ESRF	**Experiment title:** **Defect creation in polar and non-polar semiconductors by focused ion beam implantation**	**Experiment number**: SI-1243
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Report:

We report on the study of two-dimensional dot lattice structures which were produced on GaAs and Si (001) substrates using a Ga^+ focused ion beam in normal incidence with a spot size of about 50 nm, an energy of 25 keV and a dose of 10^{14} cm^{-2}. The resulting implantation depth is in the range of 18 nm for GaAs and 24 nm for Si. The fabricated 2D-lattice structures consist of dots of almost circular shape with an area of about 2000 nm^2 and a period of 250x250 nm^2. The whole implanted area has a size of less than 0.2 mm^2. We have investigated the interaction of the implanted ions with the host lattice as a function of the implantation conditions using grazing incidence diffraction at the ID1 beam line of the ESRF. High spatial resolution is achieved using an analyser in front of the detector; an x-ray energy of 8keV was used.
The diffraction patterns are much more complicated than a simple 2D quadratic dot structure. The blurring along the K-direction in the reciprocal space maps in figure 1 is caused by the way how the implanted structure is created. Measuring at two symmetry equivalent reflections allows us to separate between resolution function effects and the pure signal caused by the implantation (hollow dots in the lower diffraction pattern of fig.1). A Fourier Transformation of this idealized diffraction pattern demonstrates the influence of the non-perfect pattern generation; the created structure consists of two nested rectangular 2D lattices – one for the forward moving and one for the backward moving of the focused ion beam.

However, the diffraction patterns of both substrates differ which can not be explained by a non-perfect technology, i.e. by the use of an “imperfect implanter”. Figure 2 compares two diffraction patterns for Si and two for GaAs; the writing direction of the focused ion beam was done exactly along the $[\bar{1}10]$ direction (Si: fig.2a, GaAs: fig.2c) and by 14 degree off (Si: fig.2b, GaAs: fig.2d).
For the Si substrates (fig.2a, 2b) we found a significant diffuse (non-structured) scattering that can be explained by an increase of the over all defects due to the implantation. If the ion beam not moved exactly along [110] direction (fig. 2b) the diffuse scattering increases slightly more. The scattering pattern due to the implanted quadratic 2D dote lattice does not depend from the implantation direction. The scattering pattern for GaAs looks different. The diffuse scattering is mainly concentrated along replication direction of the meander like focused ion beam movement (see inset off the FFT in figure 1). The scattering pattern gets

strongly enhanced (in intensity and size) if the focused ion beam moved off oriented by 14° with respect to the [110] direction.

Specific interactions of the implanted ions with the different crystalline structures of the Si and GaAs crystals could be a possible explanation. A simulation taking into account the crystalline structure of GaAs shows an increase of the channelling effect into low-indexed crystallographic directions (<110>, <100>, <311>) that may be different in the case of the Si crystal (further simulations are under way). Another reason for the differences in the Si and GaAs crystals might be a site dependent defect creation in GaAs: An implanted Ga atom may act differently in the Ga and As sublattices; exchange processes where one Ga atom is substituted by an other do not change crystal quality. On the other side the implanted Ga atom should behave differently in the As sublattice; an implanted Ga atom may create easily an antiside defect.

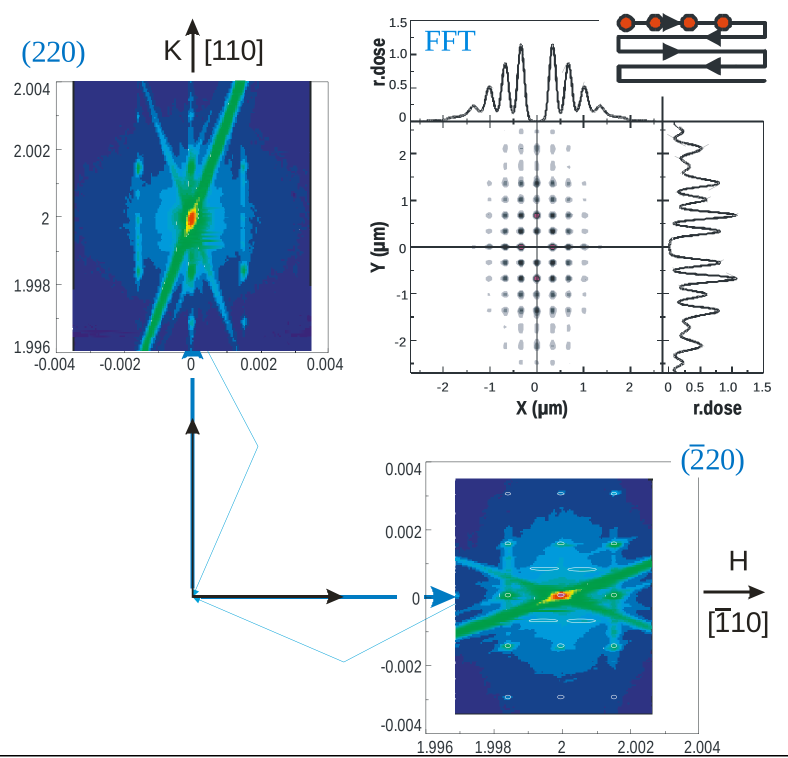

Figure 1
GID diffraction pattern of two by 90° rotated {220} reflection of a Si substrate. The diffraction pattern consists of three parts the resolution function, the reciprocal space representation of the implanted 2D structure and an almost homogenous distributed diffuse scattering background. The fast fourie transformation (FFT) of the idealized scattering pattern (white hollow dots) is shown as well. The upper right inset shows the movement of the focused ion beam.

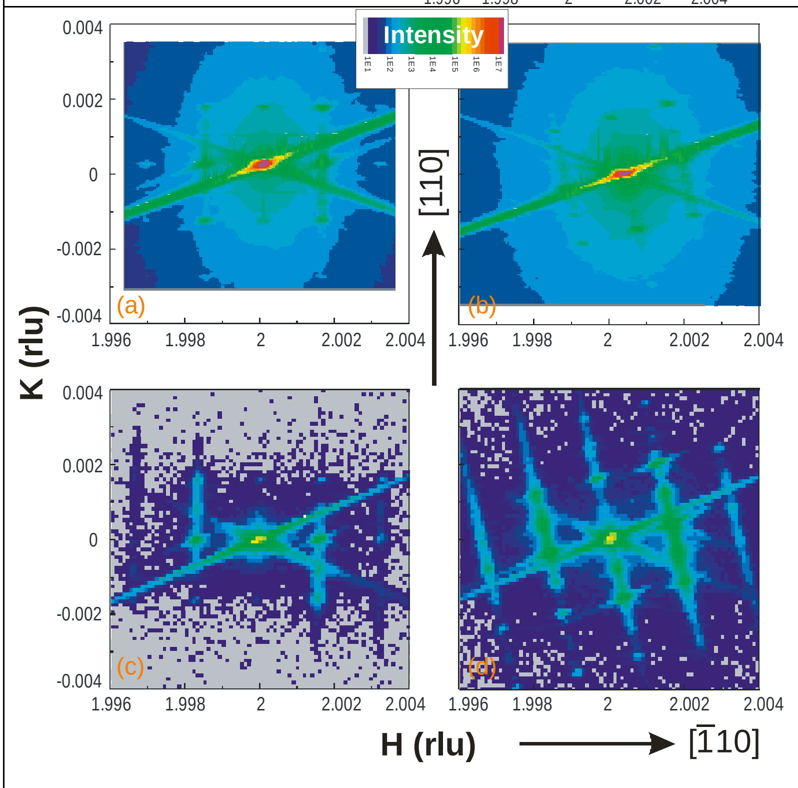

Figure 2
Comparison of the scattering patterns in Si (a, b) and GaAs (c, d) for two different implantation conditions (ion beam movement along [$\bar{1}$10] - b and by 14° off - d) The scattering pattern in Si do not depend on this parameter whereas in GaAs the scttering pattern gets stronger (d)