



Feedback control of GaN layer thickness by EpiTT

In cooperation with the Technical University Berlin, LayTec has developed a feedback control for MOCVD growth of GaN buffer layers using LayTec's in-situ sensor EpiTT, which yields the actual growth rate during growth. This feedback control allows determining accurate time for growing a predefined layer thickness after the first complete Fabry-Perot oscillation. Controlling the buffer layer thickness by feedback control enables the control of light output characteristics of LEDs. This document describes the method

The feed-back control was performed with LayTec's EpiTT, simultaneously measuring both reflectance and wafer temperature during growth. Using accurate temperature dependent refractive indices for both, substrates and epilayers, at 950 nm wavelength, EpiTT is able to determine the current growth rate during growth by real-time fitting of the growth rate to the Fabry-Perot oscillations of the just growing layer. Endpoint triggering between the epitaxy control software and the sensor control unit was applied in order to switch between buffer layer growth and the following epitaxy steps. With this approach, reliability and reproducibility of mass-production epitaxy process can be improved as the effective growth parameters are measured during growth and a fast feedback control to the in situ epitaxy control is provided.

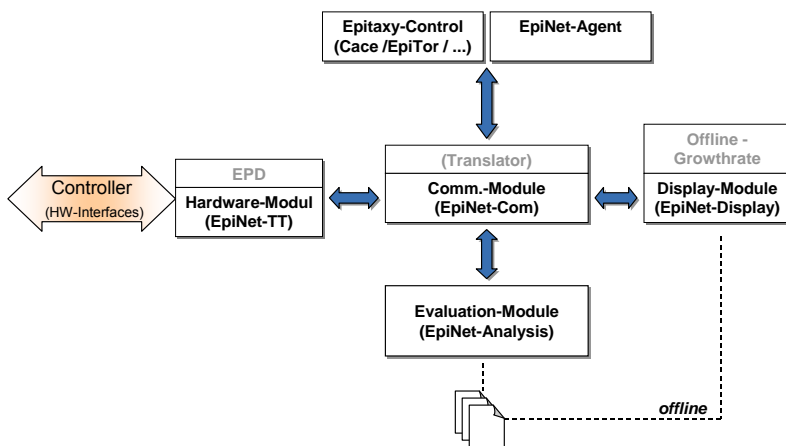


Fig. 1: Interaction scheme of software modules of the feedback control

Feedback control is a set of different modules (Fig. 1). The hardware module collects raw data according to the system time resolution mainly depending on reactor type (1 - 6 s per data set). The collected data are forwarded to the analysis module via a communication module. The analysis module determines the actual growth rate by fitting a simulated transient to the measured transient in real time

using a set of n- and k-parameters taken from a well-developed database for nitride materials. Already after the first completed period of the Fabry-Perot oscillations, an accurate growth rate is obtained and updated every second. From the real-time measured growth rate, an updated growth time is calculated according to the intended growth thickness. The hardware of the endpoint trigger module is programmed according to the updated growth time and releases the digital trigger signal after the programmed time is passed by. The epitaxy control software was set to wait for the trigger signal, so, the next step starts immediately after receiving the trigger signal.

For fail-safe operation special algorithms have been implemented both in the epitaxy software and the feedback control. For example, the measured growth rate is used to calculate the required

time for completing the layer thickness only if the deviation from the predefined growth rate in the growth recipe is within certain limits. Otherwise, the initial growth time of the recipe is held as valid.

This feedback control was used during growth of GaN buffer layers on Si(111) substrates. The growth starts with an AlAs nucleation layer that is converted to AlN, afterwards. On top of the nucleation layer, the GaN buffer layer was grown at surface temperatures of 1050°C. The predefined growth time for the buffer layer was 30 minutes for 1 µm layer thickness. However, the growth rate reduces with increasing liner coverage due to parasitic deposition processes. Therefore, the epitaxy control was set to wait for the trigger signal from the feedback control. Fig. 2 shows the evolution of the measured growth rate and the estimated growth time. The trigger signal was finally released after 26,4 min. – about 14 % earlier than assumed in the recipe. The thickness of the GaN layer was measured to be 1.02 ± 0.02 µm using SEM cross section images (Fig. 3). This thickness approaches the 1.0 µm goal much better than the thickness as obtained from the predefined time step of 30 min.

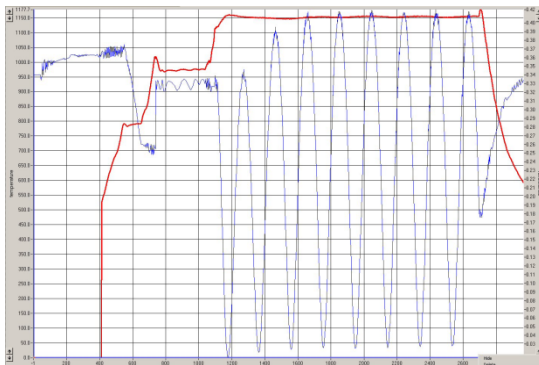


Fig. 2: Measured reflectance transient and surface temperature

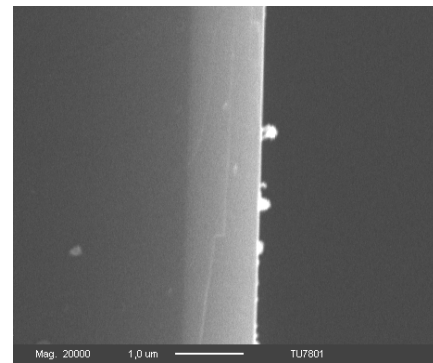


Fig. 3: Cross-section SEM image of GaN buffer layer on Si(111) substrate

This feedback mechanism provides tight control over buffer layer thicknesses and allows to improve the reproducibility of LED fabrication. For example, it was shown that light output of LED device structures grown on SiC depends on the thickness of the buffer layer [1]. Strain induced disordering of the InGaN/GaN multiquantum well structure was argued to be one reason for the thickness dependence. Furthermore, the output color of LEDs – an important merit for most LED applications – might be also thickness dependent since the emission spectrum is modulated by the spectral separation of interference fringes. These fringes appear due to the interference effect of the cavity formed between the surface and the substrate-epilayer interface. So, the control of the buffer layer thickness enables precise and reproducible color tailoring of LED output.

The presented feedback control is already laid out for more sophisticated tasks like thickness control of multilayer structures. As an example, the growth of AlGaAs/GaAs-based VCSEL structure containing several DBR mirrors has been controlled by the same concept but with Reflectance Anisotropy Spectroscopy (RAS) as in-situ sensor (to be published).

Further reading: [1] J. Baur, U. Strauss, G. Bruederl, D. Eisert, R. Oberschmid, B. Hahn, H.-J. Lugauer, S. Bader, U. Zehnder, M. Fehrer, V. Härle, J. Cryst. Growth 230 (2001), 507-511

[2] A. Strittmatter, L. Reißmann, D. Bimberg, T. Trepk, S. Uredat, T. Schenk, J.-T. Zettler, **Feedback control of GaN buffer layer thickness for precise reproducibility of nitride based devices** presented at the 11th European Workshop on MOVPE, Lausanne, Switzerland