

Accurate wafer temperature for GaN/Si power electronics with Pyro 400

Temperature measurements during MOCVD growth of GaN-on-silicon (GaN/Si) devices are rather challenging. Theoretically, conventional infra-red (IR) pyrometry should be sufficient because the silicon substrate is IR absorbing in the full range of relevant growth temperatures. However, one artifact makes the feed-back control difficult and prohibits precise statistical process control in industrial applications. Fig. 1 shows this phenomenon: when GaN is grown, the temperature signal (red) starts oscillating by ± 2 K.

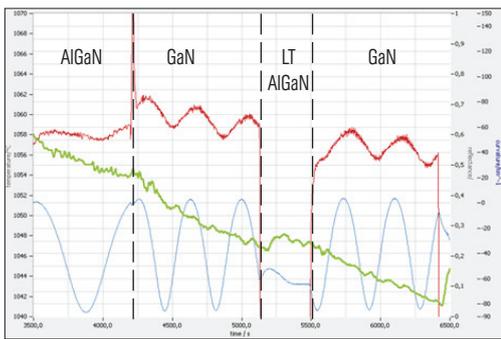
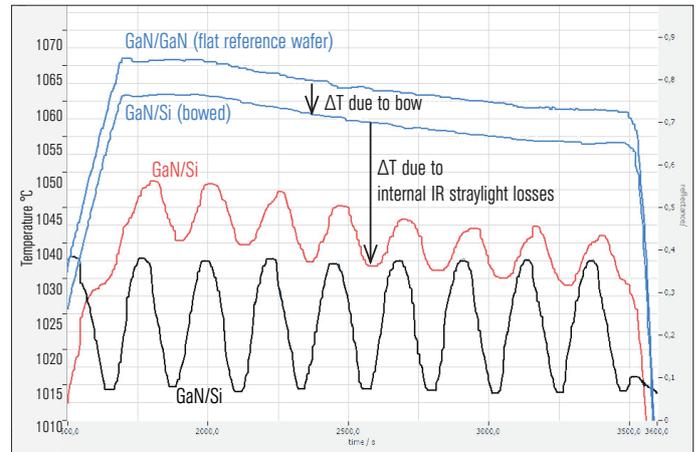


Fig. 1: GaN/Si template run for creating a compressively pre-strained buffer (as can be seen in the curvature data).
Red - temperature
Green - curvature
Blue - reflectance (950 nm)

Data courtesy: OvG University Magdeburg

Together with our partners at Otto-von-Guericke University of Magdeburg (Prof. Dr. Armin Dadgar and his team) and Ferdinand-Braun-Institute (Dr. Frank Brunner) we searched for a solution and found out that, no matter how perfect the IR pyrometer is, these oscillations are inevitable. They are caused by a complex interaction between two effects: on the one hand the IR transparent GaN/AlGaIn strain-engineering layers together with the defect reducing buffer structure and on the other hand the thermal IR radiation out of the silicon wafer that passes through the grown structure. Our solution was to use a pyrometry wavelength range in which the complex buffer layer structure Si/AlGaIn/GaN/LT-AlGaIn/GaN is not "visible" for the pyrometer. Hence, we took LayTec's ultra-violet (UV) pyrometer **Pyro 400**, which was developed some years ago for GaN-on-sapphire growth in LED industry. The results are demonstrated in Fig. 2. The same wafer as in Fig. 1 was transferred to a reactor at FBH with two in-situ tools: **Pyro 400** for UV pyrometry and **EpiCurve® TT** for IR pyrometry (950 nm emissivity corrected), reflectance as well as wafer bow measurements. The UV pyrometer (Fig. 2 - blue) gives a very stable wafer temperature signal without oscillations during GaN growth. Measurements on a reference GaN/GaN wafer in the same run (not shown here) verified that both IR pyrometer and **Pyro 400** are well calibrated and give exactly the same temperature on an ideally flat and smooth GaN/GaN wafer. Fig. 2 shows UV pyrometry measurements clearly indicating that the true GaN surface temperature of the GaN/Si template wafer is ~ 5 K lower than that of the basically flat GaN/GaN wafer due to the $\sim 100 \text{ km}^{-1}$ convex bow of the Si template measured by **EpiCurve® TT**.



Data courtesy: FBH

Fig. 2: Overgrowth of template of Fig. 1 with GaN in a planetary G3 reactor: blue - UV pyrometry, red - IR pyrometry, black - reflectance (950 nm)

Temperature of the GaN buffer measured by **Pyro 400** (lower blue curve) is completely free of Fabry-Perot oscillations. The IR temperature (red) shows again oscillations, but, which is even more essential, is also downshifted by ~ 15 K from the true temperature of its GaN surface!

Furthermore, it became clear: the remaining oscillations in the IR pyrometry signal (red) are not the most important artifact. Due to interactions of the thermal IR radiation with the internal structure of the GaN/Si buffer, there is an additional downshift in this temperature signal by about 15 (!) K. This effect is attributed to the fact that the thermal IR radiation coming out of the silicon suffers intensity losses while passing the highly defective region at the Si/GaN interface. These internal straylight losses depend on the Fabry-Perot resonance within the total GaN thickness and, therefore, also contribute to the IR temperature oscillations. A scientific paper with a detailed root cause analysis is in the pipeline and will be published later this year. We report a rough outline of these results with this newsletter because of their importance to the power electronics industry. For more information please contact info@laytec.de or visit www.laytec.de/power-rf-electronics.

You can meet us at the following workshops, conferences and trade fairs:

1-2 March 2016 | **CS International** | Brussels, Belgium

Dr. Marta Borasio (LayTec) presents: "Reliability and yield limiting variances in power electronic manufacturing - early detection by advanced in-situ monitoring."

15-17 March 2016 | **SEMICON China** | Shanghai, China

LayTec presents two talks "Advanced in-situ metrology to enable emerging LED application (UV and Nano Wire LED)" in LED Forum and "Reliability and yield limiting variances in power-electronic manufacturing - early detection by advanced in-situ monitoring" in Power Semiconductor Forum.