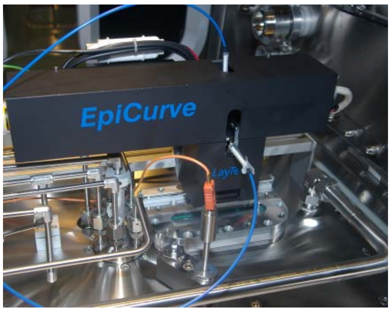
Application Note 45

In-situ control of InGaAs on GaAs in MOVPE by high resolution EpiCurve® TT sensor



LayTec's in-situ sensor EpiCurve® TT enables correction of bowing effects on wafer temperature measurements and helps optimise growth via minimising bowing effects. It allows real-time measurements of wafer curvature, emissivity-corrected wafer temperature and double-wavelength reflectance for growth rate analysis.

Ferdinand-Braun-Institute in Berlin uses **EpiCurve® TT HighRes** (high resolution) sensor for measuring the indium composition of InGaAs quantum wells (QW) embedded in GaAs. Some interesting results were presented by Dr. Martin Zorn at IC MOVPE in 2006. The sensor measured wafer curvature with an outstanding resolution of 1 km^{-1}! Furthermore, in-situ controlled strain compensation by GaAsP was achieved after QW growth by adjusting the layer thickness of the strain compensating GaAsP.

Due to the larger lattice constant of InGaAs as compared to the GaAs substrate, with increasing indium content an increasing amount of compressive stress is incorporated in the layer structure. Therefore, using InGaAs QWs the maximum reachable wavelength lies around 1240 nm at a low growth temperature of 510°C. The InGaAs multiple quantum well structures were grown on exact oriented $\text{GaAs}_{(0\,0\,1)}$ substrates with a thickness of 350 µm in an Aixtron 200/4 MOVPE system. The change in the wafer bowing signal 1/Rc for a given InGaAs QW/GaAs structure was calculated by Stoney's equation, which allows obtaining a direct correlation between curvature change and the indium content.

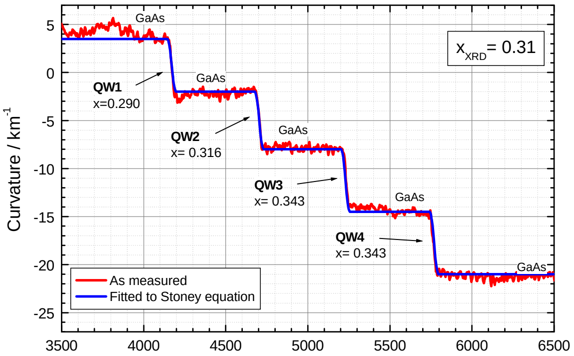


Fig. 1: Wafer curvature measured during growth of four 5.5 nm thick InGaAs QWs separated by 50 nm thick GaAs barrier layers (red line) together with the calculated curvature change (blue line) according to equations. The fit result for the indium content of every single QW is indicated.

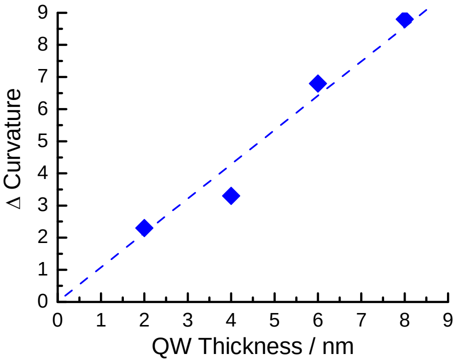


Fig. 2: Dependence of the change in curvature on the QW thickness for an indium content of x = 0.31 together with theory values (blue line) obtained in a different experiment

Fig. 1 shows the curvature measurement of the subsequent growth of four $\mathrm{In}x\mathrm{Ga}_{1-x}\mathrm{As}$ QWs with a targeted thickness of 6 nm separated by 50 nm thick GaAs spacer layers. The used integration time of only 10 s was fully sufficient to resolve the influence of each QW on the substrate curvature. The QW growth rate was 0.2 nm s^{-1}. During growth of the GaAs barrier layers, the substrate bowing remained unchanged. A simulation of the measured data by using Stoney's equation shows a perfect agreement between curvature theory and measurement.

Next, the dependence of the curvature change on the quantum well thickness was investigated. Fig. 2 shows the dependence of the curvature change on QW thickness together with the expected behaviour as calculated from Stoney's equation (blue line in Fig. 1) for QWs with an indium content of x = 0.31. A linear dependence in good agreement with theory can be seen. This shows that even QWs with a thickness as thin as 2 nm can be resolved.

Besides, a method of in-situ strain adjustment more time-efficient than X-ray-based optimization has been developed (Fig. 3). The growth of two InGaAs QWs separated by a 50 nm thick GaAs spacer layer was followed by a GaAsP strain compensating layer. As expected, the growth of the two QWs led to a convex substrate bowing. The growth of the GaAsP layer, which followed, bowed back the substrate into the opposite (concave) direction due to its smaller lattice constant as compared to the GaAs substrate. Finally, growth of the GaAsP layer was stopped after the curvature effect of the QWs had been exactly compensated. During growth of the GaAs capping layer, the curvature stayed constant at the initial GaAs level.

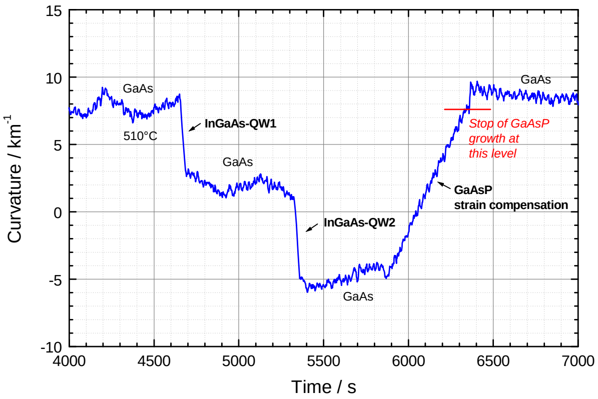


Fig. 3: Development of curvature during growth of two InGaAs QWs followed by a GaAsP strain compensating layer. The growth of the strain compensating layer was stopped after the curvature had reached the initial GaAs level.

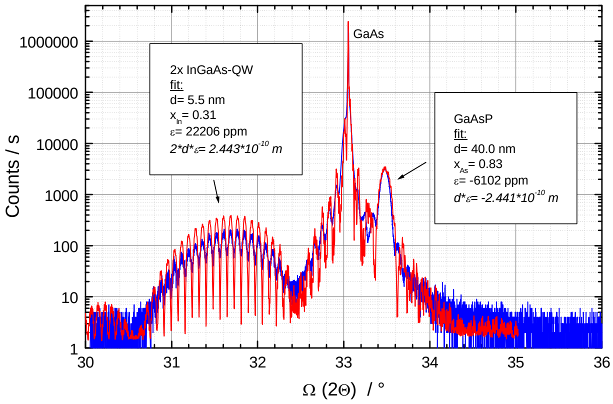


Fig. 4: X-ray measurement (blue) and fit (red) of the layer structure grown in figure 3.

The grown in-situ strain-compensated layer structure was afterwards investigated by ex situ x-ray diffraction. The check showed that full and exact strain compensation was achieved by using the in-situ adjusted strain compensating layer.

Further reading: M. Zorn, F. Bugge, T.Schenk, U. Zeimer, M. Weyers, J.-T. Zettler: **Feedback controlled growth of strain-balanced InGaAs multiple quantum wells in metal-organic vapour phase epitaxy using an in-situ curvature sensor.** Semiconductor Science and Technology 21 (2006) L45-L48

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