



## 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.



	<b>Experiment title:</b> Nucleation conditions for diamond nanocrystals in amorphous silica matrix	<b>Experiment number:</b> HS3849
<b>Beamline:</b> BM20	<b>Date of experiment:</b> from: 15.4.2009 to: 21.4.2009	<b>Date of report:</b> 27.8.2009
<b>Shifts:</b> 18	<b>Local contact(s):</b> Carsten Baecht	<i>Received at ESRF:</i>
<b>Names and affiliations of applicants (* indicates experimentalists):</b> *Maja Buljan, Department of Condensed Matter Physics, Charles University in Prague, Czech Republic and Ruđer Bošković Institute Zagreb, Croatia *Jörg Grenzer, Forschungszentrum Dresden Roßendorf, Germany *Václav Holý, Department of Condensed Matter Physics, Charles University in Prague, Czech Republic		

## Report:

The aim of the beamtime was to investigate the crystallization of carbon nanoclusters in-situ during annealing of C-implanted amorphous silica layers in forming gas (mixture of Ar and H). However, we found that the diffraction peaks of crystalline carbon inclusions (diamond inclusions, fcc-carbon or simple-cubic carbon) are not measurable, since they were covered by an intense background due to the scattering from amorphous silica. Therefore we decided to study the spatial arrangement of Ge nanocrystals in silica, using grazing-incidence small-angle x-ray scattering (GISAXS).

Introducing regularity in the spatial arrangement of Ge quantum dots (QDs) is proven to affect their properties; in particular, collective QDs vibrations appear a distribution of their sizes is much narrower [1]. Moreover, the wavefunctions of carriers confined in periodically arranged quantum wells may overlap creating minibands of eigenenergies with broad optoelectronic applications.

The formation of regularly ordered QDs arrays is usually obtained during the growth of crystalline multilayers (MLs) [2,3] where the mismatch of the lattice parameters causes elastic forces which induce QDs ordering. Some very recent studies [4] showed the possibility of the production of spatially correlated Ge QDs also in amorphous MLs, where the ordering is achieved by the interplay of diffusion and surface morphology mechanisms. However, in such systems, regions with ordered dots appear in small, randomly oriented domains, and only ordering of the positions of next neighbors in QD arrays (short-range ordering) can be achieved.

In the reported beamtime we have investigated the growth of Ge QDs in (Ge+SiO<sub>2</sub>)/SiO<sub>2</sub> multilayers after ion beam irradiation under oblique incidence angle ( $\phi_{irr} = 60$  deg). The irradiation is used for induction of regular ordering of QDs, which are nucleate along the rods in irradiation direction [4]. We have performed series of reflectivity, diffraction and grazing incidence small angle X-ray scattering (GISAXS) measurements of the system consisting of 20 (Ge+SiO<sub>2</sub>)/SiO<sub>2</sub> bi-layers deposited on Si(111) substrate. The purpose of the measurements was investigation of temperature dependence of structural properties of the irradiated multilayer and of the crystalline quality of the formed QDs. Therefore, the measurements were taken before after and during the in-situ annealing in vacuum in temperature range from 200-900°C. GISAXS maps of the multilayer measured during annealing treatment are shown in Fig.1. All maps taken on ML annealed below 800°C show presence of tilted Bragg sheets. The tilt angle ( $\phi_{tilt} = 90 - \phi_{irr}$ ) correspond to formation of QDs which are correlated along the irradiation direction. For annealing temperature higher than 700°C, the Bragg-

sheets are not visible in GISAXS maps showing destruction of the multilayer structure and regular QDs ordering.

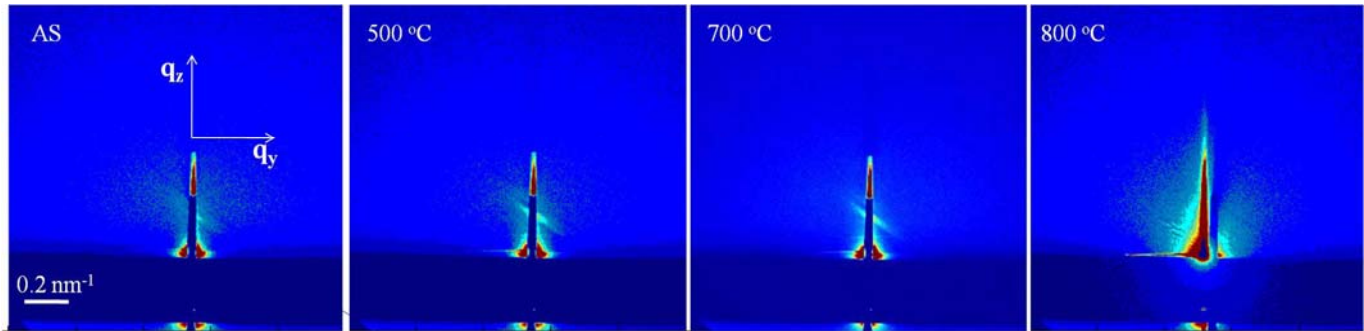


Fig.1. GISAXS maps measured on the irradiated (Ge+SiO<sub>2</sub>)/SiO<sub>2</sub> multilayer during in-situ annealing. The incident X-ray beam was set perpendicular to the plane of the irradiation.

In the following, we are going to analyze the GISAXS data. We have formulated a model describing the ordering of the QDs along the ion tracks and we are dealing with numerical fitting of the GISAXS data to this model.

- [1] M. Buljan, U.V. Desnica, G. Dražić, M. Ivanda, N. Radić, P. Dubček, K. Salamon, S. Bernstorff, V. Holy Nanotechnology **20**, 085612 (2009)
- [2] G. Springholz, V. Holy, M. Pinczolics, and G. Bauer, Science **282**, 734 (1998).
- [3] M. Buljan, U. V. Desnica, M. Ivanda, N. Radić, P. Dubček, G. Dražić, K. Salamon, S. Bernstorff, and V. Holý, Phys. Rev. B **79**, 035310 (2009).
- [4] M. Buljan, I. Bogdanović-Radović, M. Karlušić, U.V. Desnica, G. Dražić, N. Radić, P. Dubček, K. Salamon, S. Bernstorff, V. Holy Appl. Phys. Lett. **95**, 063104 (2009)