EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

Experiment Report Form

The double page inside this form is to be filled in by all users or groups of users who have had access to beam time for measurements at the ESRF.

Once completed, the report should be submitted electronically to the User Office using the **Electronic Report Submission Application:**

http://193.49.43.2:8080/smis/servlet/UserUtils?start

Reports supporting requests for additional beam time

Reports can now be submitted independently of new proposals – it is necessary simply to indicate the number of the report(s) supporting a new proposal on the proposal form.

The Review Committees reserve the right to reject new proposals from groups who have not reported on the use of beam time allocated previously.

Reports on experiments relating to long term projects

Proposers awarded beam time for a long term project are required to submit an interim report at the end of each year, irrespective of the number of shifts of beam time they have used.

Published papers

All users must give proper credit to ESRF staff members and proper mention to ESRF facilities which were essential for the results described in any ensuing publication. Further, they are obliged to send to the Joint ESRF/ ILL library the complete reference and the abstract of all papers appearing in print, and resulting from the use of the ESRF.

Should you wish to make more general comments on the experiment, please note them on the User Evaluation Form, and send both the Report and the Evaluation Form to the User Office.

Deadlines for submission of Experimental Reports

- 1st March for experiments carried out up until June of the previous year;
- 1st September for experiments carried out up until January of the same year.

Instructions for preparing your Report

- fill in a separate form for each project or series of measurements.
- type your report, in English.
- include the reference number of the proposal to which the report refers.
- make sure that the text, tables and figures fit into the space available.
- if your work is published or is in press, you may prefer to paste in the abstract, and add full reference details. If the abstract is in a language other than English, please include an English translation.

ESRF	**Experiment title:** Iso-strain grazing-incidence x-ray scattering from InGaAs selfassembled quantum dots grown in inverted pyramids in GaAs	**Experiment number**: SI-896
Beamline:	**Date of experiment**: from: 13.11.2004 to: 19.11.2004	**Date of report**: 02.02.2005
Shifts: 18	**Local contact(s)**: Bärbel Krause	*Received at ESRF:*

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Report:

The chemical composition and strain in self-assembled semiconductor nanostructures are important quantities determining to a large extent the electronic properties. We have used x-ray diffraction in order to obtain this information on $Ga_{1-x}In_xAs$ islands with a nominal composition as small as x=10%. The islands are embedded in a multilayer, which is deposited on a prepatterned GaAs(111) substrate with an array of holes. These holes are fabricated by electron beam lithography and wet chemical etching, leading to pits with the shape of inverted pyramids with (111) side facets.

On top of this susbtrate a stack consisting of the following layers has been deposited: $Al_{0.55}Ga_{0.45}As$ | $Al_{0.3}Ga_{0.7}As$ | $In_{0.1}Ga_{0.9}As$ | $Al_{0.3}Ga_{0.7}As$ | $Al_{0.55}Ga_{0.45}As$. The layers have been grown by chemical vapor deposition. As the islands are in the deep pits and contain only 10% In nominally (it can be expected that the In content decreased even further during capping of the islands), it is clear that the scattering will be dominated by the GaAs. In order to reduce this scattering contribution, we tuned the x-ray wavelength at beamline ID01 to 12.65 keV, slightly above the Ga K-edge, as for this energy the scattering factor of the weak (226) GaAs reflection becomes minimal.

Although the choice of energy reduces the elastic scattering from GaAs, it leads to a strong inelastic scattering signal (fluorescence) from the GaAs. The energy resolution of the position sensitive detector we used for this measurement is by far not sufficient to separate the elastic

and inelastic scattering contributions. Hence we used an analyzer crystal in front of the detector in order to remove the inelastic part. In principle, the Graphite (110) crystal available at ID01 provides sufficient resolution for this purpose. Unfortunately, however, it does not provide enough resolution in reciprocal space to resolve the structure of our sample: with a pit spacing of 500 nm, an angular resolution in the 0.002° range is required (depending on the reflection) in order to resolve satellite maxima due to the periodic pit and island arrangements. Although for the evaluation of strain and composition it is sufficient to

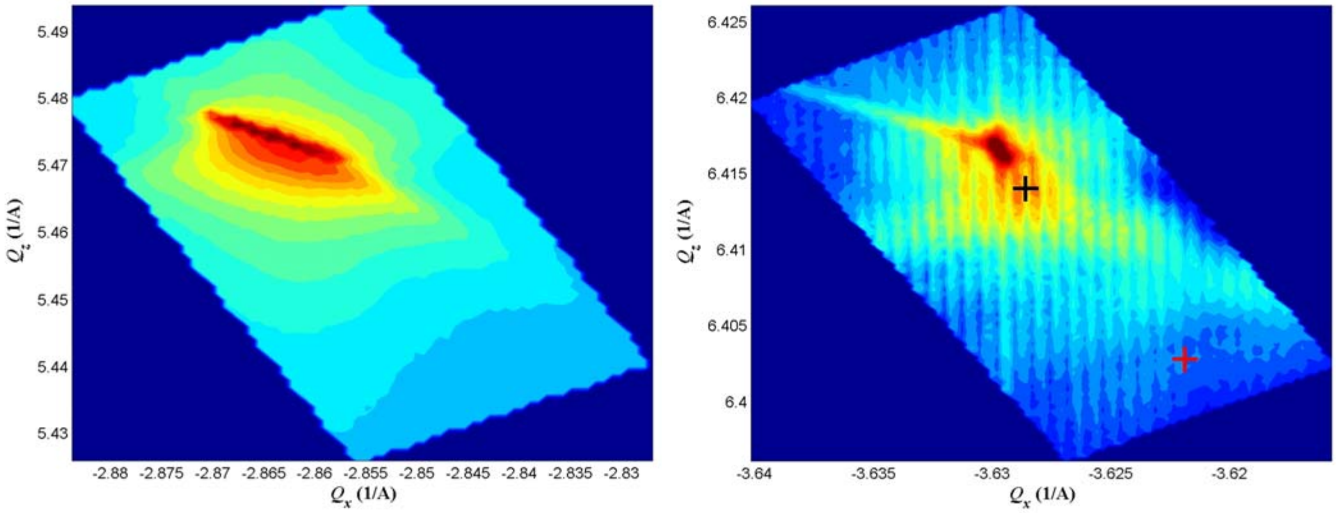

Figure 1. Reciprocal space maps recorded around the (226) reciprocal lattice point of GaAs at an energy of 12.56 keV. The left panel shows the measurement with a graphite(110) analyzer, right is the measurement with the Si(111) analyzer.

measure the envelope of the satellite maxima, the result obtained with the graphite analyzer is still distorted due to the influence of the diffuse scattering around the substrate reflection, as can be seen in Fig. 1 (left panel). Therefore we used a Si(111) crystal analyzer to record the reciprocal space map (right panel of Fig. 1). In order to obtain the structural parameters of the islands, finite element simulations of the strain fields have to be performed. This is a very time-consuming procedure due to the rather complicated geometry of the etched pits with the InGaAs islands embedded into a multilayer. A first crude aproximation of the In content based on the maximum of the satellite envelope (marked by a black cross in Fig. 1) and Bragg's law yields a very small value of x_{InAs}=0.5%. This can be underestimated, as a hydrostatic pressure component, which is present for overgrown islands [1], is not taken into account. However, it is unlikely that the InAs content is close to that of the deposited alloy (10%): As indicated by the red cross in Fig. 1, already a InAs content of 3% would result in a significantly different peak position than observed. A more elaborate analysis including finite element calculations is currently under way.

References

[1] A. Hesse, et al., Phys Rev. B 66, 085321 (2002).