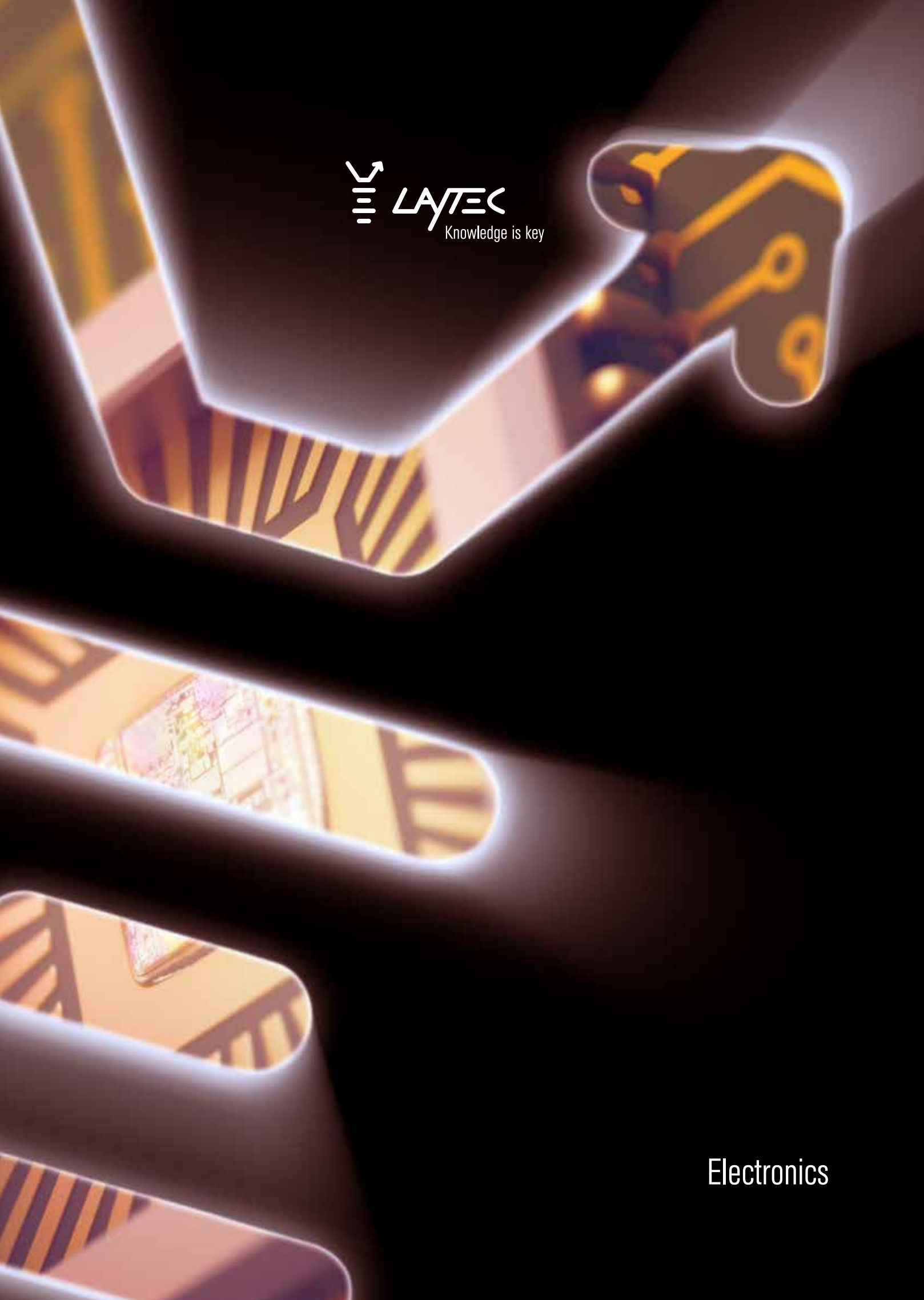

LAYTEC
Knowledge is key
Electronics

Why choose LayTec?

- We are the leading manufacturer of integrated optical metrology systems for all thin-film processes: LayTec systems can be customized for every specific process.
- For more than a decade LayTec metrology has defined the performance and quality standards.
- The majority of global compound semiconductor device producers have chosen LayTec metrology.
- We offer cutting-edge technology made in Germany through a worldwide distribution and service network.

Challenges

The market for semiconductor devices is highly competitive. A sustained, commercial success requires permanent efforts to continuously improve device performance and steadily reduce cost. Improving deposition and etch processes is a very effective way to optimize performance and costs.

SUBSTRATE

Substrate yield loss:
- Particles
- Stains
- Scratches
- Pits

DEPOSITION

Deposition yield loss:
- Pits & cracks
- Composition deviations
- Thickness deviations
- Non-uniformity
- Topography defects

DIES ON WAFER

Front-end yield loss:
- Patterning defects
- Overlay errors
- Film uniformity deviations

DIES / PACKAGE

Back-end yield loss:
- Dicing defects
- Probe marks
- Residues, peeling, contamination
- Pad damages

Tight in-situ monitoring during the deposition / etching helps you enhance related process yields and optimize the performances of your devices.

IN-SITU MONITORING

- Reflectance at 3 wavelengths
- Wafer temperature
- Pocket temperature
- Wafer bow

ENGINEERING

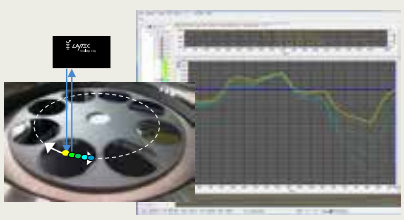
- Process optimization
- Fast failure analysis
- Prevention of spec deviations
- Uniformity control
- Process reproducibility tuning

All in real-time!

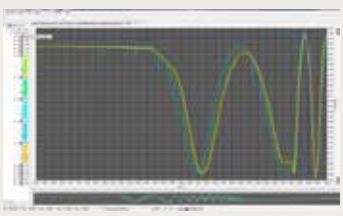
COMMERCIAL SUCCESS

- Yield improvement
- Cost reduction
- More competitive device structures

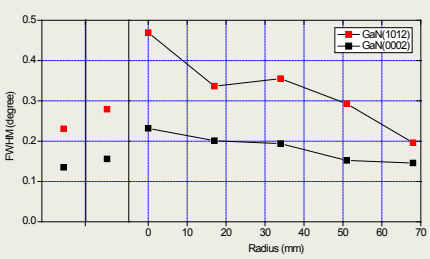
LayTec's in-situ metrology systems are powerful tools in your hand – providing in-situ information on the process state in real-time. By tightly controlling surface conditions across every single wafer you will be able to optimize your growth processes and achieve the best device performance and uniformity.



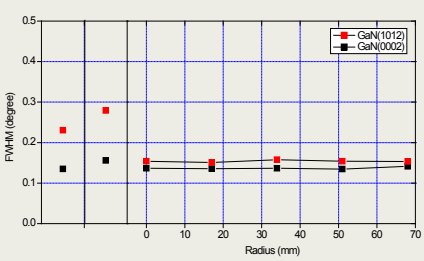
Wafer bow during initial AlN/ AlGaN buffer layer growth



In-situ reflection monitoring growth rates and surface morphology



XRD 1 before optimization



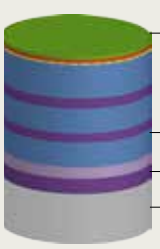
XRD 2 after complete optimization

Optimization of the initial layer structure for GaN on Si power devices. In-situ monitoring was used to optimize the crystalline quality across the complete wafer.

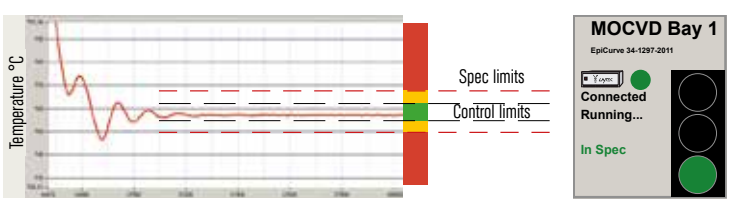
Solutions

Monitoring every process step

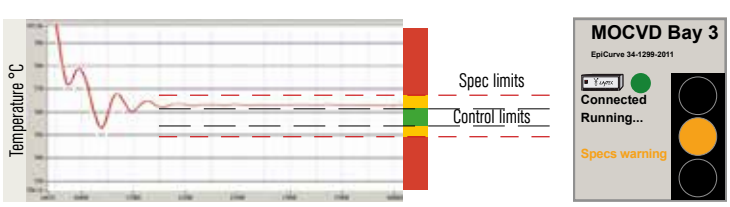
Our in-situ metrology helps you predict and control the final properties of your products. Find out at an early stage which wafers do not meet the specifications and save the costs for their processing.

YOUR DEPOSITION PROCESS (e.g., GaN / Si HFET)	LAYTEC'S REAL-TIME MONITORING	PROPERTIES OF YOUR FINAL DEVICE
Step 1  Nucleation layer Substrate	Step 1 Nucleation layer quality: – Surface morphology – Growth rate homogeneity	Step 1 – Low defect density
Step 2  Buffer incl. strain engineering layers Nucleation layer Substrate	Step 2 GaN buffer quality: – Surface morphology – Thickness, growth rate – Thickness homogeneity – Film stress – (Indirect) doping homogeneity – Final wafer bow	Step 2 – High buffer resistivity – High breakdown voltage
Step 3  GaN Cap AlGaN / GaN 2DEG Buffer Nucleation layer Substrate	Step 3 AlGaN / GaN active layer – Thickness – (Indirect) composition	Step 3 – High carrier density – High mobility – Low sheet resistance

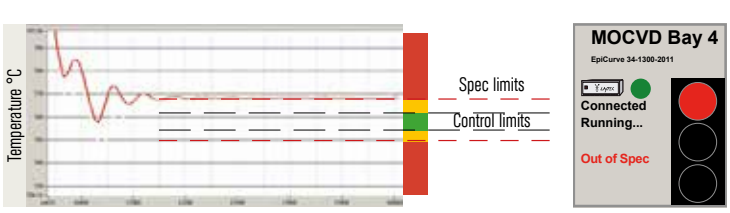
The traffic lights in LayTec's EpiNet software will ensure that your operators make the right decisions.



Case 1:
When all run data are within the pre-defined control limits, e.g., wafer surface temperature, the traffic light is green.



Case 2:
When the value exceeds the control limits, but is still within the spec limits, the traffic light turns yellow.

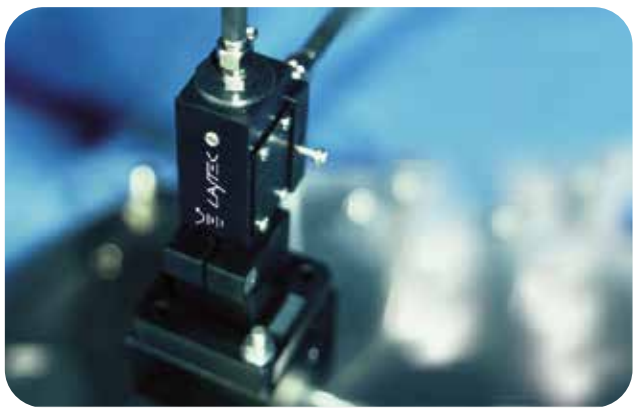


Case 3:
When the value has exceeded both control and spec limits, the traffic light turns red. This is a signal for the operator to stop the run and re-adjust the growth conditions.

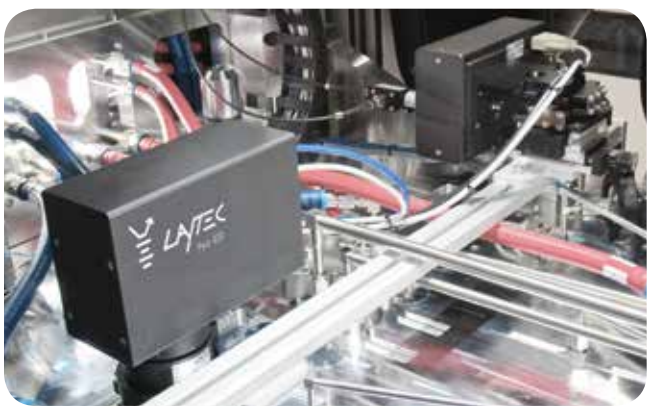
Products

Modular metrology platform for your specific application

Thanks to our modular in-situ metrology concept, we offer you the perfect combination of tools for your specific process, deposition system and wafer size.



EpiTT



Pyro 400 and EpiCurve® TT

EpiTT LayTec's EpiTT family of products is the standard solution for temperature and thickness measurements for applications where only a marginal amount of wafer bow is induced (e.g., small wafer diameter).

EpiCurve® TT EpiCurve® TT, which includes wafer curvature measurements and all features of the EpiTT family, is needed to overcome increasing wafer curvature challenges occuring at larger wafer diameters or for complex structures of different materials. These systems can be equipped with an advanced resolution option for additional asphericity control of your wafer (EpiCurve® TT AR).

Pyro 400 Pyro 400 and EpiCurve® TT form the premium package for complete control and are essential for monitoring $Al_{1-x}Ga_xN$ or $Al_{1-x}In_xN$ growth. Pyro 400 measures precisely and directly the temperature of GaN layers during the growth on sapphire, SiC and silicon wafers, enabling to control the growth temperature of $Al_{1-x}Ga_xN$ or $Al_{1-x}In_xN$ active layers. EpiCurve® TT adds curvature, emissivity corrected pyrometry and reflectance measurements.

Find the tool for your needs:

Substrate / material	Pocket temperature	Reflectance: growth rate & morphology	Wafer bow	Wafer surface temperature	Product family	Package
GaN on sapphire, 6H-SiC, 4H-SiC, GaN on Si	✓	✓			EpiTT	Standard
	✓	✓	✓		EpiCurve® TT	Advanced
	✓	✓		✓	Pyro 400 & EpiTT	Premium
	✓	✓	✓	✓	Pyro 400 & EpiCurve® TT	
III-Vs on III-Vs, Si, SiN_x, SiO_2 on Si		✓		✓	EpiTT	Standard
		✓	✓	✓	EpiCurve® TT	Advanced
		✓	✓	✓	EpiTT & EpiCurve® TT with customized wavelength	Premium

Standard

EpiTT – Yield improvement through temperature uniformity

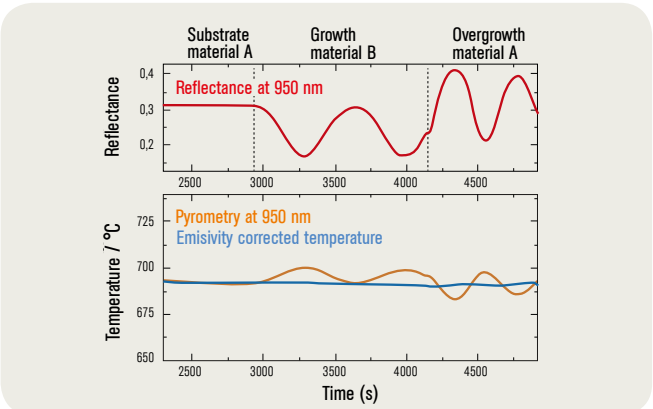
During deposition processes conventional pyrometry without emissivity correction shows oscillations due to interference. To see the true temperature (TT) we combine two methods:

- Intensity measurement of thermally emitted light (950 nm pyrometry)
- Normal incidence reflectometry at 950 nm

LayTec's EpiTT system offers both Emissivity Corrected Pyrometry (ECP) and growth rate measurements.

Pyrometer features:

- Adaptable temperature ranges between 450 °C - 1500 °C and 900 °C - 1700 °C
- Accuracy better than ± 1 K
- Wafer and area selective measurements
- True wafer temperature for opaque semiconductor wafers such as III-Vs on Si, III-Vs on III-V or dielectrics on silicon
- Pocket temperature for IR transparent substrates (GaN, sapphire, SiC)
- Multi-head options: EpiTwin TT, EpiTriple TT, EpiTT with four optical heads



EpiTwin TT - the twin brother of EpiTT containing two measurement heads

AbsoluT: ± 1 K temperature calibration

LayTec's AbsoluT is a convenient handheld device for high-precision on-site temperature calibration. In a few minutes, your engineer will be able to set up exactly the same absolute temperature reference point for pyrometry measurements on different rings and in different reactors and runs (ring-to ring, reactor-to-reactor and run-to-run calibration).

The benefits:

- Exact absolute growth temperature calibration
- Stability & accuracy of growth temperature
- Precise GaN buffer and active layer temperature measurement
- Stable growth temperature for many production cycles on all reactors in all chambers on all wafers

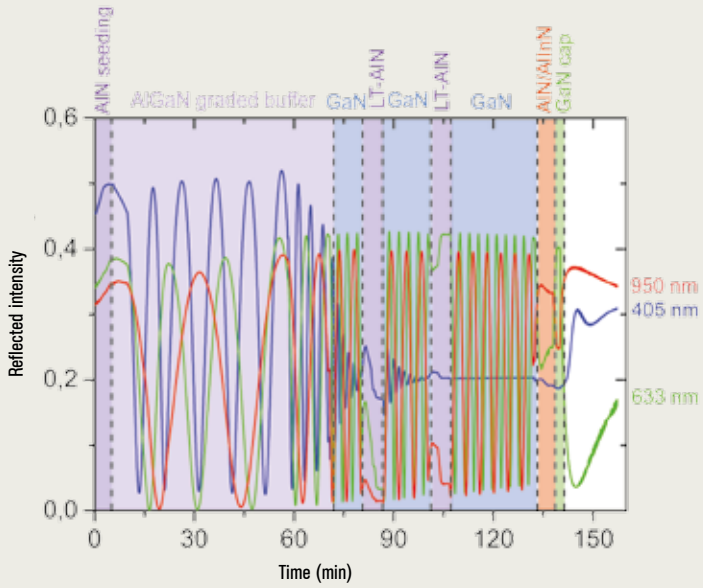
Temperature measurement with EpiTwin TT before and after calibration with AbsoluT

AbsoluT used by engineer for temperature calibration

Standard

EpiTT – Growth rate, thickness and morphology

Three wavelengths reflectance makes it possible to monitor all essential properties of the growing layers, such as growth rate, layer thickness, surface roughness and others. In addition, LayTec uses 950 nm reflectance for emissivity correction of the pyrometry measurement.



405 nm for thin layers
- Growth rate of thin layers
- Interface quality
- Surface roughness

633 nm - for GaN buffer layers
- Growth rate and thickness analysis

950 nm
- Correction for emissivity changes (True Temperature)
- Growth rate and thickness analysis for high growth rates

Other wavelengths are available on request (e.g., 365 / 280 nm for thin dielectric films).

By courtesy of Otto von Guericke University Magdeburg, Germany

LayTec systems for temperature and reflectance

Both emissivity corrected temperature monitoring and reflectance measurement at three wavelengths are included in all products of the EpiTT family and other metrology systems that include EpiTT features. EpiTT offers industry-standard metrology for any kind of epi-growth systems and is compatible with different main rotation frequencies in the range from 0 up to 1500 rpm.

Models for multiple wafer ring reactors

LayTec offers multi-head configurations of EpiTT and EpiCurve® TT families of products which are specifically designed for multiple wafer ring reactors. These models have two (EpiTwin TT) three (EpiTriple TT) or four optical heads for temperature and reflectance measurements at independent positions. Virtually all LayTec systems can be upgraded to multi-head systems.

EpiTriple TT

Advanced

EpiCurve® TT – Flat wafers by strain engineering

Challenges of 4”, 6” and larger wafers

Wafer bowing → Different distance from pocket surface to wafer in the center and at the edges of the wafer → Temperature deviations across wafer → Composition inhomogeneity reduces yield

EpiCurve® TT makes a difference

In-situ control for strain-optimized structures → Minimize temperature inhomogeneities due to wafer bowing → Better composition uniformity, better 2DEG uniformity, higher yield, low final wafer bow

LayTec systems for curvature, temperature and reflectance

EpiCurve® TT includes:

- Wafer selective curvature measurements
- Curvature range from -7000 km^{-1} (convex) to +800 km^{-1} (concave)
- Blue laser for GaN based electronics
- Aspherical bowing measurements with Advanced Resolution (AR) option
- All features of EpiTT: emissivity corrected pyrometry and growth rate / thickness measurements by 3 wavelength reflectance

EpiCurve® TT

Application examples:

- GaN / Si electronics
- III-V electronics
- SiO_2 / SiN deposition
- R&D for new materials and devices

For multiple wafer ring reactors, a combination with one or two additional EpiTT heads is recommended: EpiCurve®Twin TT, EpiCurve®Triple TT.

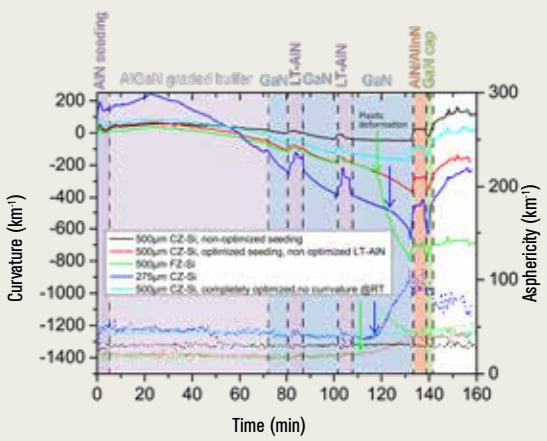
EpiCurve®Twin TT

Advanced

EpiCurve® TT – For III-Nitride growth on silicon, SiC

When substrates and epi-layers have a large lattice mismatch and a large mismatch of thermal expansion coefficient, the related high levels of stress cause critical wafer bowing and, finally, film cracking. Therefore, the production of high performing electrical and electro-optical devices based on GaN-on-Silicon requires precise strain engineering to achieve a high quality material. LayTec's in-situ metrology systems provide direct monitoring of the critical growth parameters for stress compensation and strain engineering.

The figure below shows in-situ curvature measurements of five different AlInN / GaN FET structures with step-by-step optimized interlayers. In addition, substrates with 275 µm SEMI thickness (preferred for subsequent processing) and semi-insulating floatzone silicon were used. In order to reach the buffer thickness required for high breakdown voltage, a minimum substrate thickness and doping level are required. The interlayers allow to compensate the curvature caused by thermal stress and lattice mismatch. As a result, for the optimized process after the cool down the wafer is flat at 0 km^{-1}.



- Compensation of large difference in thermal expansion coefficients by advanced strain engineering
- Goal: flat final wafer at room temperature - by introduction of strain compensating interlayers
- Introduction of compressive strain (LT - AlN)
- Strain engineering requires precise curvature control to avoid overcompensation leading to plastic deformations
- The use of thicker, doped substrates increases the tolerance against strain.

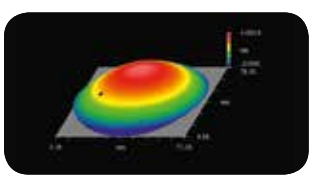
By courtesy of Otto von Guericke University Magdeburg, Germany, Dep. Semiconductor Epitaxy

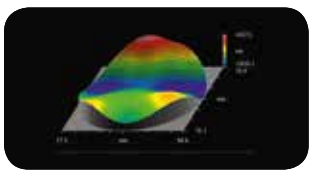
EpiCurve® TT AR – Asphericity monitoring with advanced resolution

One of the challenges during GaN / Si buffer growth is the increasing asphericity of the wafer. For such processes, we offer the EpiCurve® TT with the Advanced Resolution (AR) option.

The advantages of the AR option:

- Provides information on wafer curvature along two perpendicular directions: radial and azimuthal
- Measures quantitatively the aspheric component of the curvature and gives access to information on layer formation
- Detects relaxation at an early stage
- Reduces signal fluctuations in the main (spherical) bow measurement caused by aspherical effects



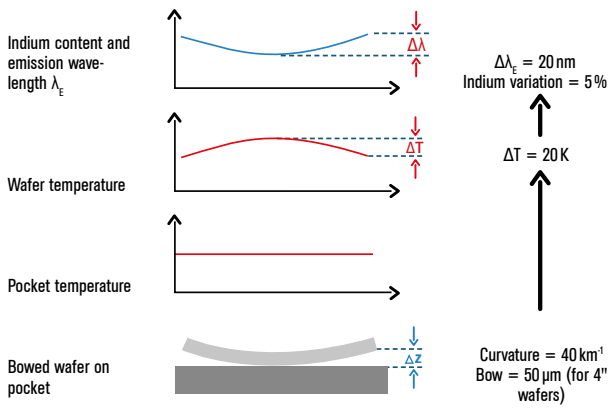


Premium

Pyro 400 – Wafer surface temperature for IR transparent substrates

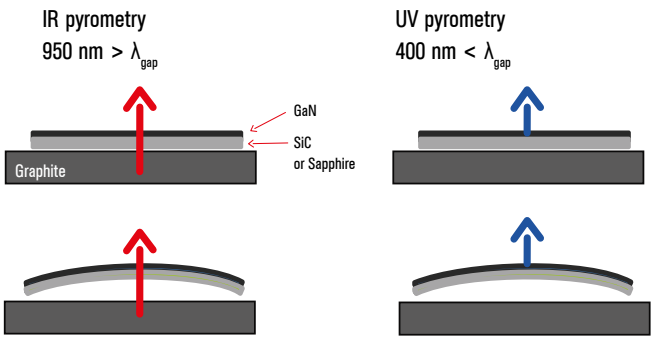
Why wafer surface temperature?

Real GaN surface temperature is the most critical parameter of the III-Nitride epitaxial process. When the wafer bows, the deviation between wafer surface temperature and pocket temperature increases e.g., for a 4” SiC substrate up to 20 K or more. This results in a significant indium content variation in the InAlN active layers and, thereby, in a strong variation of the 2DEG properties. In other words, surface temperature is fundamental for the homogeneous growth of the active layers and the performance of the final device.



IR transparent substrates (sapphire or SiC)

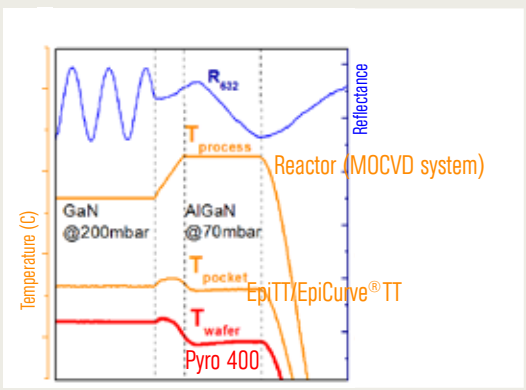
When it comes to bowed IR transparent substrates like sapphire or 6H-SiC, a conventional infrared (IR) pyrometer can measure only the pocket temperature. The GaN surface temperature can only be measured by an ultraviolet (UV) pyrometer because GaN absorbs and thermally emits only below 400 nm.



Surface temperature variations during GaN / SiC HFET growth

In this example the conventional IR pyrometer does not “notice” the drop in wafer surface temperature by 20 K after changing the reactor pressure. But Pyro 400 does! The red curve in the graph below shows the exact wafer surface temperature as measured by Pyro 400.

The exact knowledge of the surface temperature distribution is a must-have for homogeneous electronic properties of all devices across the wafer.



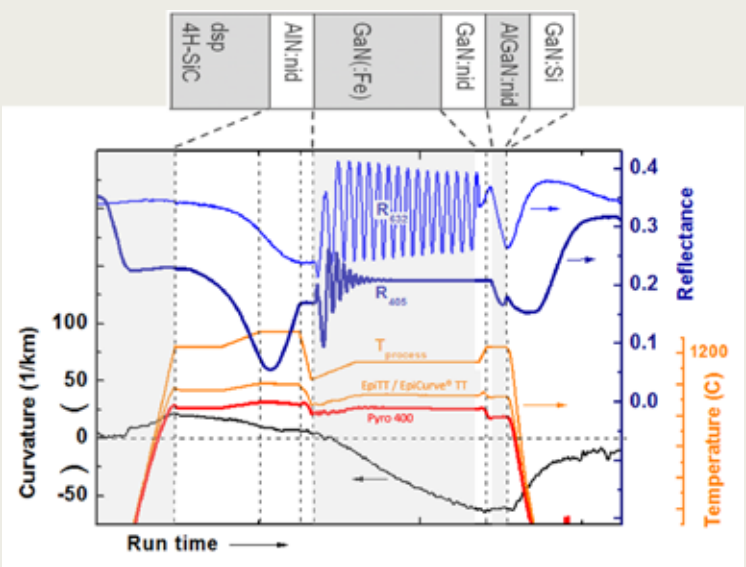
By courtesy of Ferdinand-Braun-Institute, Berlin, Germany

Premium

Pyro 400 & EpiCurve® TT – Maximum control for transparent substrates

LayTec's premium in-situ solution is a combination of Pyro 400 and EpiCurve® TT. These tools will give you all real-time growth parameters and the best access to real-time strain engineering for GaN / Si and GaN / SiC power eletronic MOCVD processes.

Example: GaN / SiC



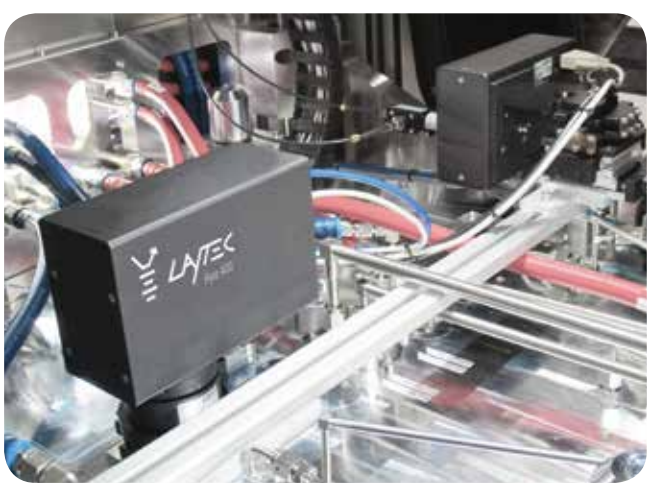
- Thickness, curvature, morphology and pocket temperature control by EpiCurve® TT
- Surface temperature control by Pyro 400
- 633 nm reflectance for thickness control by EpiCurve® TT
- 405 nm morphology control by EpiCurve® TT

By courtesy of Ferdinand Braun Institute, Berlin, Germany

Premium package for IR transparent structures

Pyro 400 and EpiCurve® TT provide:

- Measurement of the real surface temperature of GaN for the best active layer uniformity on sapphire and SiC substrates, using ultraviolet pyrometry
- Emissivity corrected pyrometry at 950 nm to measure pocket temperature for root-cause failure analysis
- Measurement of reflectance at three wavelengths for growth rate, thickness and surface morphology analysis and pyrometry correction
- Curvature measurements for strain engineering and in-situ control of ternary composition
- Suppression of stray light artefacts in GaN / Si temperature sensing



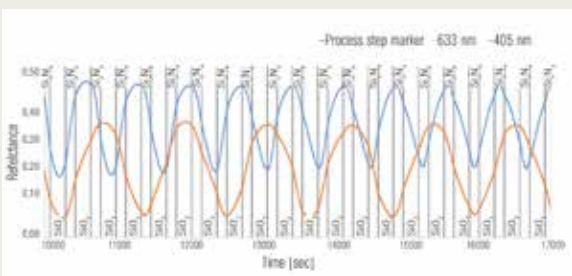
Pyro 400 and EpiCurve® TT installed on one growth system

Advanced Silicon

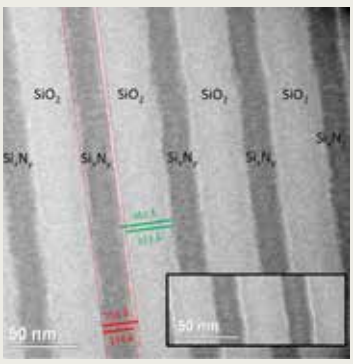
EpiTT UV for PECVD multilayer stacks

EpiTT UV, LayTec's latest reflectometer, can be provided with an additional short wavelength (280 nm / 365 nm) detection head. It measures stacks of very thin layers (200 Å or thinner) with the highest precision. With the 405 / 365 / 280 nm reflection wavelength it successfully monitores the growth of complex multilayer stacks in plasma-enhanced chemical vapor deposition (PECVD), atomic layer deposition (ALD) as well as other epitaxial methods.
The tool is ideally suited to monitor complex deposition processes in-situ. Such material stacks are used in the fabrication of next generation devices like new memories and logic circuits (More Moore) or MEMS and miniaturized optical components (More than Moore).

EpiTT UV installed on Oxford Instruments Plasmalab System 100 ICP CVD system to measure the layer thickness of SiO_2 and Si_xN_y layers during deposition of a multilayer stack consisting of 50 alternating SiO_2 / Si_xN_y layer pairs. By courtesy of Imenau Technical University.



405 nm (blue trace) and 633 nm (orange trace) transients as obtained during the growth of a multilayer stack of 50 layer pairs of 400 Å of SiO_2 and 180 Å of Si_3N_4. The process steps are indicated by the grey lines.



Transmission electron microscope image of the multilayer stack illustrated in Fig. 2. SiO_2 layers appear as bright regions whereas Si_xN_y layers are dark. From this image a SiO_2 thickness of 323-361 Å and a Si_xN_y thickness of 214-251 Å was determined. The range of thickness is due to the appearance of an interlayer seen at the wafer side interface between Si_xN_y and SiO_2. This interlayer becomes particularly visible in the inset.

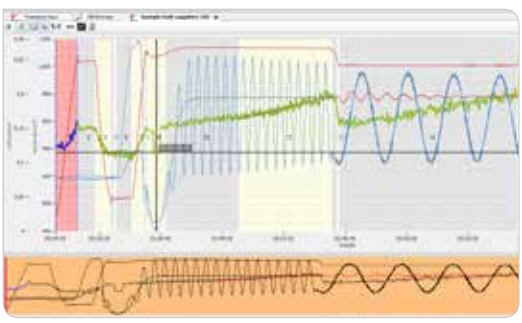
The complexity of such devices requires entirely new methods of process control for various reasons: On the one hand, post-process metrology applied to dedicated test fields on the wafer cannot resolve the properties of these 3D structures with sufficient precision. On the other hand, the deposition processes for these multilayer structures are significantly longer than the processes for simpler devices. If processes deviate from the specifications, in-situ metrology can provide early-warnings to avoid unproductive deposition time. It can also provide timely indication helping plan scheduled maintenance.

Helping improve the productivity, EpiTT UV constitutes a powerful tool to accelerate both integration and market of these next-generation devices.

Control and analysis software

EpiNet - Improve yield and process capacity

All LayTec in-situ systems are equipped with LayTec's EpiNet software specially developed for process optimization, analysis and control. Our software solutions support operators when making "stop or go" decisions. It lets you visualize wafer measurements, browse through previous runs and explore the wealth of information which is captured during your process. EpiNet gives you the calculation tools you need to extract key figures about your wafers and your epitaxy. In run-to-run control and in statistical process control these key figures allow you to improve your yield and process capacity.



With EpiNet you can:

- Turn raw in-situ data into valuable information
- Drill down to single process steps
- Speed-up R&D analysis
- Improve your epitaxy yield
- Maximize your process capacity
- Save money with automation

Features

Measurements

- Time resolved, wafer resolved, zone resolved measurements for all LayTec in-situ products incl. emissivity corrected pyrometry, multi wavelength reflectometry and wafer curvature
- Both spherical and aspherical wafer curvature can be measured simultaneously when using EpiCurve® TT AR (Advanced Resolution)
- Full linescan capabilities included (available during run and post run)

Data handling

- Storage of all measurements and automated configuration of analysis data in SQL database to complete the accessability of results
- Run type management for easy repetition of identical or similar runs regarding measurement positions and analysis recipes
- Export filters for XML, CSV, SQL and others for easy processing in upstream systems
- Comprehensive visualization and data analysis options

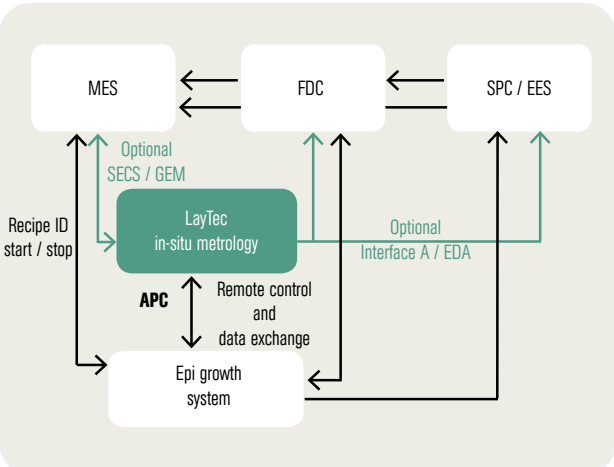
Advanced analysis

- Analysis recipe for synchronized step-by-step analysis of the growth process
- Fast determination of growth rate, layer thickness and optical constants even for very thin layers
- Extensive data base of optical constants for numerous material (e.g., GaN, AlN, Si, SiO_2, SiN_x, SiC)
- Statistical analysis: average, maximum, minimum, standard deviation and determination of the slope (e.g., temperature, curvature...)
- Dedicated analyses for specialized applications (e.g., AlGaN composition)

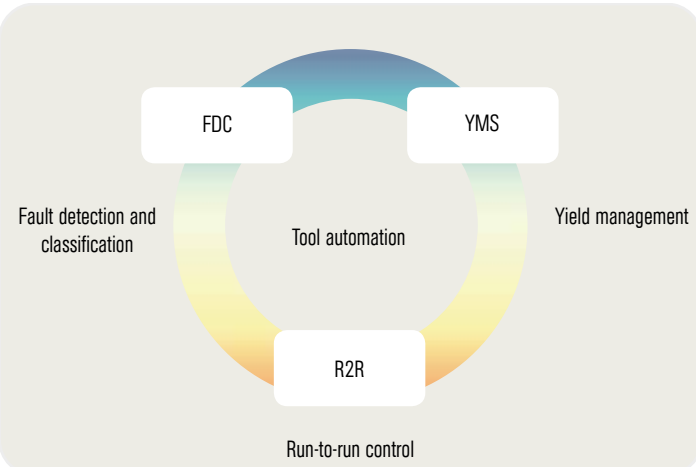
Fab integration

Interfacing to MES / EES

Modern fabs are organized in a multi-layered logical structure of data acquisition, consolidation, analysis and documentation. Interconnected data flows are mandatory for material tracking, equipment performance tracking, statistical process control and much more.
LayTec's EpiNet software can be integrated horizontally and vertically into the fabs' logical structure using a wide range of protocols and interfaces, starting with low-end analog and digital signals over field buses to the most complex high level SEMI standards like SECS / GEM. This allows to connect to host systems such as MES (manufacturing execution system) and EES (equipment engineering system) using SECS / GEM and EDA / Interface A based on AIS FabLink.



APC integration models



APC integration according to Rudolph Technologies

EpiNet provides process-aware algorithms superior to any standard production control system. It can provide process information not available to the growth equipment like complex uniformity information on each wafer. Information which then is intelligently compacted into data that can be handled and analysed by statistical systems.

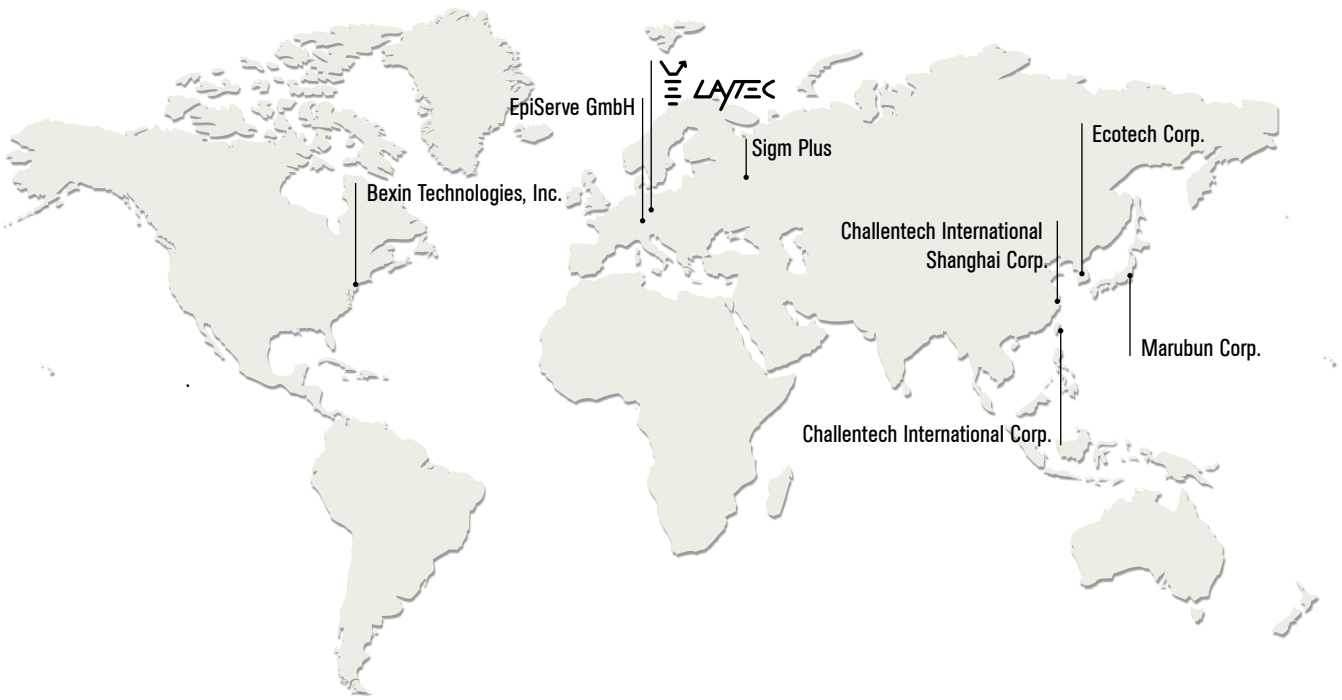
Connection to	SPC
SPC / MES	Deliver input for statistical analysis run-to-run, shift-to-shift performance
Fault detection	Forward key parameters (growth rate, strain) for fault detection directly
Deposition equipment	Fast closed-loop control, run-to-run control
Sensors	LayTec can integrate 3rd party sensors and data sources for combined comprehensive data analysis

Selection of supported protocols

- SECS / GEM
- SQL
- PC
- TCP / IP
- EtherCAT
- ProfiBus
- CANBus
- RS485 / RS232
- Voltage
- Current
- TTL
- Modbus

LayTec is ready to customize the software interfaces and adapt new ones to the requirments of your software systems.

Global Network



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LayTec's service includes:

- Emergency service with response times within a few hours
- Free online support during warranty
- Spare parts worldwide from stocks in China, Taiwan, Korea, Japan, USA and Germany
- Quick replacement of parts and on-site repair visits within a few days
- Fast module exchange for minimum downtime of customer's system
- Advanced data analysis support on demand
- Preventive maintenance
- On-site calibration service
- Multi-level training
- Service contracts

Knowledge is key

Learn more!

LayTec AG
Seesener Str. 10-13
10709 Berlin, Germany

Tel.: +49 (0)30 89 00 55-0
Fax: +49 (0)30 89 00 55-180
Email: info@laytec.de
Web: laytec.de