EUROPEAN SYNCHROTRON RADIATION FACILITY

INSTALLATION EUROPEENNE DE RAYONNEMENT SYNCHROTRON

ESRF

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:** Characterization of quantum dots structure by surface sensitive EXAFS	**Experiment number**: HS-2263
Beamline: BM26A	**Date of experiment**: from: 26-11-2003 to: 02-12-2003	**Date of report**: 22-04-2004
Shifts: 18	**Local contact(s)**: Nikitenko Serge	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Nikitenko Serge
Katolieke Universiteit Leuven
Celestijnenlaan 200F
B-3001 Heverlee-Leuven
Belgium

Bras Wim
DUBBLE/CRG ESRF
BP 220
6 rue Jules Horowitz
F-38043 Grenoble Cedex
France

Erenburg Simon
BESSY
Albert-Einstein-Strasse 15
D-12489 Berlin
Germany

Bausk Nikola
BESSY
Albert-Einstein-Strasse 15
D-12489 Berlin
Germany

Report:

Report on the beam time use at ESRF

"Quantum dots structural properties by the surface sensitive EXAFS method".

The goal of project is a determination of microstructure parameters of quantum dots and heterostructures appearing during their formation by molecular beam epitaxy (MBE) depend on substrate pretreatment, temperature conditions and composition variations. For the heteroepitaxial systems having a mismatch of lattice constants the initial growth may occur by layers. Formation of thicker layers leads to a tendency towards the elastic strain relaxation and elastic energy decrease due to disturbing the two-dimensional growth and forming isolated islands, the so-called Stranski-Krastanov growth. In present work the Ge/Si- and InAs/GaAs- sandwich heterostructures formed from components with the lattice constants mismatch have been studied.

EXAFS and XANES spectra at the GeK and InK edges have been measured using a surface sensitive fluorescent yield detection mode at about 2° incidence angle [1].

At the first step the microstructure of Ge/Si sandwich heterostructures has been studied depend on effective thickness of Ge thin films deposited on Si(001) at 300°C and separated by Si spacer layers deposited at 500°C.

It has been detected a monotonic growth of the Ge - Ge effective coordination number at the same time with an increase of the effective thickness of germanium film from 4 to 10 monolayers. These data indicate of the monotonic size evolution of germanium nanoclusters.

At the next step the Ge/Si heterostructures were prepared with the spacers and surface protected by Si layers. The deposition temperature has been lowered to 300°C in this case.

It has been found that Ge-Ge and Ge-Si interatomic distances are equal to 2.41Å and 2.37Å respectively. These results are in accordance with [1] and not changing within ±0.01Å error bar for the deposition temperature of spacer's layers are varied from 500°C to 300°C. It should be emphasized that the determined Ge-Ge distances are less by 0.04 Å than it is for Ge bulk. At the same time, the effective coordination numbers of the Ge-Ge and Ge-Si are changing radically in parallel with the same temperature variation. It has been shown for the samples with equivalent thickness of Ge films in 4 monolyers (ML) the effective coordination numbers of Ge-Ge and Ge-Si are equivalent to 1.7 and 2.3 respectively if the Si spacer are deposited at 500°C. The coordination numbers are changed on the contrary to 2.7 and 1.3 if the spacer deposition temperature is changed to 300°C. This fact gives evidence that such lowering of the Si spacer deposition temperature leads to a substantial decrease of the diffusion between the phases Ge/Si and the formation of sharp phase boundaries between Si and Ge layers.

Using the different experimental methods it was shown in series of relatively recent studies [2-3] that the features associated with the zero-dimensional density of the states can be observed in electronic spectra of heterostructures for certain thickness of theGe film epitaxially grown on Si(001). These features appear due to the dimensional quantization of the hole spectrum in the Ge islands appearing during disturbed two-dimensional growth.

The attempt to obtain some information concerning of the energy structure of quantum dots free states by XANES data analysis for samples doped with boron has been made in the context of realization of the present project. The doping was taken by a special procedure causing a substantial electron deficit in the Ge bulk and Ge nanoclusters. The samples under study revealed discrete energy spectra peculiarities by preliminary optical measurements.

For the sample 1 covered by Si layers at 300°C the equivalent thickness of Ge layers equals 5ML while for the sample 2 covered at 500°C this thickness equals 8ML. The boron doping has been performed strictly into Ge layers for the sample 1 while the electrons deficit in the QD for the sample 2 has been caused by boron doping into Si layers adjacent to Ge layers. For the sample 1 no any atomic mixture between Si and Ge phases has been found while for the sample 2 it is valuable.

A comparative analysis of these obtained spectra has shown a presence of absorption maximum at the distance about 0.95eV for the sample 1 (Fig.1) and 1.2 eV for the sample 2 from the inflection point of the GeK absorption edge which is located close to the conduction zone bottom.

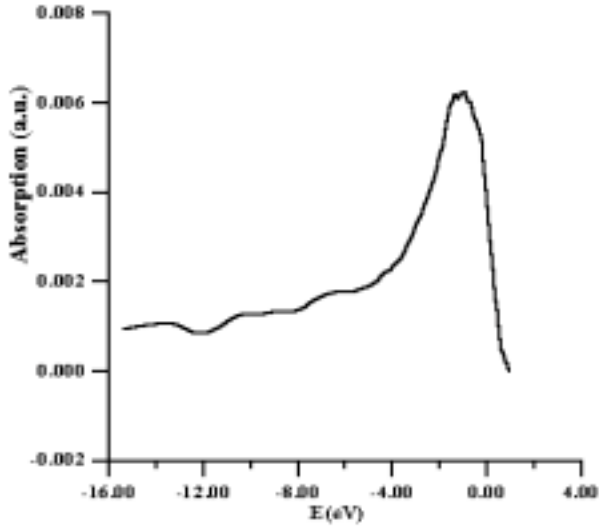

Fig. 1. Relative difference of absorption intensity in the XANES spectra of sample 1 containing Ge nanoclusters with and without boron dopant.

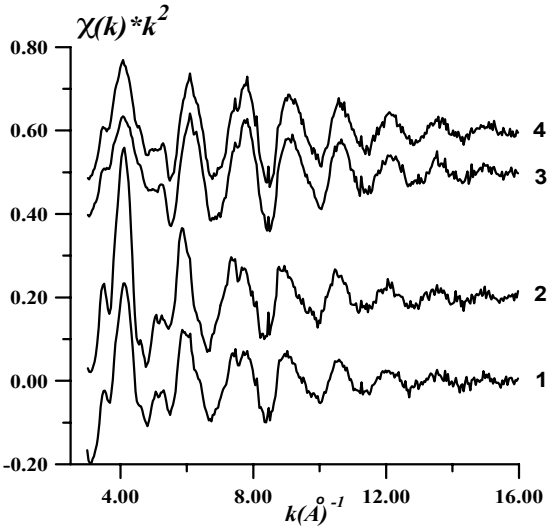

Fig. 2. GeK k^2-weighted normalized oscillating part of the X-ray absorption coefficient measured on geterosystems synthesized with (1, 3) and without (2, 4) of Ge cations.

It has to be mentioned that this maximum is not revealed for all samples without dopant. It was established the maximum is appeared due to the free levels formation at the top of the Ge bulk valence band and at a depth of 0.25-0.4 eV from the top of valence band for the samples with quantum dots. The interphase Si-Ge diffusion causes an increase of the forbidden zone width by 0.7 eV for the Ge nanoclusters and an increase of the absorption maximum distance for the sample 2 up to 1.2 eV. These data are in accordance with previous theoretical and experimental results obtained by other methods [4].

A number of samples with various equivalent thicknesses of Ge layers (5ML - for 1, 2; 7ML - for 3, 4) have been synthesized with MBE procedure at 350°C accompanied by simultaneous irradiation of the substrate by Ge cations with energy about 100eV by special procedure. In comparison with ordinary MBE without the irradiation we have found in this case some increase of the effective Ge-Ge coordination number (particularly for 1 compared to 2) which can be explained by the "three-dimensional" Ge islands formation even at the first stages of the epitaxial procedure (Fig.2).

Preliminary results of InAs/GaAs- system microstructure have been also obtained.

References

1. Erenburg S.B., Bausk N.V., Stepina N.P., Nikiforov A.I., Nenashev A.V., Mazalov L.N., Nucl. Instr. & Meth. Phys. Res. A., **470**/1-2 283 (2001).
2. Yakimov A.I., Adkins C.J., Boucher R., Dvurechenskii A.V., Nikiforov A.I., Pchelyakov O.P. and Biskupskii G., *Phys. Rev. B*, **59** 12598 (1999).
3. Yakimov A.I., Dvurechenskii A.V., Stepina N.P. and Nikiforov A.I., *Phys.Rev.B*, **62** 9939 (2000).
4. Dvurechenskii A.V., Nenashev A.V. and Yakimov A.I., *Nanotechnology*, **13** 75 (2002).