



TT measurements: double side polished vs. single side polished sapphire substrates

LayTec's sensors are state-of-the-art in situ growth monitors for basic growth studies, process development, process transfer and for enhancing run-to-run reproducibility in production environment. This document shows the effects of double side polished sapphire wafers versus single side polished wafers to the true temperature measurement of LayTec sensors.

Dr. Hilde Hardtdegen and Dr. Nicoletta Kaluza at Research Center Juelich investigated in two identical subsequent GaN buffer growth runs the effect of the Sapphire substrate backside polishing on the true temperature signal. The only difference in the growth parameter was the substrate type: wafer #1 was a sapphire 2" wafer with a rough backside, and wafer #2 a double side polished 2" sapphire wafer.

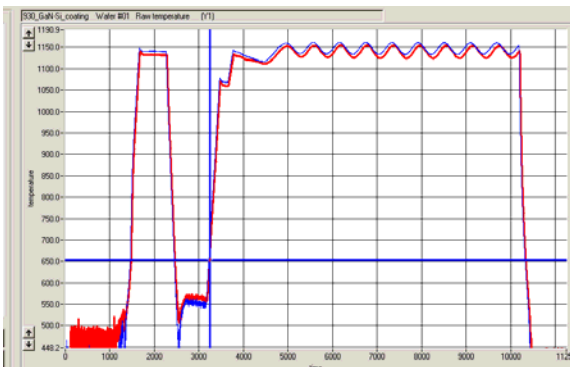


Fig. 1: Pyrometer raw signal: red for a single polished sapphire wafer, blue for a double polished wafer.

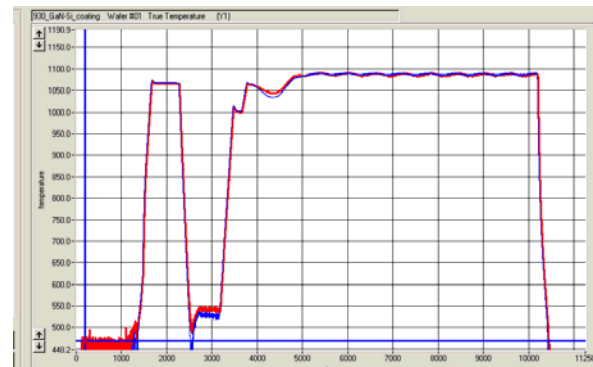


Fig. 2: LayTec's true temperature signal: red for a single polished sapphire wafer, blue for a double polished wafer with the corrected *.cal file.

The pyrometer raw signal (Fig. 1), when measured on transparent substrates (either single-side or double-side polished), originates from the thermal radiation from the susceptor just under the wafers. Obviously, the back side polished sapphire leads to a slightly higher (~10K) pyrometer raw signal. The origin for this behaviour is that the rough wafer back side of the single-side polished wafers additionally scatters away a larger part of the thermal radiation. For the double-side polished wafer a part of the light is of course reflected at the back side of the double-side polished wafer, which also reduces the thermal radiation out of the susceptor surface in this case, but only by ~7%. For single side polished wafer, however, the thermal radiation is reduced by ~12% in total.

The effect of wafer back-side related thermal radiation losses can be corrected in the calibration parameters (in the *.cal file in the **EpiTT** software). By adapting this calibration parameter, the correct wafer temperature for both types of wafers can now be determined as shown in Fig.2. It is interesting that the remaining Fabry-Perot oscillations in the wafer temperature are slightly smaller



for the double side polished wafer. In addition, the measured nucleation layer growth temperature is lower ($\sim 530^{\circ}\text{C}$) for double side polished sapphire instead of $\sim 545^{\circ}\text{C}$ for single side polished sapphire. For both effects we expect that light scattering at the rough back side of the single side polished wafer is responsible by directing a small amount of additional thermal radiation from other hot parts of the reactor to the pyrometer.

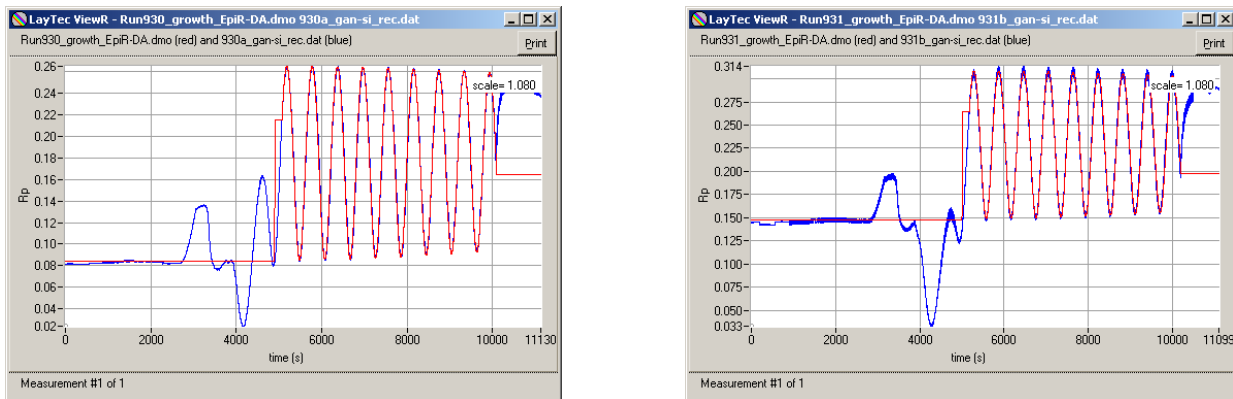


Fig. 3: Reflectance at 980nm (pyrometer wavelength): the measurements on both types of substrates (blue) are compared to simulated data (red). The identical growth model has been used with only the growth rate of run #931 (0.350nm/s) being less than 1% higher than the growth rate of run #930 (0.348nm/s).

The effect of the double side polished sapphire on the reflectance signal is a certain increase in the average reflectance (the back side reflectance contribution) and a relative shrinking of the Fabry-Perot oscillation amplitude. All these effects could be perfectly modelled by the LayTec's AnalysR software (red lines in Fig. 3).

The growth on the standard substrate is shown in Fig. 3 (left side). The reflectance of the bare substrate at 1060°C is 7.8%. For direct comparison to the measured data (blue lines) a scaling factor of 1.08 has been applied, which corrects only the setting of the alpha parameter in the configuration file. Both measurement and simulation on the bare substrate at high temperature ($\sim 2000\text{s}$, substrate nitridation) are in full agreement. The Fabry-Perot oscillations of run on the single side polished substrate have been fitted by a growth rate of 0.348nm/s , a 60nm range of GaN close to the substrate that is less dense (refractive index of 2.30 instead of 2.37).

With exactly the same growth model, the run with the double side polished substrate (Fig. 3, right side) could be modelled (the only difference: growth rate of 0.350nm/s). The optical model, of course, differed in the double side reflecting sapphire substrate. Interestingly, the magnitude of the reflectance at the back side had to be reduced by 11% as compared to the theoretical value for sapphire. This, however, had been expected because this back-side is slightly off-focus of the sensor head and the respective reflectance is not fully directed into the optical fibre.

LayTec is currently implementing a new wafer selective feature in the **EpITT** software that allows to choose these different wafer types when loading the wafers, so that the customer is able to measure correct wafer temperature and reflectance data for growth rate determination of single and double polished wafers even when mixed in one growth run.