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

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(LayTec – COO)

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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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General Remarks

- 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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General remarks

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

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

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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

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Key target: optimized cost of ownership in MOCVD production

- Sequence of requirements to meet

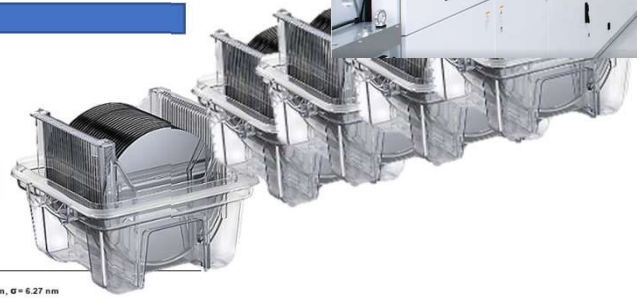
  Optimized cost of ownership!

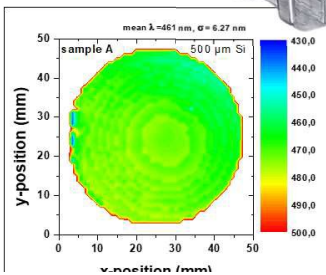
S2S

R2R

W2W

on wafer





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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)

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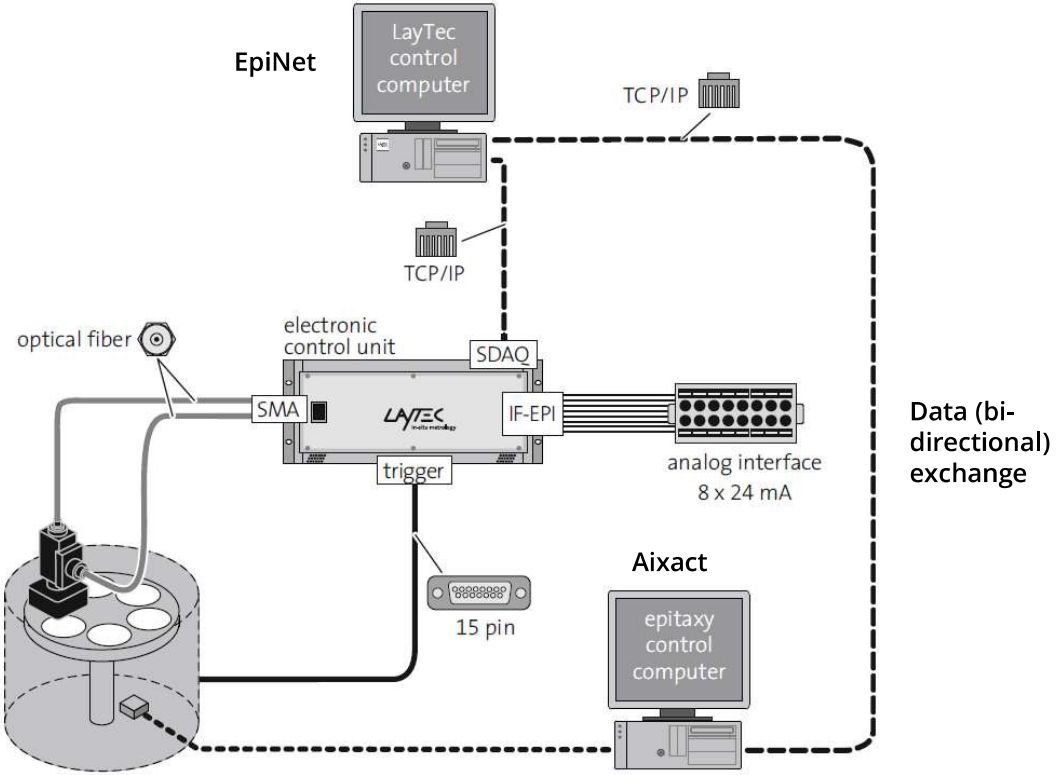
Growth system and in-situ metrology interactions

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



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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
- Focussed semiconductor laser for curvature detection

P400

- UV pyrometer

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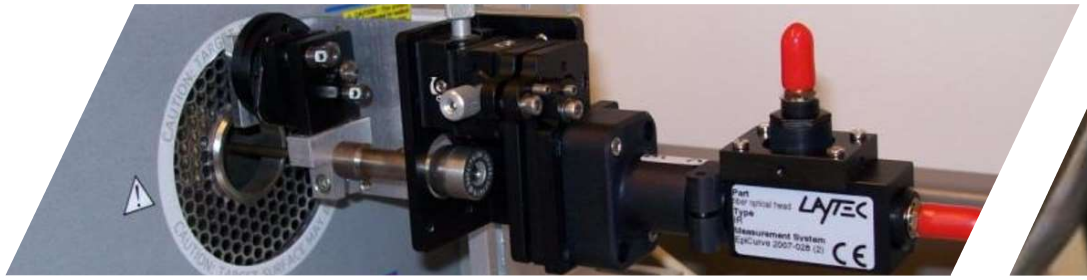
Important background of LayTec systems

- 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

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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!

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Influence of reflectance measurement

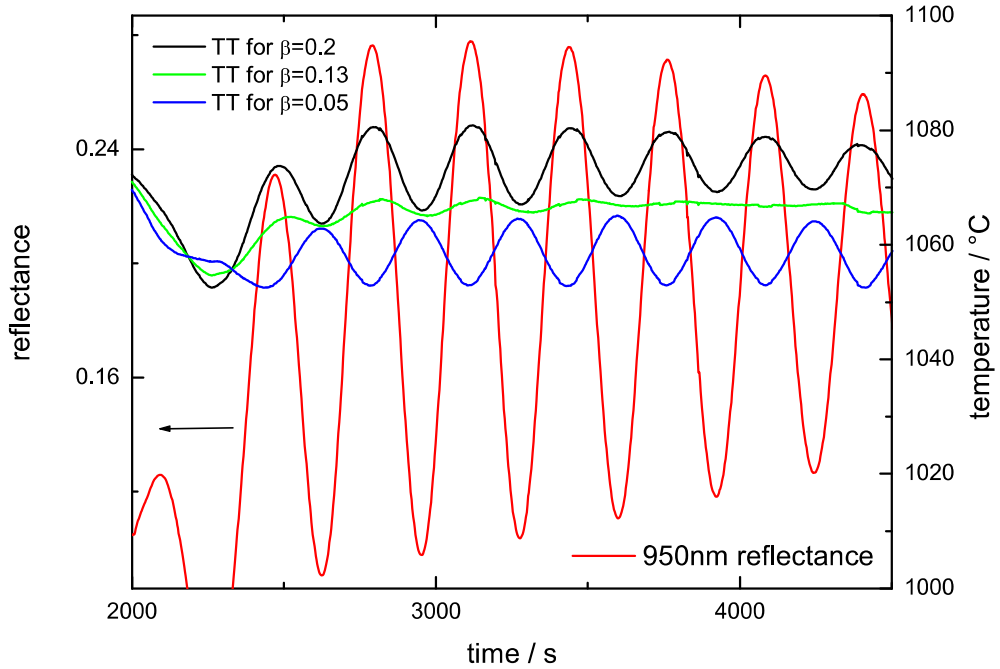
- Absolute correct reflectance value is the key to ecp!

  --- 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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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	×	

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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	×	
Wrong handling of AbsoluT	×	

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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	×	
Wrong handling of AbsoluT	×	
Bad eutectic calibration	×	

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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	x	
Wrong handling of AbsoluT	x	
Bad eutectic calibration	x	
Misalignment	x	x

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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	x	
Wrong handling of AbsoluT	x	
Bad eutectic calibration	x	
Misalignment	x	x
Window coating	x	x

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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	x	
Wrong handling of AbsoluT	x	
Bad eutectic calibration	x	
Misalignment	x	x
Window coating	x	x
Damaged fiber cables	x	x

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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	x	
Wrong handling of AbsoluT	x	
Bad eutectic calibration	x	
Misalignment	x	x
Window coating	x	x
Damaged fiber cables	x	x
Fibers connections crossed	x	x

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True Temperature: typical errors

Root causes	Impact on temperature calibration (delta)	Impact on reflectance calibration (alpha)
Defect or uncalibrated AbsoluT	x	
Wrong handling of AbsoluT	x	
Bad eutectic calibration	x	
Misalignment	x	x
Window coating	x	x
Damaged fiber cables	x	x
Fibers connections crossed	x	x
Wafer table errors - wrong substrate - wrong template - zones too far out (already on graphite) - PSS		 x x x x

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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	×	

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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	×	
Transparent materials	× Missing True Temperature	

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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	×	
Transparent materials	× Missing True Temperature	
Rough surfaces, (interfaces?)	× e.g. nucleation	

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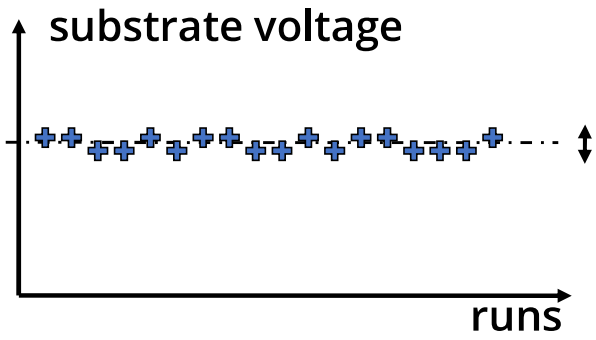
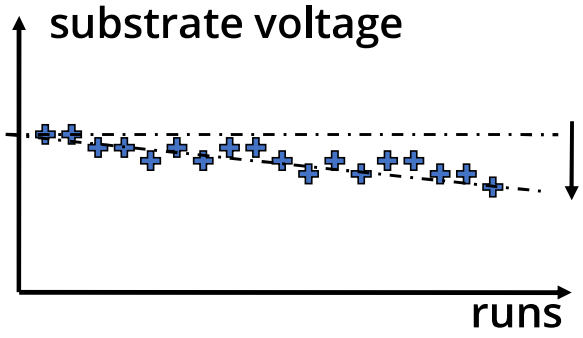
Monitoring the "raw voltage"

- 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



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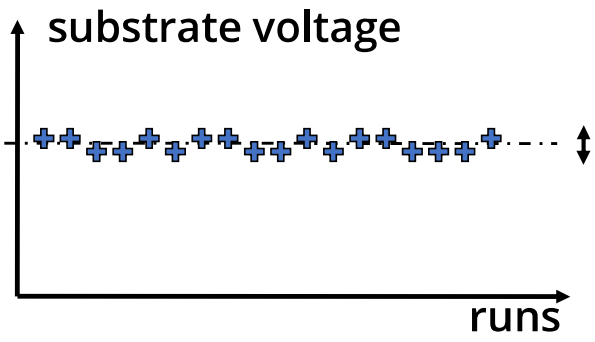
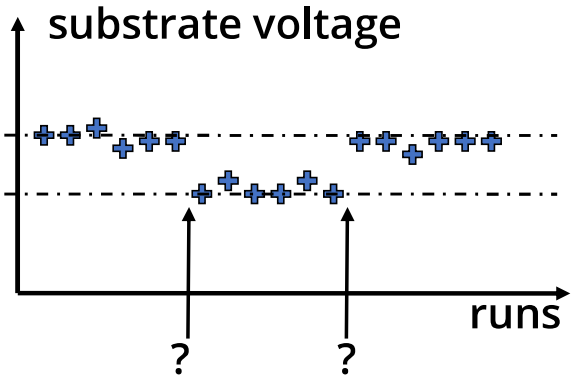
Monitoring the "raw voltage"

- 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



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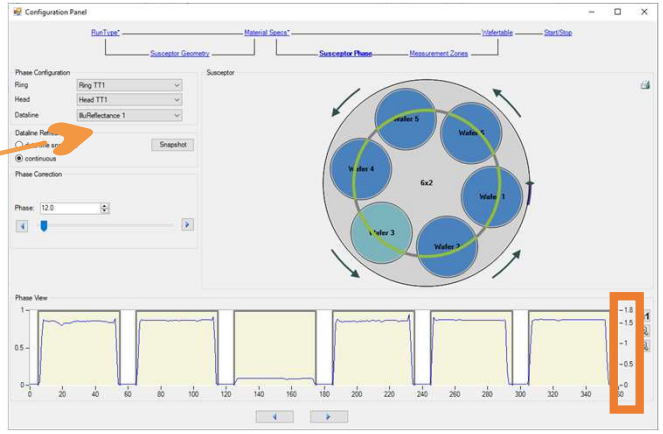
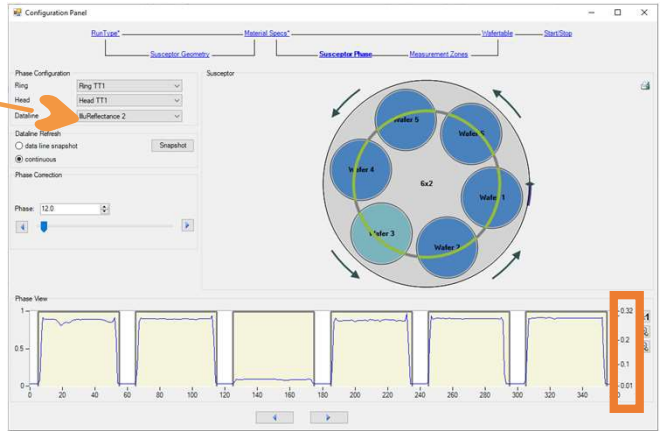
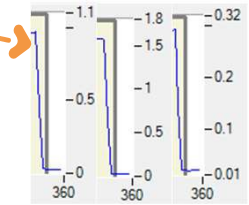
EpiNet 2 Display - Configuration Panel







- 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

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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

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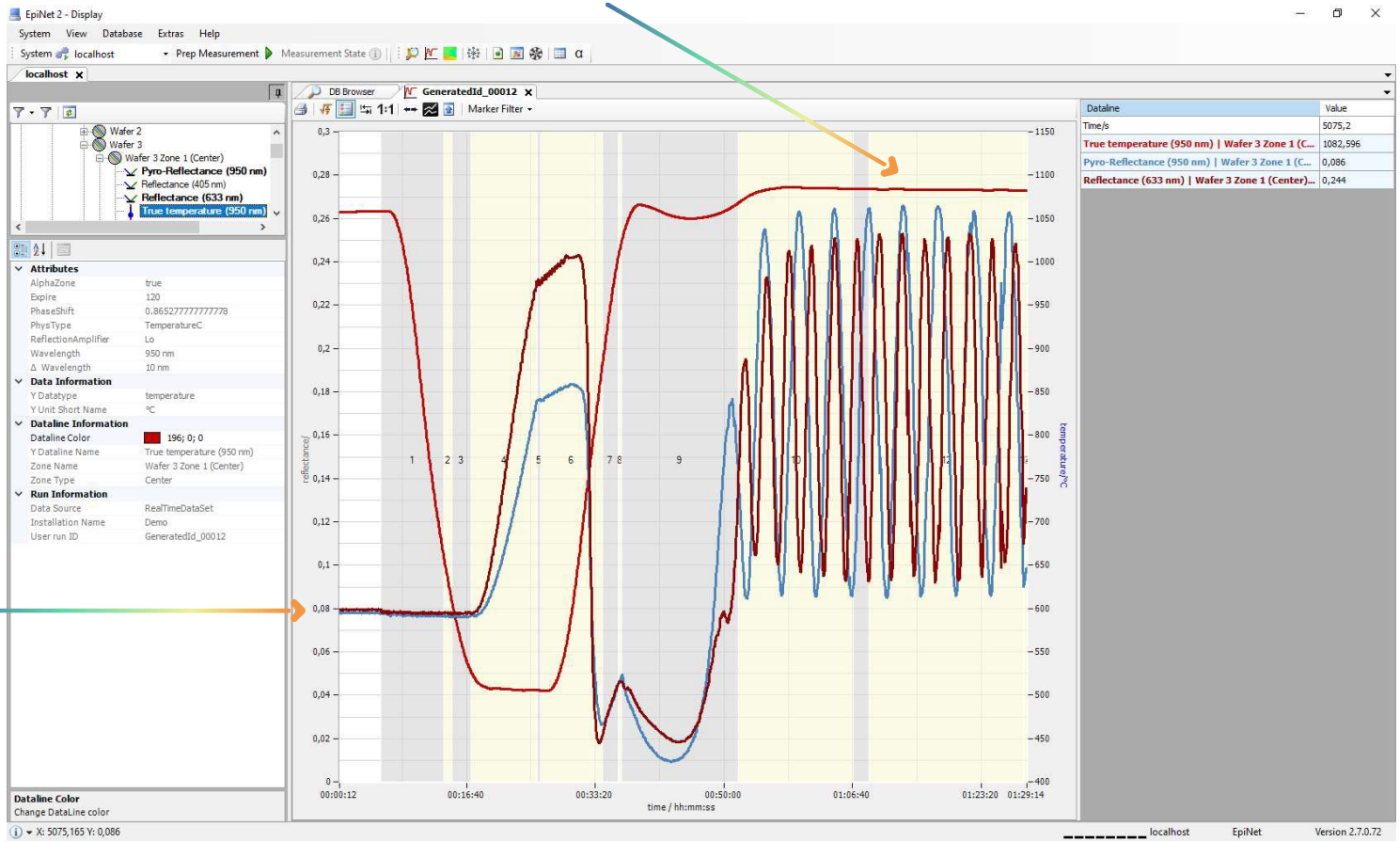
Correct reflectance

TT flat at 1083°C

R = 0.075
Sapphire



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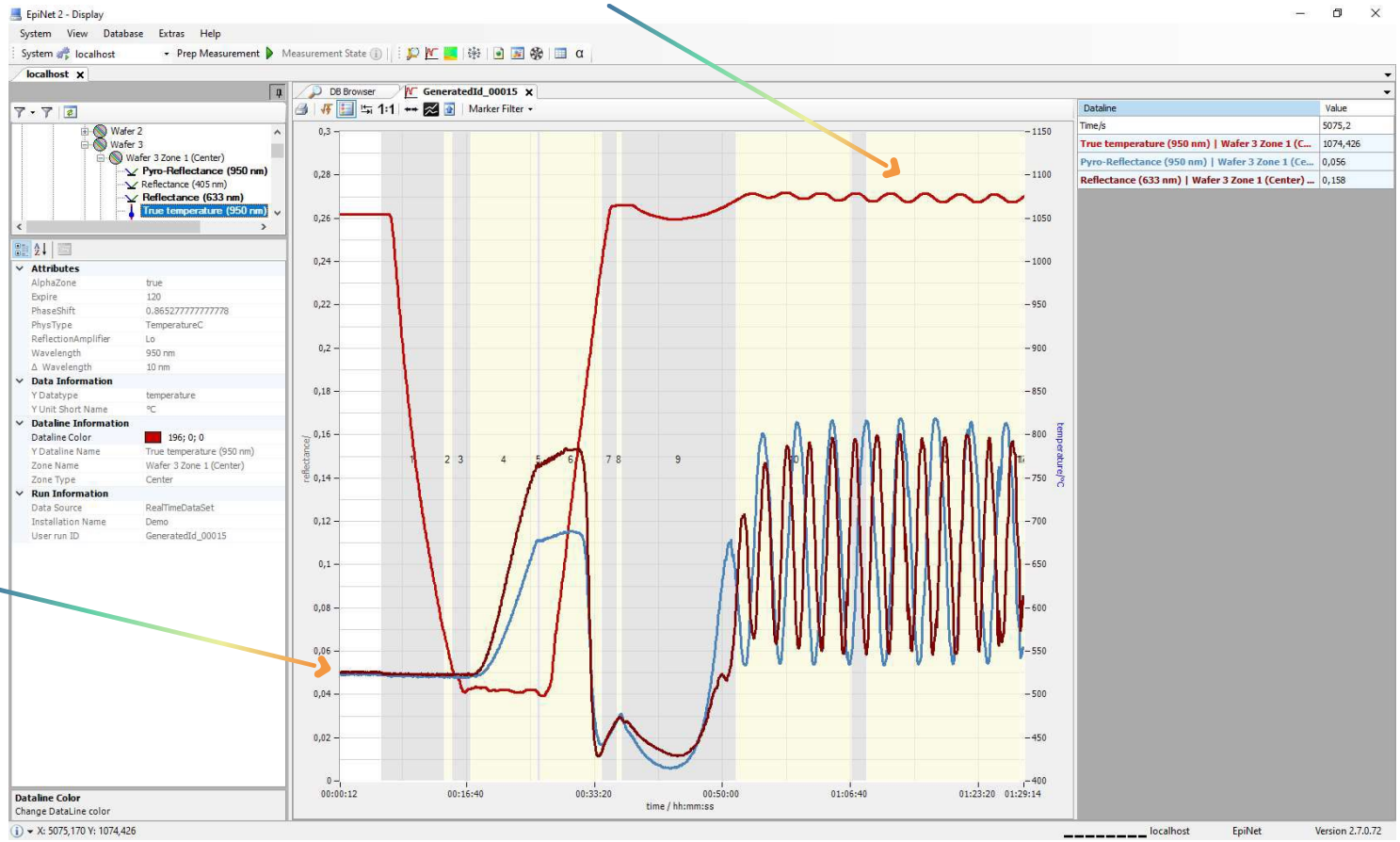
Incorrect reflectance

TT oscillates and drops (~1074°C)



R=0.05
(too low)

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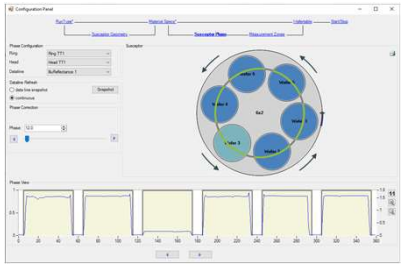
Use EpiTT to evaluate wafer load

- 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**



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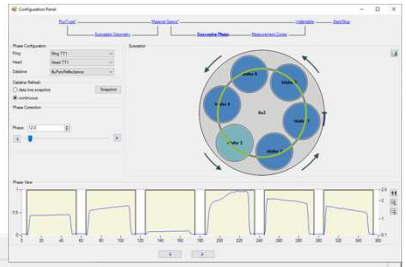
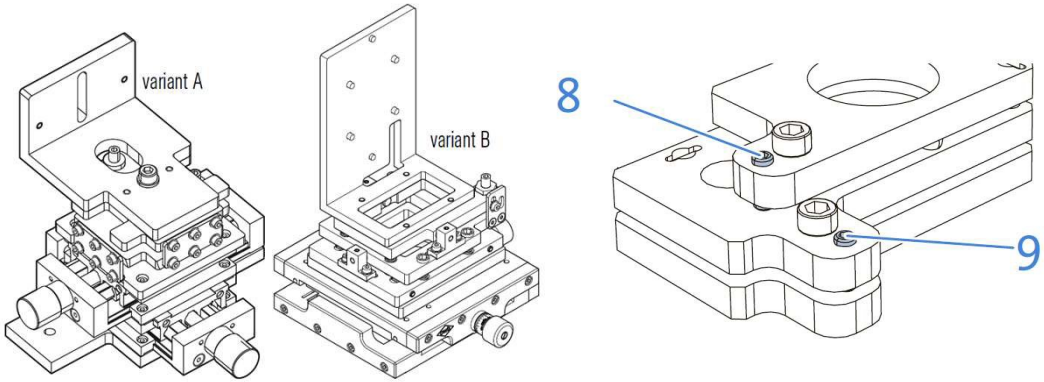
All wafer profiles are affected

- The optical head is not aligned correctly:



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



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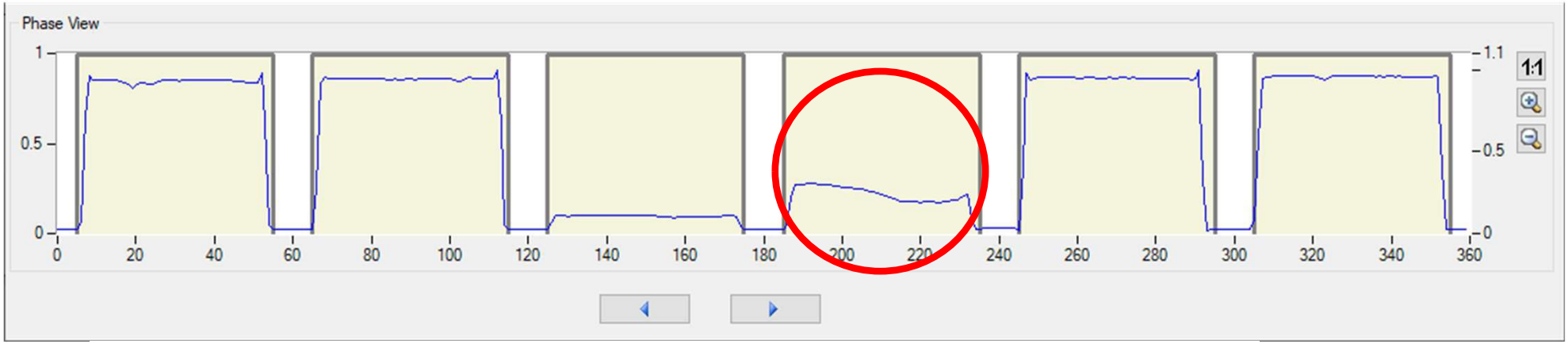
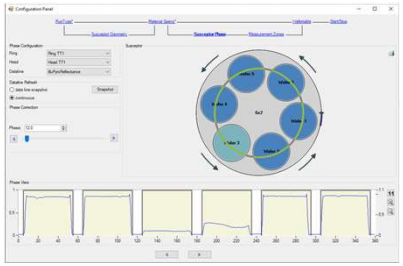
Only one wafer is affected



- 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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Conclusions

- 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

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Outlook for Aixtron-LayTec-Customers

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

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Knowledge is key

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20 October
2021

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