ROBL-CRG	Experiment title: Study of self-organized dots on the surface of implanted and annealed silicon	Experiment number: 20_02_017
Beamline: BM 20	Date of experiment: from: 21.2.99 to: 28.2.99	Date of report: 10.8.99
Shifts: 18	Local contact(s): Dr. N. Schell, F. Berberich	Received at ROBL: 12.8.99

Names and affiliations of applicants (\* indicates experimentalists):

F. Eichhorn \*, J. Sass (a), K. Mazur (a), N. Schell \* (b), F. Berberich \* (b)

Forschungszentrum Rossendorf, Institute of Ion Beam Physics and Materials Research P.O.B. 510119, D-01314 Dresden, Germany

- (a) Institute of Electronic Materials Technology, ul. W\lczy\%ka 133, PL 01-919 Warszawa, Poland
- (b) present address: ROBL-CRG at ESRF Grenoble

## **Report:**

To follow the stability of semiconductor material under non-standard conditions of treatment Si(001) wafers were implanted with 2.5x10<sup>15</sup> cm<sup>-2</sup> Ge<sup>+</sup> (E = 1 MeV, or 4 MeV) and annealed at 650 °C for 1 h. The samples were characterized by high-resolution XRD, REM and AFM, respectively. As revealed by XRD a strain gradient perpendicular to the surface is formed by the implantation process. The strain reaches values of 0.00140 after 1 MeV and 0.00116 after 4 MeV implantation. Due to subsequent thermal treatment the strains are reduced to 0.00085 and 0.00106, respectively, and lattice defects grow as indicated by the diffuse scattering. Furthermore, transverse intensity oscillations were observed in the reciprocal space map. It was confirmed by AFM and SEM that the reason for them is a self-organized system of dots on the surface. The dots are nearly cones with a bottom diameter of 360 nm and a height of 40 nm. Their mean distance is about 1.5 μm and they are preferently arranged in rows along

<110> directions. Storing the samples at mormal laboratory conditions the dots disappear after about 8 and 16 months, respectively.

The aim of the experiment is to reproduce the conditions for the growth of the dots by in-situ thermal treatment and their detection by a quick x-ray scattering method. A formerly implanted (2.5x10<sup>15</sup> cm<sup>-2</sup> Ge<sup>+</sup> of 4 MeV) and annealed (at 650 °C for 1 h) Si(001) wafer was heated in a furnace from 600 °C to 905 °C in steps of 50 °C for 20 min in each case. According to the findings above, it is expected that during this annealing procedure surface dots grow. The grazing incidence small-angle x-ray scattering (GISAXS) geometry [1], highly sensitive to mesoscopic dots at the surface, is the suitable tool to study surfaces independent on their crystalline or non-crystalline nature. At an annealing temperature of 850 °C some marks of an ordered surface structure (see Fig. 1, arrows mark fringe maxima) may be seen. From them a surface structure period of 320 nm can be calculated. At other temperatures such fringes were not be observed.

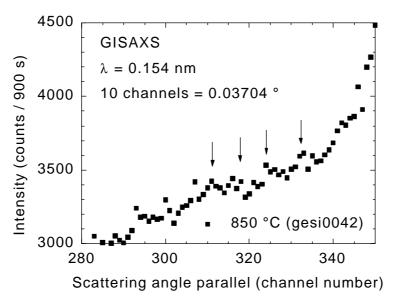


Fig. 1 GISAXS diagram of Si(001) implanted with  $2.5 \times 10^{15}$  cm<sup>-2</sup> Ge<sup>+</sup> (4 MeV) and formerly annealed at 650 °C for 1 h as-measured for an annealing temperature of 850 °C

The authors acknowledge the assistance of Dr. T. H. Metzger, Ludwig-Maximilians-Universität München, in the GISAXS measurements.

[1] T. H. Metzger, I. Kegel, R. Paniago, J. Peisl, J. Phys. D: Appl. Phys. 32 (1999) A202.