ESRF

	Experiment title: Depth resolved strain analysis at lateral nanostrutures defined by ion implantation	**Experiment number:** SI-787
Beamline: ID 10B	**Date of experiment:** from: 05.06.2002 to: 11.06.2002	**Date of report:** 26.08.2002
Shifts: 18	**Local contact(s):** O. Konovalov	*Received at ESRF:*

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Report: We report on the strain analysis of a Si-wafer which was laterally patterned by focused ion-beam implantation using either a Au (dose: $2\cdot 10^{14} cm^{-2}$) or a Ge (dose: $9\cdot 10^{14} cm^{-2}$) source. Using a focused ion beam with a diameter of about $250nm$ and an energy of $70keV$ we produced stripes with a width of almost $300nm$ building up a lateral grating with a period of $550nm$ along the [100] direction. The implanted area on the Si-wafers amounts to a size of $0.6 \times 0.6mm^2$.

The implanted ions penetrating normal to the surface into the sample produce a large number of vacancies and interstitials which are cause a local deformation of the lattice constant. Due to the interaction of the penetrating ions with the host lattice the ion beam spred off. Therefore no sharp interfaces and a strain profil changing with depth are expected.

We studied the strain distribution of the as-implanted samples by means of X-ray grazing-incidence diffraction using the multi-purpose eight-circle diffractometer at $ID10B$. To investigate depth resolved the lateral structure of the prepared grating we measured at different incidence angles (all values in the region of the critical angle) two symmetry equivalent in-plane reflections, the strain sensitive (400) and the strain insensitive ($0\bar{4}0$) reflection [1],[2].

In figure 1a are shown strain insensitive diffraction patterns of the Au implanted sample and in figure 2a the corrsponding pattern for the Ge implanted sample. These measurements are only sensitive to the material composition. Two orders of the grating peaks can be clear identified for the Au implanted sample for the Ge implanted only one grating peak can be found which implies a more sinusoidal form of the grating. The material contrast vanishes below $200nm$ for both samples.

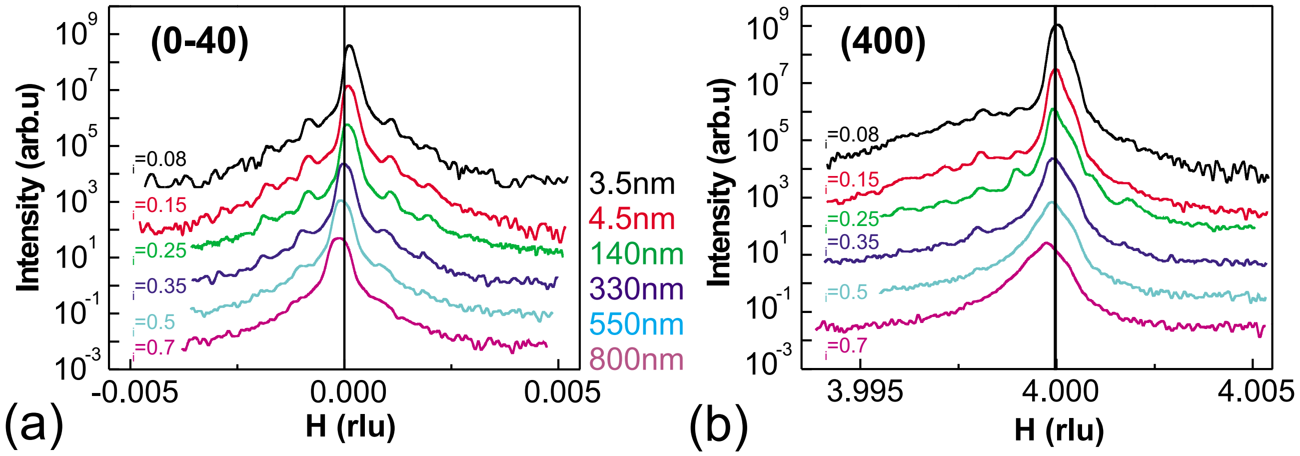

Figure 1: Strain insensitive (a) and sensitive (b) scans for the Au as-implanted sample.

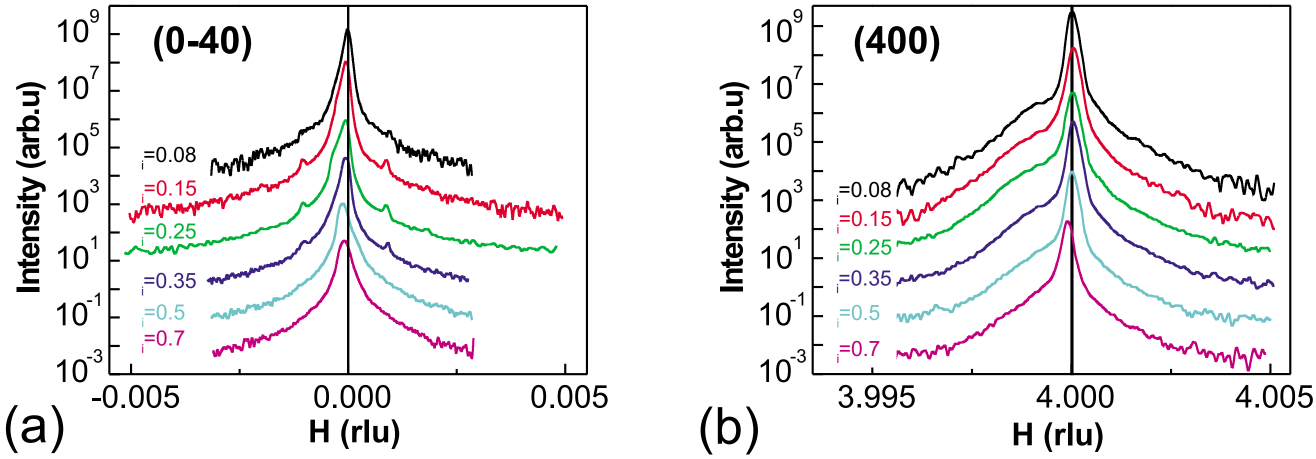

Figure 2: Strain insensitive (a) and sensitive (b) scans for the Ge as-implanted sample.

In figure 1b are shown strain sensitive diffraction patterns of the Au implanted sample and in figure 2b the corrsponding pattern for the Ge implanted sample. Whereas for the Au implanted sample a strain modulation can be clear identified we found no clear modulation for the Ge implanted sample. In both samples we found at the surface (depth: 3..5nm) a tensile residual strain corresponding to the implanted dose we found a value of $-3.5 \cdot 10^{-4}$ for Au sample and $-1 \cdot 10^{-4}$ for the Ge sample. Below a depth of 350nm the residual strain is almost zero (detection limit: $< 2 \cdot 10^{-5}$) and in the diffraction pattern of the Au sample almost no grating peaks were observed. The samples behaved different at larger penetration depths whereas the Au sample showed with increasing penetration depth a increasing FWHM of the (400) substrat reflection (from $2.1 \cdot 10^{-4}$@3nm) to $5.5 \cdot 10^{-4}$@800nm) which was acompanied by a small increase of the lateral lattice constant of about $< 0.01\%$. We found an almost constant FWHM of about $1.5 \cdot 10^{-4}$ and starting at a penetration depths of about 800nm a pronounced (due to the smaller FWHM) increase of the lateral lattice constant of about 0.015% indicating a high lattice quality of the formed surface grating.

We would like to acknowledge Dr. L.Bischoff, FZR Rossendorf, for providing the samples and O.Konovalov for the support during the measurements.

References

[1] U. Zeimer, J. Grenzer, U. Pietsch, ESRF Report SI-488 (2001).

[2] J. Grenzer, N. Darowski, U. Pietsch, A. Daniel, S. Rennon, J.P. Reithmaier, and A. Forchel, *Appl.Phys.Lett.* **77**, 4277 (2000).