ESRF	**Experiment title:** Strain and interdiffusion in InAs quantum dots overgrown by GaAs cap layers	**Experiment number**: HS 1547
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ESRF, ID1

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Report:

A series of InAs quantum dot samples has been investigated using the novel method of contrast variation by anomalous scattering at the weak GaAs/InAs (200) superstructure reflection. This method has been developed at ID1 and has successfully been tested during inhouse research beam time in June last year. During the beam time in November several improvements to the method have been implemented.

The method is based on the anomalous scattering behaviour at the resonant wavelength of an atomic shell. This effect is enhanced significantly in combination with a superstructure reflection of a compound. As GaAs and InAs crystallizes in the Zinc-Blende structure, the structure amplitude F_{hkl} of the (200) superstructure reflection has the form $F_{200}=4(f_{Ga}-f_{As})$. The (complex) scattering factor $f_{Ga,As}$ changes with energy, in particular close to an absorption edge.
The intensities of the (200) reflection calculated from $|F_{200}|^2$ for GaAs and InAs close to the K-edge of As are shown in Fig. 1. By chosing an x-ray energy above the K-edge of As (12.38 keV) the intensity contribution of the GaAs matrix can be reduced by a factor of about 500, whereas the factor is less than 10 at the K-edge of As (11.86 keV).

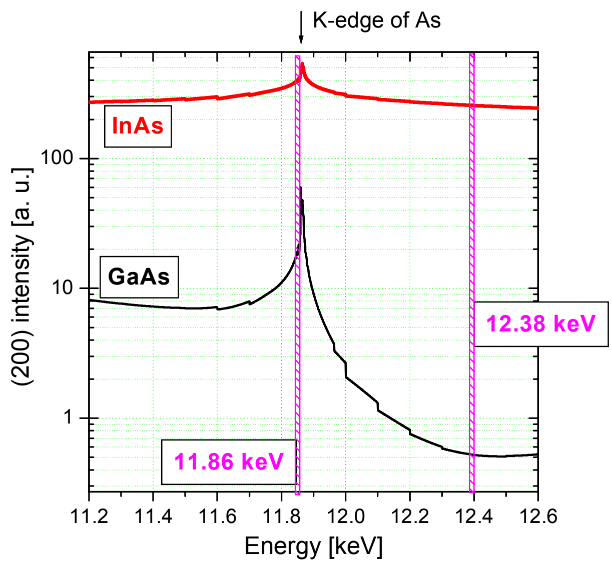

Fig. 1: Energy dependence of the relative intensity in the (200) reflection of InAs and GaAs. The two energies where the experiment has been performed are marked.

For data collection we have used a position sensitive detector (PSD). As this detector provides no energy resolution we observed a strong background of fluorescence scattering above the K-edge of As during the first experiment. By using a PSD in combination with a graphite analyser during the recent experiment we were able to improve the resolution substantially. We encountered no more problems with fluorescence and thus have chosen the energies for the experiment at 11.86 keV, approximately at the K-edge of As, and at 12.38 keV to take advantage of the maximum difference in contrast.

The samples we have investigated were supplied by the Walter Schottky Institute at the technical university in Munich. They were composed of self-organized grown $In_{0.5}Ga_{0.5}As$ quantum dots (8 ML) on a GaAs (001) substrate. In particular we investigated a single layer of InGaAs quantum dots both freestanding and capped with 100Å GaAs. A second pair of samples (freestanding and capped) consisted of a double layer of InGaAs quantum dots with a spacer layer of 130Å GaAs.

The measurements were performed at two different energies in the geometry of grazing incidence diffraction (GID) to attain surface sensitivity. Reciprocal space maps were recorded at different incident angles around the (200) and (400) Bragg reflections.

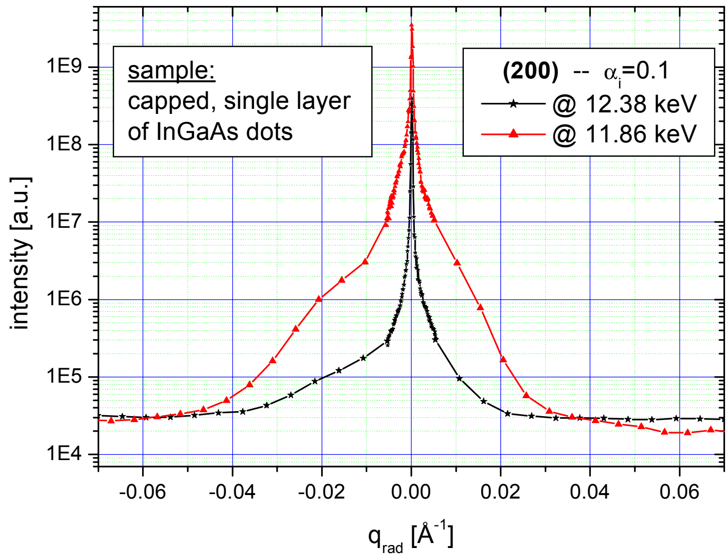

Fig. 2: Radial scan over the (200) Bragg reflection at an incident angle of $\alpha_i = 0.1°$. The measurements were performed at two energies at and above the K-edge of As.

Fig. 2 shows a radial scan over the (200) Bragg reflection of the capped sample with a single layer of quantum dots. In the measurement performed at 11.86 keV the mutual strain in InGaAs quantum dots and the surrounding GaAs matrix leads to an overlap of both scattering contributions. In comparison a significant change can be observed by changing the x-ray energy to 12.38 keV: the strong scattering contribution from the GaAs matrix is widely suppressed.

Using these measurements it is now possible to separate the contributions of the InGaAs quantum dots and the GaAs matrix and to determine strain, shape and interdiffusion of quantum dots overgrown by a GaAs cap layer.

Fig. 3 shows a reciprocal space map of the sample with a double layer of InGaAs quantum dots. Due to the chosen energy above the K-edge of As at the (200) Bragg reflection the scattering from the quantum dots can be enhanced to an extend that the GaAs matrix scattering vanishes almost completely and the signal stems primarily from the InGaAs dots.

As the experiment took place recently a quantitative evaluation of the data is currently under way.

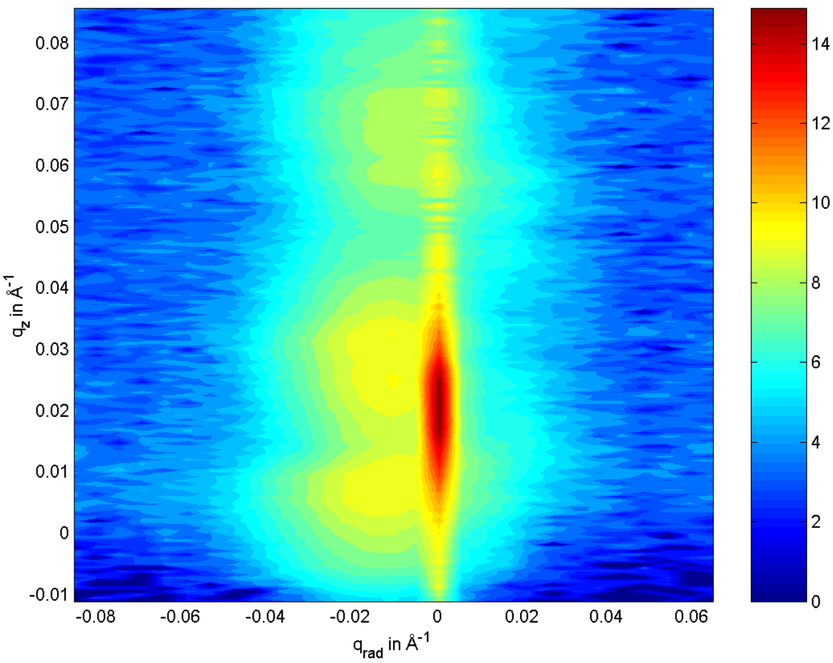

Fig. 3: Double layer of InGaAs quantum dots: reciprocal space map around the (200) Bragg reflection at an incident angle of $\alpha_i = 0.1°$. The measurement was performed at 12.38 keV.