

# Optimizing epitaxial layer uniformity by combining in-situ and ex-situ metrology



The combination of ex-situ wafer mapping and optical in-situ measurements during metal-organic chemical vapor deposition (MOCVD) for laser devices constitutes a powerful method for obtaining maximum layer uniformity across the wafer. This efficiently improves the process yield on the die level with a strong impact on device cost. In this application note, we report results obtained by Dr. André Maaßdorf et al. at the Ferdinand-Braun-Institute (FBH) in Berlin, Germany

Achieving the highest possible degree of uniformity is key for producing complex multi-layer devices such as vertical-cavity surface-emitting laser (VCSEL) or edge-emitting laser structures economically. Ex-situ mapping measurements by means of white light reflectance (WLR) and photoluminescence (PL) are well-established methods for ensuring sufficient uniformity for efficient processing in expensive dicing and packaging processes. Unfortunately, such measurements usually do not directly reveal the root-cause of an inhomogeneity that might be observed in these measurements. In contrast, in-situ measurements by means of emissivity-corrected pyrometry (ECP), reflectance or curvature directly reveal the effect of certain process parameter changes like heater or gas flow settings on the wafer temperature or layer composition. However, due to the fact that in-situ measurements never cover the entire wafer area and do not probe the layers under device operating conditions these measurements cannot replace ex-situ mapping methods. But if both methods are combined in a smart

way, they constitute a very efficient way for identifying the parameter mostly affecting the uniformity thereby paving the path for rapid process conditions towards most uniform layer properties across the wafer and cost-effective production processes.

In this Application Note, we present recent results of an optimization process of the gas flow profile and the susceptor configuration of FBH's AIX 2800 G4 IC2 (12x4") epitaxial deposition system for AlInP/AlGaInP edge emitting diode lasers. In Fig. 1a) the susceptor configuration for the 12 4" wafers is shown. On this epitaxial deposition system, a LayTec EpiCurve TT AR VCSEL+ is mounted on the reactor lid (see. Fig. 1b)). This metrology tool combines the curvature, the three-wavelengths reflectance and emissivity-corrected pyrometry (ECP) of an EpiCurve TT with additional spectral reflectance capability. Here, mainly the ECP results were used for improving the layer uniformity whereas curvature and reflectance measurements served for optimizing the layer composition and

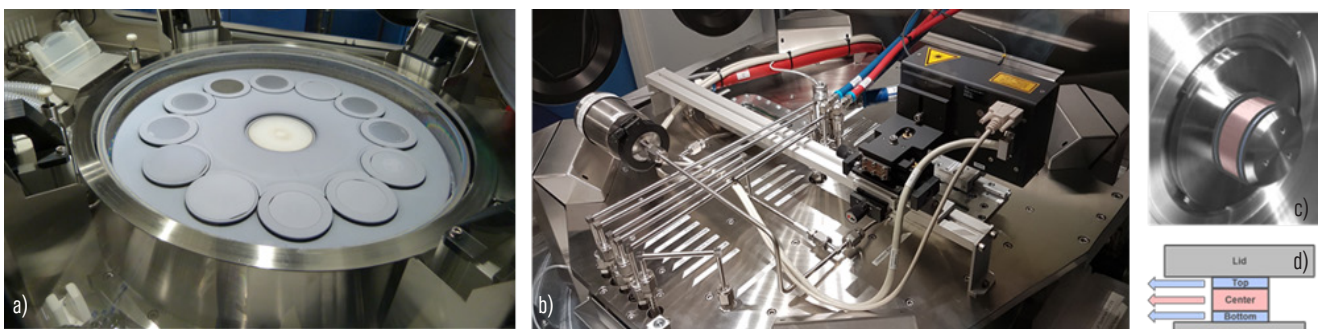


Fig. 1 a) Epitaxial deposition system AIX 2800 G4 IC2 (12 x 4") in its opened state as it was used for the work presented in this report. b) LayTec in-situ metrology system EpiCurve TT AR VCSEL+ mounted on the lid of the reactor. c) Triple inlet injector for realizing sophisticated gas flow configuration. d) Schematic sketch of the gas injector with three dedicated inlets.

emission properties [1]. The reactor was equipped with a triple inlet reaction gas injector (Fig. 1 c), d)) which allowed for knowledge-based manipulation of the process conditions resulting from the analysis. For wafer mapping, a LayTec EpiX mapping station was used. In Fig. 2 a) and b) the EpiX system and its internal mapping stage equipped with WLR PL on an automated xy stage is shown. Besides, WLR and PL maps, analysis algorithms can be applied to deduce properties like layer thickness, emission wavelength etc. In Fig. 2 c), an exemplary layer thickness map can be seen. Similarly Fig. 2 c) a significant deviation in layer thickness had been observed in the beginning of the optimization process. At this time, a W-shaped thickness profile (rel. deviations  $\leq 8\%$ ) was observed (Fig. 3 a) (black trace)). Then the mapping data was compared to in-situ ECP data obtained during deposition (Fig. 3 b) revealing that the wafer temperature profile also exhibits a similar non-uniformity at the edges. Additionally, further non-uniformities exist in the wafer center. To address the edge temperature, firstly, the absolute gas flow was increased in three steps, yielding a gradual improvement of the profile (grey to red to green trace). After each step, the effect on the temperature profile was investigated in-situ and correlated to the corresponding thickness map. Next, the gas flow distribution was modified using the triple inlet injector. Again, this improved the uniformity (blue traces). Finally, the recess of the wafer satellite was redesigned as it strongly affects the local wafer temperature.

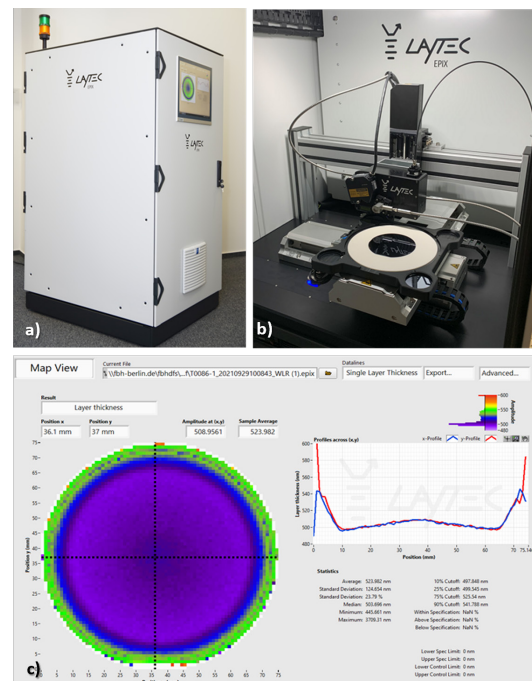


Fig. 2 LayTec's EpiX wafer mapping metrology system and exemplary result screen: a) EpiX metrology station cabinet; b) internal measurement stage of the EpiX system shown in Fig 2 a). c) Result screen of a VCSEL wafer mapping result screen displaying the layer thickness uniformity derived from white light reflectance measurement results.

This change was key for achieving an almost perfectly flat thickness profile (pink trace). These results clearly demonstrate the advantage of combining ex-situ wafer mapping for detecting wafer non-uniformities with in-situ measurements for understanding their root-cause thus indicating the path for optimization.

For more information visit [laytec.de/vcsl](http://laytec.de/vcsl), [laytec.de/products/lab-line/epix](http://laytec.de/products/lab-line/epix) or contact [info@laytec.de](mailto:info@laytec.de).

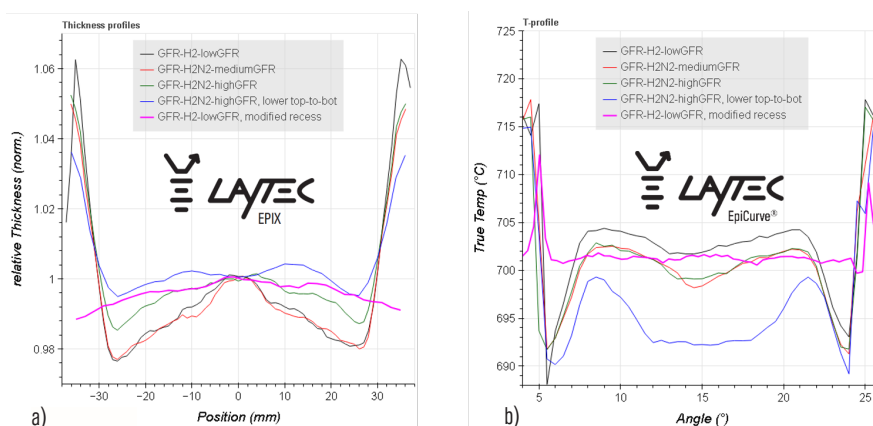


Fig. 3 a) Layer thickness wafer uniformity for various experimental configurations. b) Emissivity-corrected temperature wafer uniformity for the same configurations. c) Schematic sketch of the wafer susceptor configuration (GFR: Gas Foil Rotation)

[1] S. Brückner, A. Maaßdorf, M. Weyers, J. Crystal Growth 590 (2022), 126696.

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