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Deadlines for submission of Experimental Reports

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

	Experiment title: SEXAFS Investigations of the local atomic structure in InP/InGaP surface undulations	Experiment number: HS-4555
Beamline:	**Date of experiment**: from: 30 November 2011 to: 5 December 2011	**Date of report**: 24 February 2012
Shifts: 12	**Local contact(s)**: Francesco d'Acapito	*Received at ESRF:*

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Report:

The evolution of well ordered one-dimensional (In,Ga)P/GaAs(001) surface undulations which are aligned along the [-110] direction has been observed. This phenomenon is of high scientific and technological relevance since the surface undulations can be used as a natural template for subsequent MBE growth of well aligned InP quantum dots [1]. The microscopic mechanisms leading to the (In,Ga)P surface undulations are, however, not understood yet. Lateral compositional modulation and $CuPt_B$ like long range atomic ordering are the most frequently discussed candidates causing the surface undulations [2]. X-ray absorption measurements restricted to the surface portion of the layers can reveal the local atomic structure around Ga and In atoms and therefore help to discover the microscopic mechanisms governing the formation of surface undulations.

Samples have been grown on (001) GaAs substrate using gas-source molecular beam epitaxy. After deposition of a 100 nm GaAs buffer layer at 550°C with a deposition rate of 0.4 ML/s a lattice matched InGaP layer has been grown at 470° C. During the growth reflection high energy electron diffraction (RHEED) patterns were monitored in-situ and a (2 x 1)-surface reconstruction for InGaP is observed. The detailed growth conditions are discussed in [1].

We have measured reflectivity and fluorescence EXAFS spectra at the Ga K edge for two different incidence angles 0.17° (below critical angle α_c of total external reflection) and 0.273° (above critical angle α_c). In the first case the small penetration depth (3.6 nm) allows us to probe only the very near surface regime of the (In,Ga)P layer, while in the second case we probe the bulk of the layer (penetration depth 43 nm). Even the second angle had to be quite small in order to prevent the GaAs substrate to contribute heavily to the spectra. Additionally, fluorescence spectra have been recorded at the In K edge for incidence angle of approximately 45°, thus probing the whole (In,Ga)P layer.

The raw absorption (μ) spectra (as an example see Fig. 1) were processed by the Athena software [3] and χ (k) were extracted and Fourier transformed to χ (r) (Fig. 2). Using the Artemis software [3] we fitted the first coordination shell starting from GaP or InP structures. The Ga-P and In-P distances are reported in Table 1. Although this simple model is quite crude, it can show differences between samples and conditions of the measurement. The application of a more complex model of an $In_xGa_{1-x}P$ alloy is presently developed.

We have calculated the mean Ga-P and In-P distances as functions of In concentration (Fig. 3) with a model similar to [4]. The In-P and Ga-P distances for high angle of incidence correspond to the In concentration of about 50%. However, the Ga-P distances obtained below the critical angle are for some samples even smaller than in GaP (see Fig. 2). Such big difference between the bulk of the layer and its surface, however, is not

possible in the unstrained state. The reason for obtaining these values is that the surface portion of the layer is under compressive strain of about 3 %, while the model calculates relaxed lattice.
The reflection spectra (Fig. 4) give the same distances of nearest neighbours as the fluorescence ones.

Sample	Ga-P distance below α_c (Ga edge) [Å]	Ga-P distance above α_c (Ga edge) [Å]	In-P distance (In edge) [Å]
HU1_1827	2.369 ± 0.005	2.383 ± 0.007	2.513 ± 0.008
HU1_1830	2.343 ± 0.011	2.393 ± 0.017	2.516 ± 0.008
HU2_0284	—	—	2.523 ± 0.007
HU2_0368	2.335 ± 0.012	2.397 ± 0.013	2.516 ± 0.006
HU2_0385	2.371 ± 0.006	2.388 ± 0.006	2.513 ± 0.008

Table 1 Fitted Ga-P and In-P distances.

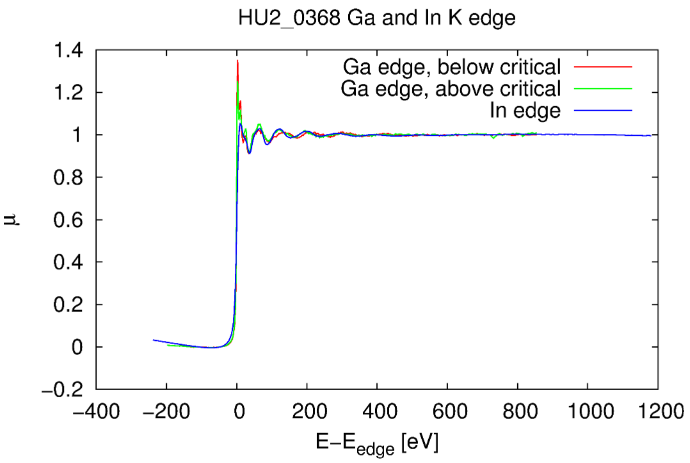

Fig. 1 Measured absorption spectra (normalized).

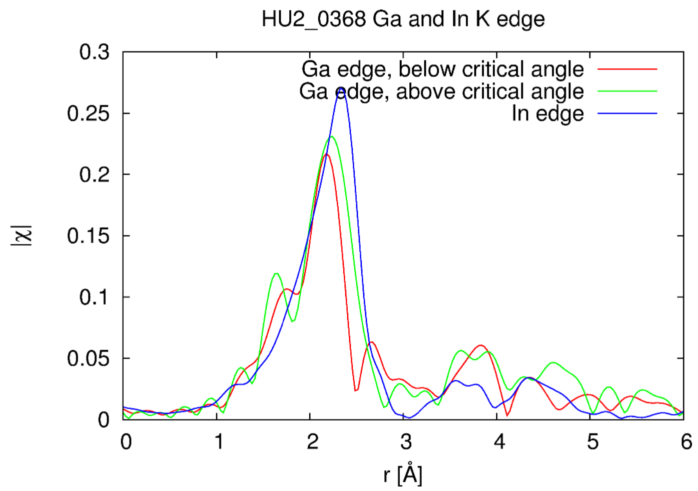

Fig. 2 Fourier transformation of the measured χ (k).

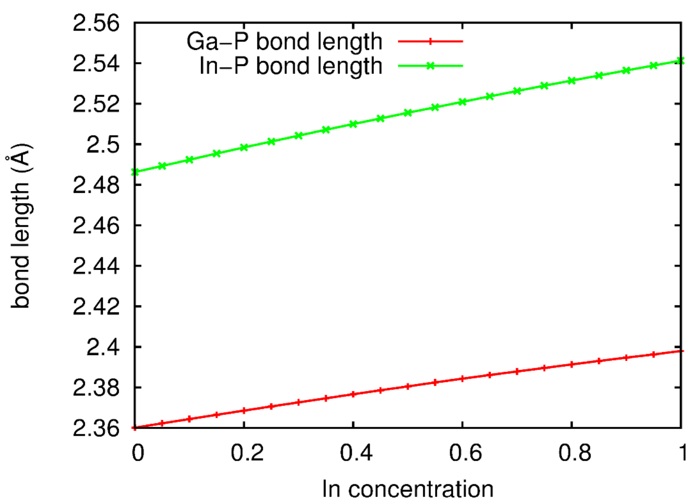

Fig. 3 Calculated dependence of Ga-P and In-P distances on the In concentration in (In,Ga)P.

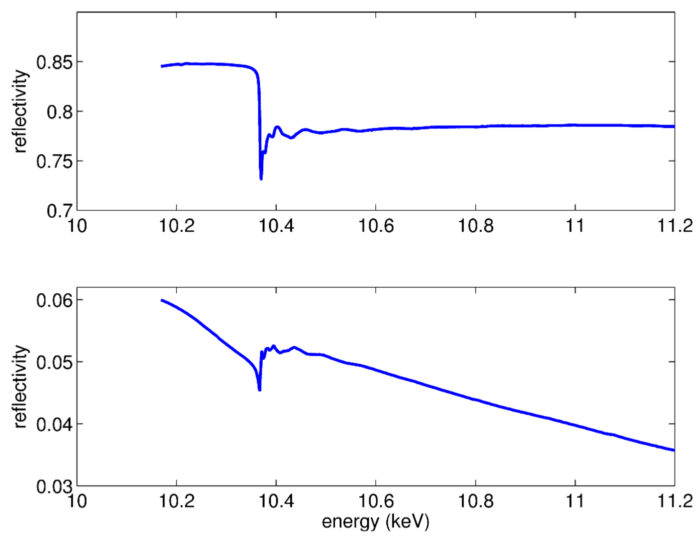

Fig. 4 Reflectivity of sample HU2_0385 below (top) and above (bottom) critical angle.

Presently we work on an improved model of the (In,Ga)P alloy to fit also second coordination shell as well as a model describing the distances in a strained alloy.

References

[1] A. Ugur et al., J. Appl. Phys. **105**, 124308 (2009)
[2] M. Schmidbauer et al., J. Appl. Phys.**111**, 024306 (2012).
[3] B. Ravel and M. Newville, J. Synchrotron Rad. **12**, 537 (2005)
[4] F. d'Acapito, J. Appl. Phys. **96**, 369 (2004)