

Best practices from the field: How to enhance epitaxy process performance by in- situ data

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Outline

General remarks

Why state-of-the-art MOCVD production
requires *in-situ* metrology

How LayTec's in-situ metrology will get you
there

True temperature - typical issues

Recommendations for daily operation

Conclusions and outlook

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- Aixtron and LayTec are honored to give the first time this tandem talk at a seminar
- The talk will focus on general approaches how in-situ tools are used to improve the MOCVD-based production process
- We cannot cover topics related to
 - Specific Aixtron-LayTec interactions (e.g. R2R/S2S matching, specific growth improvements)
- Aixtron and LayTec customers are invited to contact:
 - support@laytec.de, oliver.schulz@laytec.de
 - techsupportgermany@aixtron.com, h.mettler@aixtron.com

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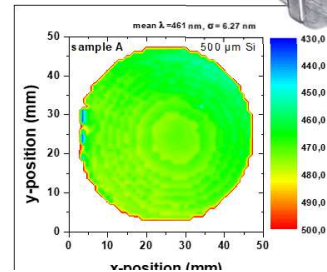
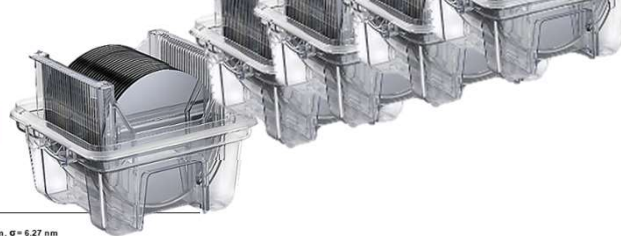
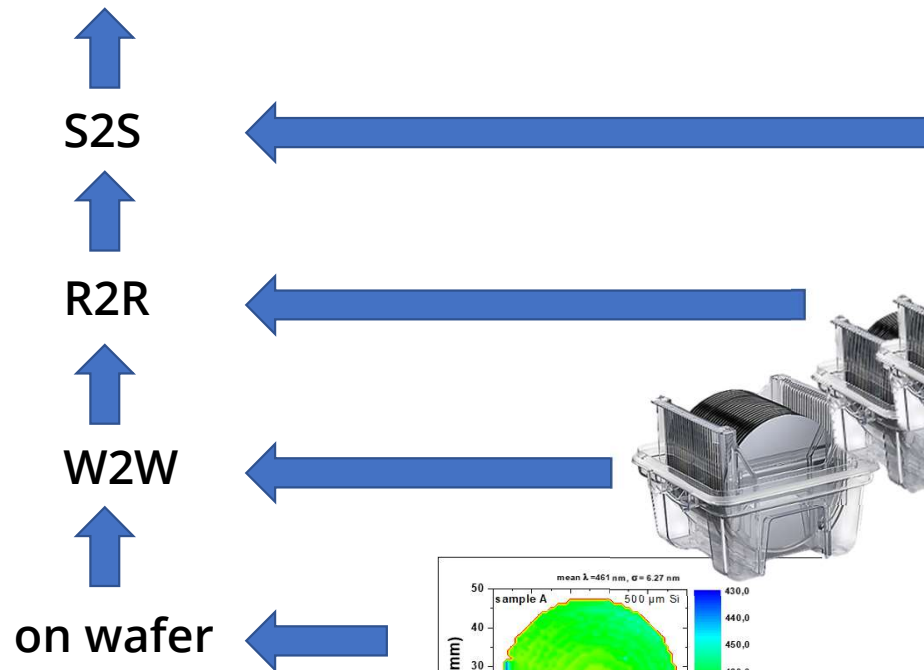
Conclusions and outlook

Key target: optimized cost of ownership in MOCVD production

- › minimizing ex-situ characterization efforts
 - › minimizing binning efforts
 - › minimizing back-end efforts
 - › minimizing costs per device (normalized)
-
- › Effect: maximized tool productivity leads to minimized COO

Key target: optimized cost of ownership in MOCVD production

- Sequence of requirements to meet
Optimized cost of ownership!



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How LayTec's in-situ metrology will get you there

EpiTT

- › IR pyrometry
- › Focussed LED lightsource for reflectance measurement
- › Enables to
 - › read True Temperature (TT)
 - › do growth analysis
 - › control growth process by True Temperature of substrate surfaces

EpiCurveTT

- › Contains EpiTT
- › Focussed semiconductor laser for curvature detection
- › Enables to
 - › do same as EpiTT
 - › get curvature detection
 - › monitor wafer relaxation
 - › do strain engineering

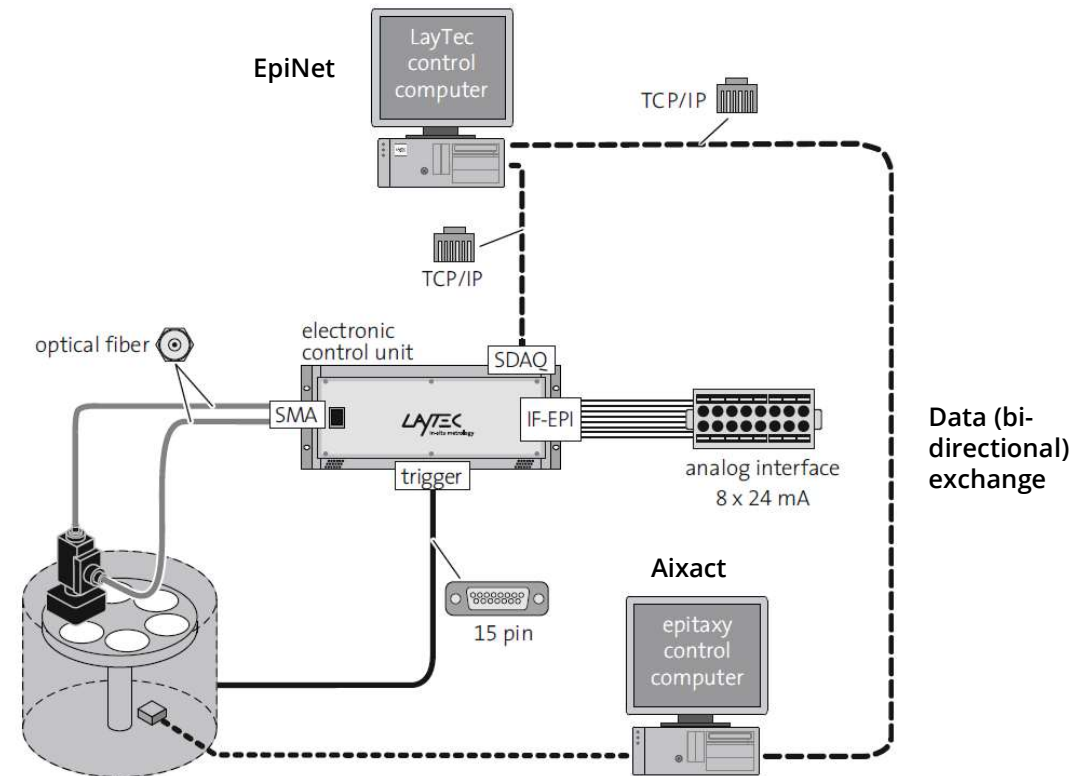
P400

- › UV pyrometer
- › Enables to
 - › Measure surface temperature on IR transparent layers
 - › get FPO free temperature measurement on GaN (e.g. on sapphire, PSS)



Growth system and in-situ metrology interactions

- Aixtron MOCVD control software → Aixact
- LayTec in-situ control and analysis software → EpiNet 1.10.x / EpiNet 2.y
- SECS/GEM interface available



Important background of LayTec systems

- All systems are set for a specific optical path (working distance, viewport)
- P400 requires in addition a straylight-protected mount

EpiTT

- IR pyrometry
- Focussed LED lightsource for reflectance measurement



EpiCurveTT

- Contains EpiTT
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P400

- UV pyrometer



Important background of LayTec systems

- Accurate temperature calibration - „How much light on the LayTec pyrometer equals which wafer temperature“
- Two-step approach:

Factory calibration against Black Body radiation source (PTB traceable) using customer's viewport

→ assures linearity



On-site calibration using AbsoluT950/400, LayTec's patented, PTB-traceable calibration device

→ assures accurate value



Important background of LayTec in-situ systems

Challenge: Emissivity material dependent and changing during growth process

EpiTT solution: Continuous emissivity correction to get true temperature (TT) →

Reflectance calibration (EpiTT / EpiCurve TT)

- For a correct temperature measurement a correct reflectance calibration is fundamental:
- Wrong reflectance values lead to a faulty emissivity correction:

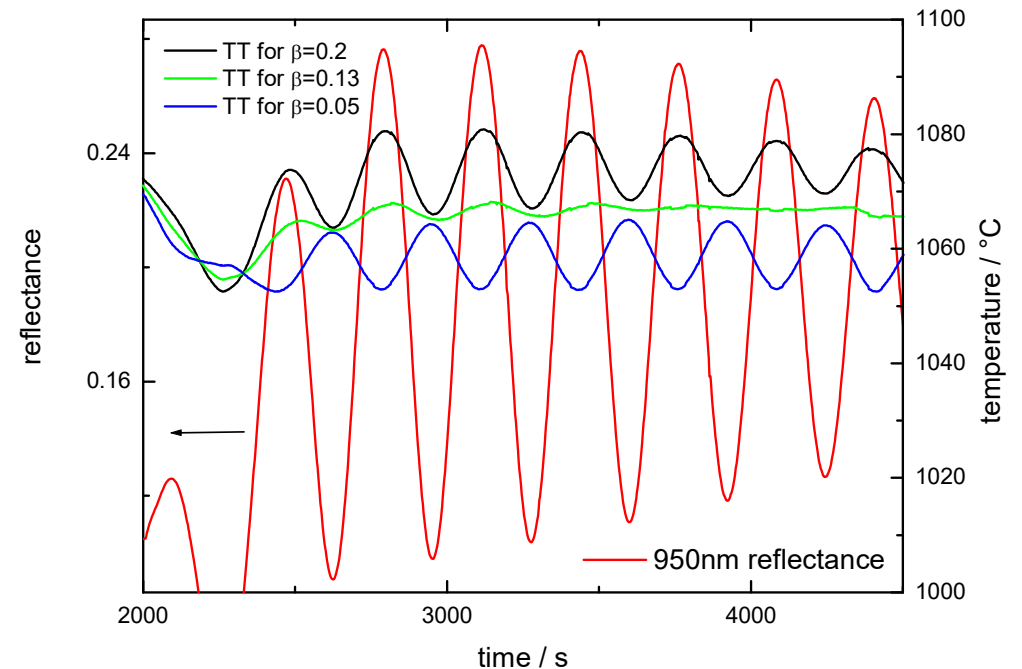
$$\varepsilon = 1 - R$$

- if R is wrong, the emissivity will be wrong
- if ε is wrong, the true temperature will be wrong

- It is essential that the reflectance measurement is correct in absolute values!

Influence of reflectance measurement

- **Absolute correct reflectance value is the key to ecp!**
 - no ecp
 - ecp correct
 - overcompensation
- **incorrectly calibrated reflectance measurement → residual oscillations**
- **always check reflectance value on substrate**
- **perform reflectance calibration if needed**



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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
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Misalignment	x	x

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Window coating	x	x

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Damaged fiber cables	x	x

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Damaged fiber cables	x	x
Fibers connections crossed	x	x

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Bad eutectic calibration	x	
Misalignment	x	x
Window coating	x	x
Damaged fiber cables	x	x
Fibers connections crossed	x	x
Wafer table errors <ul style="list-style-type: none"> - wrong substrate - wrong template - zones too far out (already on graphite) - PSS 		x x x x

True Temperature: typical errors II

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Mixing the hardware – MPC/controller/modules → wrong calibration parameters	x	

True Temperature: typical errors II

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Transparent materials	x Missing True Temperature	

True Temperature: typical errors II

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Mixing the hardware – MPC/controller/modules → wrong calibration parameters	x	
Transparent materials	x Missing True Temperature	
Rough surfaces, (interfaces?)	x e.g. nucleation	

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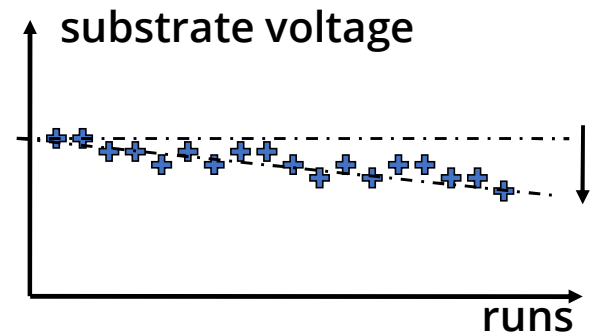
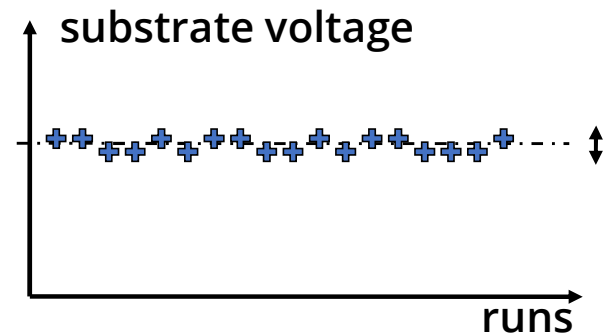
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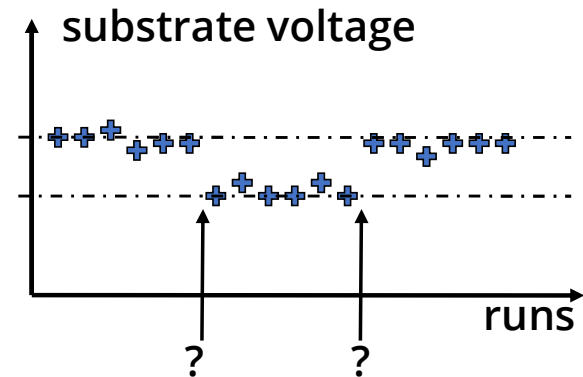
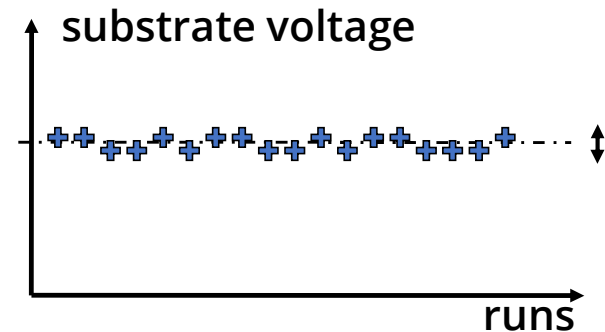
Monitoring the "raw voltage"

- normal run-run variation
- EN2: alpha history is available (attend the EN2 live demo)
- not normal: continuous decrease
 - check if all wavelengths are affected with the same ratio.
 - if shorter wavelength is affected more strongly, assume window coating!
 - light source can be at end of lifetime
 - also possible for individual wavelengths only



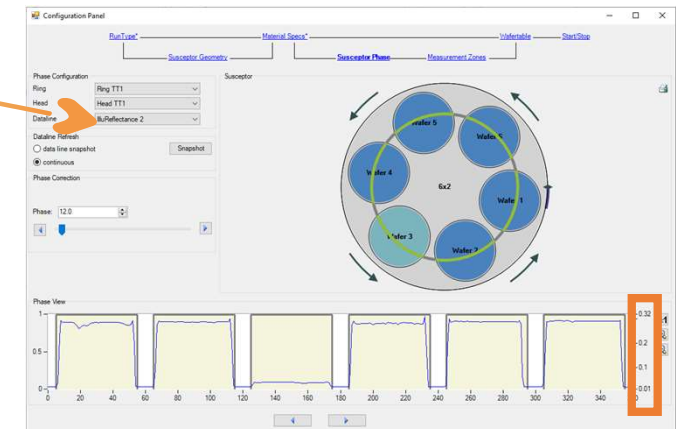
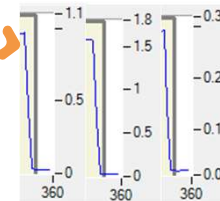
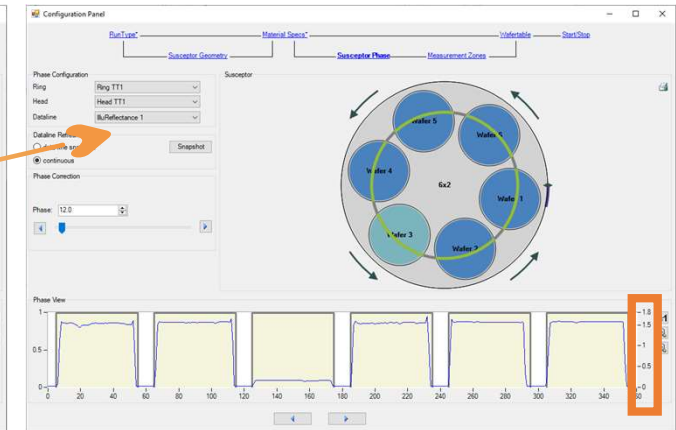
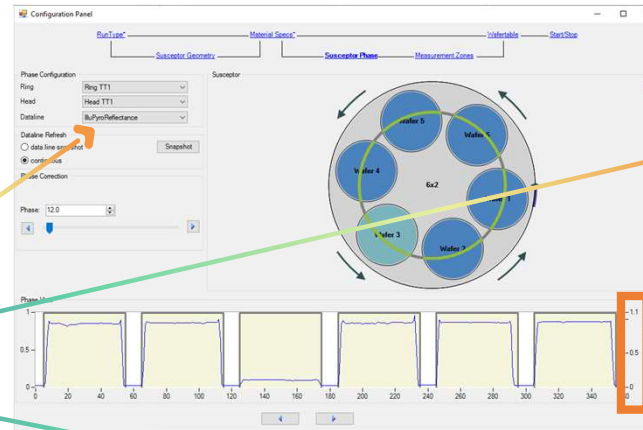
Monitoring the "raw voltage"

- normal run-run variation
- not normal: sudden drops
 - check if steps are associated with reactor maintenance or equipment change – all forms of misalignment will affect the measurement
 - did distance wafer to optical head change?
 - fiber cable broken?
 - Kinked?
 - bending radius too small



EpiNet 2 Display - Configuration Panel

- › select a wavelength
- › compare the voltage values on defined substrates over time
 - › a stronger decrease in 405nm indicates window coating on nitride systems
 - › save the linescan or a screenshot for documentation
- › define the wafertable.xml in the known procedure



What to do if intensity drops?

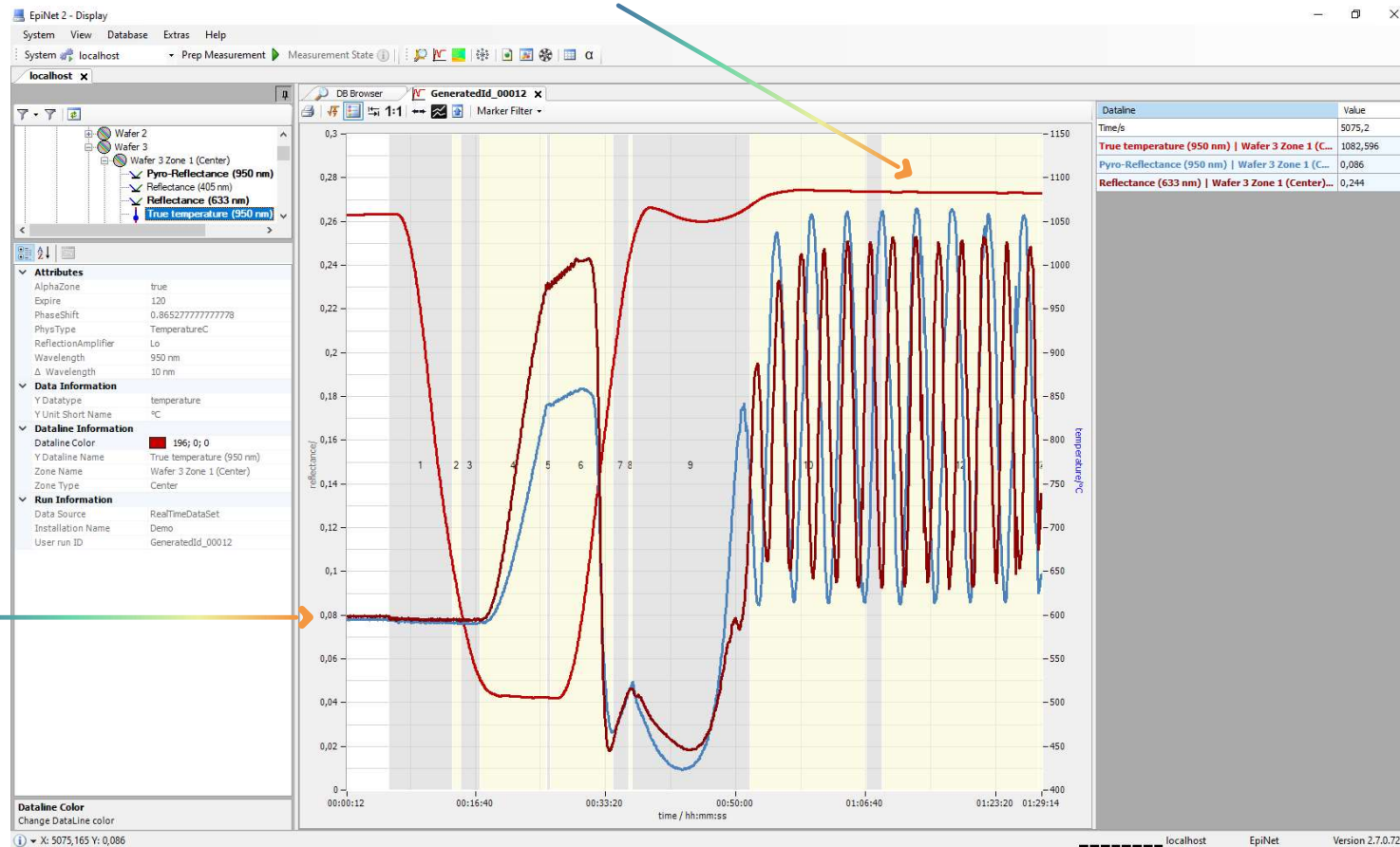
measured intensity smaller than before → three possible reasons

- sub-optimum alignment
→ re-align (please see your sensor's manual)
- window coated
→ clean window
- light source degradation
→ if significant (< 50%): exchange light source
→ if not significant: perform reflectance calibration

Correct reflectance

TT flat at 1083°C

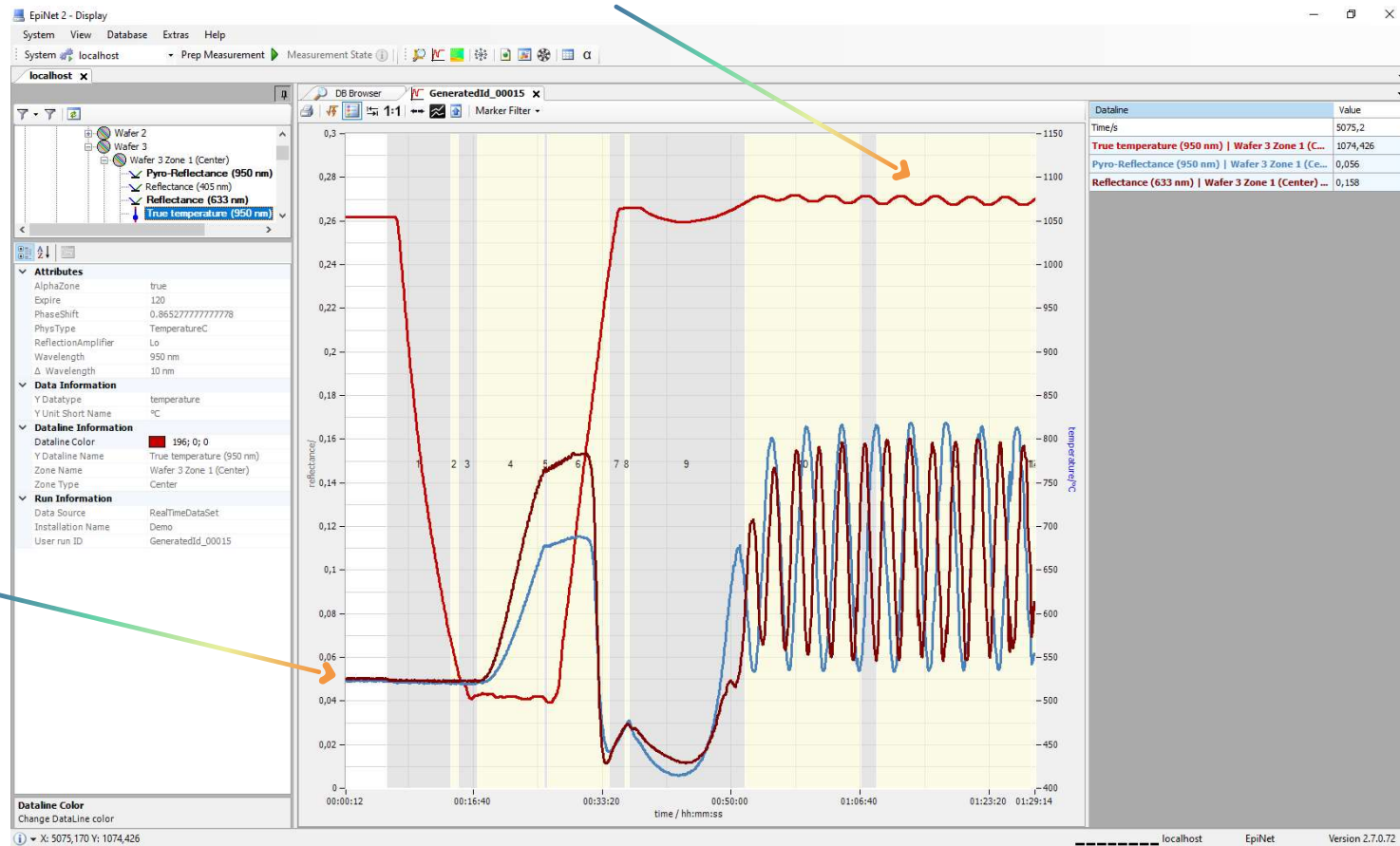
R = 0.075
Sapphire



Incorrect reflectance

TT oscillates and drops ($\sim 1074^{\circ}\text{C}$)

$R=0.05$
(too low)

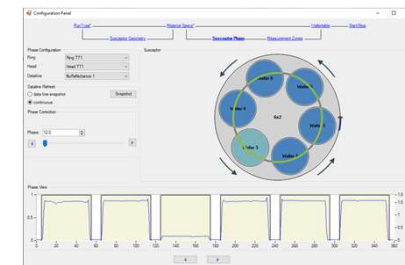


Use EpiTT to evaluate wafer load

- Open the EpiNet Display Configuration Panel and click the workflow item “Susceptor Phase”.
- The envelope of the plateaus across wafers tells important information about the alignment of the EpiTT head and the susceptor.



- In this example: w1, w2, w4, w5, w6 are silicon and w3 is sapphire

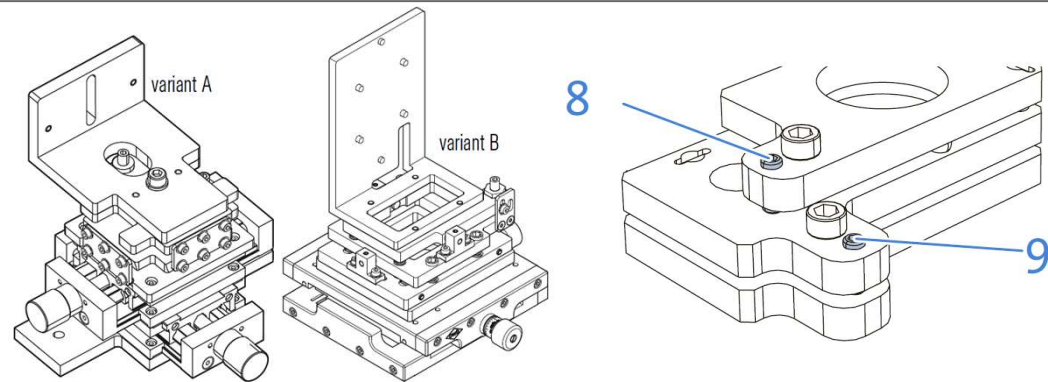


All wafer profiles are affected

- The optical head is not aligned correctly:



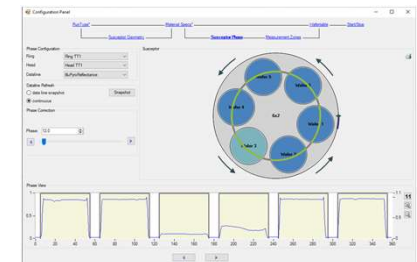
- The optical head needs further adjustment.
- Please contact your service partner.



Only one wafer is affected



- The optical head is right but one wafer is tilted (e.g. flake) and needs to be adjusted before growth.
- Open the reactor and place the wafer right!
- EpiTT/EpiCurve TT indicate potential problems before growth start!
- Please attend the afternoon live demo of EN2 for new features



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- Strong in-situ metrology integration into MOCVD production is the key to optimal cost of ownership
- True temperature is the key parameter
- Ensure valid calibration → Settings on MPC → be careful with changes
- Check the in-situ metrology status on a regular base – as done with the MOCVD system

Outlook for Aixtron-LayTec-Customers

- Joint knowledge tour (schedule depends on COVID-19 travel restrictions)
- Alternative – online sessions
- Aixtron & LayTec continuously improve their products and interaction to meet your future production requirements

The background features a dark, abstract design with diagonal lines and glowing light effects. On the left, there are bright, blurred light streaks in white, green, and yellow. On the right, there are solid geometric shapes in blue and orange. The central text is white and stands out against the dark background.

Knowledge is key
www.laytec.de