comptek solutions

BOOSTING THE EFFICIENCY
OF COMPOUND SEMICONDUCTOR DEVICES

推进高效率化合物半导体器件技术

nature research awards

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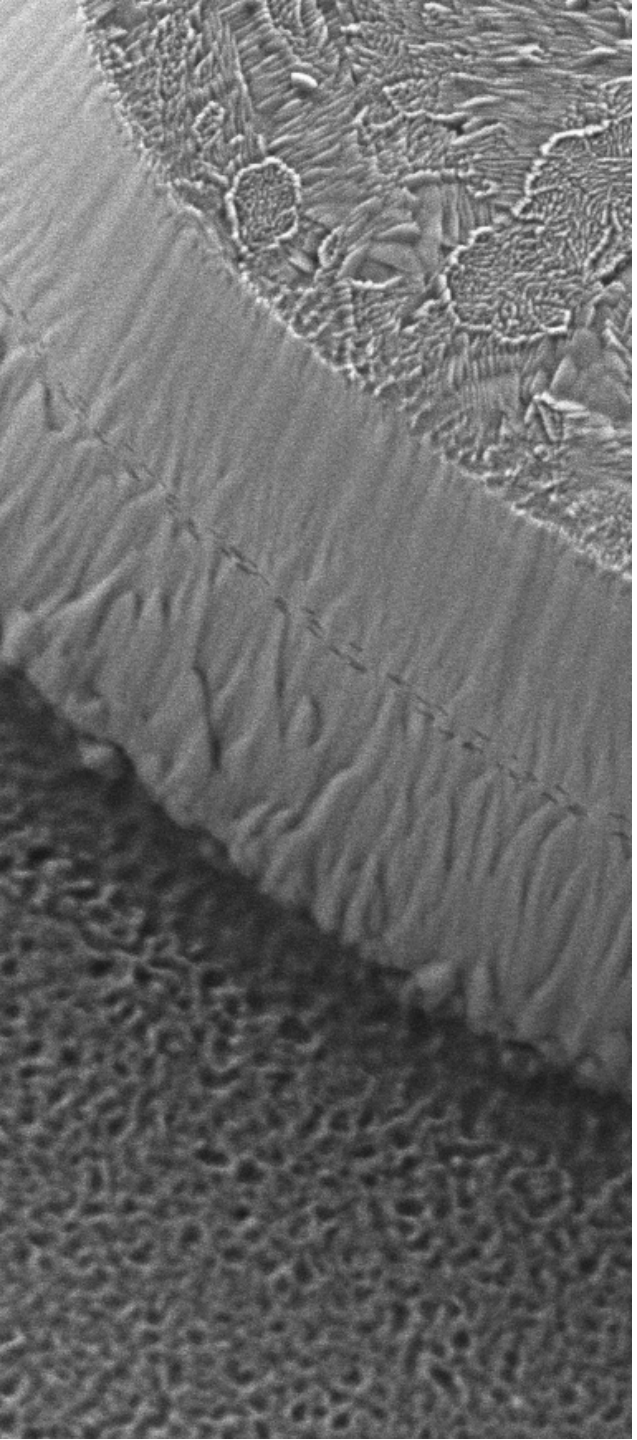


Passivation of compound semiconductors – key enabler for high-efficiency µLED devices

Dr. Jouko Lång
CTO, Comptek Solutions

EPIC Online Technology Meeting on Mini/Micro LED

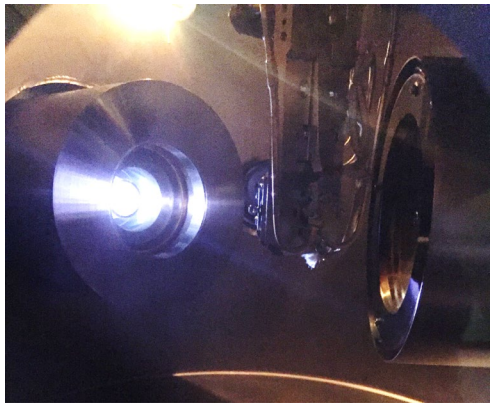
25/03/2021

- **Forerunner in III-V compound semiconductor atomic scale engineering**
- **Founded 2017, office and labs in Turku, Finland**
- **7000 sq ft labs with ISO 5 cleanroom**
- **Top expertise in III-V passivation**
- **State-of-the-art process measurement and characterisation services**

Kontrox™

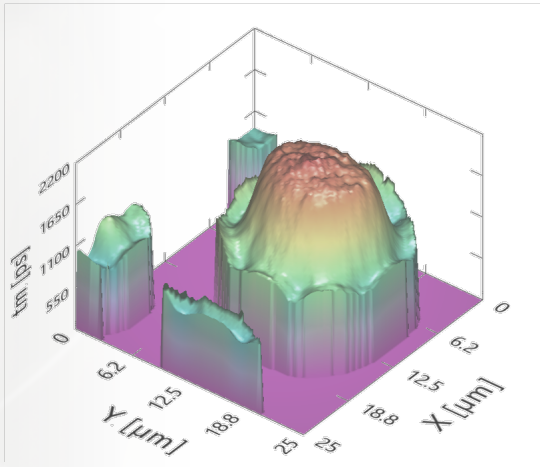
State-of-the-art process- and characterization capabilities

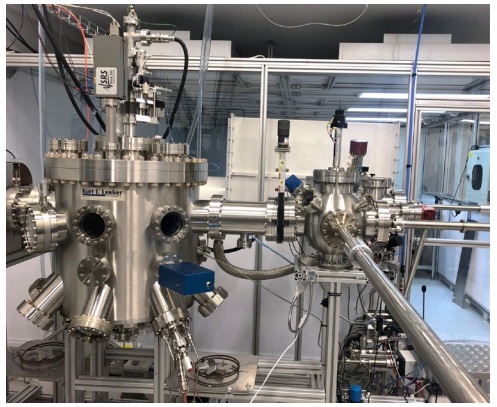
Customized cleaning and passivation techniques

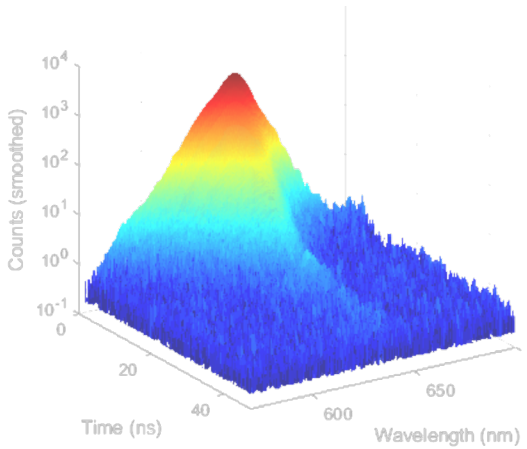


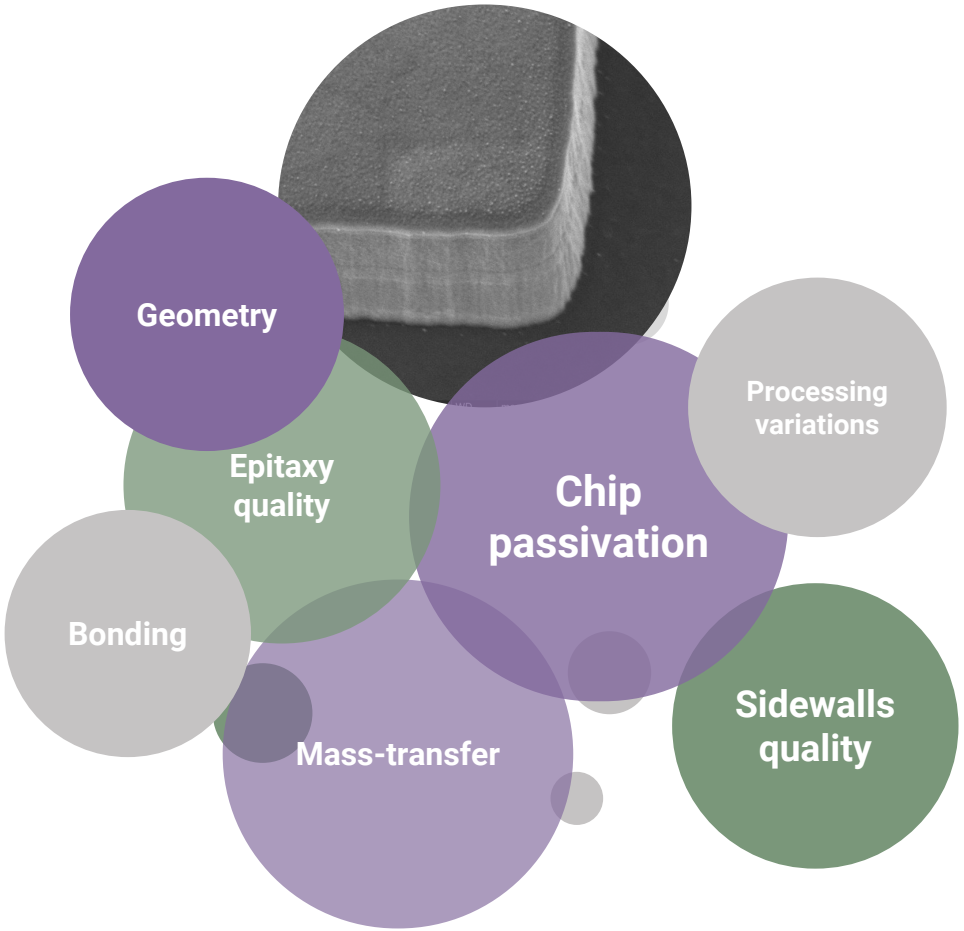
State-of-the-art characterization methods

(from atomic level to device)









Principal factors affecting microLED performance

The smaller the LED, the more influence the defects have in the overall performance

MiniLED and microLEDs sizes ranging from 150µm down to 1µm.

The surface/volume ratio increases when chip size is reduced.

The sidewall surface quality and differences arising from the processing steps start to contribute substantially to the overall µLED performance when the chip size decreses.

Sidewall damage and **oxidation**

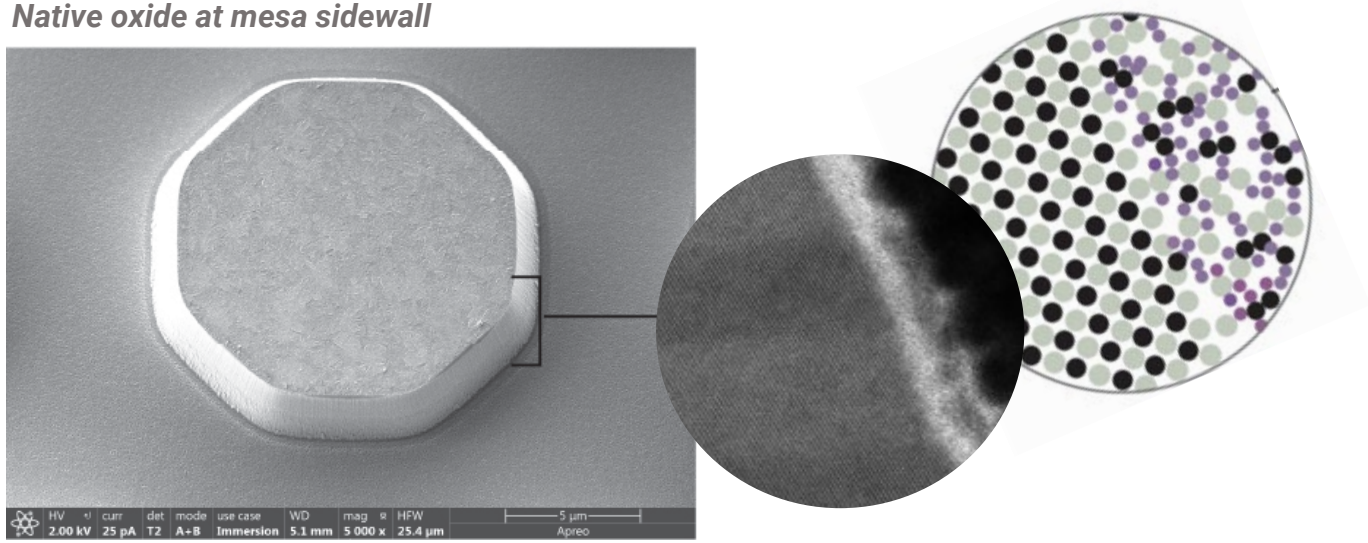
During the chip manufacturing III-V materials easily oxidize generating high density of defects.

Surface/interface defects result in:

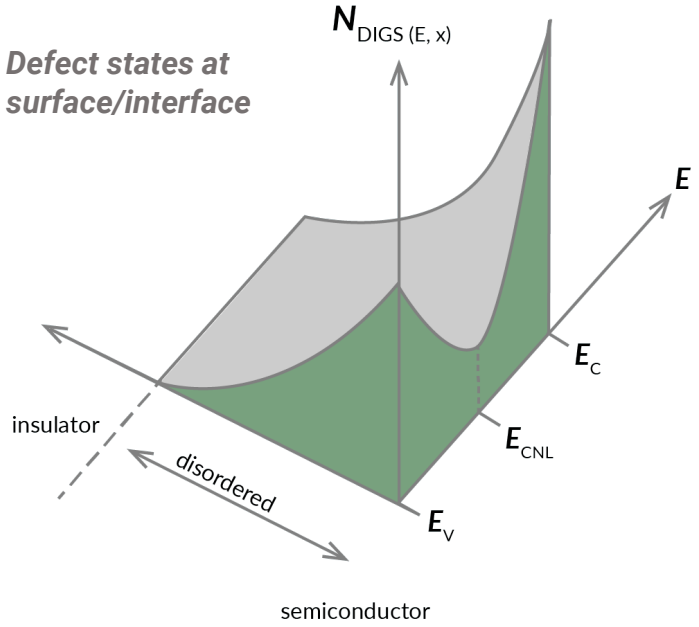
- **Performance- and device efficiency losses**
- Increased probability of defective devices causing **lower production yields.**

The negative effect of surface defects becomes more prominent as the chip size gets smaller due to high surface-to-volume ratio.

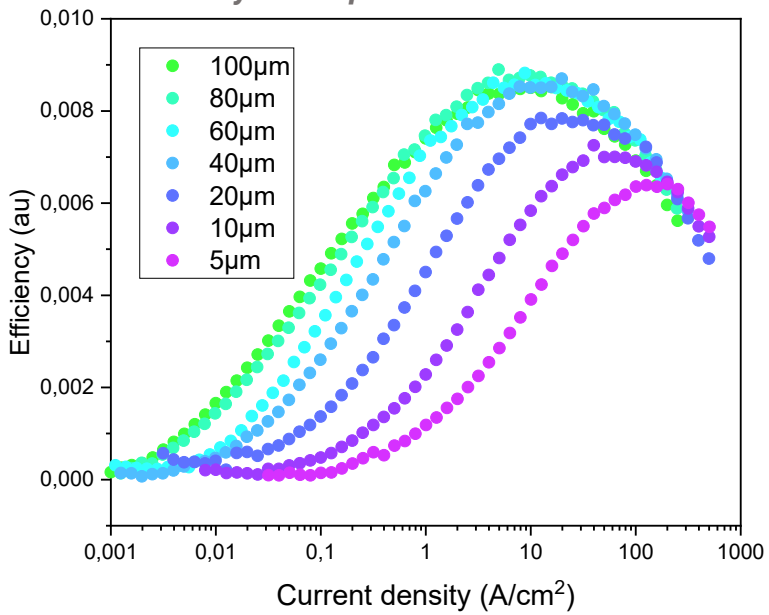
Native oxide at mesa sidewall



Defect states at surface/interface



Efficiency vs. chip size

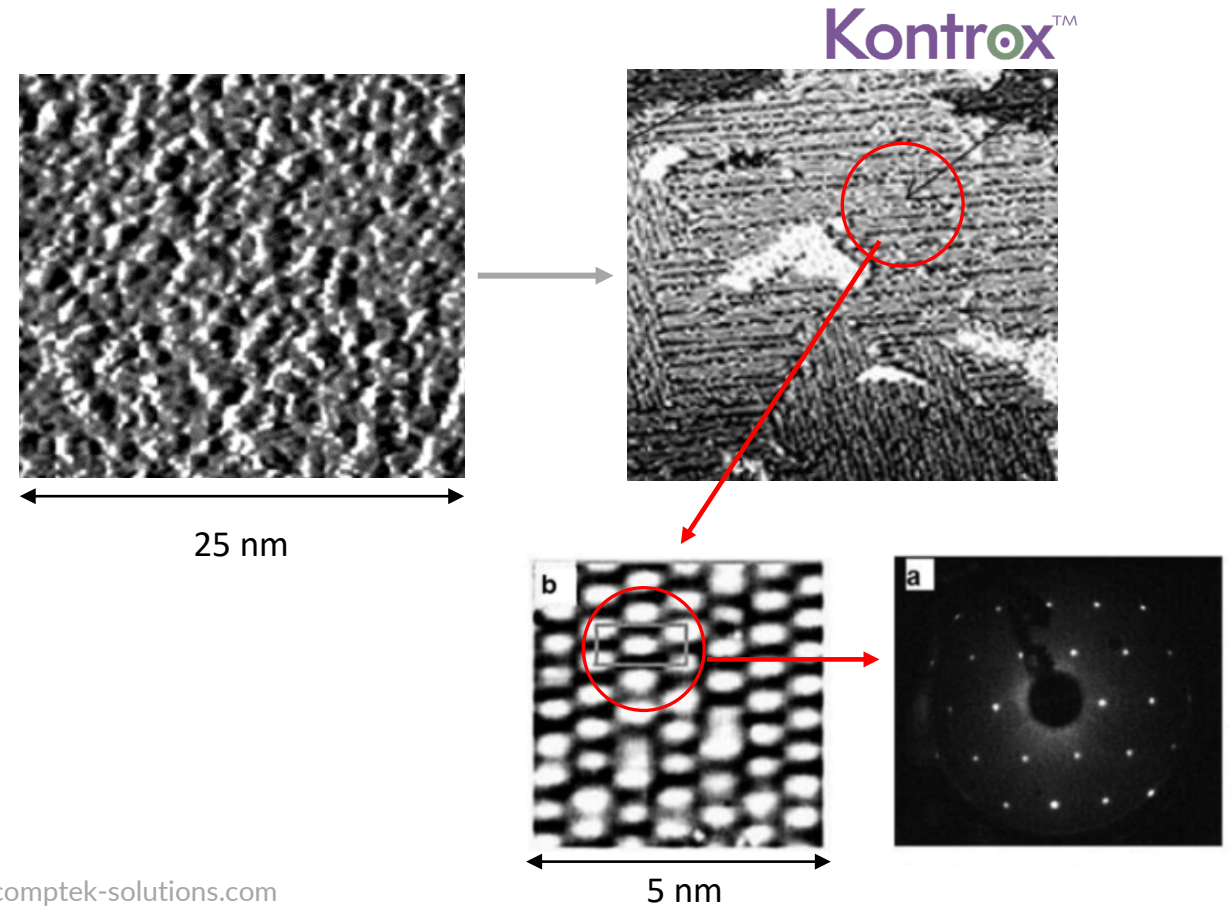


Our solution:

Achieving up to 98% reduction of interface defect state density compared to existing methods

Outcome:

Kontrox™ transforms the external layer of the materials into perfect **crystalline oxides stable under air exposure**



QUALITY

Perfect crystalline III-V oxide with 98% reduction of defect states

STABILITY

Stable against air exposure and high temperature annealing

PERFORMANCE

Reduced non-radiative recombination, IQE improvement

IMPLEMENTATION

High vacuum, dry and conformable process, applicable to majority of III-V materials

Materials scope:

OPTOELECTRONICS

- Mesa sidewall passivation
- Barrier layer in QW stack
- AR coating passivation

- Protective layer during processing
- Facet passivation

Laser diode
GaAs
AlGaAs
InAlGaAs
InGaAs
InP
GaInP
AlGaInP

LED
GaN
AlGaN
InGaN
GaAs
AlGaP
AlGaInP
GaP

CPV
AlInP
GaInP
GaAs
InGaAs
AlGaInP
AlGaAs

IR detectors
GaAs
InGaAs
InSb
InP
GaSb

CMOS

- Key enabler for III-V MOS based transistors for gate dielectric passivation

MOS III-V
InAs
InGaAs
InSb

RADIO FREQUENCY

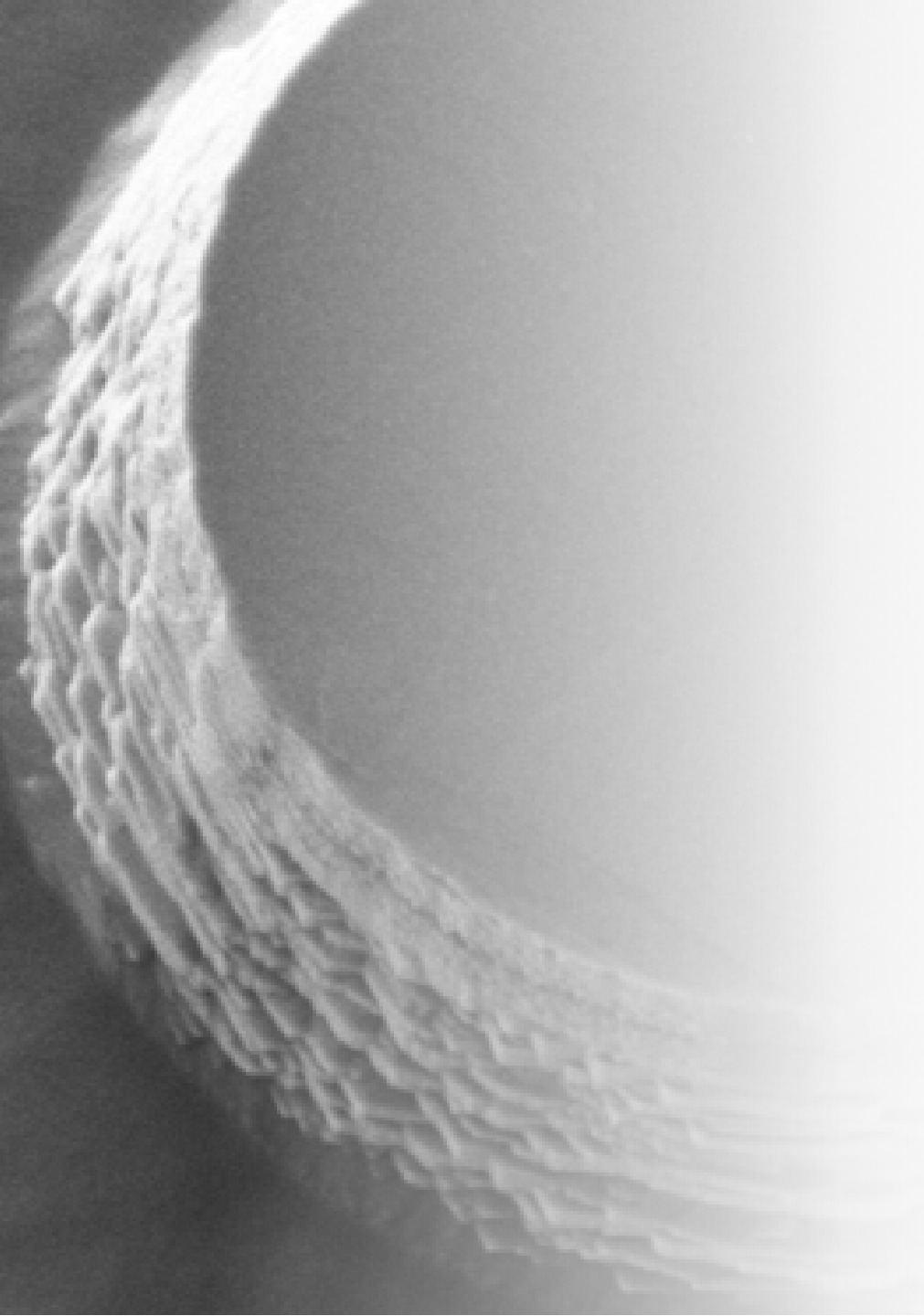
- Interface passivation layer for MOS-HEMT

p-HEMT
GaAs
AlGaAs
GaInP
InGaAs

m-HEMT
InP
InGaAs
GaInP

POWER ELECTRONICS

GaN
GaN
AlGaN
InGaN



Kontrox for microLEDs

- **Optimized and customized processes to enhance chip EQE**
- **Applicable to GaN (blue and green) and InGaAlP (native red) microLEDs**

STEP 1

PREPARATION

Selected processes to achieve an optimal quality for the chip side walls, e.g. ICP damage Healing and Native Oxide removal

STEP 2

PASSIVATION

A very controlled process performed in UHV conditions to form a high-quality oxides on the sidewalls and exposed surfaces of the µLEDs

STEP 3

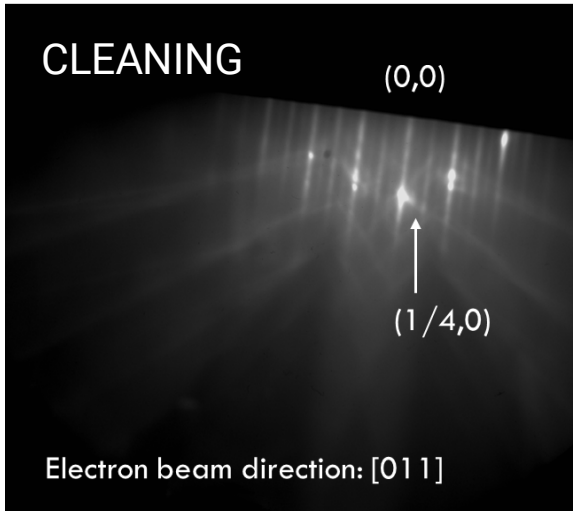
OVERCOATING

Traditional overcoating on top of Kontrox. - ALD, PECVD, etc. Kontrox ensures defect-free interface between the sidewall and overcoating

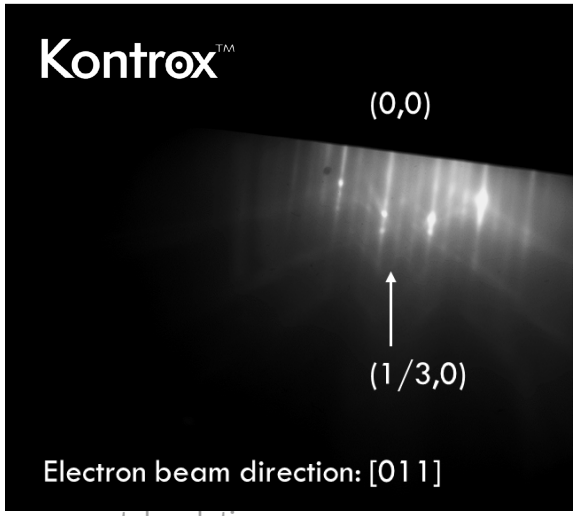
Enabling native red

Material-level

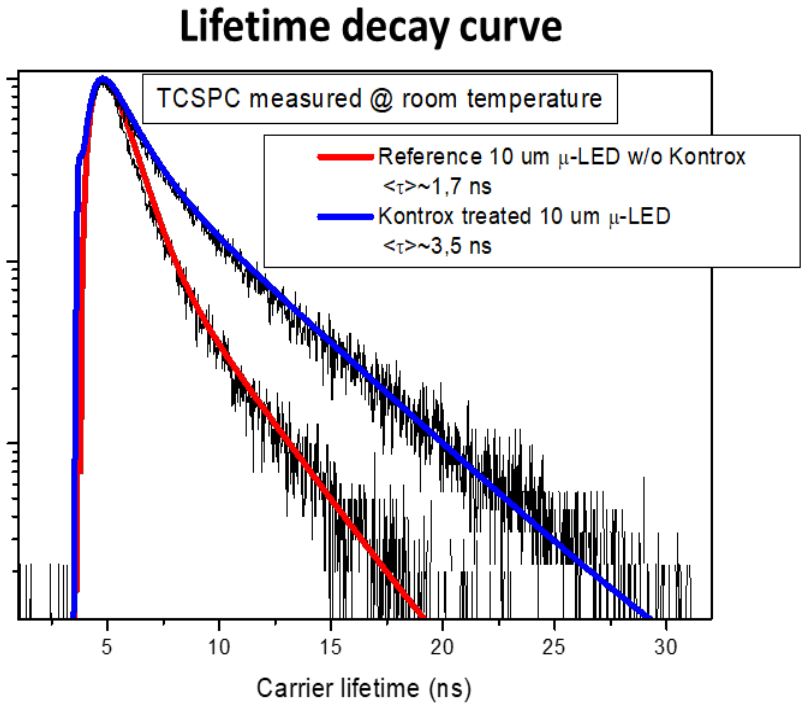
Clean InGaAlP(100)(4×2)



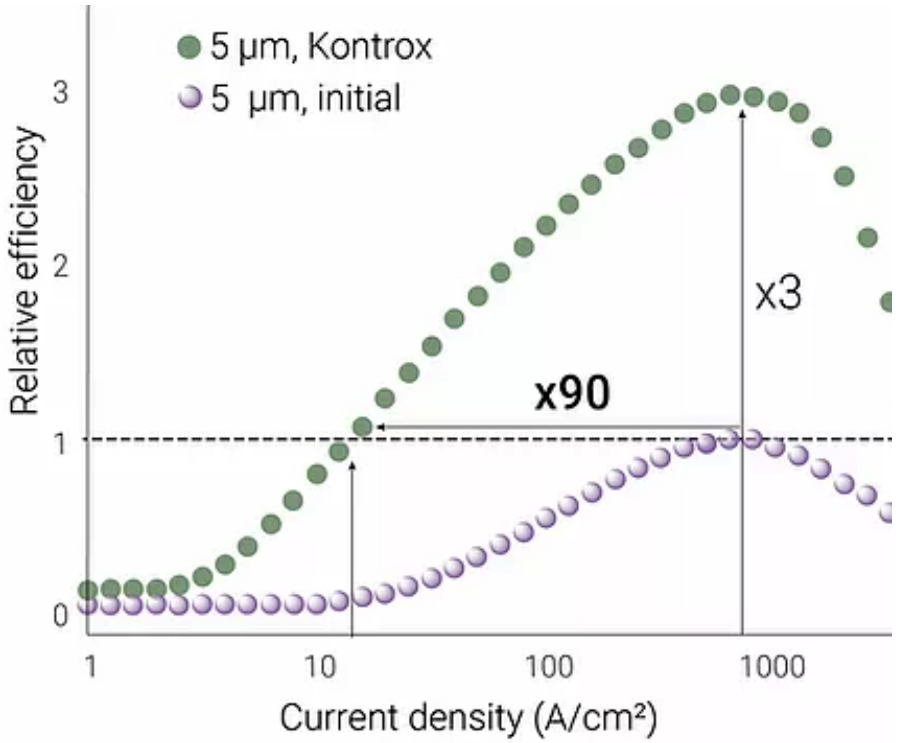
KONTROX InGaAlP(100)(3×1)



Mesa-level

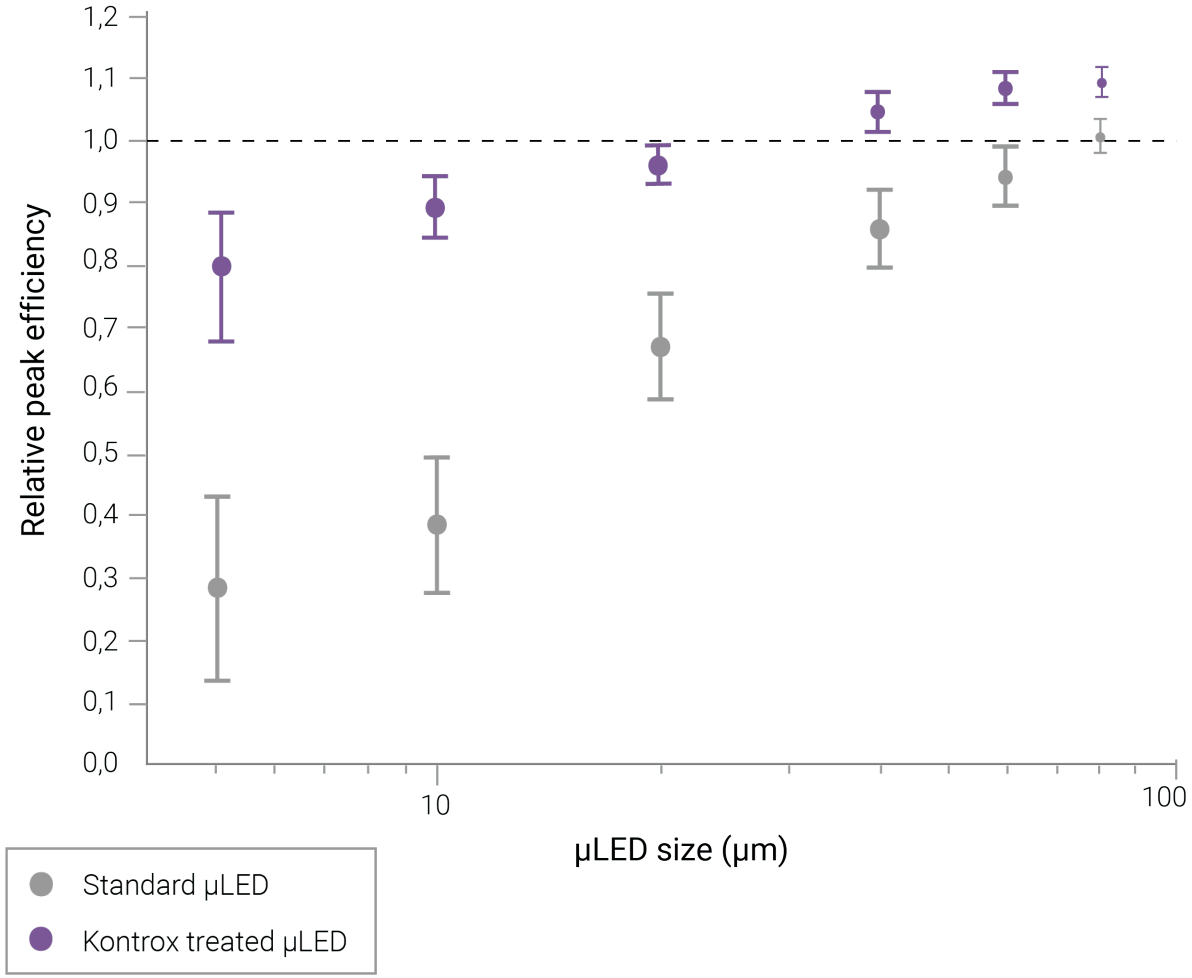


μLED-level

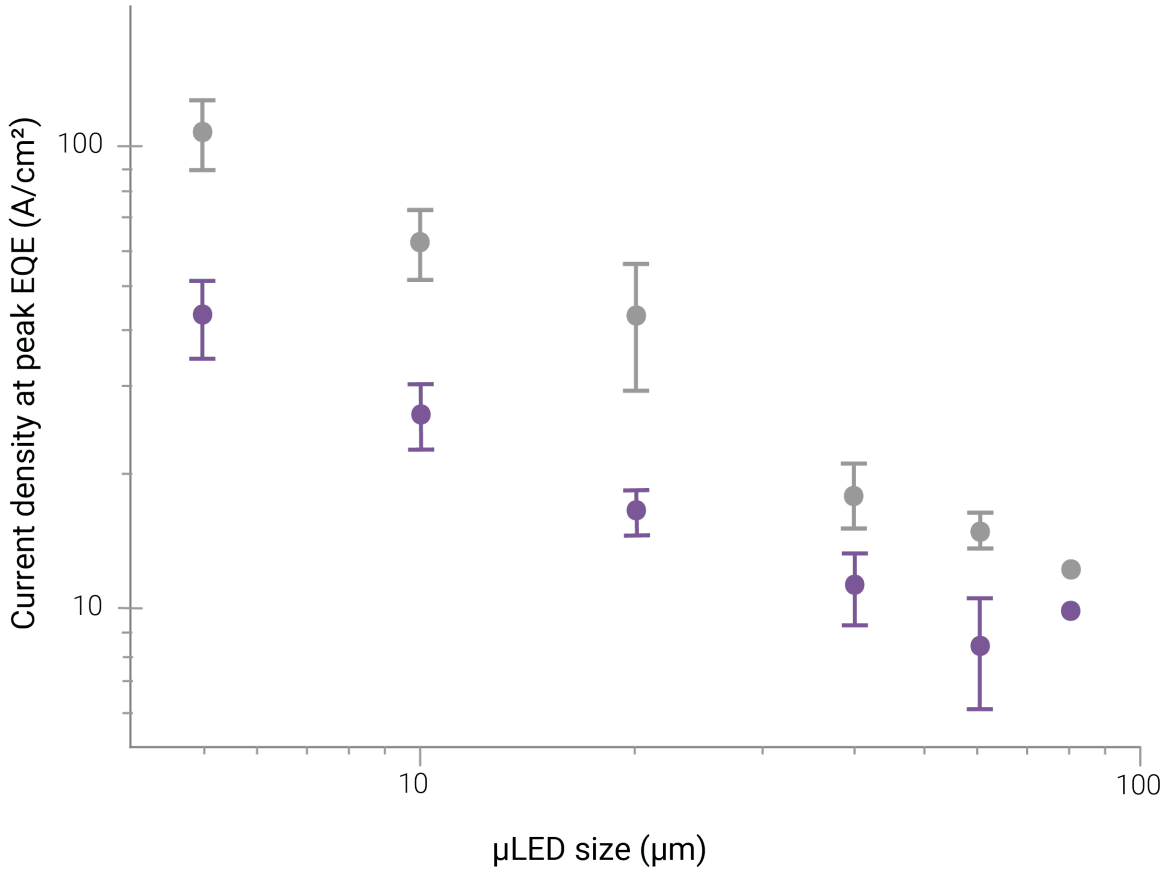


Improving efficiency and performance uniformity

Relative size dependent peak EQE vs. standard 80µm µLED



Current density @ peak EQE



Added value for microLED:

HIGHER EQE FOR **MAXIMUM DISPLAY BRIGHTNESS**

EQE improvements of **40% for blue chips and up to 250% for red chips**

ENABLING **NATIVE RGB**

Kontrox™ is the **most effective technology to improve the efficiency on InGaAlP** based devices.

LESS POWER CONSUMPTION

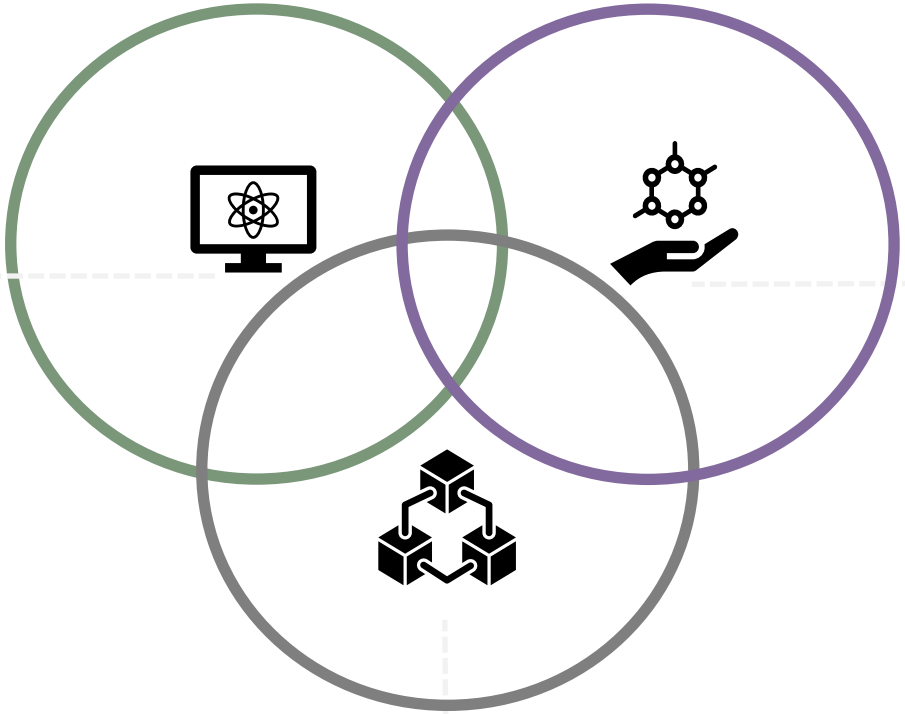
Up to 100 times lower current density vs untreated sample

INCREASED MANUFACTURING YIELD

Kontrox™ improves the uniformity between chips reducing binning activities

Turn-key technology implementation solutions

ACCESS TO
COMPTEK'S **IP PORTFOLIO**



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SERVICES
AND **LIFETIME SUPPORT**

PROCESS OPTIMIZATION & IMPLEMENTATION SERVICE, **CUSTOMIZED EQUIPMENT VIA RIBER**

IN SEARCH OF IMPROVED PERFORMANCE
FOR OPTOELECTRONIC DEVICES?

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