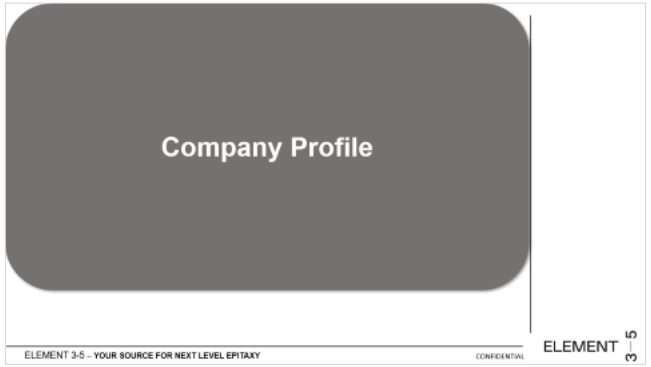
ELEMENT 3-5

Next Level Epitaxy (NLE) for Compound Semiconductors

A novel approach for the volume production

Setting new standards in the semiconductor industry

Presented by Ghassan Barbar


Company Profile
ELEMENT 3-5 – YOUR SOURCE FOR NEXT LEVEL EPITAXY
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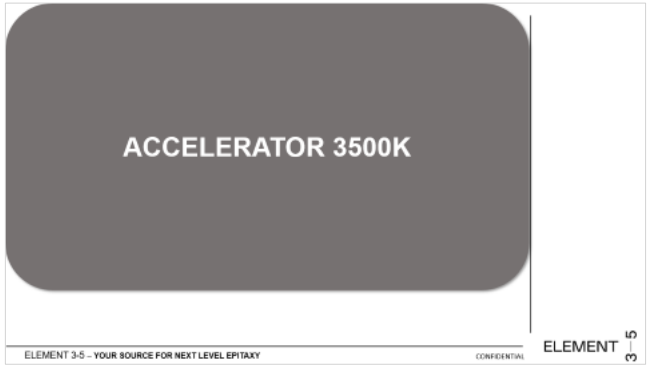
ACCELERATOR 3500K
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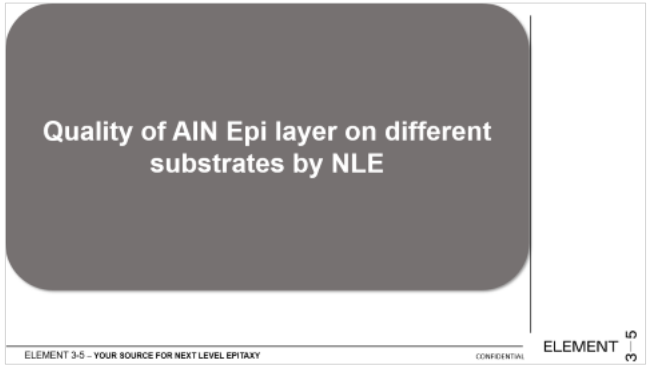
Quality of AlN Epi layer on different substrates by NLE
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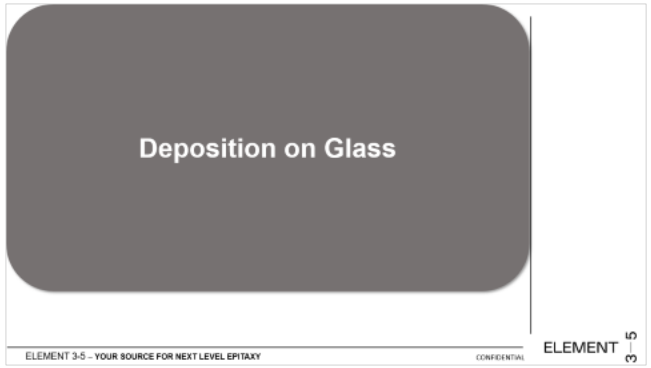
Deposition on Glass
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Summary
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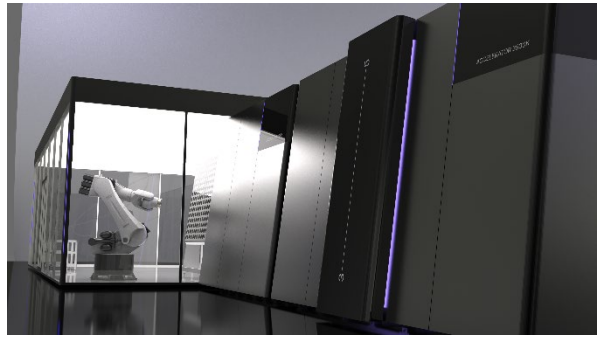
Company Profile

ELEMENT 3-5

Company Profile



Motivation

ELEMENT 3-5 is an equipment supplier with a disruptive approach for the growth of wide bandgap semiconductors.

Dedication

With its patented Next Level Epitaxy ELEMENT 3-5 enables customers to

- reduce disruptively their production costs
- reduce complexity
- environmental menace
- and to exploit functional advantages.

Target Markets

Light emitting diodes (LED), high-electron-mobility transistors (HEMT) and bulk acoustic wave filters (BAW).

Foundation

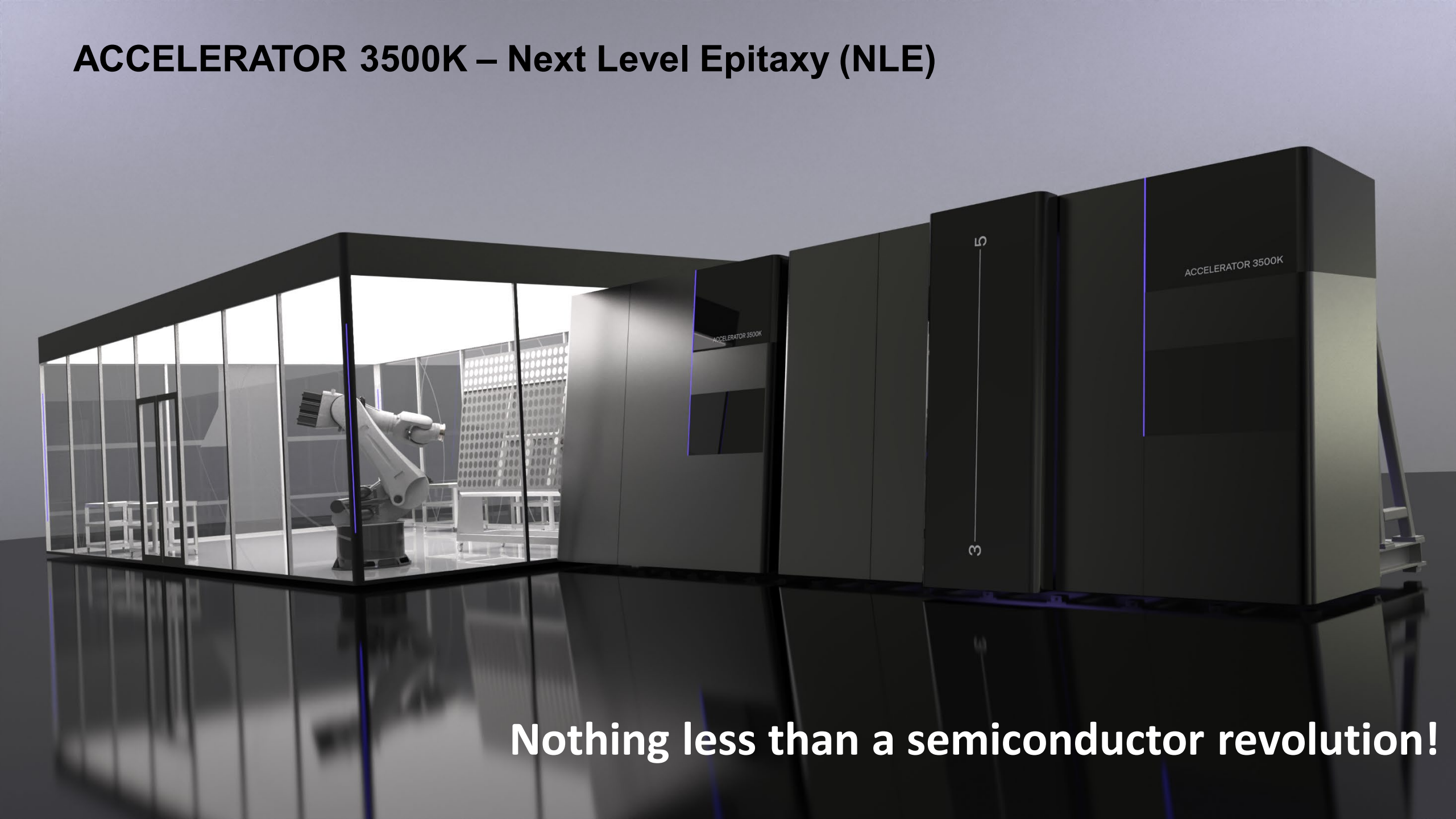
ELEMENT 3-5 was founded in 2010.

Location

ELEMENT 3-5 is headquartered in Baesweiler, Germany.

ACCELERATOR 3500K

ACCELERATOR 3500K – Next Level Epitaxy (NLE)

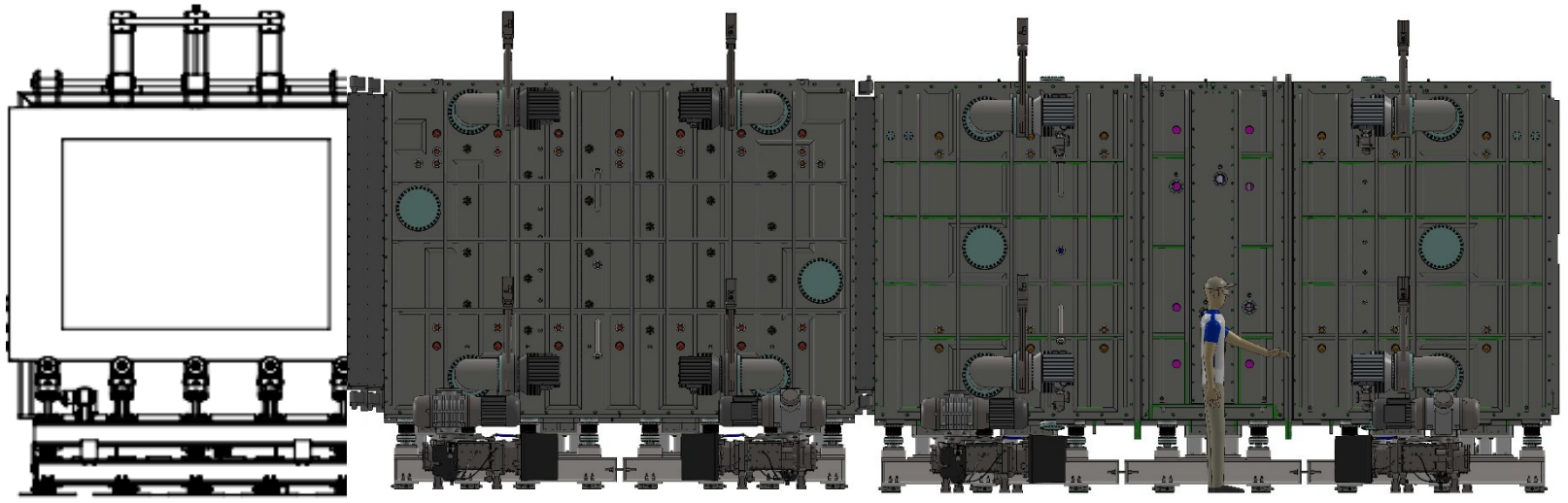


Nothing less than a semiconductor revolution!

ACCELERATOR 3500K – Next Level Epitaxy (NLE)

A look behind the scene …

Line source in Next Level Epitaxy Production System allows a massive efficiency gain versus MOCVD circular reactor



Loading

In cleanroom ISO3 the robot system loads and unloads fully automatically the wafers from and onto the carrier.
Thus up to 300 wafers (100mm) are handled efficiently within the cycle time.

cleaning chamber

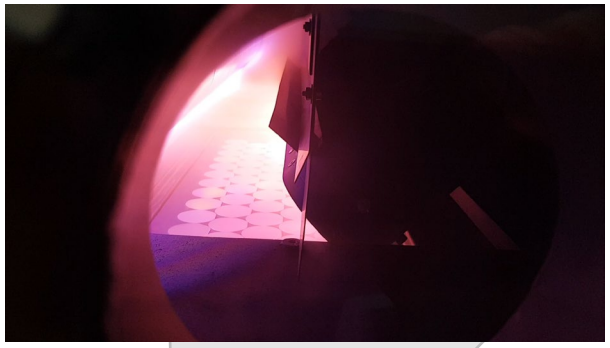
The wafers undergo an intense cleaning to eliminate residuals from previous process steps. Thus an utmost yield is secured.

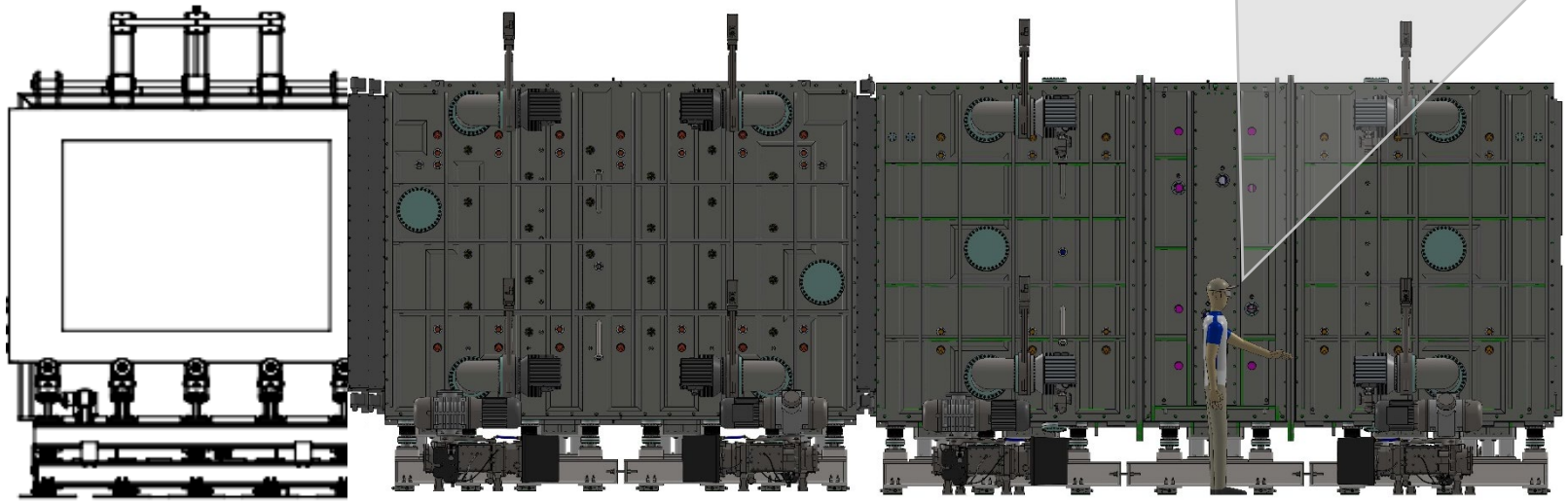
process chamber

A unique combination of PVD and CVD allows a single crystal growth at 300°C. The active line sources secure an outstanding homogeneity and excellent crystal quality of the generated layers.

ACCELERATOR 3500K

A look behind the scene …





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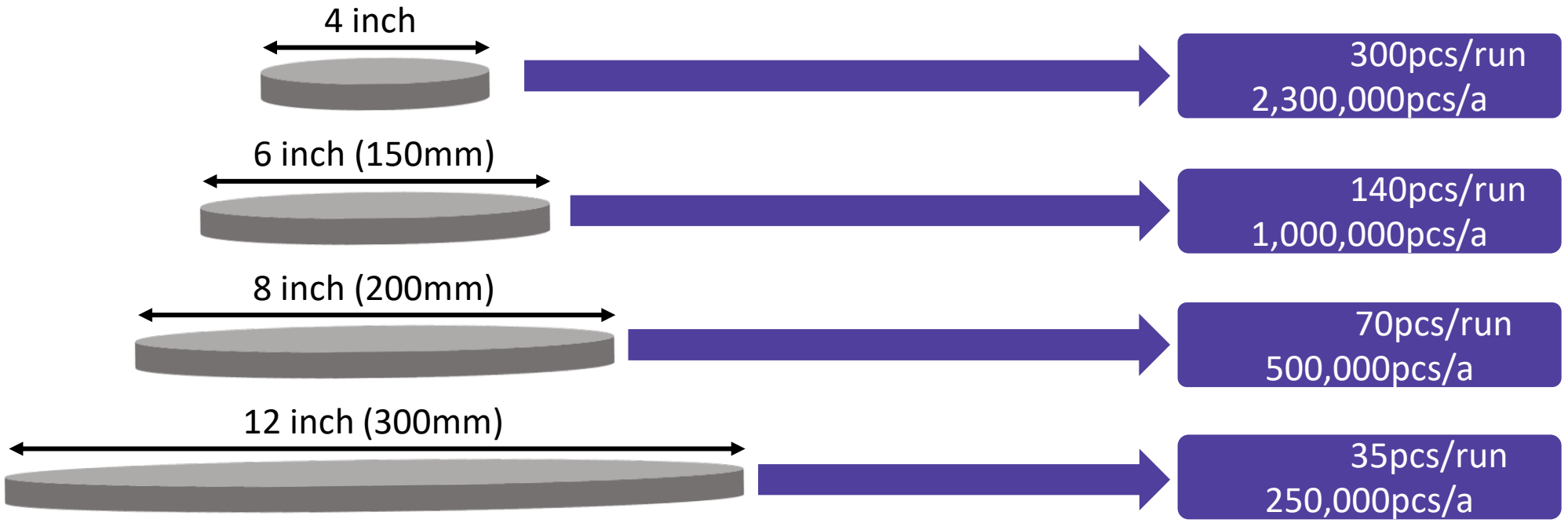
ACCELERATOR 3500K

A close look at the capacity

Serial NLEpi production system »ACCELERATOR 3500K«

- source materials: aluminum and nitrogen
- Substrate Material: sapphire or silicon
- Layer Thickness: 50nm
- substrate carrier size: 1500 x 2000 mm²

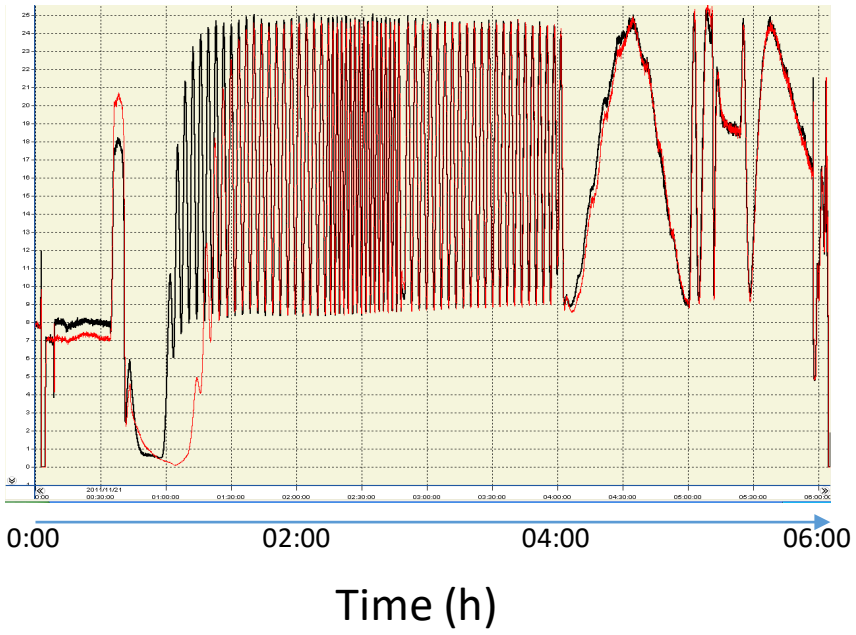


Quality of AlN Epi layer on different substrates by NLE

Layer characteristics

GaN overgrowth of NLE templates by MOCVD

- Typical MOCVD epitaxial growth of GaN structure
- The processing time is about 6 hours

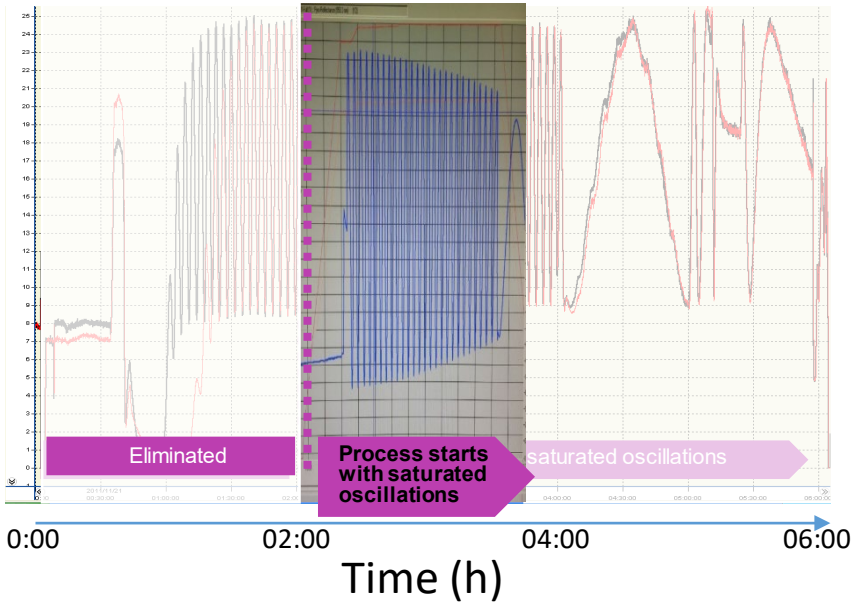


Layer characteristics

GaN overgrowth of NLE templates by MOCVD

- By using ELEMENT 3-5 single crystal templates the in-situ cleaning, the growth of a nucleation layer, its recrystallization and overgrowth with a slow growth rate can be skipped.

- Elimination of 2-3 hours processing time of MOCVD time can be saved which enables cost reduction

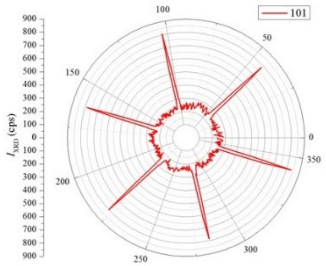


- High quality GaN layer is generated directly from the beginning.
- **Cost and time savings on starting layer generation + capacity on costly MOCVD reactors**

Layer characteristics

AlN layer growth on sapphire by Next Level Epitaxy

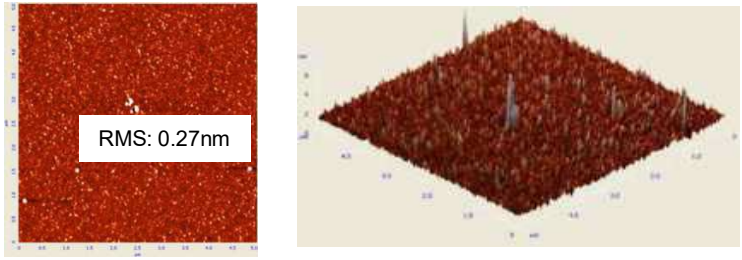
Phi-scan around 101 peak of 50 nm thick AlN layer on sapphire.



Only allowed peaks of hexagonal AlN crystal visible.

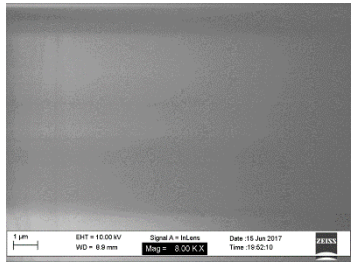
➡ **Single crystal quality!**

AFM of AlN on sapphire



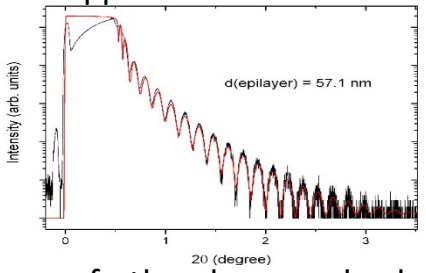
- RMS values below 0.3 nm are achieved.
- No columnar growth can be observed.
- Re-machining of deposited layer not necessary.

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.

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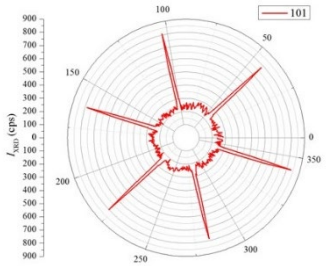
Phi-scan around 101 peak of 50 nm thick AlN layer on sapphire.



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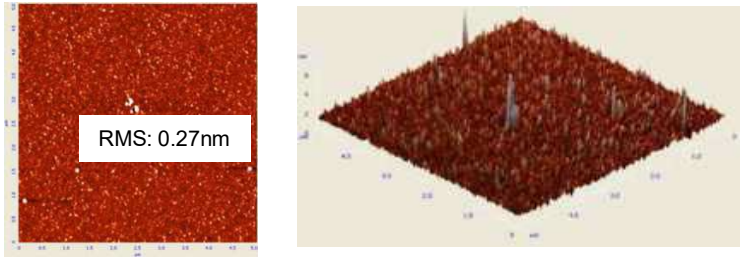

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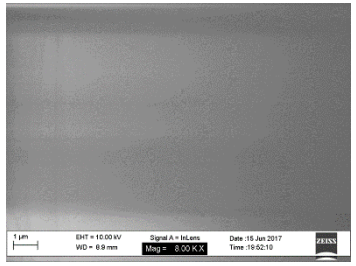

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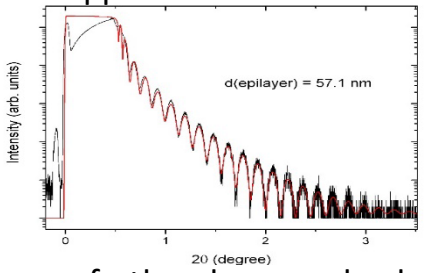

- Thickness of the layers checked by X-ray reflectometry (XRR) measurement.
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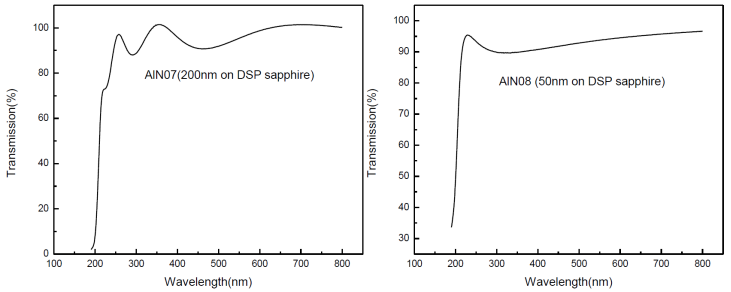
Layer characteristics

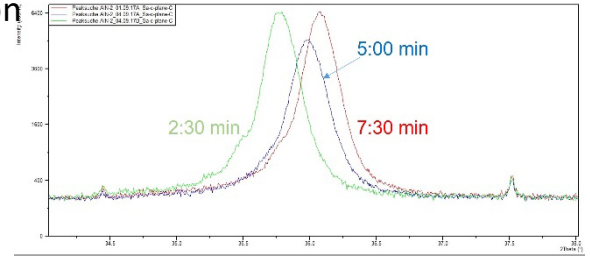
AlN layer growth on sapphire by Next Level Epitaxy

Transmission and absorption of AlN on sapphire



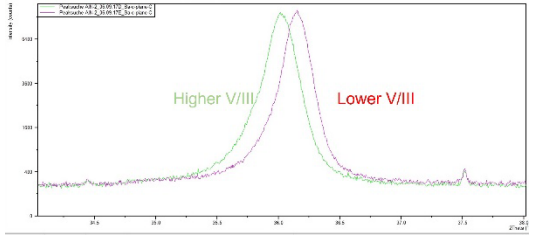
- Transmission and absorption edge around 200 nm.
- High transmission around 240 -260 nm.

Influence of low growth rate AlN/ nitridation duration



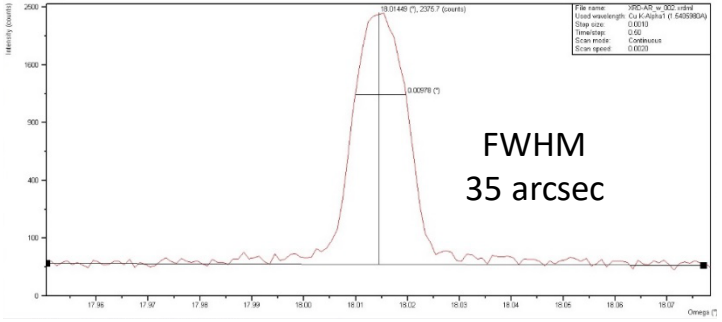
- Process tuning as known from MOCVD or MBE.
- The AlN strain can be changed from compressive strain to tensile strain by low growth rate AlN /nitridation.

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.

HR-XRD 002 rocking curve of AlN on sapphire



- High quality AlN on sapphire can grown by novel low temperature plasma process.

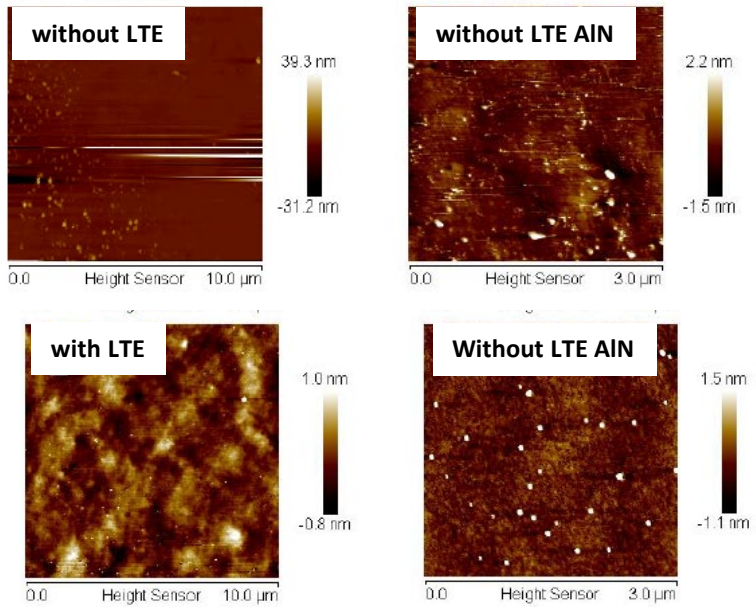
Overgrowth with LTE process

Feedback from partner company after overgrowth of their MOCVD AlN

- ELEMENT3-5 has overgrown MOCVD AlN with AlN grown by LTE process on top.
- For comparison the wafer was halved to check the change after the overgrowth.

XRD results and AFM imgages:

	002 FWHM	102 FWHM
1 µm MOCVD AlN	0.2294°	0.5705°
1 µm MOCVD AlN + 130 nm ELEMENT AlN on top	0.221°	0.4912°

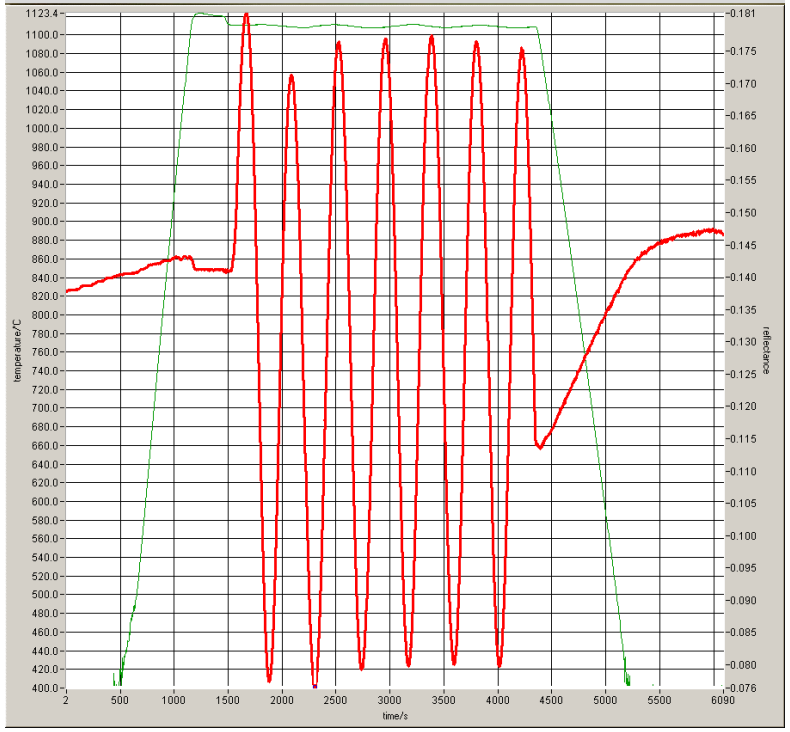


- Improved XRD and AFM quality of overgrown MOCVD AlN by our AlN,
- Other than in MOCVD the growth by LTE growth process is in thermodynamic equilibrium and is according to Frank and van der Merve growth mode.
- These results prove the epitaxial growth characteristics of ELEMENT`s LTE process.

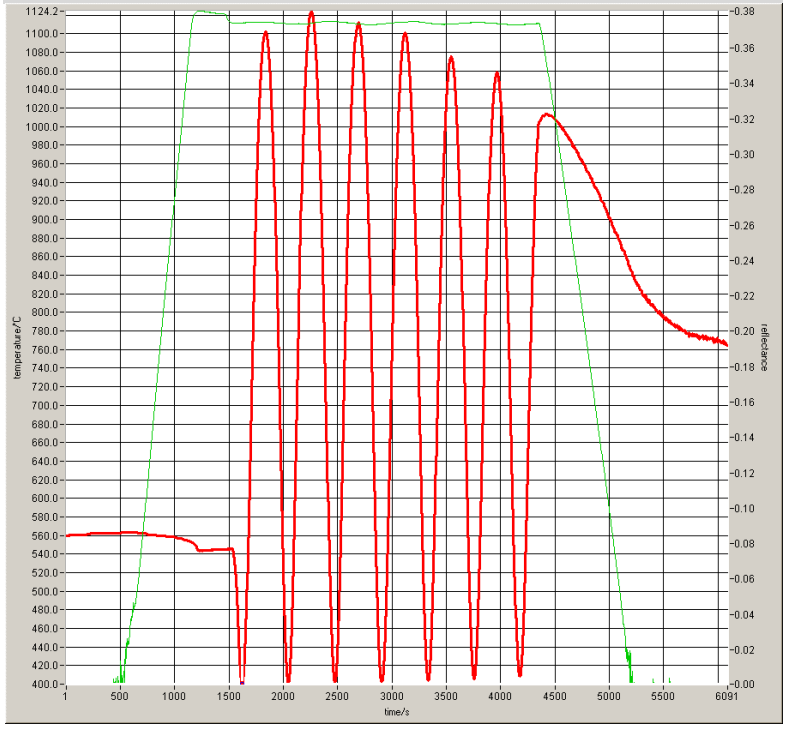
Overgrowth with AlN by MOCVD

Direct MOCVD growth on NLE templates

Overgrowth of NLE template on **sapphire** with AlN by MOCVD



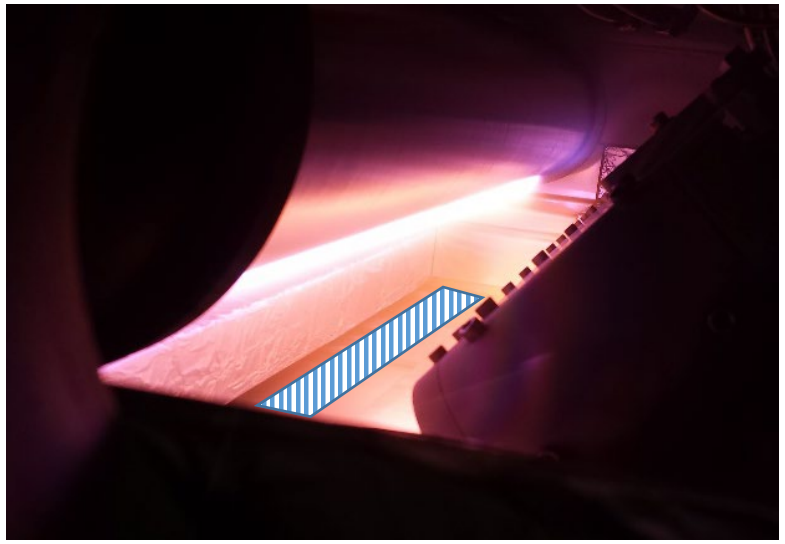
Overgrowth of NLE template on **Si(111)** with AlN by MOCVD



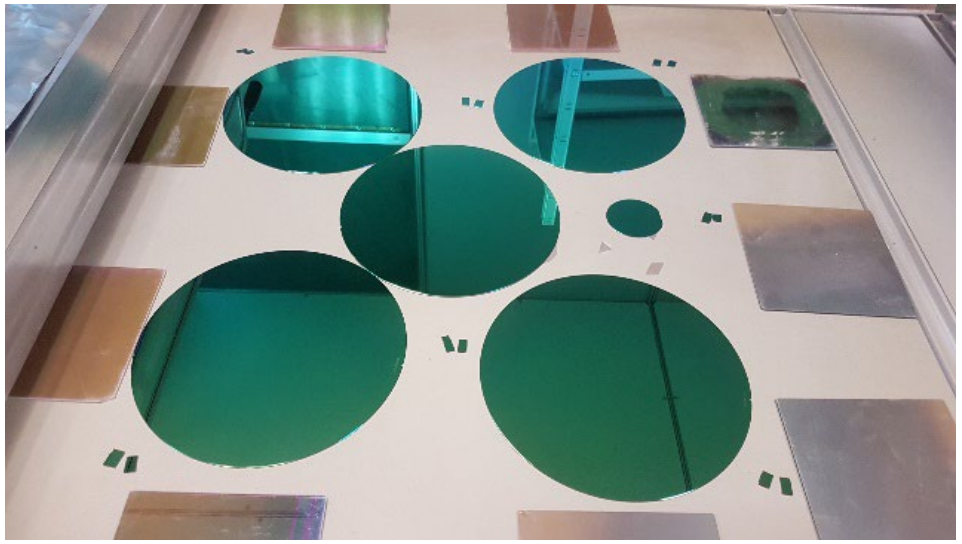
- In-situ reflectivity graph of MOCVD AlN on NLE templates.
- NLE AlN was grown on sapphire and Si(111).
- Overgrown material show saturated oscillations from growth start on.

Layer Characteristics

AlN layer growth on sapphire by Next Level Epitaxy



Growth chamber through viewport. Overlap of both sources is important.



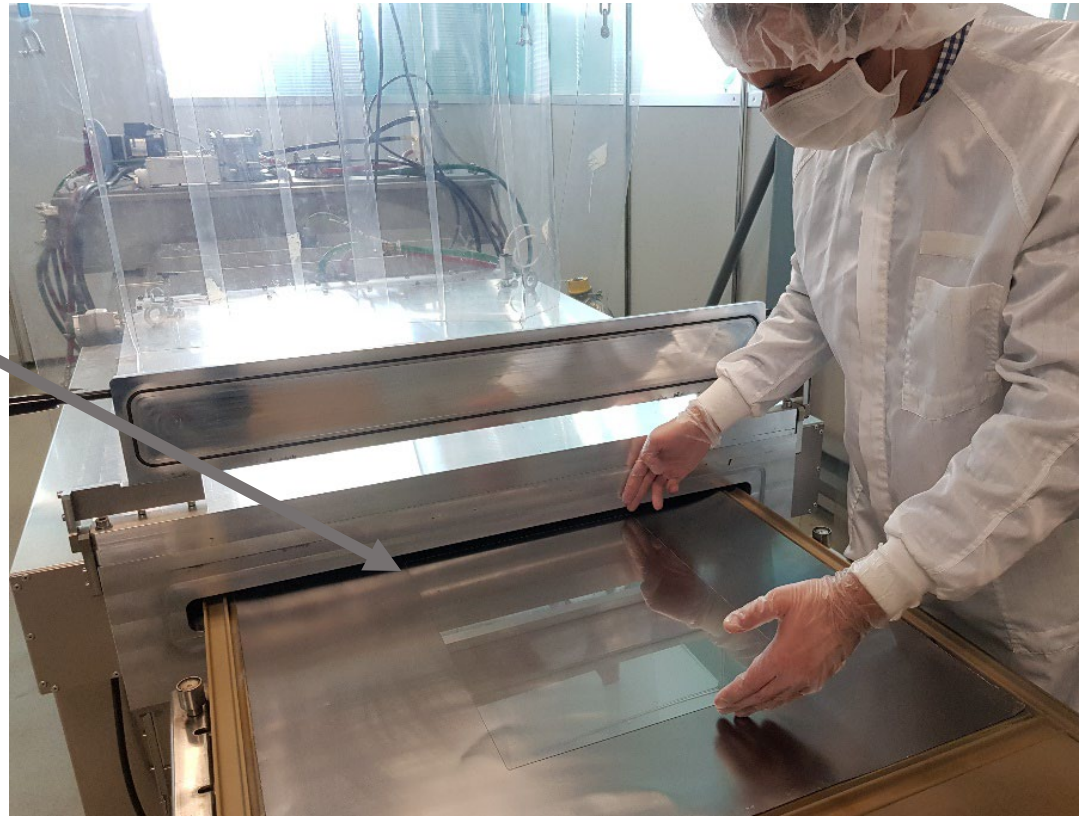
5 x 1.3 µm thick AlN on 200 mm Si(100), showing homogenous growth.

- With our epitaxy system high **quality AlN can be grown in a very homogenous way.** Thick AlN on silicon shows same color, indicating **superior uniform deposition** (see right photo above).
- This technology allows to **split the growth process into many process steps in different chambers** resulting in a real **in-line production**. For complete structures every layer can be grown in separate chamber, so that depending on the number of chambers every hour (or less) a complete batch of wafers can be finished.

Deposition on Glass

Effective crystal growth with Next Level Epitaxy

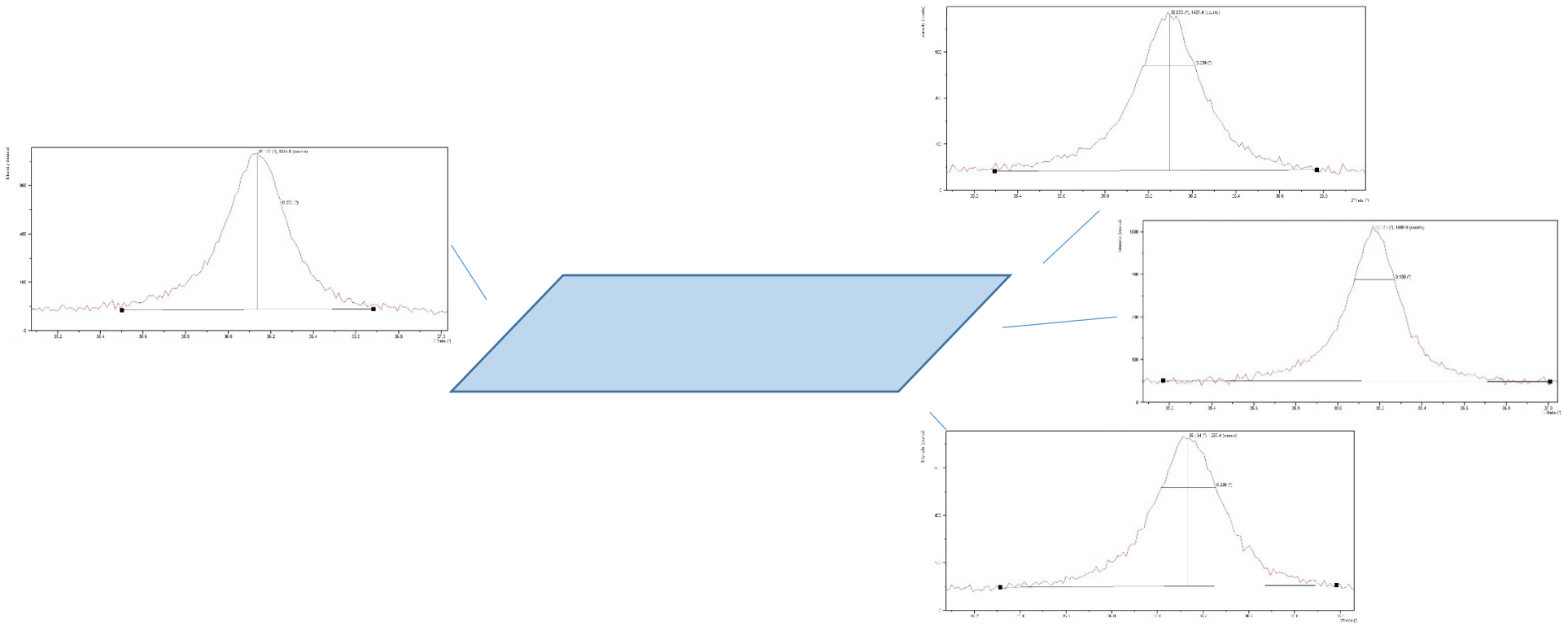
Material development NLE system on glass and other substrates



- The lab system has already the capacity of the current generation of one MOCVD system.
- Capable to grow AlN layers on wafer and display scale.
- Breaking off the geometrical constraints of MOCVD.

Deposition of AlN on Display Glass

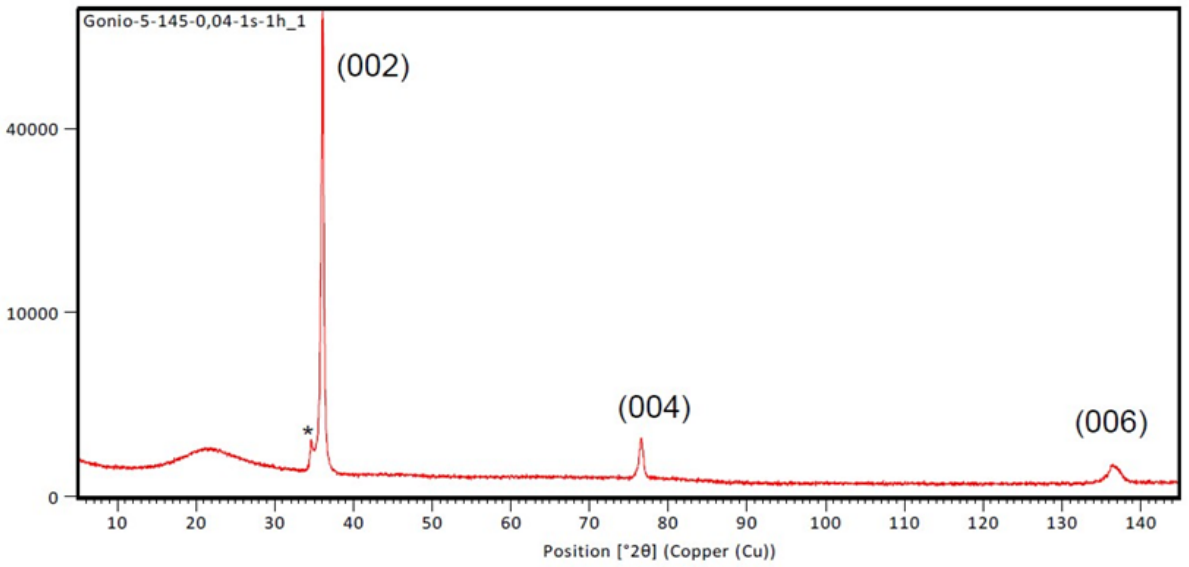
Live sized tests with display glasses of 470 x 370 mm² dimension

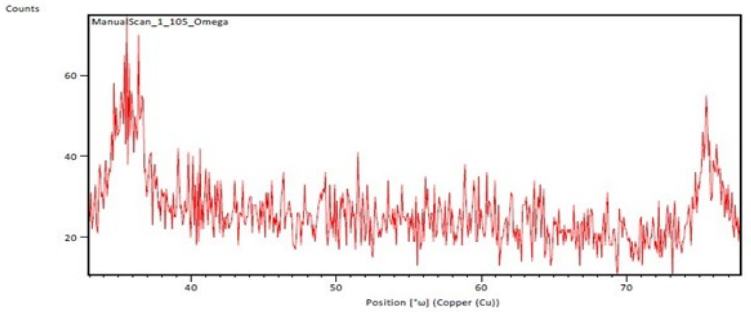


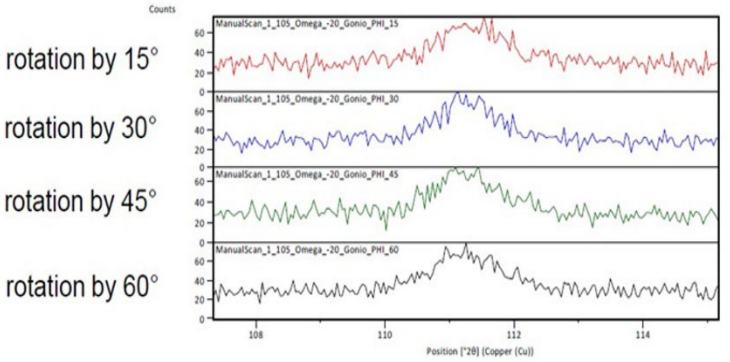
- The AlN layers show a dominant growth in C-direction.
- The XRD values at the different positons are similar indicating a high homogeneity along and perpendicular to the line sources.

Effective crystal growth with Next Level Epitaxy

XRD results of 250nm AlN on glass





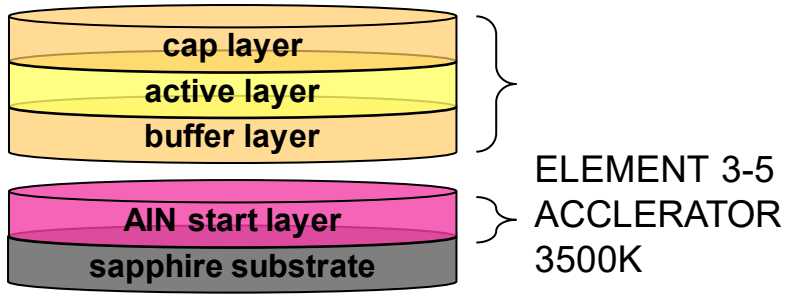


- Standard XRD scan shows hexagonal AlN. Only (001) reflections perpendicular to the c-axis are detectable.
- As expected, the crystallographic a-directions are disordered.

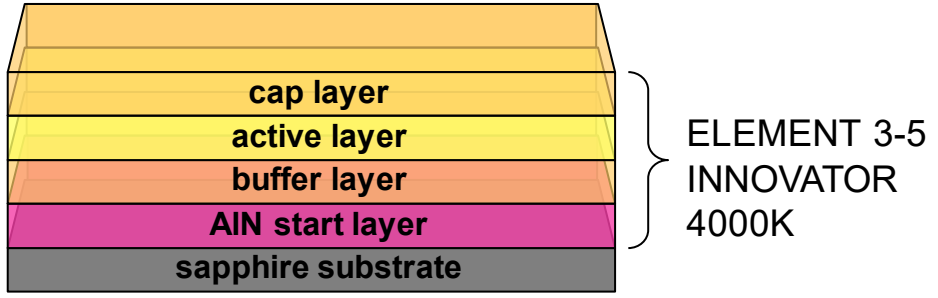
How Can NLE Help to Bridge the Gap for MicroLED Displays?

Three options how to make use of disruptive cost reductions

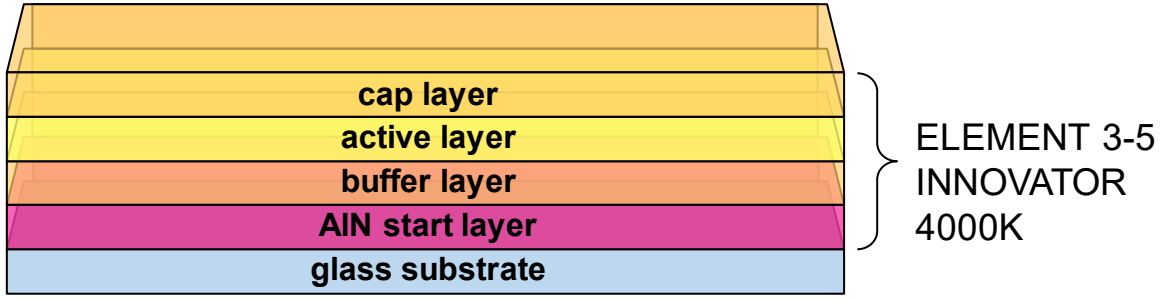
1 **Existing MOCVD eco system enhanced by NLE Template System**
Substrate: Sapphire



2 **Pure NLE In-Line Production System**
Substrate: Large (and option for non-rotational) sapphire

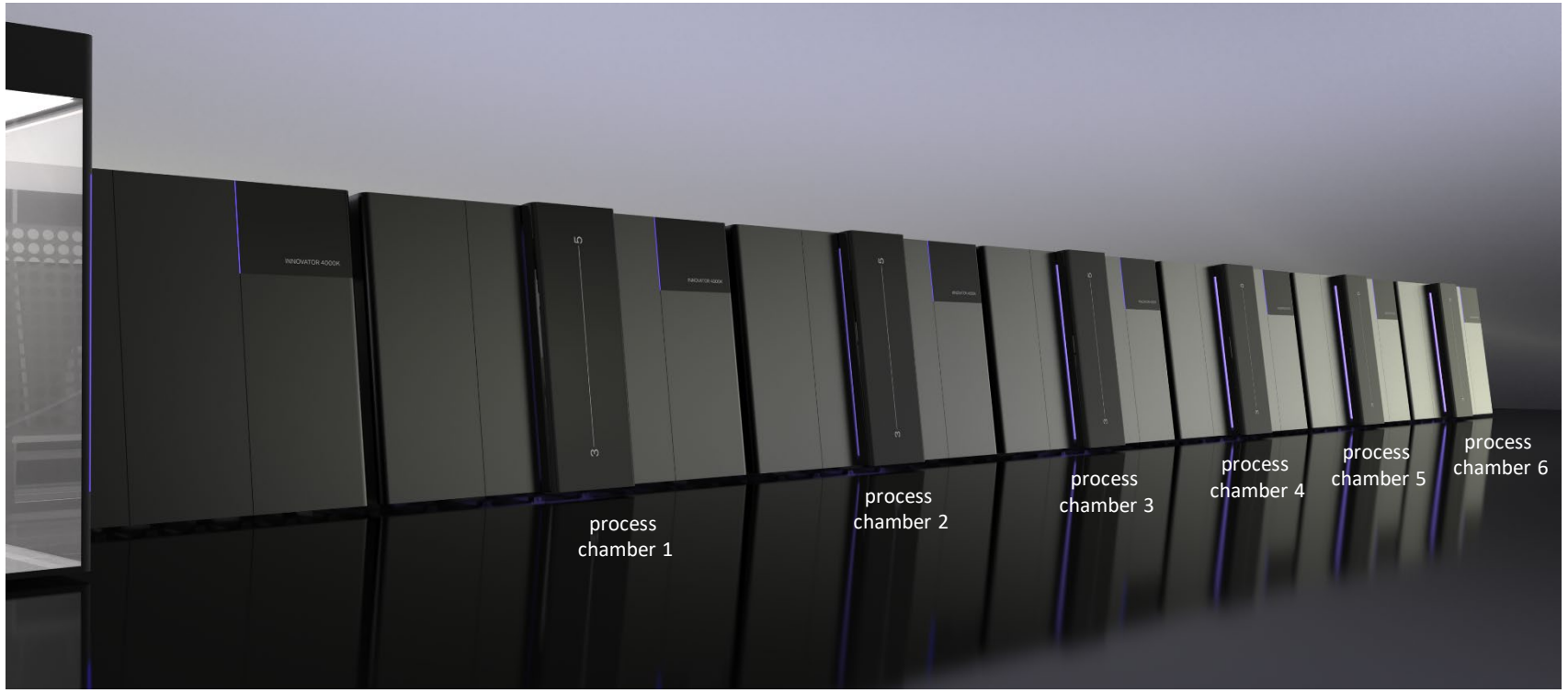


3 **Pure NLE In-Line Production System**
Substrate: Large, rectangular glass
⇒ **No assembly!**



INNOVATOR 4000K

In-line production tool for complete epi-process with NLE



- Low temperature allows **easy temperature control** during transfer of substrates from one chamber to the next one.
- **Vertical, rectangular system architecture** is advantageous for easy workpiece transfer in-line and for large substrate formats.
- **Manufacturing time** can be **reduced** by a **factor of 6 … 7.**

Summary

Next Level Epitaxy - NLE

Effective crystal growth with an unique novel technology

- **By 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**

- **Cycle times 2 to 7 times lower**
- **Capacity increase by a factor of 10**
- Highest throughput; any substrate material and dimension
- 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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Due to its excellent price performance ratio ELEMENT 3-5's **Next Level Epitaxy** is a game changer in existing and enabler in future markets.

Company Profile
ACCELERATOR 3500K
AlN epi on different substrates
Deposition on Glass
Summary

Next Level Epitaxy Template Production

Disruptive increase in efficiency for every MOCVD user

70% Cost reduction

90% energy savings

- **NLE Template Production Tool** substitutes the cleaning and starting layer growth step in the MOCVD reactor.
- MOCVD **process time is reduced by 2-3h**!
- The MOCVD **throughput is increased by 30…40%**!
- NLE Template Production Tool is **installed at customer site**.
- ELEMENT 3-5 NLE Template Production tool can **feed more than 40 MOCVD.**

10 x higher capacity

700% gain in productivity

Next Generation Displays based on microLEDs

Next Level Epitaxy offers a combination of unique advantages

Source: ProReview

Low temperature: Only epitaxial process that works on a glass surface without damaging the substrate!

No geometrical constraints: Only epitaxial process to deposit on large surfaces!

Monolithic manufacture: Direct epitaxy on glass substrate avoids cost intensive´assembly of microLEDs!

In-line manufacture: Only epitaxial process to be integrated in the existing process chain!

→ NLE is the only process with potential to manufacture the next generation of display and large format lighting at a disruptive cost level!

ELEMENT 3|5

YOUR SOURCE FOR NEXT LEVEL EPITAXY

THANK YOU FOR YOUR ATTENTION

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