HVPE growth of bulk GaN controlled by EpiTT 3λ

Hydride Vapour Phase Epitaxy (HVPE) is an epitaxial method for production of compound semiconductor materials that offers a high growth rate and a controlled geometrical size. It is well known that tight growth monitoring is indispensable during the HVPE growth. In the first tests conducted at Ferdinand-Braun-Institut (Berlin, Germany) on an AIXTRON / Epigress vertical HVPE system, LayTec's in-situ sensor EpiTT proved to be a powerful tool for a precise growth control of bulk GaN substrates.

For HVPE application an **EpiTT** providing growth monitoring at three wavelengths was developed, featuring: reflectance at 400 nm for the most sensitive surface roughness control, reflectance at 633 nm for growth rate determination during the growth of the first 10 µm and reflectance and pyrometry at 950 nm, where reflectance has the potential of growth rate measurements for very high growth rates. Besides, pyrometry measurements at 950nm give the temperature of the wafer carrier simultaneously. These temperature measurements showed that the substrate temperature during heating was more than 100°C higher than that measured by the thermo-couple from the back side of the heating system. This result already proves the advantages of pyrometry measurements, which helped optimize the heating ramp and growth conditions in this case tremendously.

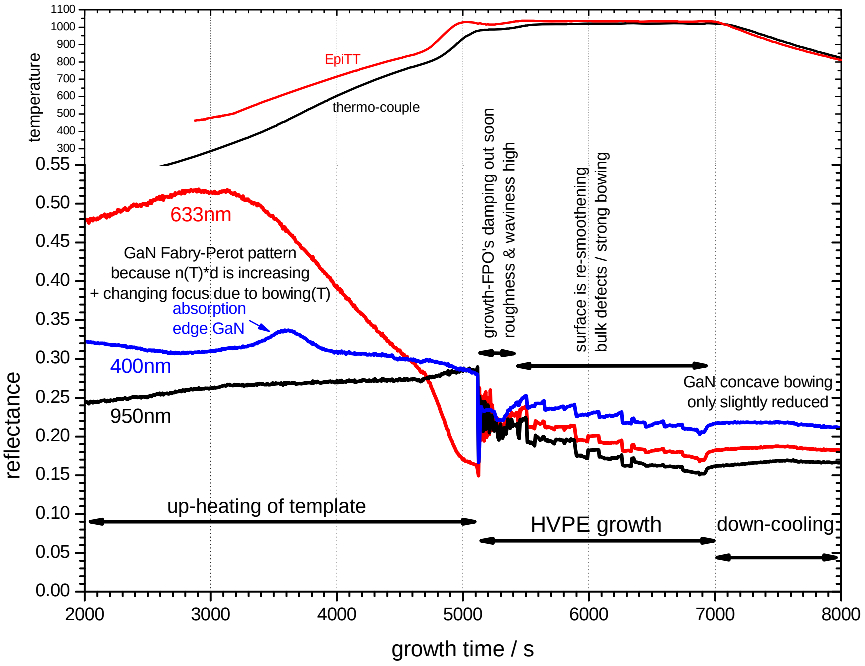

Fig. 1: HVPE of GaN on a GaN/sapphire template in an AIXTRON / Epigress vertical HVPE system. The growth is initiated after 5100s. The surface starts to recover after 200s of growth (at ~5300s).

Fig. 1 shows the reflectance and pyrometry data as measured during growth of a 127µm thick GaN layer at 1020°C on a GaN/sapphire template. All reflectance data was normalized to the nominal values at the beginning of the growth. The reflectance traces were used for evaluating and improving the HVPE process. As the result of the improvements, a very thick GaN film with a mirror like surface was achieved.

When the substrate is heated, a Fabry-Perot response is clearly visible in the reflectance data at 633nm. Since the optical thickness (n*d) increases due to the increase of the refractive index of GaN at higher temperatures, the reflectance signal shows a modulation with temperature. The 400nm reflectance signal gives a signature at ~500°C when the thermal band gap shift makes the GaN template opaque for this wavelength. Additionally, reflectance intensities are superimposed by intensity changes due to wafer bowing.

When the HVPE growth starts (after 5100s), the 400nm reflectance decreases due to surface roughening and both the 633nm and 950nm reflectance move towards their average values because of the increasing substrate waviness. After 200s of growth the surface starts to recover and the 400nm reflectance improves. However, due to crack and defect formation the increase of the 400nm reflectance signal is regularly interrupted by intensity losses. Measurements at 633nm and 950nm are less sensitive to roughness and only affected by the overall reduction of the measured reflectance due to stray light losses. When the growth is stopped, the reflectance at all three wavelengths increases by about two percent. This might be attributed to the temperature change.

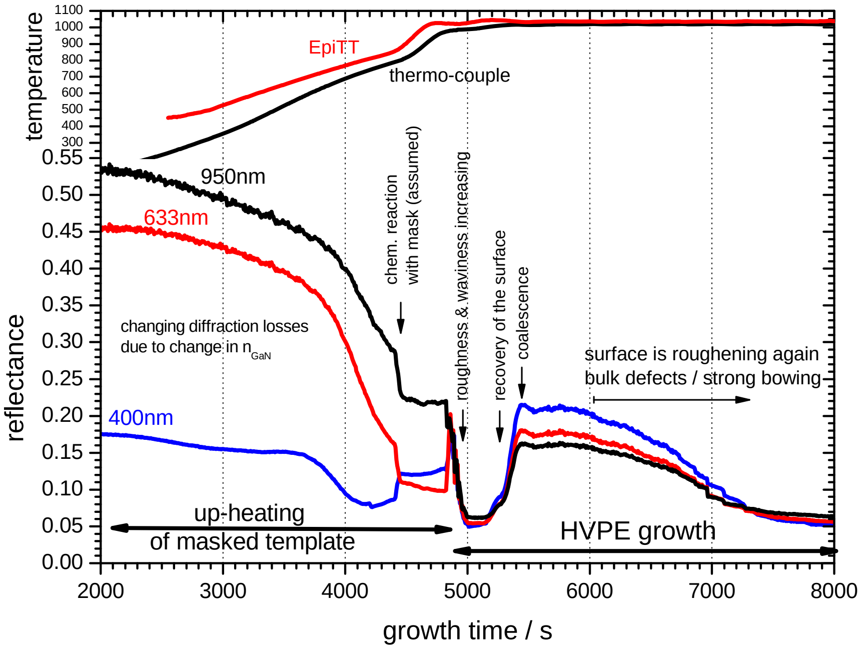

Fig. 2: HVPE of GaN on a WSiN masked GaN/sapphire template.

Fig. 2 demonstrates an even more complex HVPE growth process on a WSiN-masked GaN template. The mask forms a 10µm hexagonal metallic pattern presenting a two-dimensional grating to the reflectance measurement. During heating the reflectance response is highly complex due to the superposition of temperature dependent diffraction and interference effects. Therefore, we normalized the reflectance to the expected reflectance levels after coalescence at about 5500s, where a continuous and rather smooth GaN surface was found.

During heating, a significant surface reaction takes place and causes a rather abrupt change in the reflectance from the mask at ~800°C (after 4400s). The start of the growth (~4800s) is followed by a decrease of the reflectance of all three wavelengths, most probably because the metallic mask area is partly covered with an amorphous film and the initial epitaxial growth on GaN is rather rough and wavy. In this case 600 μ m of GaN were grown in 120min.

After ~700s of the growth (at ~5500s) the reflectance of all three wavelengths completely recovers due to coalescence. The subsequent constant reflectance level indicates an ideal growth. However, at about 6000s, the reflectance of all three wavelengths deteriorates again with the most significant relative drop in intensity at 400nm. Light scattering effects attributable to the increasing surface roughness dominate the measurement, which is confirmed by the very rough surface of the sample after growth.

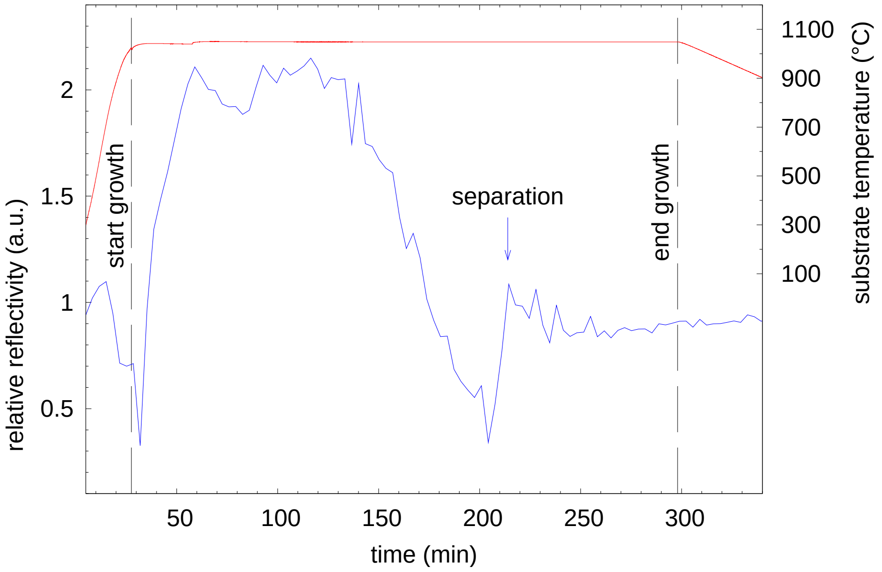

Fig. 3: 620 µm thick layer grown over mask C. Separation of the GaN layer is indicated by a rapid change of the reflectivity.

In the HVPE growth run shown in Fig. 3 the separation of the GaN layer from the sapphire substrate already during growth (due to intrinsic tensile strain of the growing GaN layer) was observed. A separation shows up in the reflection transient by a rapid recovery of the reflectivity and a rather constant level during cool down afterwards. [1]

The tests have proved that LayTec's EpiTT sensor can be successfully applied to monitor GaN growth in VHVPE systems and to optimize the HVPE growth process. All stages of HVPE growth – nucleation, growth rate, coalescence and crack formation – can be monitored in situ.

[1] **Further information:** Ch. Hennig, E. Richter, M. Weyers, G. Tränkle: Self-separation of thick two inch GaN layers grown by HVPE on sapphire using epitaxial lateral overgrowth with masks containing tungsten, accepted for publication in proceedings of IWN 2006 (phys. stat. sol.)

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