True wafer temperature measurements in MBE

LayTec's in-situ 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. These sensors are offered for a variety of growth systems in MBE, MOVCD and other growth techniques. All sensors are available with LayTec´s True Temperature measurement mode based on emissivity corrected pyrometry: EpiTT, EpiR TT and EpiRAS TT.

All LayTec True Temperature (TT) products are based on the principle of emissivity-corrected pyrometry shown in Fig. 1. For opaque semiconductors like GaAs and InP at 950nm, the sum of absorption and reflectance is 1 (conservation of energy). Thus, the measurement of the reflectance and the emissivity of the growing layer at exactly the same detection wavelength allows a real-time emissivity correction of the pyrometer signal. This results in an accurate and stable (non-oscillating) temperature signal even during growth of hetero-structures.

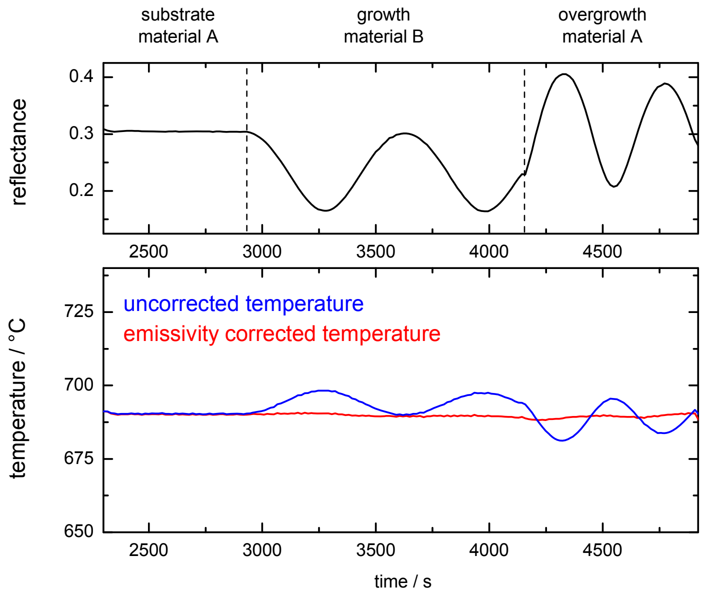

Fig. 1:
Principle of emissivity corrected pyrometry:

conservation of energy:
$\alpha + r + t = 1$

opaque semiconductor:
$\alpha + r = 1$

$\Rightarrow \varepsilon = 1 - r$

→ measure r and correct for changes of ε

Using **EpiRAS TT, EpiR TT** and **EpiTT**, the wafer temperature can be determined with an accuracy of better than ± 1K even during growth of hetero-structures for a temperature range from 400-1000°C or 500-1400°C. Fig. 2 shows data as measured from an AlGaAs/GaAs growth performed at ETH Zürich. On the left, the uncorrected pyrometry signal is shown, on the right - the correct true temperature signal. Effects of shutter opening sequences on the TT measurement are currently an object of further investigations. The accuracy of the measurement is well below 1K, the resolution is even 0.2K.

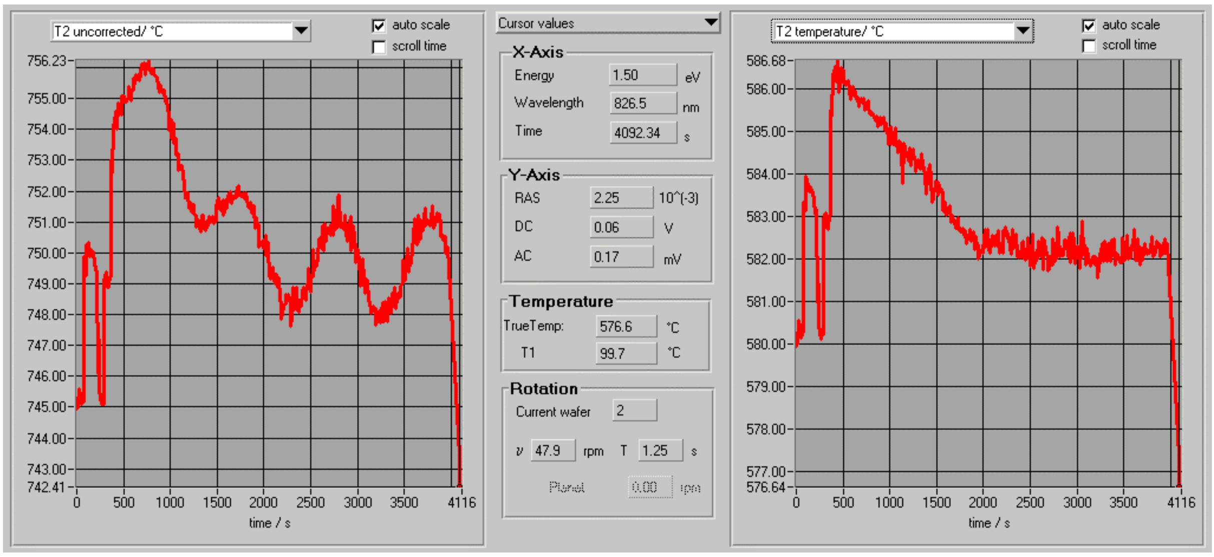

Fig. 2: uncorrected and corrected temperature as measured during growth of AlGaAs on GaAs: the temperature can be measured with a resolution of 0.2 K.

Fig. 3 provides an example of true temperature measurements and the corresponding RAS data during de-oxidation and annealing of a GaAs substrate. The temperature trace shows heating steps, overshooting and stabilizing of the surface temperature. The oxid desorption was controlled parallel by RHEED and RAS measurements. The RAS signal is sensitive to surface stoichiometry changes caused by surface reconstruction changes during heating.

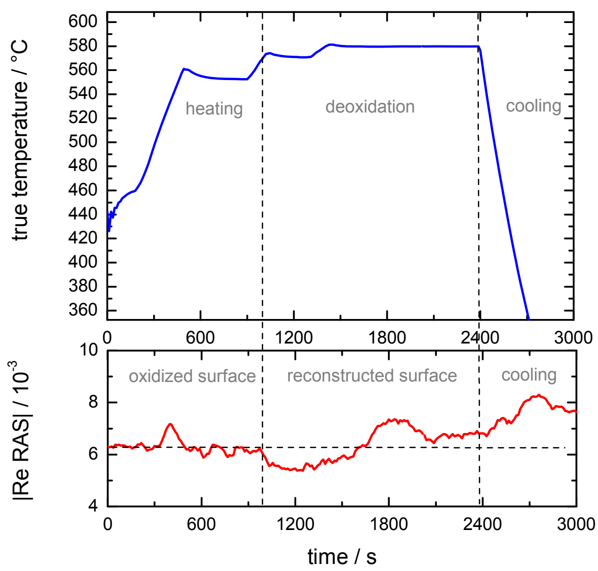

Fig. 3:
True Temperature and RAS measurement at 1.5eV during oxid deoxidation of a GaAs wafer and cooling down procedure.