer

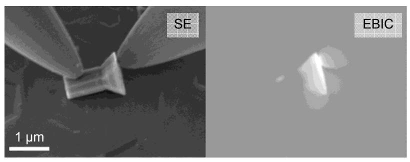


Specific example: Diameter of 0.56 µm with thin Pd/Au p-contact



LED pillars with 300 nm diameter still show a light output

- EL signal visible from the first nA
- Light output saturates and even decreases with higher currents
- Droop characteristic



Conclusions & future work

- Processing of high aspect ratio fin structures as a basis for nanoLED arrays
- Small LED light sources have been produced and characterized with a dedicated micro manipulator setup

→ Light sources with dimensions smaller than the wavelength can be produced and still emit light

- Usage as a new microscope technique
- Applications in tissue engineering and optogenetics

Acknowledgement

This work has been supported by **European Union's Horizon 2020** research and innovation programme under grant agreement No 737089 – **ChipScope**.

The presented work has been partly performed within the **epitaxy competence center** (**ec^2**), a joint research institute between **TU Braunschweig** and **Osram Opto Semiconductors GmbH**.

epitaxy competence center ec^2

Contact: Jan Gülink, *j.guelink@tu-braunschweig.de*