ALLOS Semiconductors

200 and 300 mm LED epiwafers: Enabling cost-competitive mass production of micro LED displays

5th June 2020, Alexander Loesing

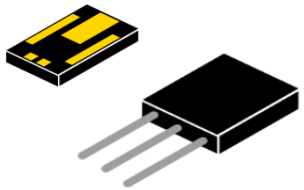
EPIC Online Technology Meeting on MicroLEDs Technology and Applications

GaN-on-Si is the key enabler for three fast-growing markets

Micro LED / LED

Only GaN-on-Si allows super-uniform, large diameter, CMOS-compatible 1 bin® epiwafers needed for large-scale micro LED display production

High power electronics (HPE)



GaN-on-Si enables more energy-efficient, less complex and smaller high power electronic (HPE) devices from existing silicon lines

Radio frequency devices (RF)

GaN-on-Si provides higher performance, smaller, more energy efficient and lower cost RF devices, for 5G base-stations, smart-phones, CATV, IoT and other RF applications

ALLOS* is a leader in GaN-on-Si with more than 16 years track-record

end of 90s — University of Magdeburg one of three birthplaces of GaN-on-Si world-wide

2003 — First to show a 150 mm epiwafer

2005 — OSRAM gets license for LED production

2009 — AZZURRO closes; ALLOS buys IP and technology for new business model

2013 — Carbon-doping free GaN-on-Si


ICNS 2017: ALLOS explains why carbon-doping is not needed to achieve high isolation in GaN-on-Si

Strasbourg, France – 28th July 2017 – At this week's ICNS scientific conference ALLOS' co-founder and CTO Dr. Atsushi Nishikawa discussed three common beliefs about GaN-on-Si: Firstly, that the usage of carbon would be inevitable, secondly that using interlayers in the buffer would be a source of leakage and thirdly that the choice of the right reactor hardware

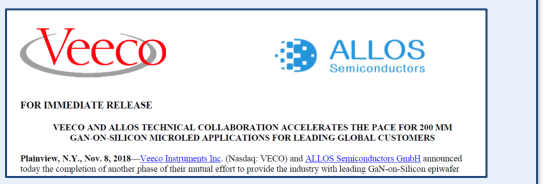
2014 — EPISTAR licenses ALLOS' technology

2015 — Total investment exceeds EUR 40 m

2016 — First to offer a commercial 200 mm epiwafer

2017 — Products for HPE, RF and LED introduced

2018 — AZZURRO founded in Magdeburg and becomes the first epiwafer vendor world-wide


FOR IMMEDIATE RELEASE

VEECO AND ALLOS TECHNICAL COLLABORATION ACCELERATES THE PACE FOR 200 MM GAN-ON-SILICON MICROLED APPLICATIONS FOR LEADING GLOBAL CUSTOMERS

Plainview, N.Y., Nov. 8, 2018—Veeco Instruments Inc. (Nasdaq: VECO) and ALLOS Semiconductors GmbH announced today the completion of another phase of their mutual effort to provide the industry with leading GaN-on-Silicon epiwafer

2019 — ALLOS shows < 1 nm wavelength uniformity on 200 mm GaN-on-Si LED epiwafer on Veeco Propel

CSindustry awards WINNER — For > 1400 V breakdown

IEMN: "Excellent trapping behavior"

CSindustry awards WINNER — Overcome trade-off between leakage and switching

* ALLOS and predecessor company AZZURRO

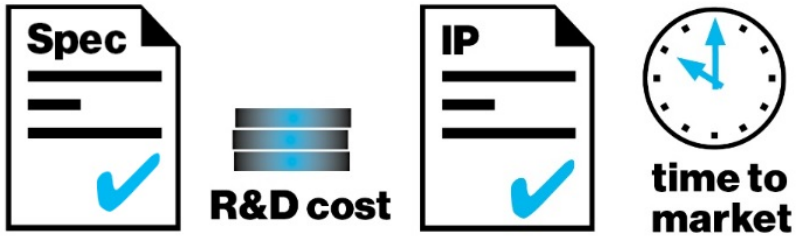
ALLOS' value proposition is to license and transfer turn-key GaN-on-Si epiwafer technology and IP

3 years?

Develop GaN-on-Si epitaxy technology by yourself

12 weeks!

Work with ALLOS



Essential requirements for micro LED achieved by ALLOS

High crystal quality

- ✓ Same low defect level as on GaN-on-sapphire: TDD ~2 x 10^8 cm^{-2}

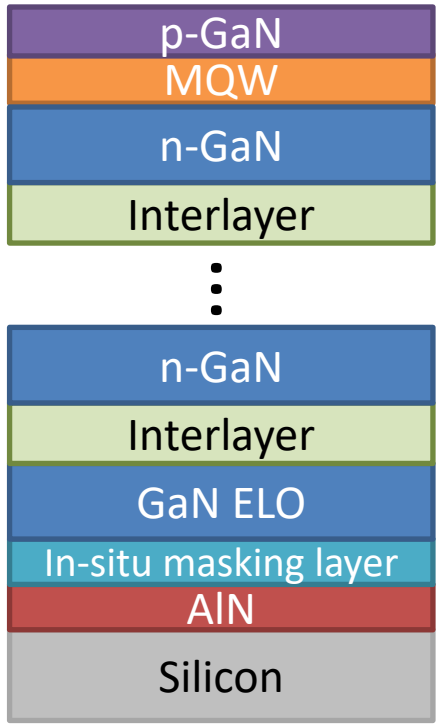
= Performance

Large diameter and CMOS ready

- ✓ 200 mm and 300 mm diameter
- ✓ < 30 µm bow for 725 µm (200 mm) and 775 µm (300 mm) thickness
- ✓ No cracks, no residual strain

= Low-cost

Typical GaN-on-Si LED structure of ALLOS*



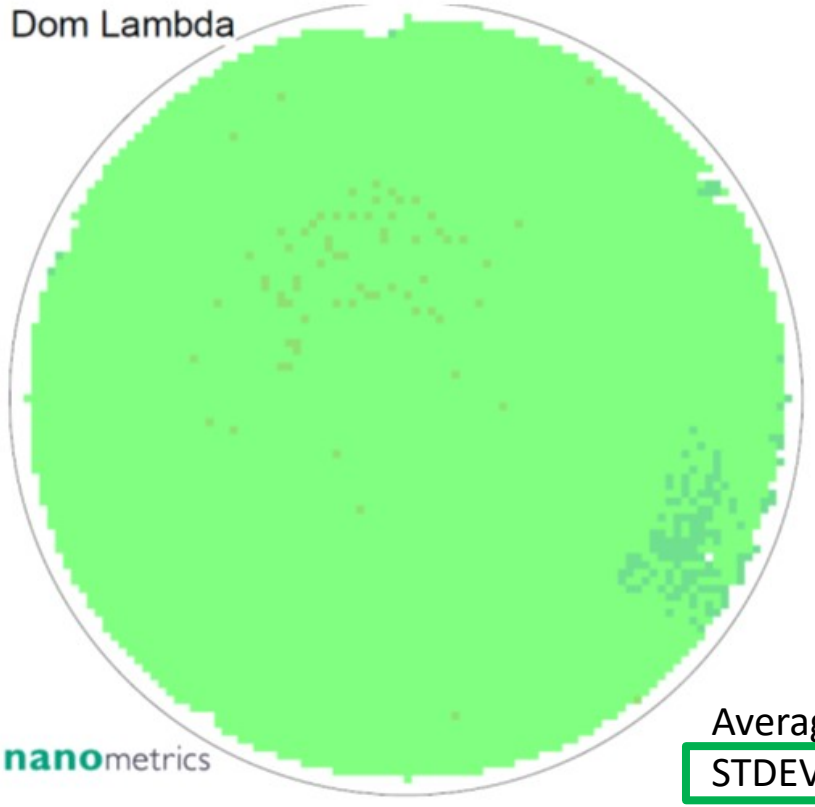
Excellent wavelength uniformity

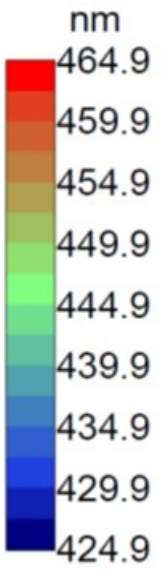
- ✓ Requires perfect conditions for MQW growth…
- ✓ … which cannot be achieved on sapphire - especially not at similar wafer diameters…
- ✓ … and needs to be repeatable

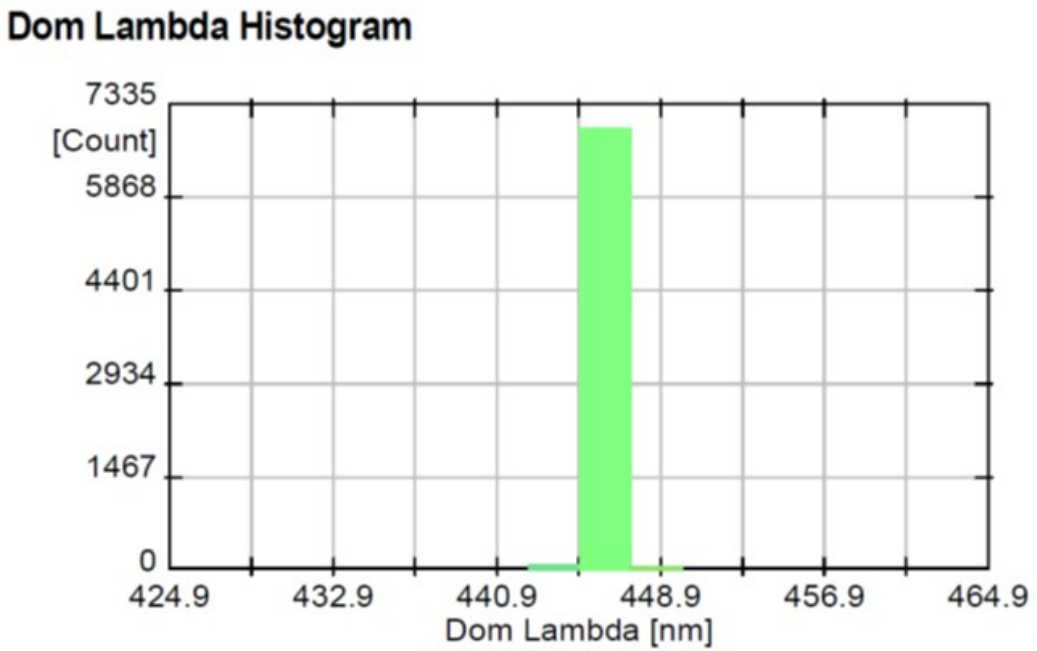
= High yield

*** Protected by ALLOS' IP; active layers can be the same structure as used by customer for GaN-on-sapphire**

Record-breaking emission uniformity < 0.6 nm is achieved on 200 mm GaN-on-Si micro LED epiwafer





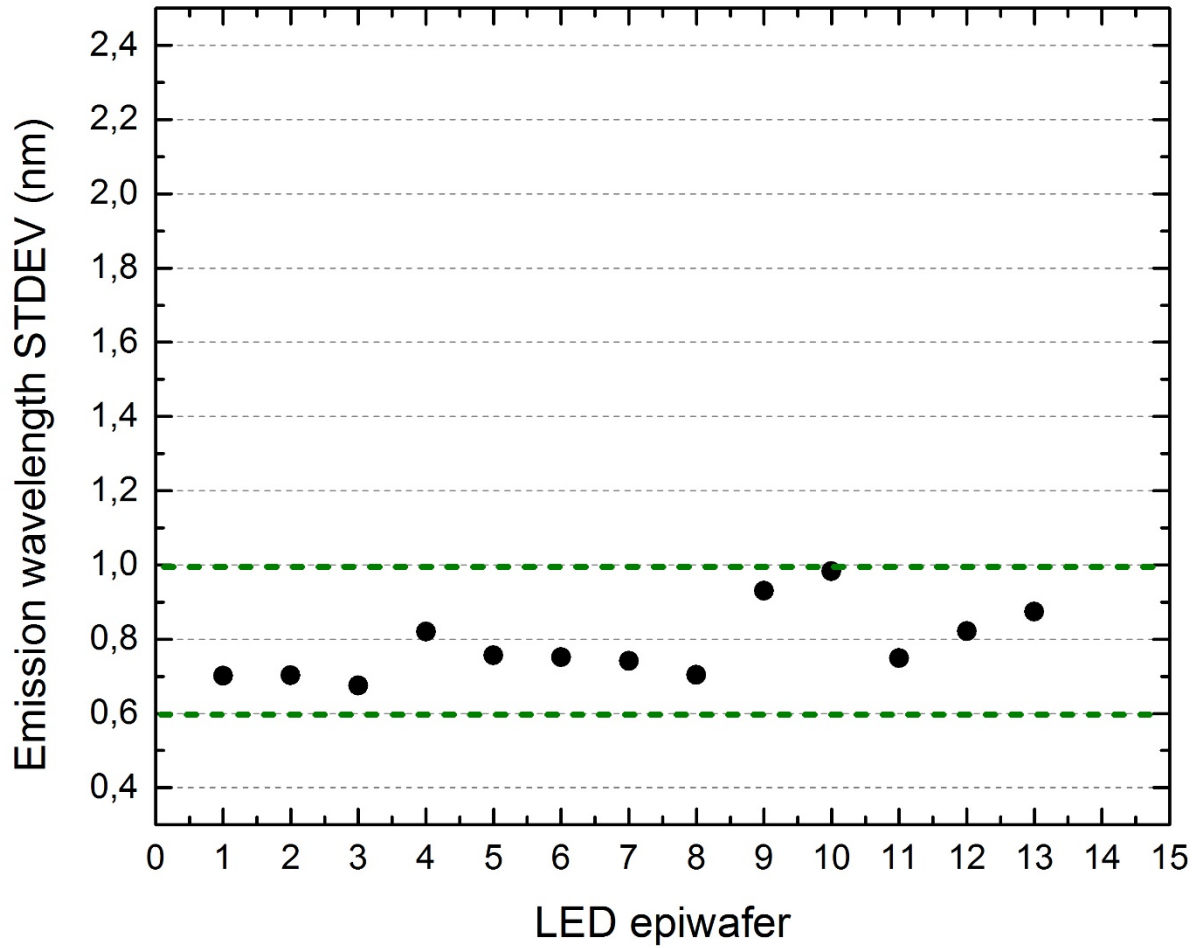


Average: 446.4 nm
STDEV: 0.566 nm (0.127 %)
Median: 446.4 nm
Min: 444.6 nm
Max: 447.9 nm

97.6 % in 2.5 nm bin
Min-max = +/- 1.65 nm

Result from customer project on Veeco Propel in February 2019

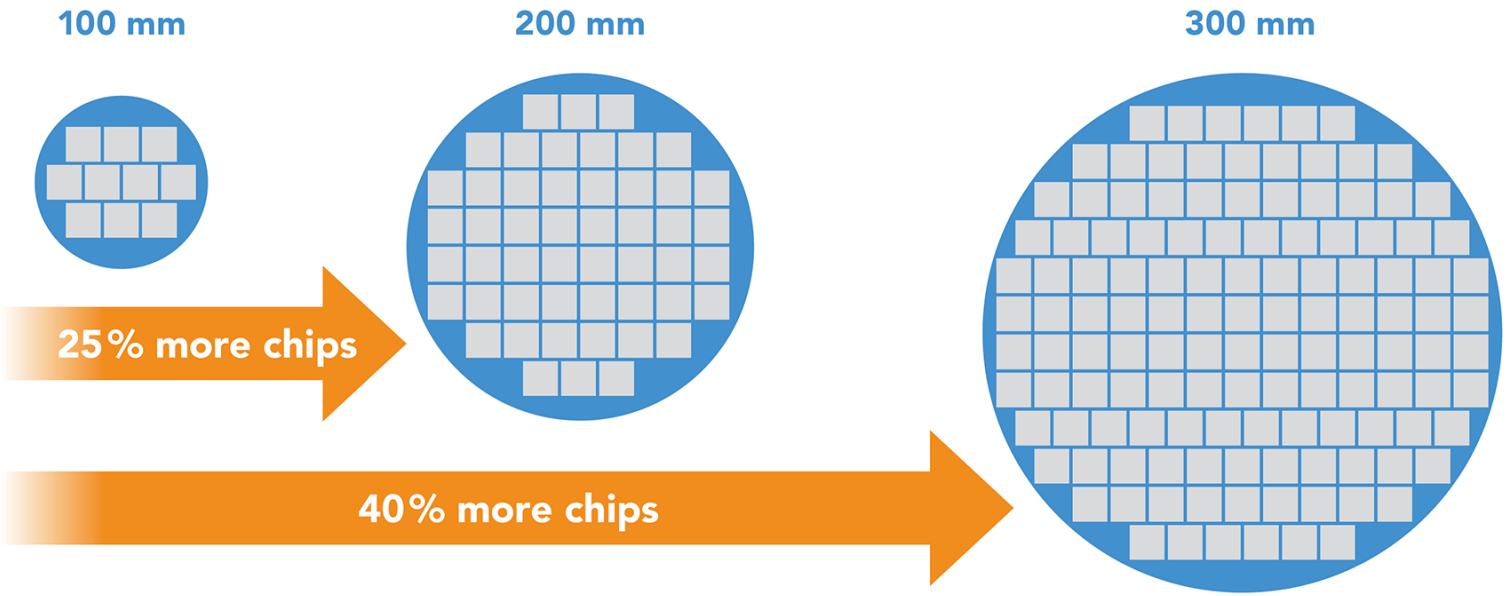
Excellent reproducibility for emission wavelength uniformity



13 repetition runs with average STDEV of wavelength uniformity of 0.79 nm and all points below 1 nm (STDEV of average value is 0.095 nm)

Result from customer project using the same recipe on Veeco Propel in January 2020

Better area utilization enables huge LED chip cost reduction



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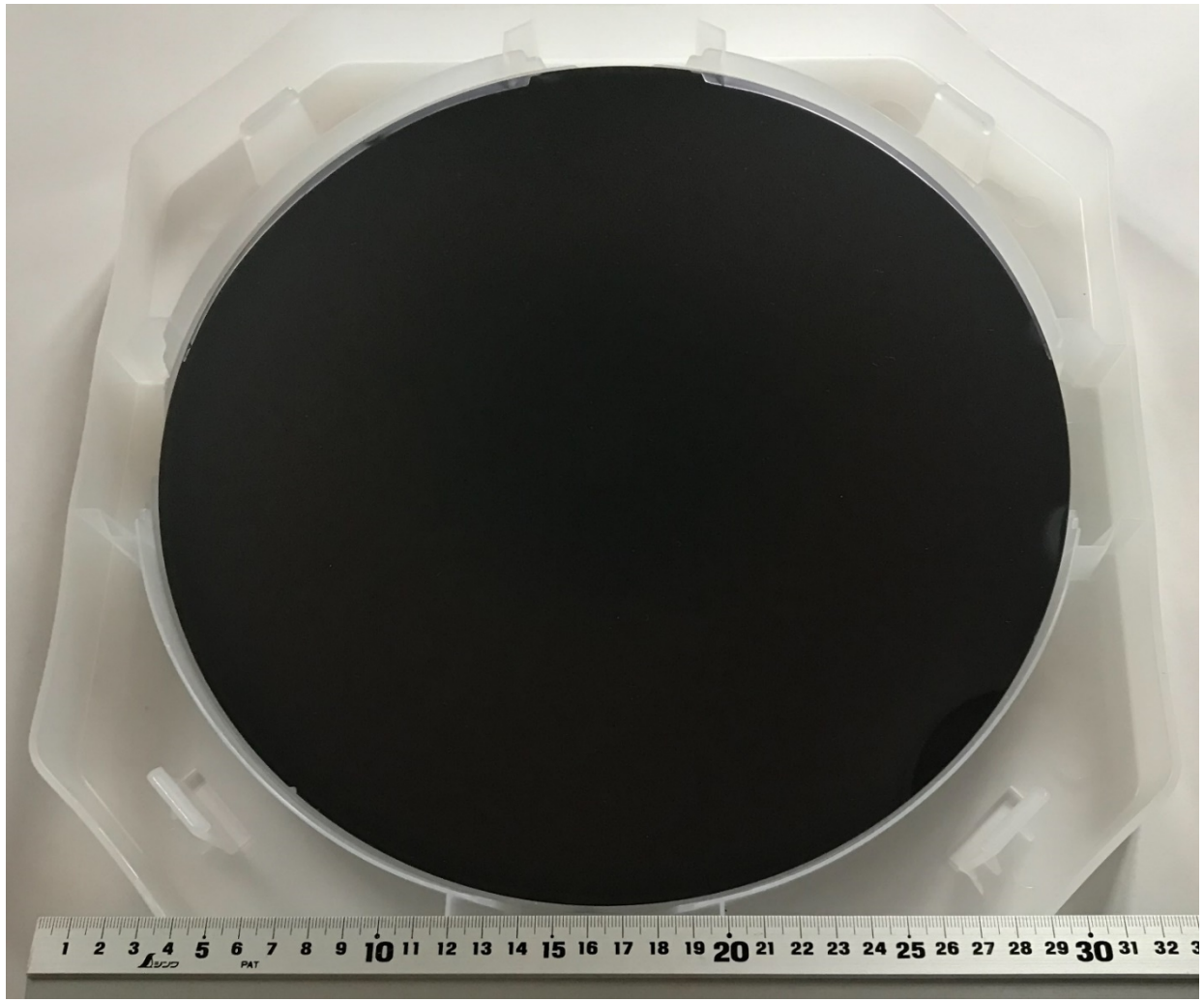
= Transfer stamp size (example)

Wafer size [in mm]	Wafer area [factor]	Amount of stamps	Cost advantage
100	1	10	NA
200	> 4	50	> 25 %
300	> 9	128	> 40 %

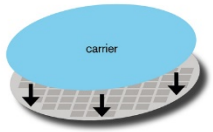
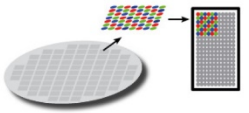
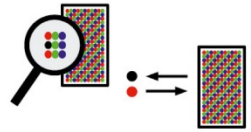
- Efficient micro LED manufacturing requires usage of a transfer stamp
- Higher transfer efficiency with larger transfer stamp
- Useable area for given transfer stamp is larger with bigger wafers
- This is in addition to all other advantages coming from using larger wafers
- Going to 300 mm gives an extra 15 % more chips than 200 mm (40 % over 100 mm)

300 mm GaN-on-Si growth is NOT the future anymore!



ALLOS' technology is already scaled to 300 mm GaN-on-Si!

Cost and yield effects of ALLOS' 1 bin® large diameter GaN-on-Si LED epiwafers on the entire production chain

GaN epiwafer	LED chip processing	Thin film (flip chip) process	Mass transfer	Inspection and repair
				
1bin® technology: • Delivers world leading wavelength uniformity which is the most critical LED yield contributor • Enables up to 300 mm diameter to reduce cost in the following LED production steps • Provides high crystal quality that is needed to guarantee excellent LED efficiency	• 200 and 300 mm diameter epiwafers from ALLOS enable the use of low cost and high yielding lines for LED chip processing (e.g. depreciated silicon semiconductor line • Epiwafers fulfil CMOS incoming wafer quality criteria	• Easy bonding of transfer-wafer to LED wafer thanks to low bow • Low cost and high yielding removal of silicon substrate (no laser lift off needed)	• Large 200 and 300 mm wafers return much more chips per wafer area when using transfer stamps • Realize the vision of 100 % LED chip yield to enable mass transfer and minimize repair: Main contributors are 1 bin® wavelength uniformity and the high yield level of silicon semiconductor lines • Cost benefits gained throughout the entire manufacturing chain enable the mass production of micro LED displays	

ALLOS' 1 bin® epiwafer technology enhances yield and reduces cost

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ALLOS' 1 bin® GaN-on-Si technology enables:

- Best-in-industry wavelength uniformity for high yield
- 200 and 300 mm LED epiwafers for low cost
- Meeting the performance of GaN-on-sapphire …

  … and all other manufacturing requirements

csindustry awards

WINNER

2018 and 2019

Thank you very much for your attention!

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