

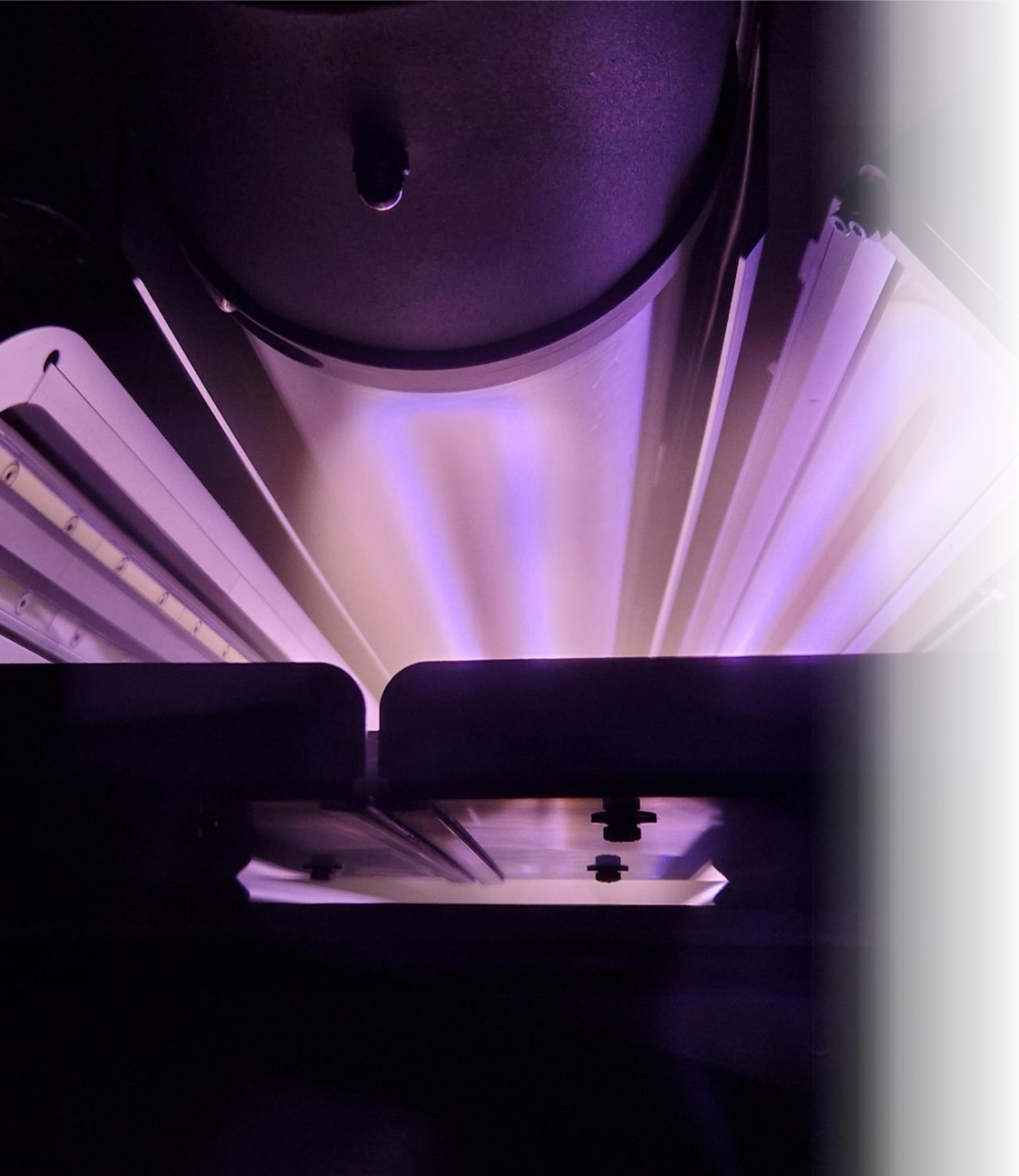
ELEMENT 3-5 - The Green Semiconductor Company

Next Level Epitaxy

A Novel Approach for the Volume Production of Wide-Bandgap Semiconductor

Dr. Sarah Spindler

SEMICON Europe, November 2025



Agenda

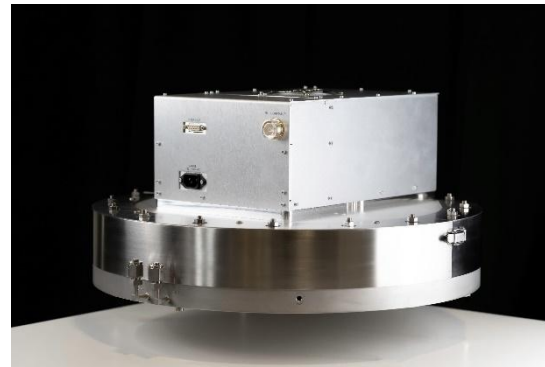
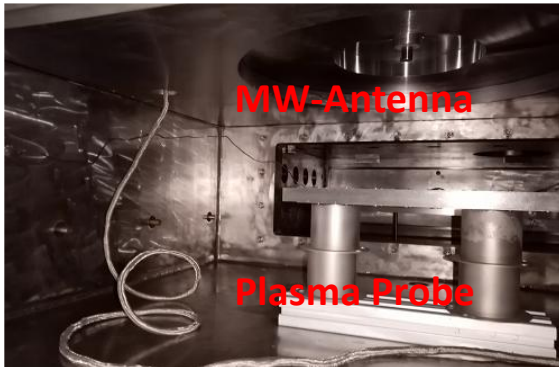
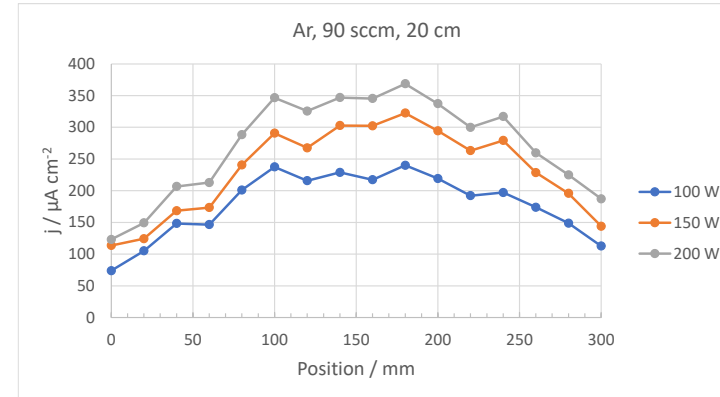
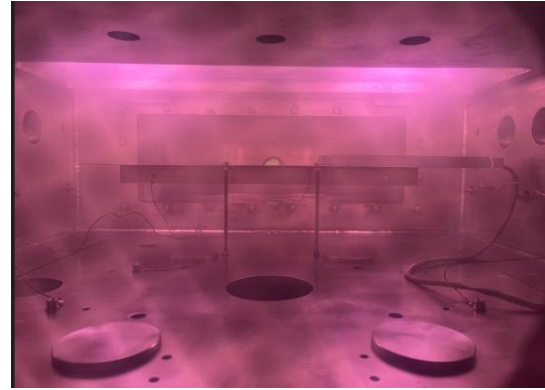
- Introduction Next Level Epitaxy (NLE)
 - Hardware NLE
 - Process NLE
 - Results of NLE
- Funded Projects and Cooperations
- Summary and Outlook

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Hardware of NLE

In-house developed plasma sources



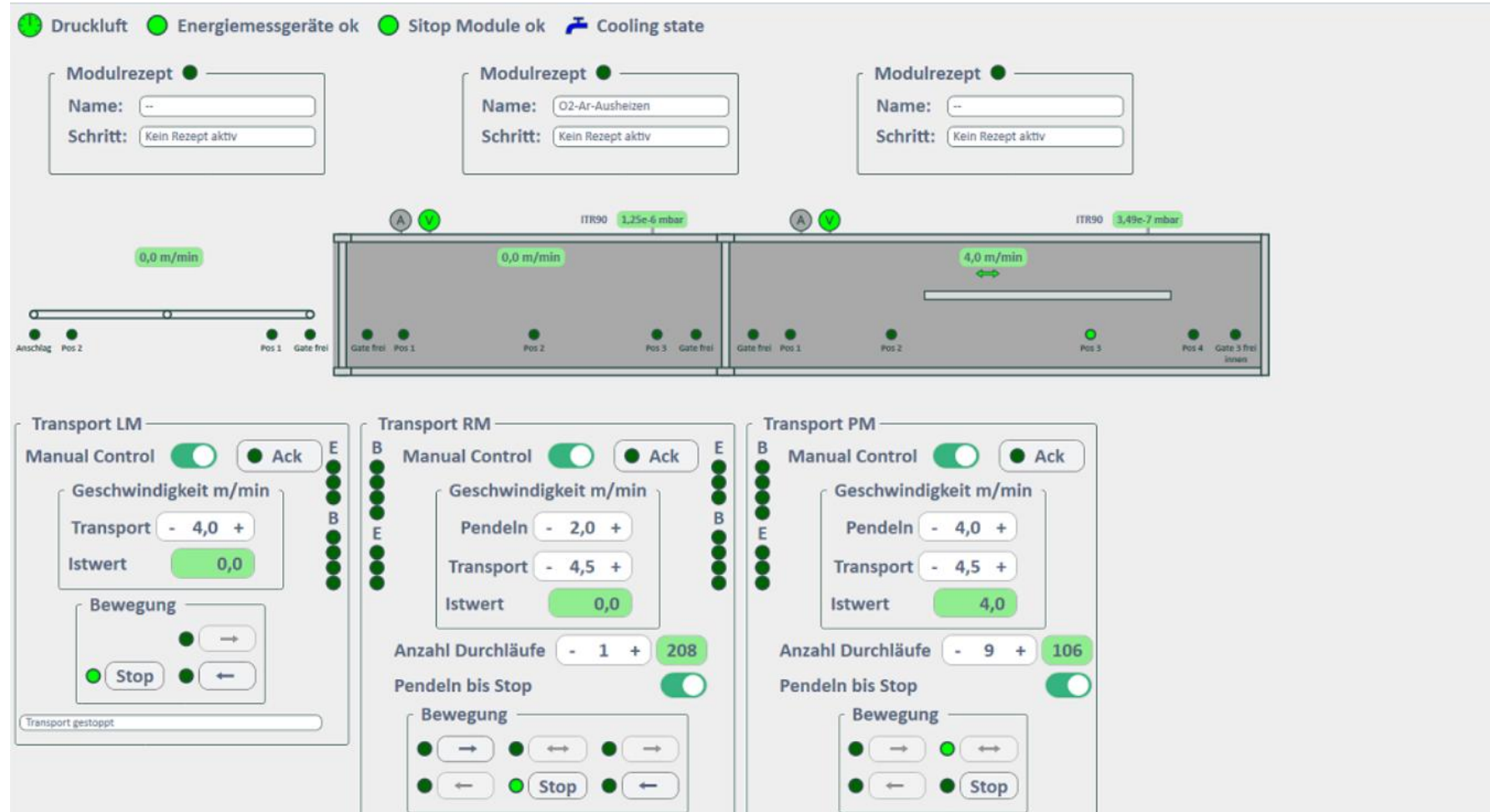
- Design and testing in house.
- Microwave plasma antenna, inductively coupled plasma sources and ion guns.

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NLE process in industrial production tool

In-house developed Software



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Effective crystal growth with NEXT LEVEL Epitaxy

ACCELERATOR 3500K



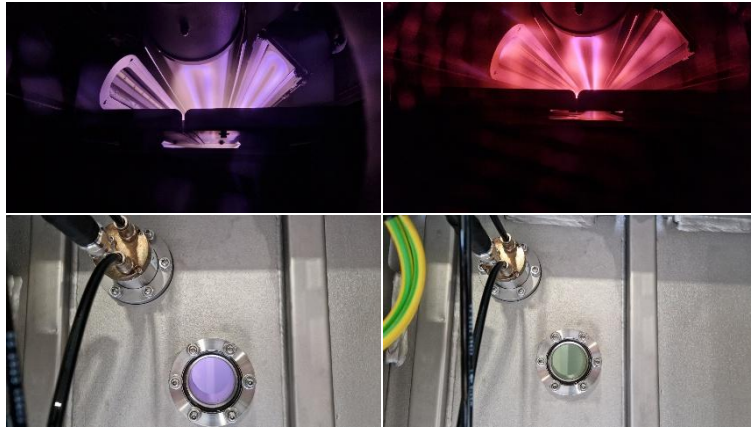
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Introduction to Next Level Epitaxy (NLE)

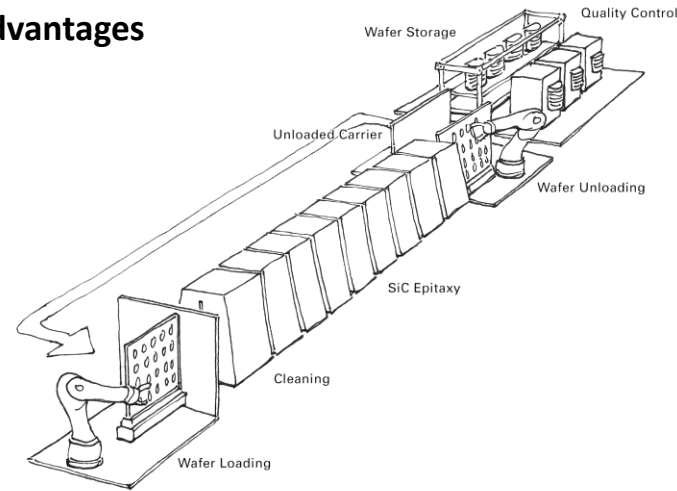
Effective crystal growth with a unique novel technology

Technology



- **Combination of PVD and CVD growth techniques**
- Process temperature **below 300°C**
- **Single crystal quality**
- Multi-wafer system design
- **In-line production** concept
- Equipment, deposition-process and over-growth **patented**

Advantages



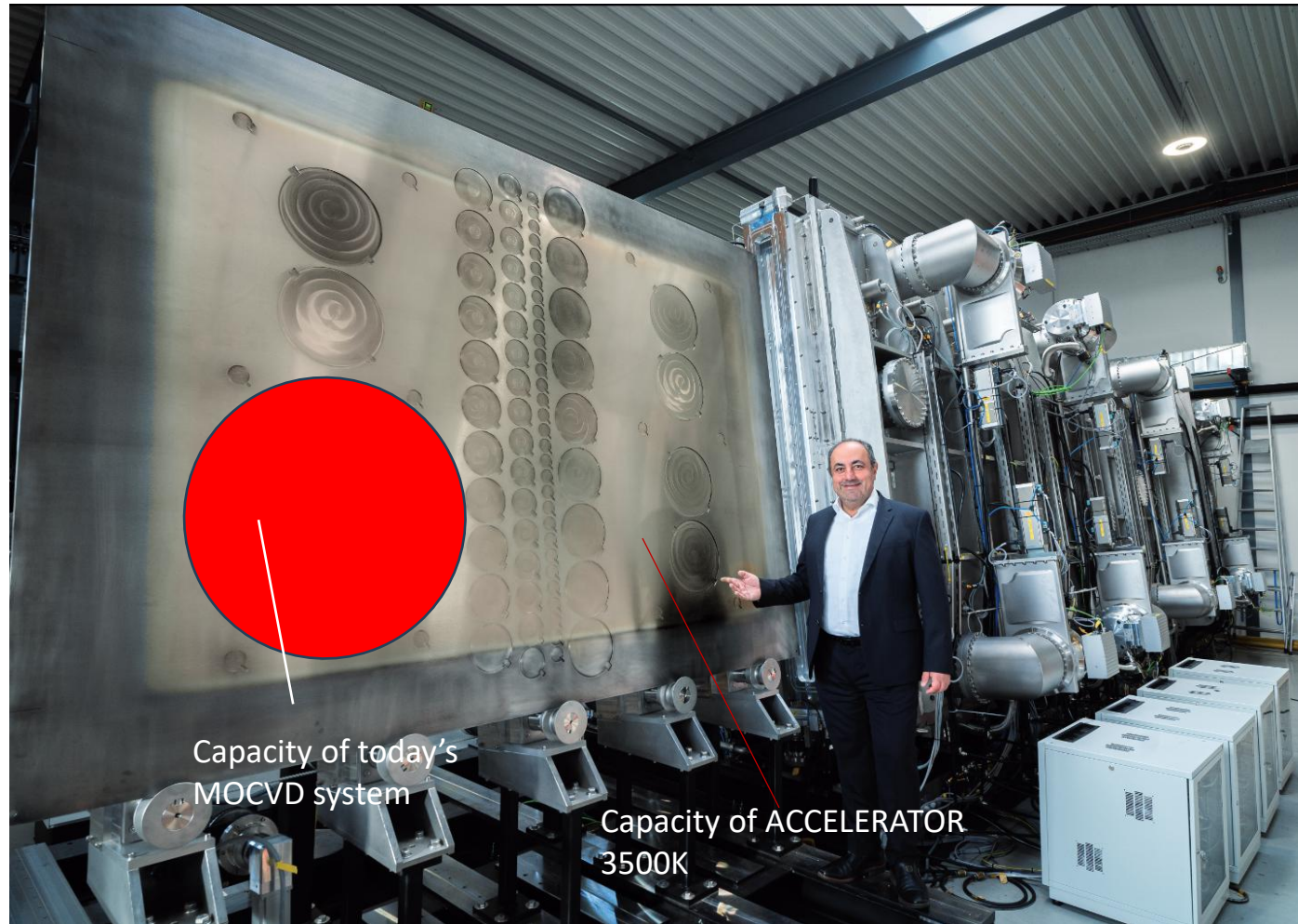
- **Cycle times 2 to 7 times lower**
- Capacity increase by a factor of 10
- **Highest throughput**
- High quality of crystal structures due to single crystal structure
- Minimized wafer stress
- Environmentally friendly
- Design freedom due to patent protection

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ACCELERATOR 3500K – A real paradigm change

Impressions of serial production system



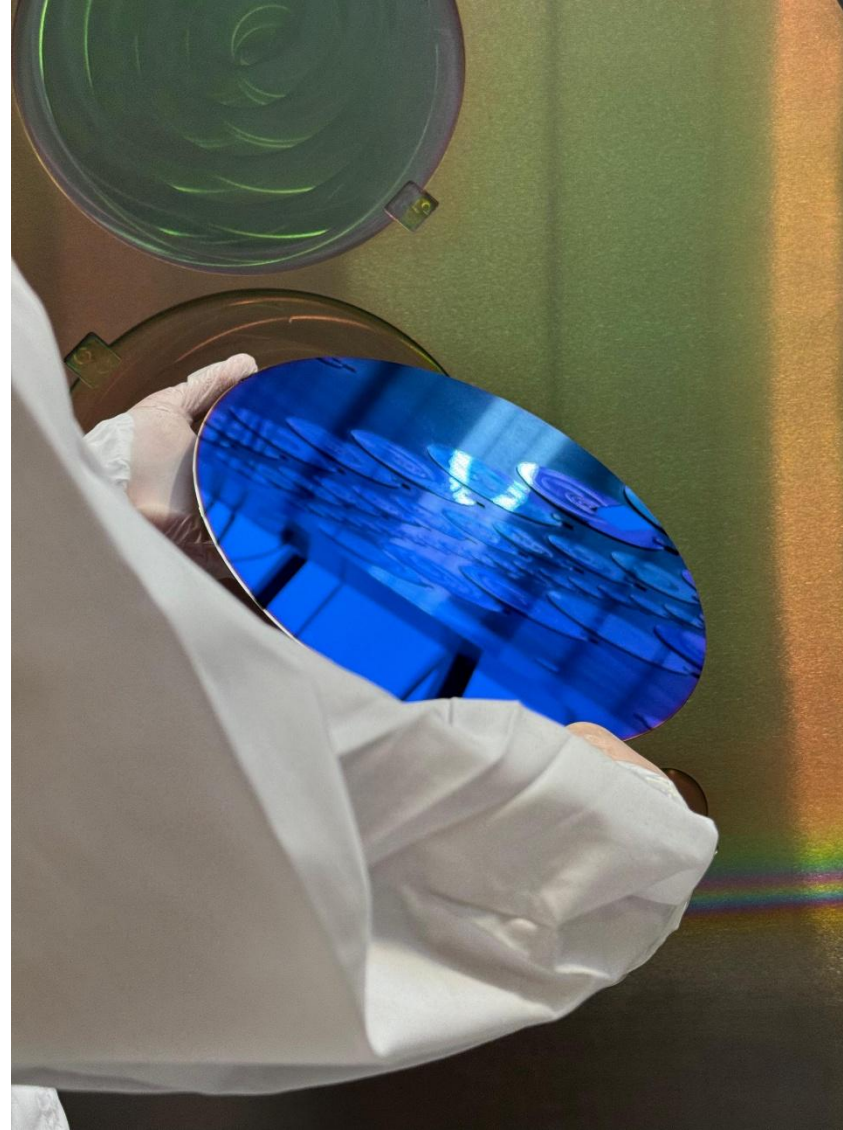
- Continuous evolution from semi-automated Prototype system to industrial production level too.
- Capacity increase from 5 x 200 mm to **70 x 200 mm per cycle**.

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ACCELERATOR 3500K

in Action



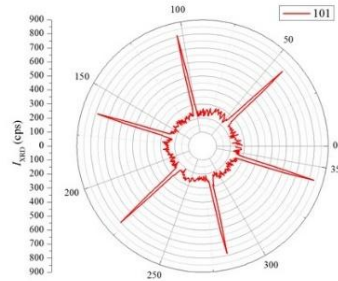
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Template Characteristics

Layer growth by Next Level Epitaxy

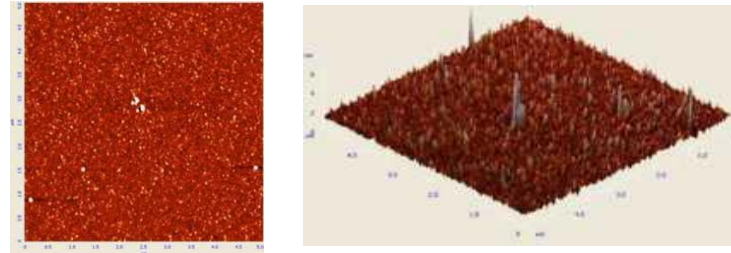
Phi-scan around 101 peak of 50 nm thick AlN layer on sapphire.



Only allowed peaks of hexagonal AlN crystal visible.

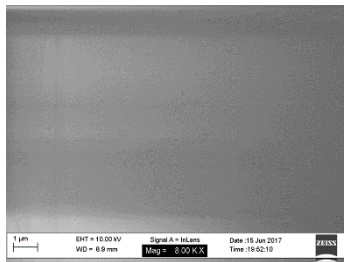
➡ **Single crystal quality!**

AFM of AlN on sapphire



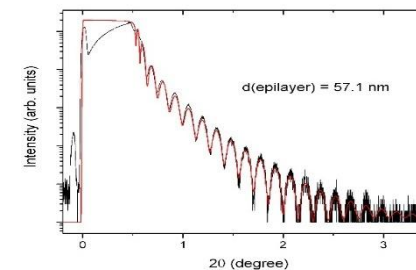
- RMS values below 0.3 nm are achieved.
- No columnar growth can be observed.
- Re-machining of deposited layer not necessary.

SEM of AlN on sapphire



- SEM show very smooth surfaces.
- The process guarantees a low density of pits.
- A re-machining of the deposited layer is not necessary.

XRR of AlN on sapphire



- Thickness of the layers checked by X-ray reflectometry (XRR) measurement.
- Measurement and simulation match perfect, indicating a very smooth surface.

Agenda

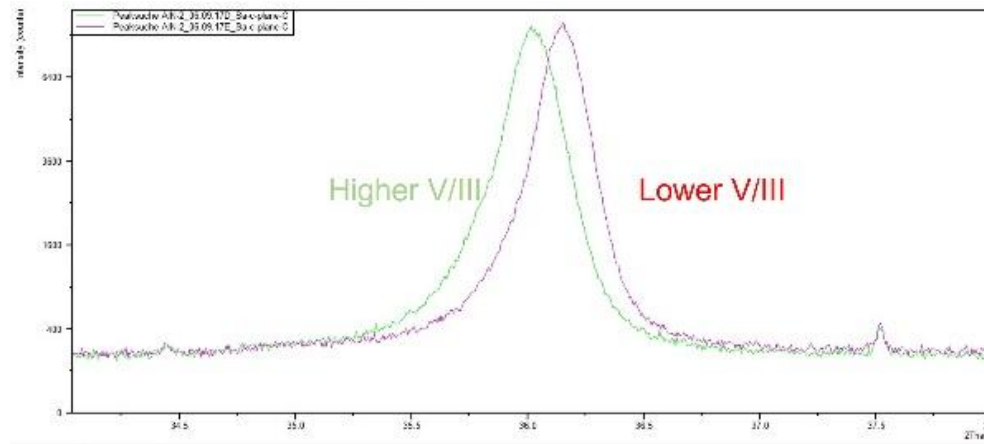
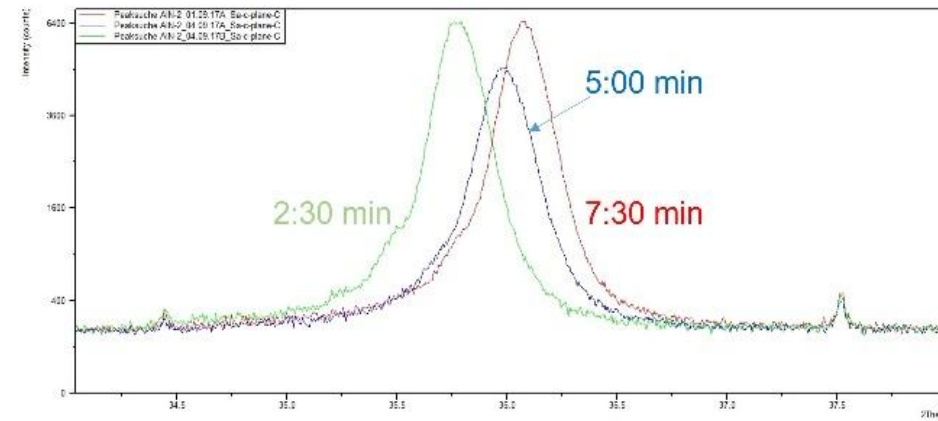
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Layer growth by Next Level Epitaxy

Influence of low growth rate AlN/ nitridation duration

- Process tuning as know from MOCVD or MBE.
- The AlN strain can be changed from compressive strain to tensile strain by slow growth rate AlN /nitridation.



Influence of V/III

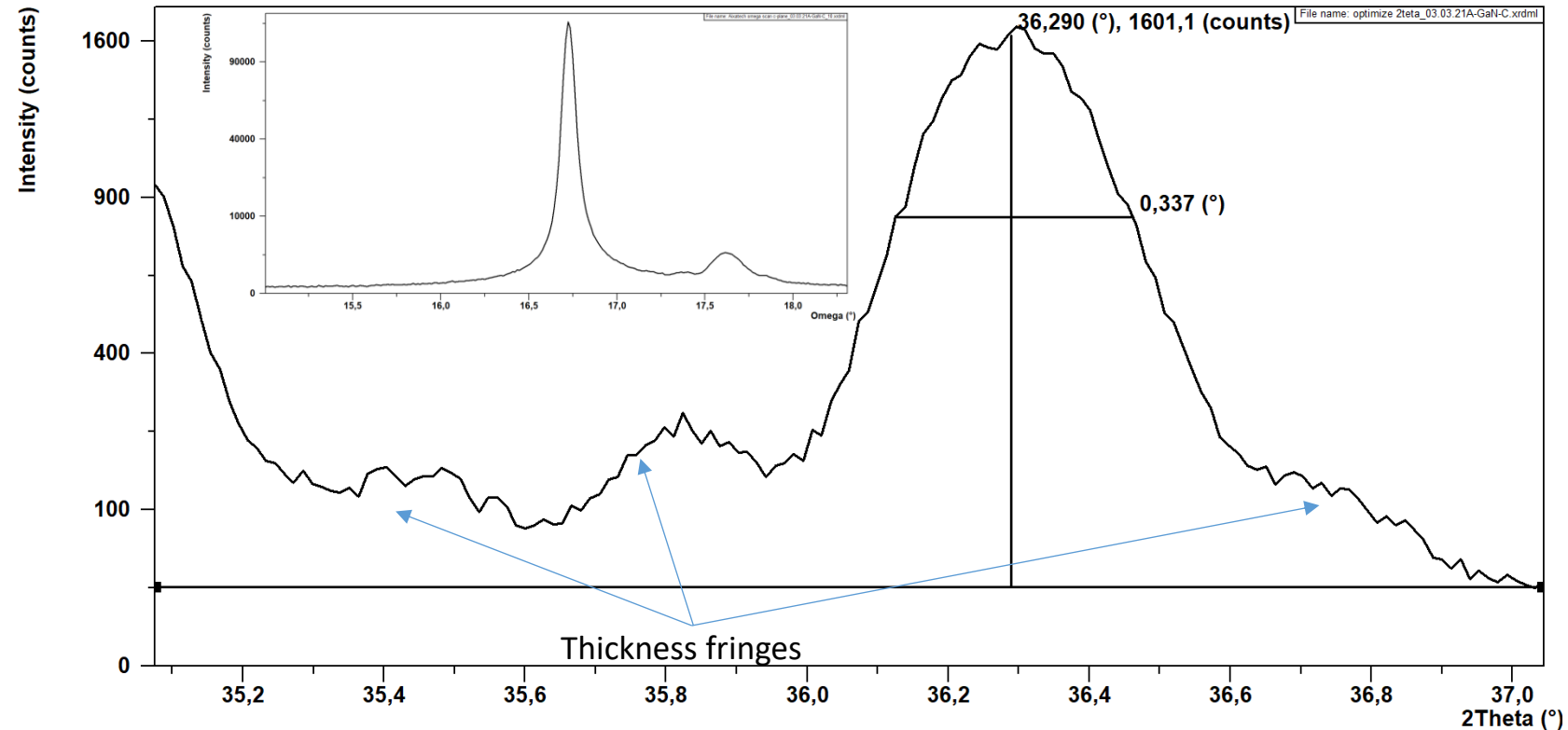
- Epitaxial process behavior.
- The AlN strain can be changed from compressive strain to tensile strain by high or low V/III.

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Overgrowth with ELEMENT 3-5 Process

Room temperature growth



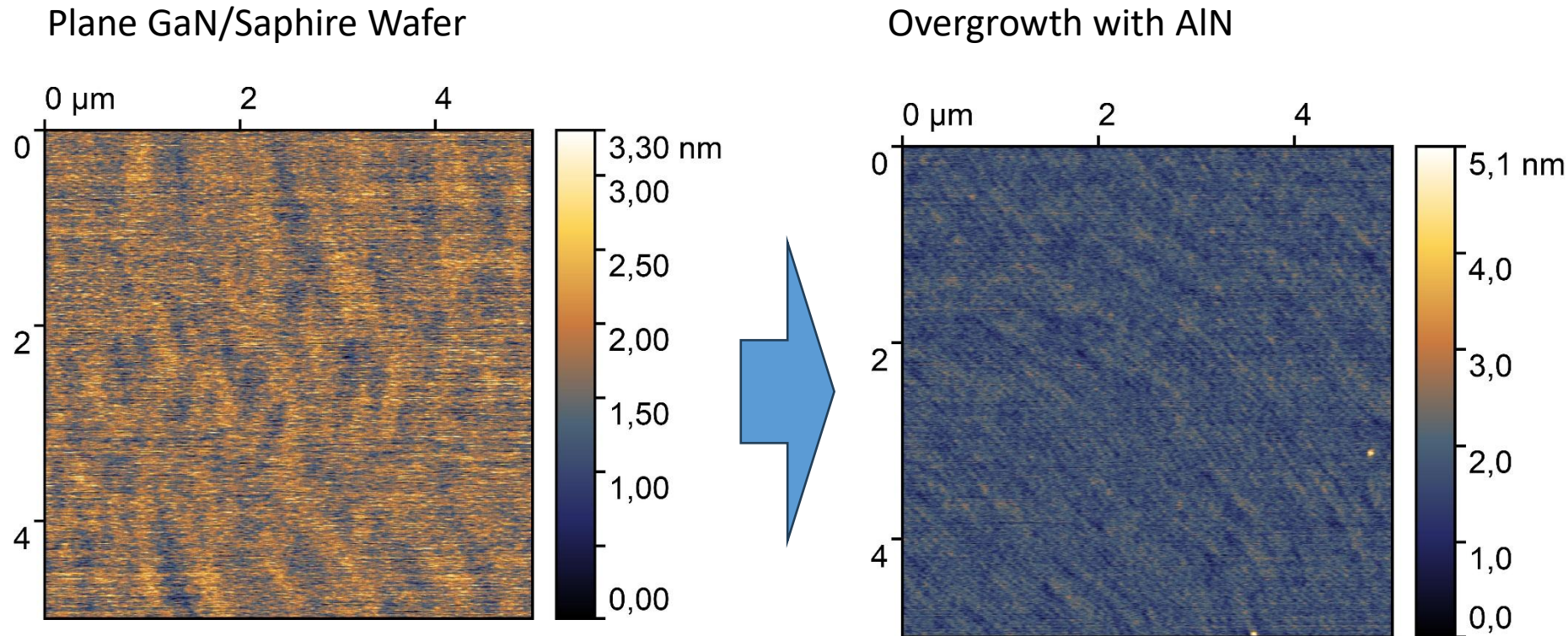
- AlN growth on MOCVD GaN on sapphire at room temperature.
- Due to the similar lattice structure epitaxial AlN could be grown with smooth surface with clear thickness fringes.
- Advantage of the used growth process: **Sufficient mobility of the adatoms on surface even at room temperature.**

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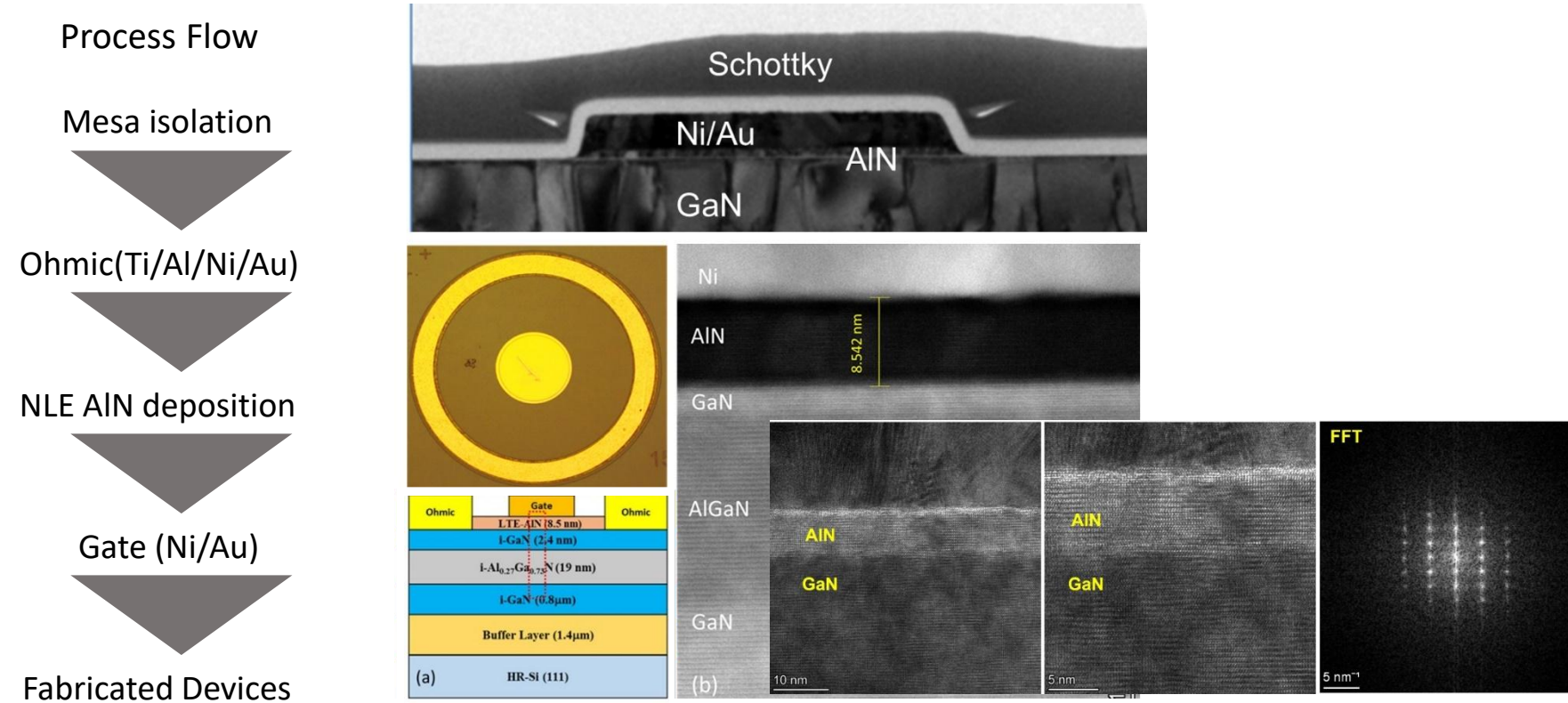
GaN overgrowth – AFM measurements



Sample	RMS roughness Sq [μm]
Substrate GaN/Sapphire	855.1, 381.9 -> 620 +/- 240
Overgrowth with AlN	338.2, 339.8 -> 339 +/- 1

ELEMENT 3-5's NLE Process is CMOS compatible

HEMT overgrowth after partly processing



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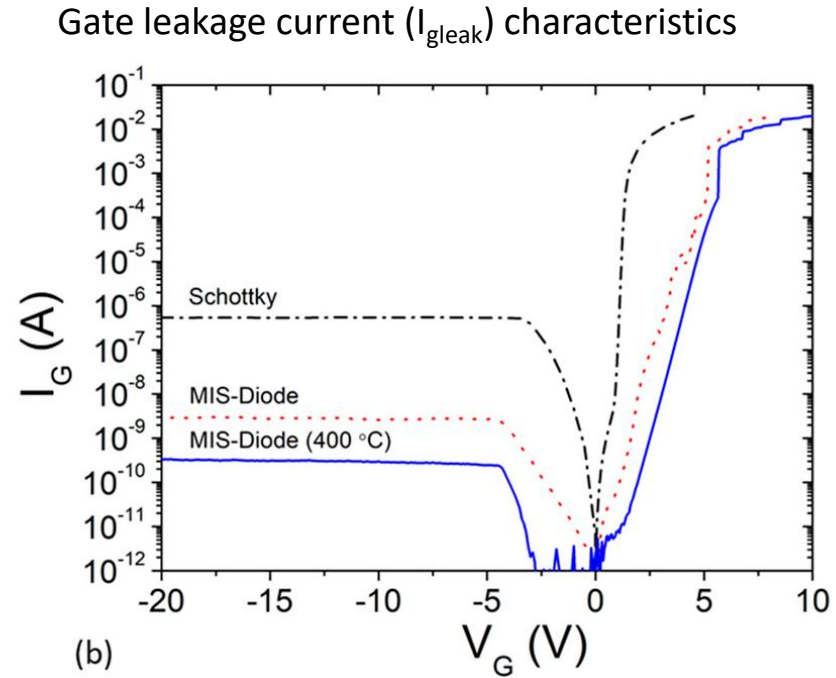
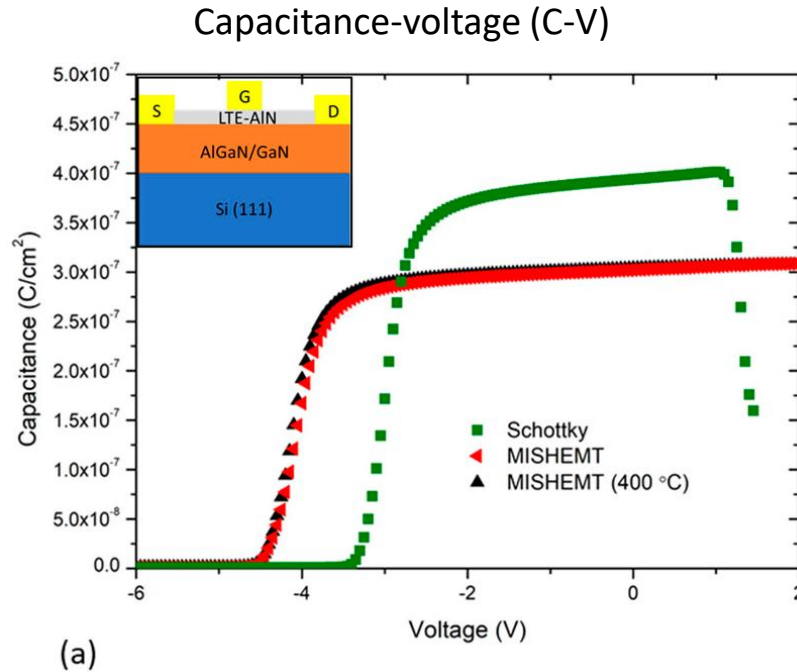
- NLE AlN growth after ohmic contact processing within the device fabrication.
- HR-TEM indicate sharp interface and a continuity of the lattice structure.
- Electron diffraction indicates very high crystallinity of the AlN grown by NLE.

Performance of ELEMENT 3-5 Templates

Nanyang Technological University NTU, Singapore

Agenda

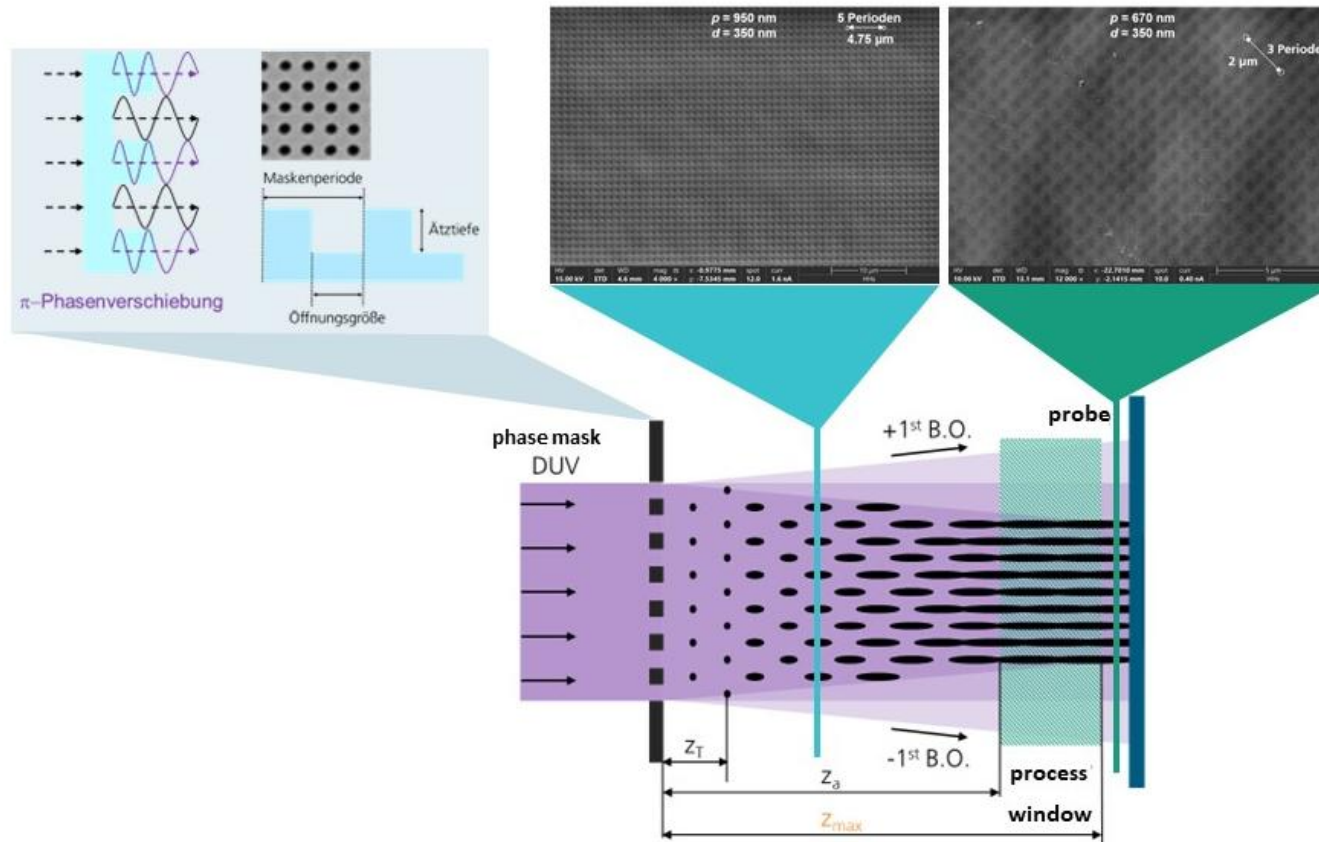
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- Characteristics of Schottky diode (MS-diode), LTE-AlN MIS-diode with and without post-gate annealing.
- With reference to Schottky diode, the **LTE-AlN MIS-diode exhibited 2 orders of magnitude lower I_{leak} at -20V (right graph). After post-gate annealing at 400°C, MIS-diodes exhibited about an order of magnitude further reduction in I_{leak} .**

Structuring with 2D Hole Grid Phase Mask

Schematic sketch and aimed results



- Structure sizes down to 150 nm feasible
- Parallel manufacture and scalable for higher throughput

ELEMENT 5
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Fraunhofer
ILT

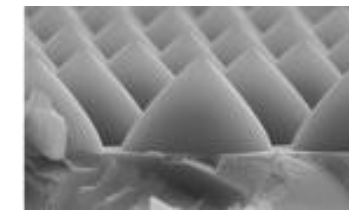
INNOLITE

COHERENT

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- Substrate structures
- (wet chemical etching)



Das Projekt „EPIWIN“ wird im Rahmen des EFRE/JTF-Programm NRW 2021-2027 mit der Fördermaßnahme „Innovationswettbewerb Industrie.IN.NRW“ gefördert



Kofinanziert von der
Europäischen Union

Gefördert durch:

Ministerium für Wirtschaft,
Industrie, Klimaschutz und Energie
des Landes Nordrhein-Westfalen

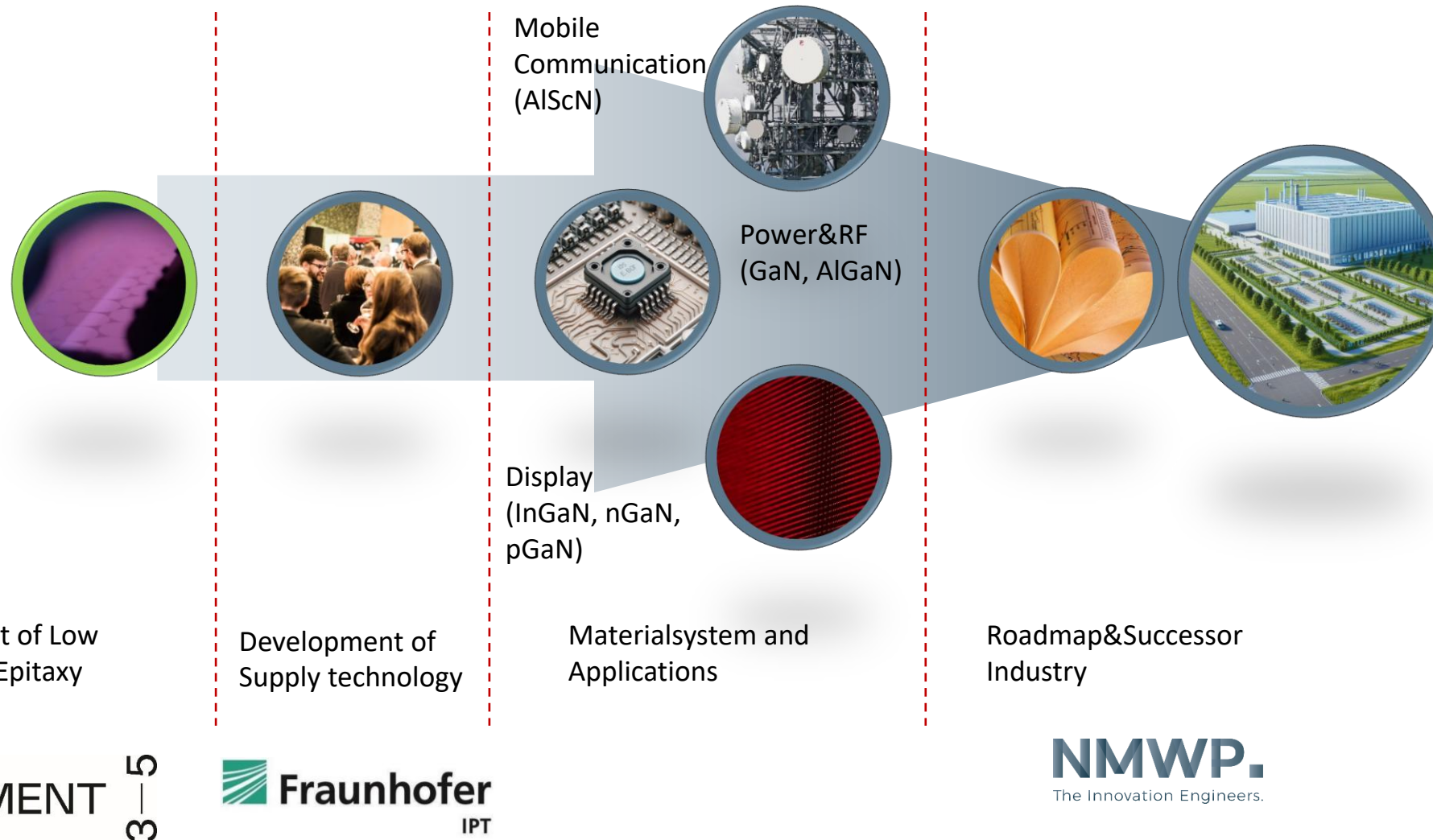


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ELEMENT 5
3

GREEN EPITAXY

Tasks and targets



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Supported by:



Federal Ministry
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and Climate Action

on the basis of a decision
by the German Bundestag

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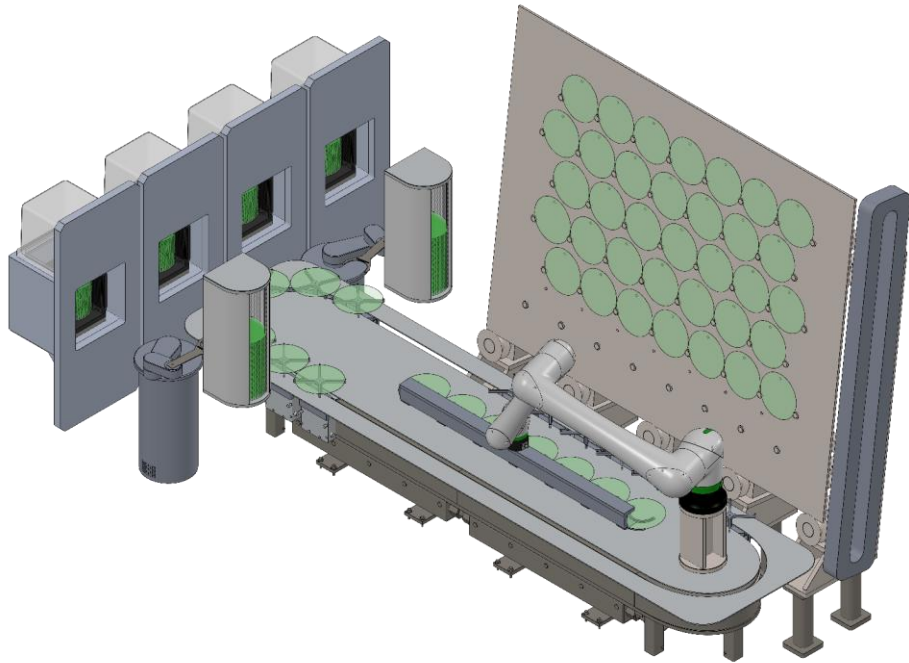


Bundesministerium
für Wirtschaft
und Klimaschutz

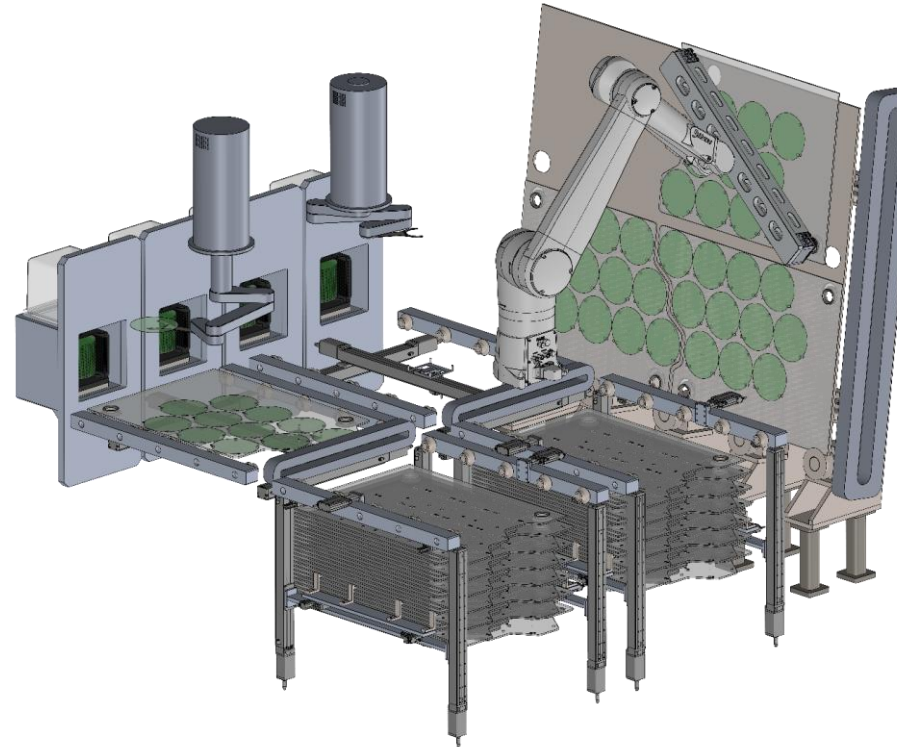
aufgrund eines Beschlusses
des Deutschen Bundestages

ELEMENT 3-5 `s production tool concept

Wafer handling concepts



Monolithic carrier -> Currently a robot system for this dimensions of carrier in a cleanroom is not available.



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Summary and Outlook

- Industrial scale production tool demonstrated.
- NLE epi results presented.
- Funded projects and cooperations started.
- Multi reactor chamber installation for high volume production of epi wafer already started.

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Thanks for your kind attention!



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