EpiX® C2C for GaN Power

Full-wafer UV-reflectance metrology for accurate, high-resolution, non-destructive extraction of AlGaN barrier and p-GaN gate layer properties in E-Mode GaN-on-Si HEMT manufacturing, enabling stable device performance and high-yield production

Reliable control of AlGaN barrier composition, AlGaN thickness, and p-GaN gate thickness are essential for achieving stable electrical performance and high manufacturing yield for E-Mode GaN HEMTs. These layers define the polarization-induced charge, the threshold voltage, on-resistance, and the dynamic behavior of GaN power devices. However, until recently, no metrology method existed that could quantify all three layers non-destructively and at full-wafer scale, particularly in E-Mode structures where the p-GaN gate absorbs all UV excitation and prevents the use of photoluminescence.

EpiX® C2C introduces a solution to this longstanding metrology gap. By combining UV reflectance spectroscopy with physics-based multilayer optical modeling, the tool enables fast, accurate extraction of E-Mode-relevant layer properties with high reproducibility. The system delivers wafer-scale mapping within minutes, allowing fabs to detect process drifts earlier, tighten their epitaxial process windows, and stabilize key HEMT performance metrics. As a result, EpiX® supports both rapid development cycles and robust, high-volume GaN manufacturing.

The metrology-gap in E-Mode GaN manufacturing

E-Mode GaN manufacturing poses a unique challenge to metrology. The p-GaN gate layer, typically on the order of 80–150 nm of thickness, strongly absorbs UV excitation. As a result, UV-Photoluminescence (PL) – a common method for extracting AlGaN composition on D-Mode wafers – cannot be applied to E-Mode structures because the excitation light does not reach the AlGaN barrier. X-ray diffraction can measure average Al content and thickness, but its large spot size, slow measurement speed, and limited lateral resolution prevent its use for wafer-scale mapping or in-line process monitoring.

The result is a blind spot: fabs have been unable to verify the most critical layers of E-Mode HEMTs at full-wafer scale without destructive methods. This limitation affects threshold-voltage stability, wafer-level uniformity, device matching, and ultimately the yield of GaN power products. EpiX® was designed to close this gap and to bring E-Mode barrier-layer metrology into a production environment.

EpiX® C2C GaN power configuration

The EpiX® C2C platform provides a metrology architecture tailored for GaN power manufacturing. It integrates UV reflectance spectroscopy, visible-range reflectance, optional UV-PL capability for D-Mode wafers, and physics-based interpretation of the measured spectra. The system is built for wafer fabs: cassette-to-cassette automation, reference normalization for long-term stability, and advanced SPC functions allow the tool to operate as a production-ready, high-throughput metrology station.

In the GaN Power configuration, the system is optimized for the spectral range 250–350 nm that is most sensitive to AlGaN and p-GaN variations. The optics are engineered for low noise, ensuring that small variations in composition or thickness generate measurable spectral signatures. This combination of optical performance, automation, and modeling capability enables EpiX® to function as the first practical metrology tool for E-Mode GaN epi.

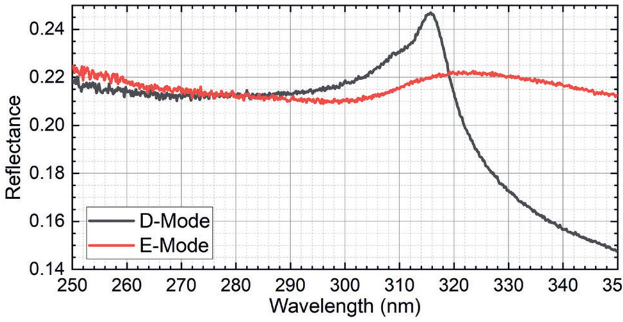

Figure 1: Measured UV reflectance spectra of two typical HEMT structures, (black) a D-Mode structure exhibiting a pronounced AlGaN band-edge peak, and (red) an E-Mode structure, where the AlGaN signature is damped and superimposed by Fabry-Pérot oscillations from the p-GaN layer.

Technical method: UV reflectance plus multilayer fitting

The key to EpiX® performance lies in the use of UV reflectance spectroscopy. In the wavelength range of approximately 250–350 nm, GaN exhibits strong absorption, meaning that only the upper ~200 nm of the epitaxial stack contribute to the reflected signal. This makes the technique inherently sensitive to the p-GaN gate and the underlying AlGaN barrier.

The measured spectra contain several features: the damped AlGaN band-edge response, Fabry–Pérot oscillations dominated by the p-GaN layer thickness, and gradual baseline variations that reflect interference within the multilayer system. A transfer-matrix optical model interprets these spectral features by returning the parameter set that best reproduces the measured reflectance. These parameters include AlGaN barrier composition, AlGaN barrier thickness, and the p-GaN thickness.

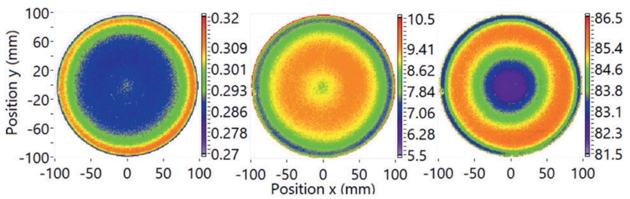

Figure 2: Obtained 2D wafer maps of the AlGaN barrier composition and thickness and p-GaN thickness (left-to-right) of an exemplary 200 mm E-Mode wafer.

In addition, the standard state-of-the-art reflectance and photoluminescence measurements can be conducted and return results with the same high-quality levels: total thickness maps are derived from visible range spectral reflectance, carbon impurity levels in the GaN buffer are quantified using GaN yellow luminescence measurements and UV-PL may give an alternative access to the AlGaN barrier composition. The measured GaN band-edge energy gives access to residual in-plane strain in the channel.

Performance benchmarks

The system achieves a reproducibility that meets and exceeds the requirements of modern GaN power fabs. On typical D-Mode wafers, Gage R&R results in approximately 0.04% for AlGaN barrier composition and about 0.05 nm for AlGaN thickness. On typical E-Mode wafers, where the p-GaN adds optical complexity, the reproducibility is around 0.15% for Al content and roughly 0.20 nm for both AlGaN and p-GaN thickness.

Throughput is equally important in a manufacturing environment. A full wafer can be mapped in under three minutes, typically covering 17k data points with high spatial resolution (e.g., 12″ wafers measured with 2 mm pitch). The resulting maps reveal subtle thickness gradients, composition variations, and indications of strain. Cross-validation with PL (for D-Mode wafers), XRR and XRD have confirmed the results, with small systematic offsets reflecting the different physical quantities probed by each technique.

Especially when comparing to UV-PL, that is still widely used for barrier composition measurements, UV reflectance leverages its advantages. As UV reflectance probes the entire barrier it returns an average composition. Growth artifacts such as unintentional compositional gradients produce characteristic signatures in the measured spectra. UV-PL, in contrast, only probes the energetic minimum within the exciton diffusion length in the barrier and cannot access the true composition for many stacks.

These performance levels make EpiX® a practical tool not only for R&D but also for everyday process control in a high-volume line, for E-Mode and D-Mode devices, for GaN power and RF.

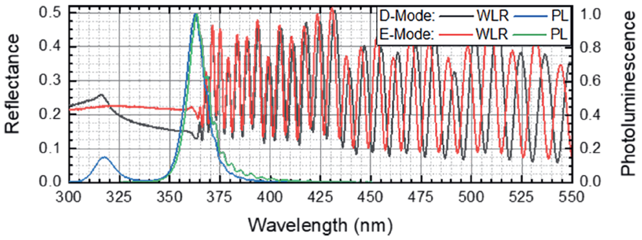

Figure 3: Measured UV-VIS reflectance of two typical HEMT structures: (black) a D-Mode structure, and (red) an E-Mode structure; as well as photoluminescence spectra: (blue) the D-Mode structure and (green) the E-Mode structure. UV reflectance yields AlGaN barrier and p-GaN properties, from the VIS reflectance the total thickness is obtained, from the UV-PL the carbon impurity levels are quantified and for D-Modes an alternative access to the barrier composition is available.

Application to yield and process control

Accurate knowledge of barrier and gate-layer properties at the wafer level enables fabs to define quantitative process windows that stabilize threshold voltage, on-resistance, and dynamic behavior. With full-wafer maps available within minutes, EpiX® allows early identification of deviations such as shifts in AlGaN barrier composition, thickness drifts due to reactor tuning, or non-uniformities introduced by p-GaN growth conditions.

The system's built-in SPC functionality helps fabs track process stability over time, flag deviations immediately, and correlate epi-level variations with downstream electrical measurements. This accelerates feedback cycles and significantly reduces the number of wafers processed under sub-optimal conditions. Ultimately, EpiX® contributes to higher yield, improved device matching, and shorter development timelines when introducing new GaN technologies or scaling to new wafer sizes.

Conclusion

EpiX® C2C provides the first non-destructive, full-wafer metrology solution capable of quantifying the most critical layers of E-Mode GaN HEMTs. Through a combination of UV reflectance, advanced multilayer modeling, and production-ready automation, the system delivers accurate and reproducible layer-property maps in a matter of minutes. This capability enables fabs to establish reliable process windows, detect drift early, and drive yield improvements across their GaN power product lines. EpiX® therefore represents a decisive step forward for industrial GaN manufacturing and provides a solid foundation for the continued scaling and commercialization of GaN power electronics.

For more information, reach out to **info@laytec.de** or visit **www.laytec.de**.

Figure 4: LayTec's EpiX® C2C system (image: 3"-8" version) optimized for high volume manufacturing. The cassette-to-cassette automation comes with slot mapping, pre-alignment, OCR and optimized automation cycles as well as enclosed cassette ports, fan-filter-unit and controlled laminar flow for minimal particle concentration. The XYZ measurement stage facilitates high throughput wafer mapping recipes and comes with integrated and automated measurement of reference samples for SPC. The system provides best-in-class measurement performance with superior reproducibility, absolute accuracy and ultra-low noise levels.

The “Connected Metrology” approach

The LayTec Connected Metrology® ecosystem enables improved process control characterizing complex layer stacks along the manufacturing chain. In a typical frontend production line, wafers are typically measured multiple times. Using LayTec systems in all of these process steps bears the potential to forward and share the respective analysis data from each step to the subsequent ones, thereby unfolding the full potential of the Connected Metrology® approach. During epitaxy, EpiCurve® TT can determine the thicknesses and composition of many individual layers as well as their in-situ. In the ex-situ wafer mapping with EpiX® C2C by white light reflectance and photoluminescence, full 2D wafer maps are acquired characterizing the 2D uniformity of critical layer thickness, layer composition and other sample properties. During sub-sequent plasma-etching processes, the thickness monitoring and endpoint detection is again performed in-situ by LayTec's TRIton®. As the wafer is advancing through the frontend production line, the amount of information on the particular wafer increases and is combined for improved analysis in downstream processes. By connecting in-situ and ex-situ metrology, we can determine the critical layer parameters of increasingly complex layer structures at die-level.

Connected
Metrology®

About us

LayTec, founded 1999 in Berlin, is a major provider of in-situ and in-line optical metrology for thin-film processes.

These metrology tools are used in a broad range of thin-film applications such as LED & laser production, power devices and transistors, thin-film photovoltaics, oxide and organic deposition as well as other large area deposition processes. LayTec’s integrated metrology provides access to all key thin-film parameters in real-time – either in-situ, during the deposition process, or in-line. Also, in-situ metrology tools for dry etching have been added expanding LayTec’s portfolio along the production chain.

Beyond these integrated methods, LayTec also offers mapping solutions which ideally complement in-situ measurements by providing uniformity analysis of the deposited layers. The implementation of LayTec metrology systems in production processes significantly shortens development cycles and enables an efficient quality control that helps to considerably reduce production and development costs.