ROBL-CRG	**Experiment title:** HRXRD measurement of the TEC of multilayer lateral nanostructures (InGas/GaAs)	**Experiment number**: 20-02-642
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Shifts:	**Local contact(s)**: C. Bähtz	*Received at ROBL:*

Names and affiliations of applicants (* indicates experimentalists):

B. Brüser* (Universität Siegen)
J. Grenzer* (FZ Dresden-Rossendorf)
S. Grigorian* (Universität Siegen)
U. Pietsch (Universität Siegen)

Report:

The aim of our experiment was to measure the thermal expansion coefficient of a pure semiconductor multilayer before and after preparation of a lateral nanostructure. In this experiment our nanostructure sample consists of a multilayer system with 5 periods of an InGaAs/GaAs multi-quantum-well grown on [001] a GaAs substrate. The Indium concentration amounts to 22 %. The surface nanostructure of the sample was prepared via holographic exposure and subsequent wet chemical etching with a lateral periodicity of 300 nm. The sample has a total superlattice thickness of 54,7 nm.

The samples were measured at ROBL BM20. The samples were mounted onto an evacuated heating stage. We used coplanar x-ray diffraction in order to measure the rocking curves ($\omega/2\theta$-scan) of the symmetric 004 reflection. Our scan direction corresponds to a longitudinal scan, i.e. it will show the oscillations of the superlattice but not the grating peaks. The curves were recorded at three different temperatures, i.e. at 20°C, 200°C and at 400°C. Considering the smallness of the expected effect we used an analyzer crystal (Si-111) in front of a scintillation counter. Our beamsize was 1mm² and the energy was set to 8.048 keV.

First, we measured the region of the non patterened area of the sample followed by measurement for the patterned part of the sample. Three typical diffraction curves of the patterned sample area are shown in Fig.1.

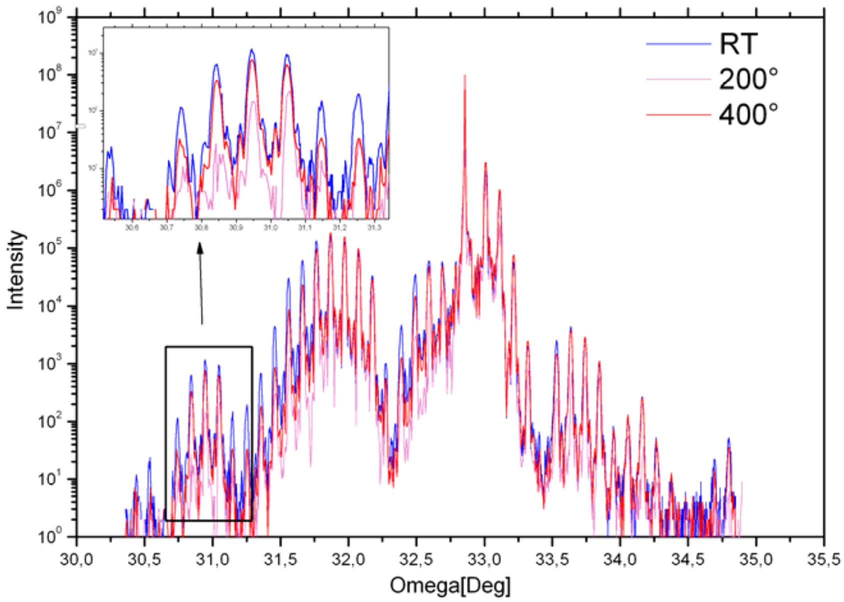

Figure 1: 004 Reflection at three different temperatures (ω/2θ-scan) revealing the superlattice structure

All of the curves show distinct superlattice peaks in addition to the Bragg peak of the GaAs substrate. The angular distance between the superlattice peaks are inversely proportional to the thickness superlattice period. Due to thermal expansion this angular distance is supposed to change at different temperatures, i.e. the thermal expansion coefficient of the superlattice can be measured from the change of the angular distance between the superlattice peaks.

From previous measurements the thermal expansion coefficient of the bulk material (GaAs) has been determined. It amounts to $\alpha_{Substrate} = 6,4 \cdot 10^{-6} K^{-1}$.

Since the multilayer has been grown pseudomorphically onto the substrate the unit cell is tetragonally strained. Previous work shows an increase of the TEC of up to 40% compared to the non-strained materials due to the tetragonal deformation [1].

Table 1: Experimentally and theoretically determined values for the out-of-plane TEC of the SL sample with and without surface grating. [2]

Surface Structure	TEC(exp.) [10-6K-1]	TEC(theor.) [10-6K-1]
Gratings	9.8 ± 3.8	7.6
Planar	12.3 ± 2.3	12.0

Evaluation of the data recorded at DELTA shows that the thermal expansion coefficient of the patterned and non-patterned multilayer systems are different (Table1).

The origin of this difference can be explained by a strain field reduction in the samples' top layer implicated by the lateral patterning. This explanation is supported by FEM simulations [2].

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References:

[1] J. Bak-Misiuk, J. Wolf, U. Pietsch, phys. stat. sol. (a) 118, 209 (1990).

[2] B.Brueser, T. Panzner, S.Grigorian, J.Grenzer, M.Zorn, U.Zeimer, U.Pietsch, phys, stat.sol. (a), [accepted].