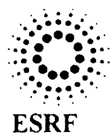

ESRF

Experiment title: Lateral ordering of self-organised Ge-dots grown on SiGe step bunch arrays studied by x-ray diffraction, reflectivity and grazing incidence diffraction	**Experiment number:** Si-347
Beamline: ID10B	**Date of experiment:** from: 24 June 1998 to: 30 June 1998	**Date of report:** 31 July 1998
Shifts: 18	**Local contact(s):** Nathalie Boudet, Detlef Smilgies	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Prof.Dr.G.Abstreiter, Technical University Munich, Garching, Germany
*Dr.T.H.Metzger, Ludwig-Maximihans Universitat, Munich, Germany
Prof.Dr.G.Bauer, Johannes Kepler Universitat Linz, Austria
Doz.Dr.V.Holy, Masaryk University, Bmo, Czech Republic
*Julian Stangl, Johannes Kepler Universitat Linz, Austria
*Ingo Kegel, Ludwig-Maximilians Universitat, Munich, Germany

Report:

The structural properties of Ge rich SiGe dots were studied by grazing incidence diffraction. The dots were grown by molecular beam epitaxy on slightly miscut (001) Si substrates (with miscut angle of 2”) on which a Si/SiGe multilayer had been deposited prior to the dot growth. The reason for the sequence of growth steps is the following: on the miscut substrate, step bunches develop during the growth of the strained Si/SiGe superlattice. The step bunches, with a typical width of about 120 nm, form a template for the subsequent growth of the Ge-rich islands. With this template the lateral dimensions of the Ge islands can be restricted. The surface morphology due to the step bunches and the surface elastic anisotropy cause some short range lateral ordering of the dots. The growth of Ge islands on templates like surfaces modulated by the presence of step bunches is a promising alternative for achieving size homogenisation and lateral ordering of quantum dots in comparison to the often used growth of dot-multilayers.

The sample studied had the following parameters: on a vicinal (001) Si surface, tilted towards the [100] direction by 2° a 20 period $Si/Si_{0.55}Ge_{0.45}$ multilayer (1 0nm/2.5nm) was grown. Finally, nominally 5 monolayers of Ge were deposited. This leads to formation of Ge islands with about 120 nm diameter: which corresponds to the terrace width. The island height is about 4 nm. By high resolution reciprocal space maps around (004), (404) and (113) reciprocal lattice points diffusely scattered intensity characteristic for dot formation was observed. At the Troika II beamline grazing incidence diffraction reciprocal space maps around the (220) reciprocal lattice points were recorded for an incident angle slightly above the critical angle. In order to observe the vertical correlation of the dot positions in the top layer and the lower lying ones the width of the Bragg sheets in the diffusely scattered intensity was measured as a function of the distance from the surface Bragg rod. Preliminary evaluation of the recorded data (the beamtime took place one month ago) shows promising results for this new technique for quantifying vertical inter-dot correlations. For future measurements we plan to extend this method to other material systems.

Since we have in mind to investigate the island growth in different semiconductor systems for a better understanding of the underlying growth processes (see long term proposal), a part of measurement time was devoted to the investigation of multilayers of pyramid shaped PbSe islands grown on (111) PbTe buffer layer, with PbEuTe layers as spacers. Atomic force microscopy images of the surface morphology revealed lateral ordering of the pyramids and a narrow size distribution. Reciprocal space maps were recorded around the (111) and (33 1) reciprocal lattice points. In Fig.2 the intensity distribution around the (331) Bragg reflection of PbTe of a 100 period multilayer is shown. Satellite peaks due to the vertical and lateral PbSe dot ordering are clearly visible, demonstrating that further investigations of this material system are promising. For the determination of the dot shape, grazing incidence small angle scattering was performed. In Fig. 3, a asymmetric pattern of side maxima, corresponding to the form factor of the pyramids is shown for a sample with only one PbSe dot layer on the surface.

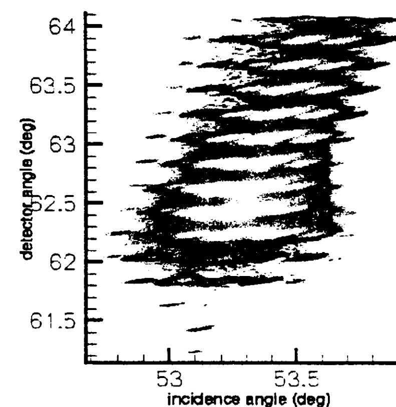

Fig 2: (331) reciprocal space map of a PbSe dot multilayer grown on (111) PbEuTe

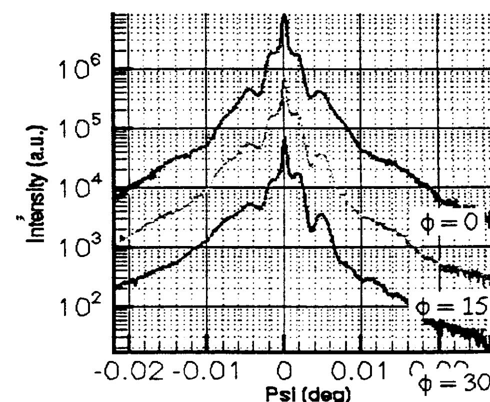

Fig. 3: GISAXS scans of a single PbSe dot layer on PbTe (111)