Curvature measurements with EpiCurve® TT in Close Coupled Showerhead® reactor systems

LayTec's in-situ sensor for wafer bowing measurements EpiCurve® TT has already proven its excellent capability on AIXTRON Planetary® reactors. The sensor enables correction of bowing effects on wafer temperature measurements and helps to optimise growth via minimising bowing effects. Now the sensor has been adopted also for Close Coupled Showerhead® (CCS) MOCVD systems.

The sensor allows real-time measurements of wafer curvature, emissivity-corrected wafer temperature and double-wavelength reflectance for growth rate analysis. Furthermore, **EpiCurve® TT HighRes** (high resolution) sensor is an enhanced version of **EpiCurve®**, which uses two view-ports on TSSEL systems and has a record accuracy of 0.3 km^{-1}! **EpiCurve® TT** can be used in 6x2" 19x2" and 30x2" Aixtron CCS reactor systems, as well as on transparent and low-reflectance substrates.

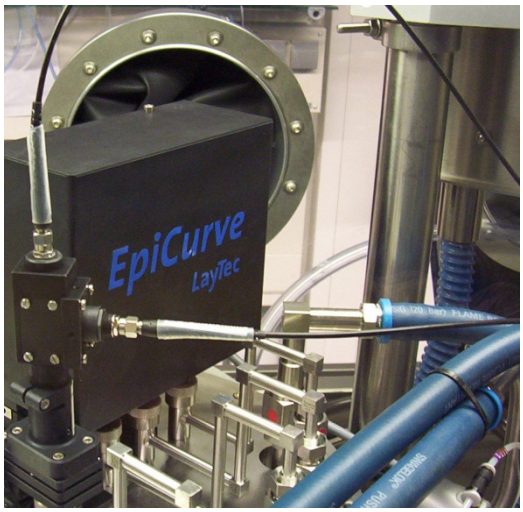

Fig. 1: EpiCurve® TT on a TSSEL system

When growing III-Nitrides on silicon, the thermal mismatch usually leads to stress in the layers, which can cause cracking of thick GaN on Si substrates especially during final down-cooling. For maximum yield it is therefore absolutely necessary to measure wafer curvature together with wafer temperature and multiple wavelength reflectance throughout the entire growth process. LayTec's **EpiCurve® TT** with its unique combination of wafer-temperature and bowing measurements allows growth recipe optimization by strain-engineering and tracking of temperature deviations caused by wafer bowing. Furthermore, substrate non-idealities (initial bowing, non-spherical bowing) can be easily detected.

Since optical access in CCS systems is limited, the curvature resolution when using a single window is also restricted to ± 10 km^{-1}. The resolution can be enhanced down to 0.3 km^{-1} when applying **EpiCurve® TT** HighRes using two view-ports.

First measurements with **EpiCurve® TT HighRes** on a CCS reactor were performed at AZZURRO Semiconductors (Magdeburg, Germany) for monitoring InGaN/GaN MQW growth for GaN LEDs on Si. Several up to 7 µm thick crack-free 150 mm GaN on Si samples were grown. The stress of the layers was investigated in situ by **EpiCurve® TT** and ex situ by PL, XRD and optical microscopy. To obtain thick crack-free layers several low temperature AlN interlayers were introduced into the

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samples to intentionally counter-balance the tensile stress that builds up during the cool-down procedure due to the different thermal expansion coefficients between GaN and Si. In situ curvature measurements verified that this procedure is very efficient: a steeper slope of the curvature signal was observed after each low temperature AlN interlayer. The barriers and wells of the MQW are well resolved. Obviously, the total stress before and after MQW growth if roughly the same.

These measurements considerably helped to develop high-yield processes for III-Nitride LEDs on silicon. The strain development in the full LED structure was carefully monitored and quantitatively and qualitatively analyzed by Dr. Armin Dadgar et al. [1].

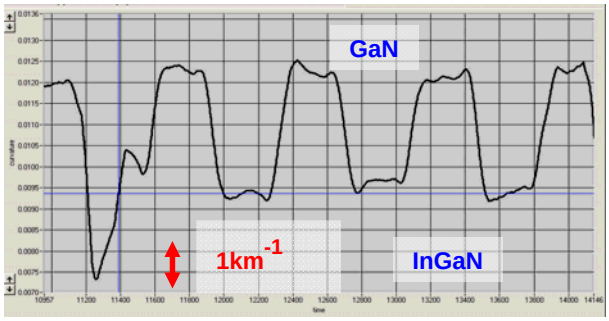

Fig. 2: Wafer bowing signal during MQW growth - the dominating strain contribution is the different growth temperature during well and barrier growth.

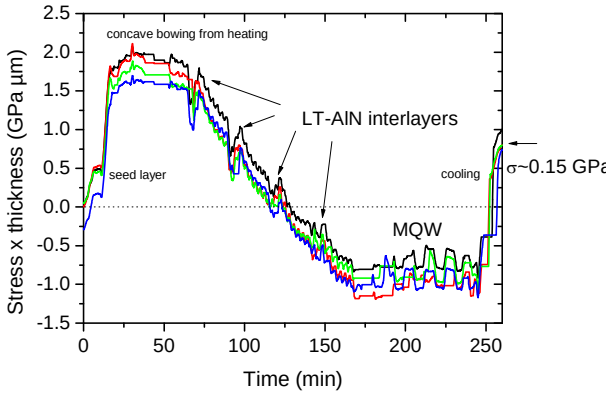

Fig. 3: Crack-free LED structure on 150 mm Si. By introducing a well defined compressive strain at growth temperature (using LT-AlN layers) crack-free structures at room-temperature result with only small remaining tensile strain.

According to **Dr. Armin Dadgar** of AZZURRO Semiconductors, "**EpiCurve® TT** gives a completely new insight into the growth of GaN based structures and devices." The sensor helps to optimize high and growth temperature strain, locate difficulties in growth and determine the concentration and critical layer thicknesses for strained ternary alloys.

Further reading:

[1] A. Dadgar, C. Hums, A. Diez, J. Bläsing, and A. Krost: Growth of blue GaN LED structures on 150 mm Si(111), Journal of Crystal Growth in print

A. Krost, F. Schulze, A. Dadgar, G. Strassburger, K. Haberland, T. Zettler: Simultaneous measurement of wafer curvature and true temperature during metalorganic growth of group-III nitrides on silicon and sapphire, Phys. Stat.sol. (b) 242, No. 13, 2570-2574 (2005)

A. Dadgar, C. Hums, A. Diez, F. Schulze, J. Bläsing, A. Krost: Epitaxy of GaN LEDs on large substrates: Si or sapphire? Proc. SPIE 6355, 63550R (2006)

F. Schulze, A. Dadgar, J. Bläsing, A. Diez, A. Krost: Metalorganic vapor phase epitaxy grown InGaN/ GaN light-emitting diodes on Si (001) substrate, Applied physics letters 88, 121114 (2006)