



EpiCurve® TT : GaN LED growth optimisation with LayTec's new bowing sensor

As the diameter of the sapphire, SiC and Si substrates for GaN LED and laser production is increasing, so does the wafer bowing. In close collaboration with University of Magdeburg, Ferdinand-Braun-Institute (FBH) in Berlin and several industrial customers LayTec has developed and applied the EpiCurve® TT sensor which measures wafer bowing, reflectance and true temperature simultaneously and in-situ. The sensor helps to understand the influence of parameter changes on the bow and to optimise LED growth under tight in-situ control.

Blue and white LEDs are mainly grown on materials with a high lattice mismatch like sapphire, SiC or Si. Numerous curvature measurements for standard GaN LED growth have been performed at FBH to understand the physical effects causing curvature changes on sapphire substrates [1].

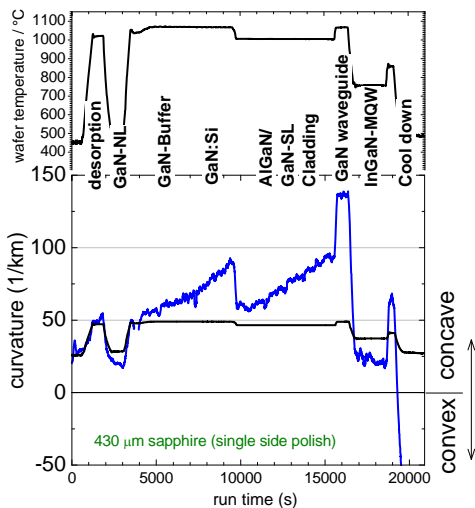


Fig. 1: Transients of surface temperature and wafer curvature during growth of a typical InGaIn/GaN laser in a planetary AIX2600G3-HT system with a 11x2" configuration.

Fig. 1 shows a typical curvature measurement obtained during growth of a GaN/AlGaIn/InGaIn structure on top of a sapphire wafer. Most wafers show a bowing effect already when the sapphire substrate is being heated up for oxide desorption. This can be attributed to the temperature gradient between the wafer back and front side which is the result of the low thermal conductivity of sapphire. Simulations of the effect showed that this vertical temperature gradient reaches a maximum of only 2K at the growth temperature of 1060°C.

When the growth of GaN is started, the wafer bow increases with growing film thickness. The slope of the curvature signal can be used to determine the lattice constant of the growing materials, as the curvature is related to the lattice constant (Stoney equation).

The third reason for the considerable curvature changes is the thermal mismatch between the growing layers: each time the temperature is ramped, a strong increase or decrease in the bowing measurements is observed. While during growth concave bowing takes place, after the final cool-down to room temperature the wafers are bowed in a convex shape! This complex interaction of at least three bowing mechanisms in a single growth run demonstrates how important in-situ control is to optimize new LED designs for higher yield and efficiency.

Any variation of the aluminum content causes a different slope in the curvature signal (see Fig. 2). Further experiments at FBH proved that a proper analysis of the curvature slope during GaN buffer layer growth enables accurate in-situ determination of Al composition by measuring and analyzing the curvature slope during the subsequent AlGaN growth [1].

However, if AlGaN films exceed the critical layer thickness, crack formation in the material leads to a reduced total stress. This effect can be clearly seen in Fig. 2b (blue curve). When growing AlGaN with 12% aluminum, the layer cracks after reaching a thickness of approximately $0.6 \mu\text{m}$ and the curvature signal no longer increases. The signal becomes more noisy because of aspheric bowing effects. Fig. 3 shows a microscope picture of the structure after crack formation for an AlGaN layer with 12% aluminium (corresponds to blue curve in Fig. 2b)

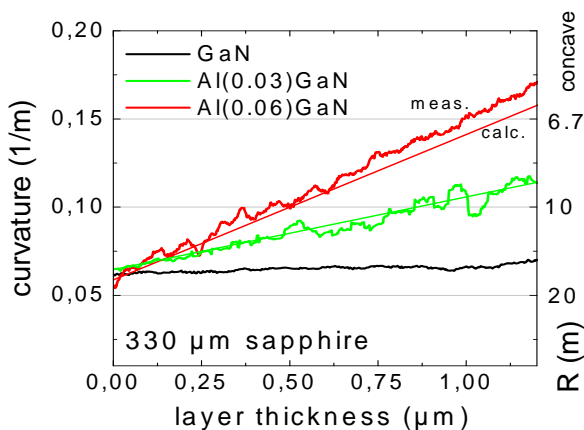


Fig. 2a: Bowing measurements during AlGaN growth with different Al-content. For comparison: calculations via Stoneys equation are plotted as straight lines.

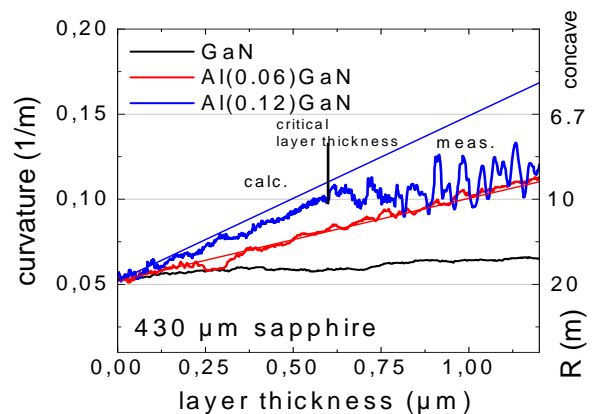


Fig. 2b: For a thick AlGaN layer (blue line) strain relaxation by crack formation leads to a visible change in slope of wafer curvature.

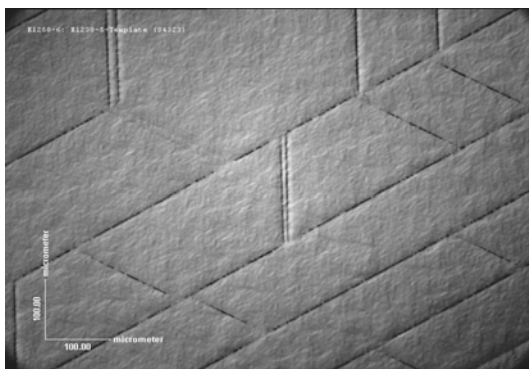


Fig. 3: Microscope picture of an AlGaN layer showing crack formation as observed with the EpiCurve® TT (corresponds to blue curve in Fig. 2b).

EpiCurve® TT sensors are available for AIX 200 RF-S and all types of Planetary MOCVD reactors as well as for TSSEL CCS reactors. Existing **EpiTT** sensors can be up-graded to **EpiCurve® TT**. For further information please contact: info@laytec.de or your local LayTec distribution partner.

[1] F. Brunner et.al., Quantitative analysis of in-situ wafer bowing measurements for III-Nitride growth on Sapphire, to be published in the ICNS conference proceedings (2007).