Optical Metrology: a navigation system for FEOL processes

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senior scientist for novel applications

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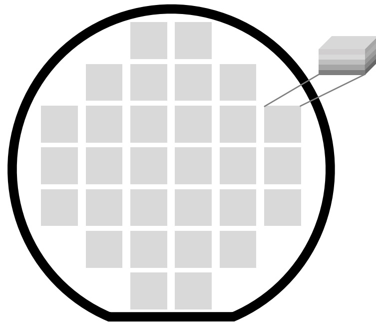
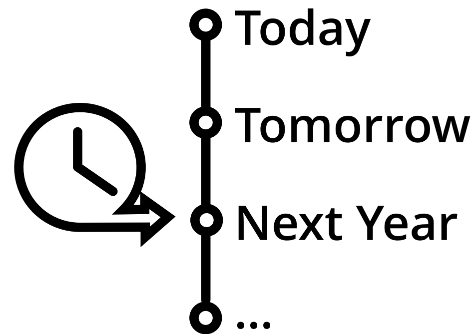
Why you do need metrology

The ideal process is uniform …

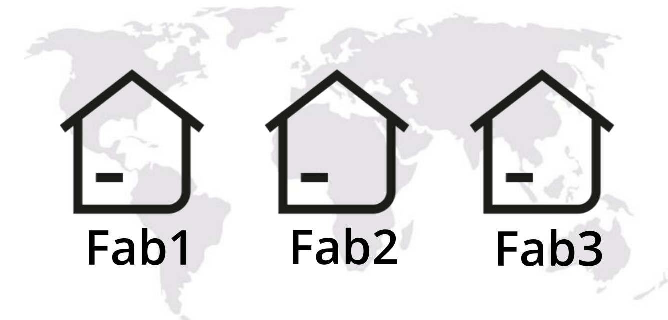
on wafer
chip-to-chip



in time
run-to-run

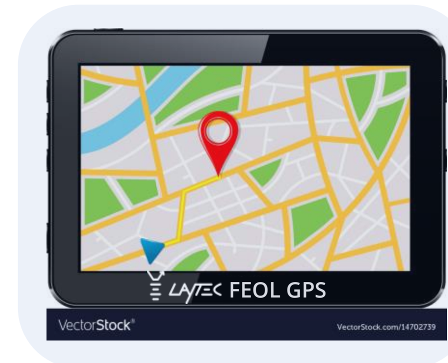


in space
system-to-system & fab-to-fab



… but neither is our world ideal nor our processes uniform

- Metrology helps us narrowing variances and navigating toward consistent processes & devices



What we can do for you

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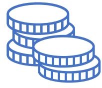
Optical Metrology Company founded 1999 in Berlin

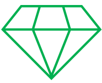
- 25 years old
- Spin-off of TU Berlin
- 90+ employees
- > 3500 systems sold
- Operating worldwide
- Member of Nynomic group

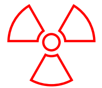
Our business: Process-integrated optical metrology

Our markets: Semiconductor and thin-film industry & academia incl. lighting, laser, PV, glass coating …

Optical metrology along the semiconductor manufacturing chain

costs 

value 

risks 

lengthy processes
high costs

high value
generation

maintain or
destroy value

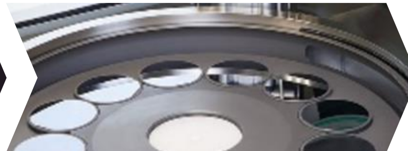
temperature
thickness
composition

unknown
uniformity

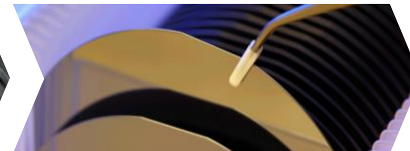
wrong
etch stop

Substrate

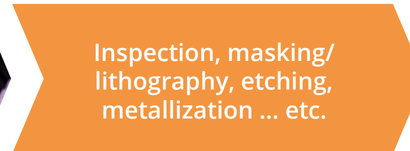
Front-end
Level 0 - Epitaxy



Epi-wafer



Front-end
Level 1 – Device Production



Inspection, masking/
lithography, etching,
metallization ... etc.

Dies-on-wafer

systems & applications

Packaged device

Die attach & interconnections,
phosphors, encapsulation &
optics, testing & binning

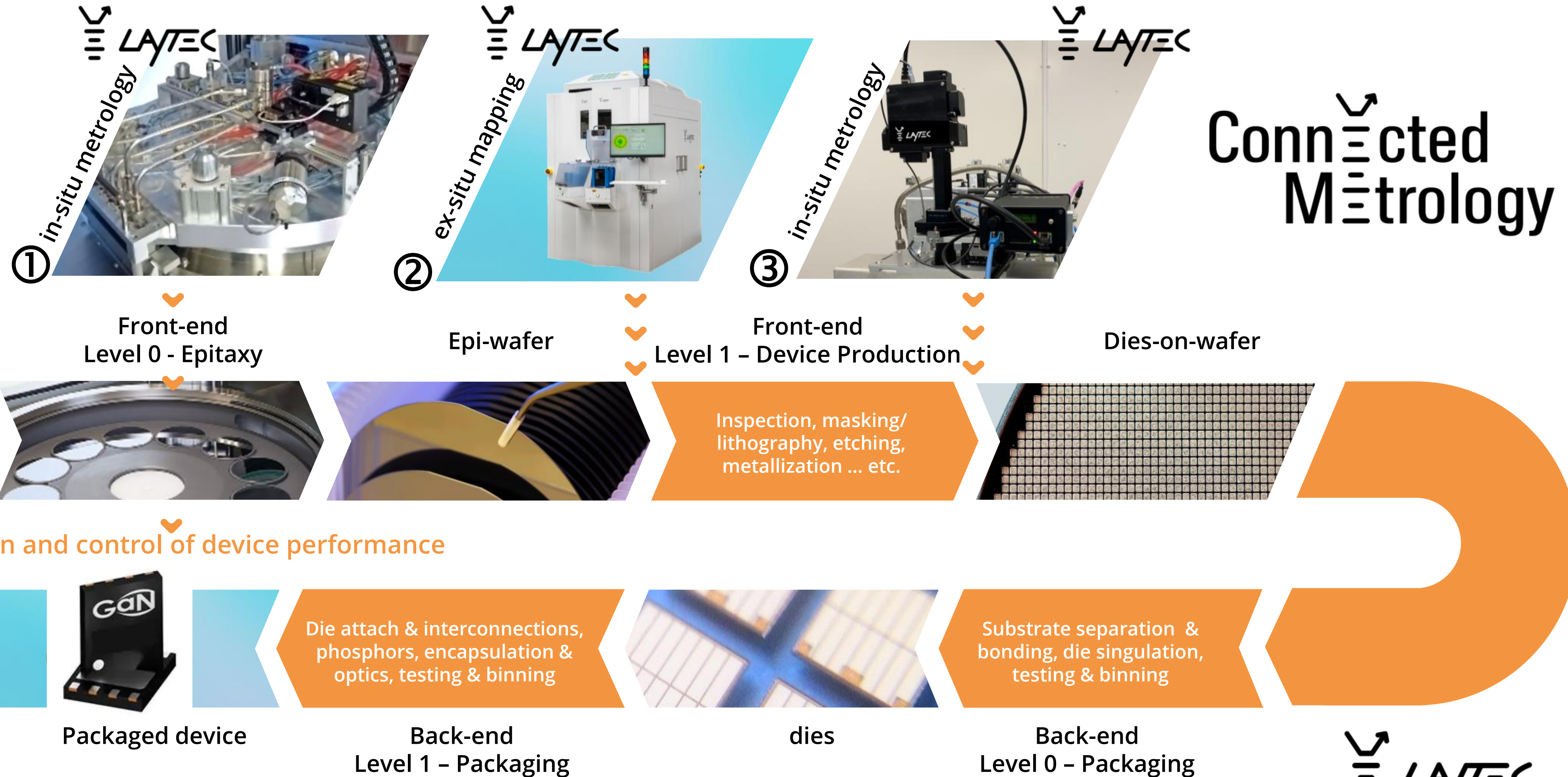
Back-end
Level 1 – Packaging

dies

Substrate separation &
bonding, die singulation,
testing & binning

Back-end
Level 0 – Packaging

Optical metrology along the semiconductor manufacturing chain



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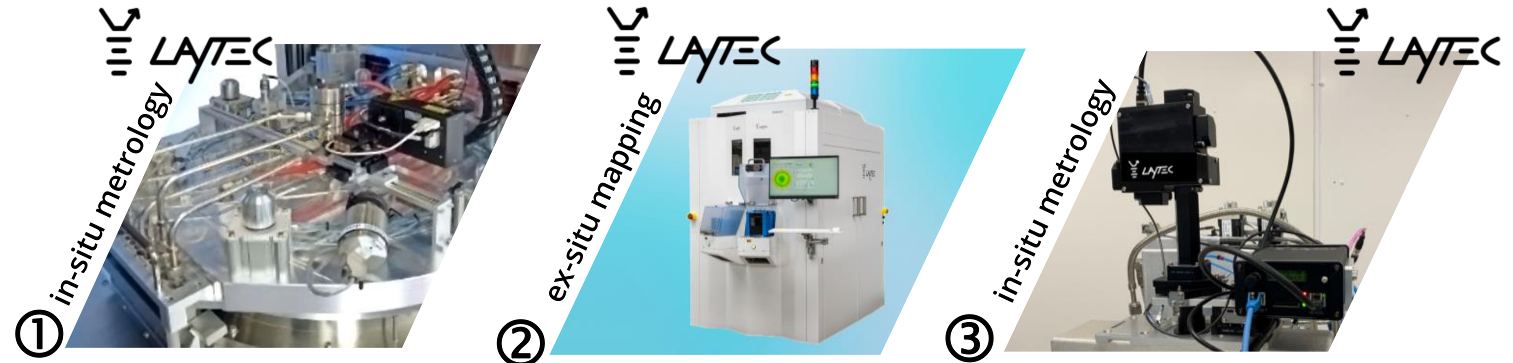
GaN/Si HEMT production – film thickness control during MOCVD and Etching

Typical E-Mode HEMT device stacks

p-GaN gate 10 nm ... 100 nm
AlGaN barrier 10 nm ... 30 nm
i-GaN channel layer 100 nm ... 200 nm
GaN/AlGaN buffer (various patented designs) complex strain-engineering 2-6 µm

- for cost reasons: large 200 mm & 300 mm silicon wafers and extreme uniform epi and etching is required
- optical in-situ control on the level of 0.5 nm (~1 atomic monolayer) is a must



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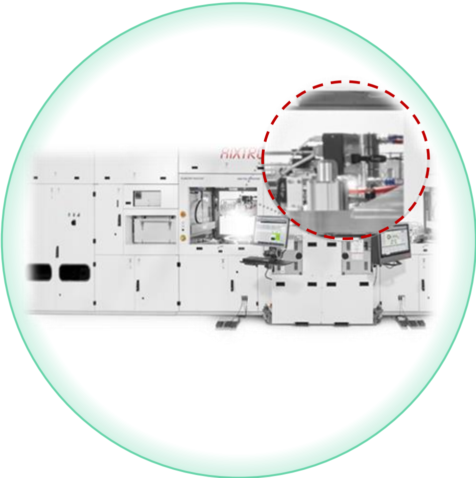
① MOCVD: in-situ measurement and control of growth parameters



- Metrology tool: **LayTec EpiCurveTT**
- every ~2 s measurement of
  - temperature
  - multi-λ reflectance
  - local curvature
- at center of specific wafer
- on radial scan across wafer
- in-situ measurement sensitivity is constant from first to last layer…
- … over typical growth times of hours
- layer-specific deviations can be detected in real-time early in the process
- state-of-the-art: used for advanced process control

slow-motion visualization of reflectance measurement

- BUT:
  - limited accuracy for very thin, ternary layers
  - only radial uniformity – no full 2D XY results
- HEMT structure – barrier layer
  - for the most critical layer, simultaneous thickness & composition measurement is not always possible

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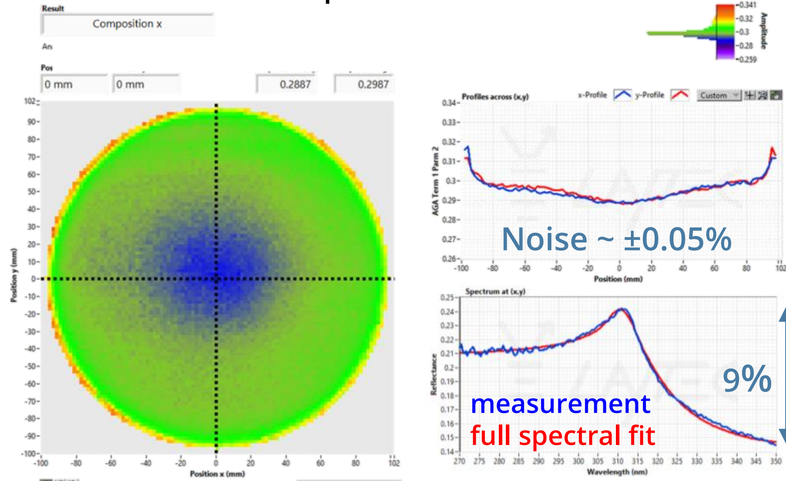
② Post epi wafer mapping

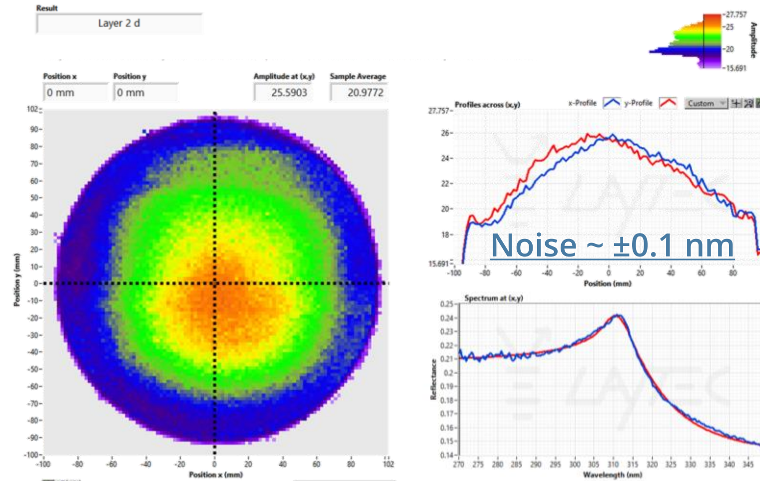
- accurate measurement & fit of UV-Reflectance of HEMT product wafers
- D-mode devices:
  - determination of AlGaN barrier composition + thickness
    - composition usually 3-4% above PL as UV-R is probing average composition
    - also applicable for complex barrier designs with varying composition

AlGaN barrier
i-GaN buffer
GaN/AlGaN buffer

- metrology tool: **LayTec EpiX**
- ex-situ wafer mapping
- white light reflectance (full spectral fit) and photoluminescence
- x,y mapping @ 250-2400 nm
- best-in-class measurement performance and accuracy
  - low spectral noise
  - superior absolute accuracy
  - superior 2D measurement uniformity
- advanced analysis algorithms



UV-R fit: AlGaN composition of D-Mode



UV-R fit: AlGaN thickness of D-Mode

- E-mode device:
  - light absorption in p-GaN top layer
    - lower signal & higher noise

      BUT
    - wafer-specific in-situ results allow improved fitting

p-GaN gate
AlGaN barrier
i-GaN buffer
GaN/AlGaN buffer

Connected Metrology

③ Etching End-Pointing

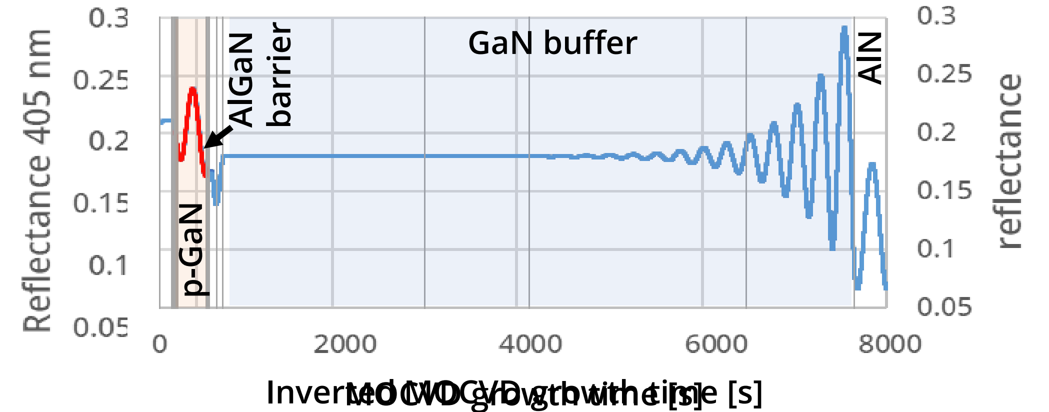
standard: Optical Emission Spectroscopy

- requires etch-stop layers
  only sensitive to interfaces

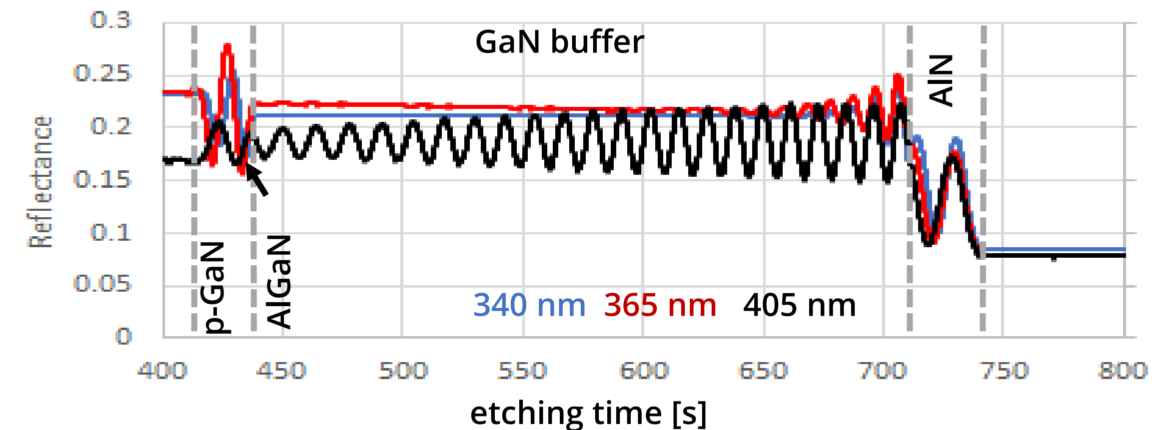
advanced: UV-Reflectance

- example: in-situ reflectance during growth/etch of GaN/AlGaN HFET structure
- Epi:
  - Fabry-Pérot-Oscillations (FPO) due to increasing layer thickness during epitaxial growth
  - highly accurate layer thickness measurements
  - ‘time inverted’ reflectance trace gives preview to etch transient measurement
- Etch:
  - FPOs due to shrinking layer thickness during etching
  - real-time analysis based on pre-existing measurements enables EPD anywhere in stack

Epi



Etch



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Summary

What can we do for you:

- **Run-to-Run, System-to-System, & Fab-to-Fab uniformity**
- LayTec connected metrology helps you narrowing variances and navigating toward consistent processes & devices

Connected Metrology

What can you do for us:

- tell us about your FEOL challenges …
- … and let us work together to overcome them

Choose LayTec metrology as your navigation system

Thank you for your attention!

Knowledge is key

www.laytec.de