

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 directly results in maximum uniformity of the devices produced from the wafer like vertical-cavity surface-emitting lasers (VCSELs) or edge-emitting laser stack structures thereby increasing the process yield on the die level with a strong impact on device cost. Ex-situ mapping measurements by means of white light reflectance (WLR) and photoluminescence (PL) are well-established methods to ensure sufficient uniformity for economic processing in expensive dicing and packaging processes. Unfortunately, they do not directly reveal

the root-cause of inhomogeneity that might be observed in these measurements. In contrast, in-situ measurements by means of emissivity-corrected pyrometry (ECP), reflectance and curvature directly reveal the effect of certain process parameter changes like heater or gas flow settings on the wafer temperature or layer composition. However, they never cover the entire wafer area and do not probe the layers under device operating conditions. Therefore, only a smart combination of both methods constitutes a very efficient way to identify the parameter mostly affecting the uniformity and thus ensures rapid process conditions towards most uniform layer properties across the wafer and cost-effective production processes.

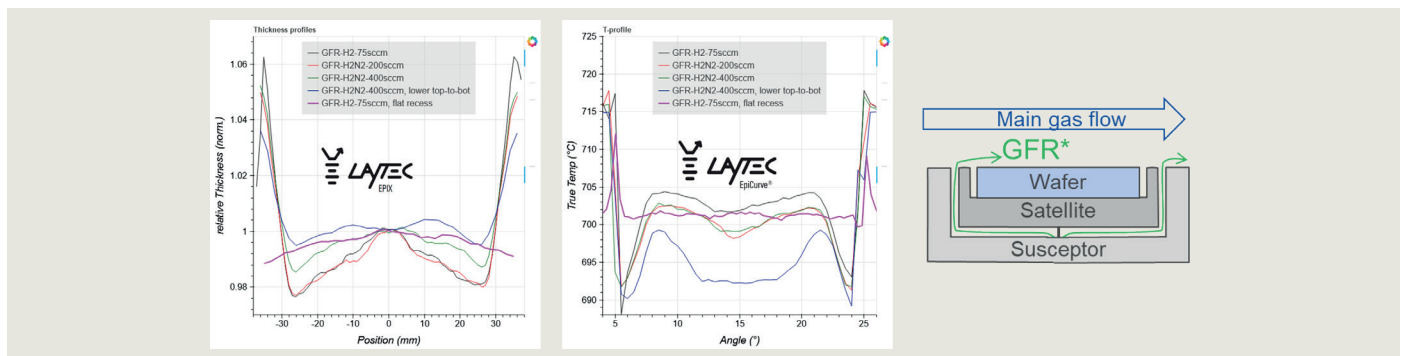


Fig. 1 a) Layer thickness wafer uniformity for various experimental configurations. b) Emissivity-corrected temperature wafer uniformity for the same configurations. c) Schematic sketch of the wafer susceptor configuration (GFR: Gas Foil Rotation) elements are shown.

A. Maaßdorf et al. at the Ferdinand-Braun-Institute (FBH) used both LayTecs in-situ measurement tool EpiCurve TT AR VCSEL+ and LayTecs EpiX mapping station to optimize the process of gas flow profile and the susceptor configuration at Aix 2800 G4 IC2 (12 x 4") epitaxial deposition system for AlInP/AlGaInP edge emitting diode lasers. EpiCurve TT AR VCSEL+ combines the curvature, the three-wavelengths reflectance and emissivity-corrected pyrometry (ECP) of an EpiCurve TT with additional spectral reflectance capability. The EpiX-Mapper equipped with WLR and PL was deployed for wafer-mapping to deduce properties like layer thickness and emission wavelength. At the beginning of the optimization process a significant deviation in layer thickness (rel. deviations $\pm 8\%$) was observed (Fig. 1a). Moreover, in-situ ECP data obtained during deposition (Fig. 2b) revealed that the wafer temperature profile also exhibited a similar non-uniformity at the edges and further in the wafer center.

To address the edge temperature, 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 to improve the uniformity (blue traces). Finally, the recess of the wafer satellite was redesigned as it strongly affects the local wafer temperature (Fig. 3c). This modification was key to achieve an almost perfectly flat thickness profile (pink trace). The obtained results clearly demonstrate the advantage of combining ex-situ wafer mapping to detect wafer non-uniformities with in-situ measurements to understand their root-cause thus indicating the path for optimization.

Since 2001 we annually offer to our customers the 'LayTec in-situ seminar' as a traditional satellite workshop at one of the international conferences. Despite the Corona pandemic, this year too we do not want to miss the opportunity for lively exchange with the epitaxy community. Therefore, we "invented" a new format for our seminar to take place between August 24-25 2020: In Berlin we will hold twin-sessions in the morning (for our European and Asian customers) and in the afternoon (for our European and American customers) where ours and your contributed talks will be presented in a combined real-life and globally transmitted web-based event. Please, stay tuned for more information from LayTec marketing and R&D and send us your short abstracts for presentations. For more information, please visit laytec.de