ESRF	**Experiment title:** X-RAY SCATTERING INVESTIGATION OF ION IRRADIATED SILICON	**Experiment number**: SI-533
Beamline: ID01	**Date of experiment**: from: 01 March 2000 to: 06 March 2000	**Date of report**: 29 August 2000 *Received at ESRF:*
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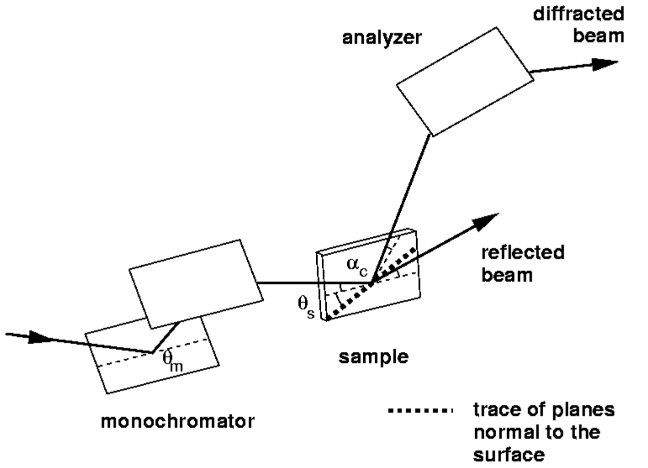
Report:

The experiments done at ID01 beamline were devoted to the investigation of silicon single crystals implanted with ions of different masses (Si, In, As). Suitable implantation energies used were to produce damaged layer thicknesses of 100-150 nm. A set of silicon samples was also implanted at ultra-low energies (0.25 – 1 keV) with 1×10^{15} B ions cm^{-2} to reduce the surface damaged thickness down to about 10 nm. The aim of the experiments was to verify whether a tickness threshold exists for the detection of sufficiently intense signal of diffuse X-ray scattering (DXS) coming from the implantation-induced defects. The relevance of these experiments is based on the fact that the size reduction of future generation silicon-based devices requires the realization of, *e.g.*, ultra-shallow p^+ source/drain implanted structures, confined well within 100 nm from the surface. These junctions will be necessary for the next CMOS technology nodes, where channel lengths of 0.15 µm in 2001 and 0.11 µm in 2005 are expected [1].

The optical geometry adopted at the beamline is sketched in Fig 1. The energy of 8 keV was selected by a pair of silicon single crystals oriented according to symmetric Bragg-case 311 reflections. A 111 single reflection silicon analyzer was placed in front of the detector and was aligned to receive the beam diffracted from {220} lattice planes perpendicular to the sample surface. The samples were oriented to receive the



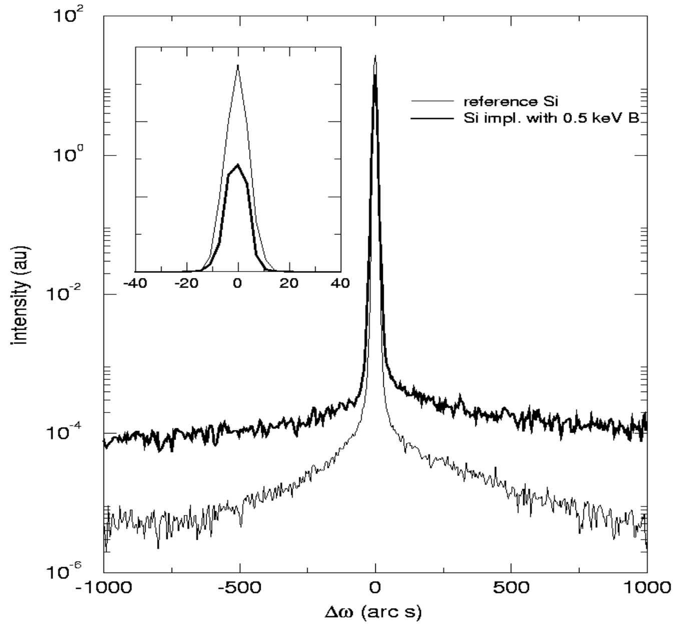


Fig. 1. Sketch of the optical geometry used at the ID01 beamline for surface diffraction.

Fig. 2. Intensity profiles obtained from {220} planes normal to the surface of a 0.5 keV B implanted Si (thick line). The profile of an unimplanted reference Si is also reported.

monochromated beam at angles near the critical one (α_c) for the total external reflection, and longitudinal scans were performed by $\Delta\omega/2\Delta\theta$ coupling of sample and analyzer. In this report we show the most interesting result obtained from one of the thinnest surface damaged layers.

In Fig. 2 we see the intensity profiles obtained from a 0.5 keV B implanted silicon and an unimplanted Si wafer taken as the reference. Both samples received the beam at the incidence angle α = 0.2 deg, somewhat smaller than α_c, which, for 8 keV X-rays, is equal to 0.223 deg. At α = 0.2 deg < α_c, the evanescent wave undergoes diffraction from a penetration depth of $\approx$10 nm. From the comparison of the profiles in Fig. 2, we observe that (i) the tail intensities of the implanted sample are higher than those of the reference sample, (ii) the high angle tail of the implanted sample is more intense than the low angle one and (iii) the intensity peak of the implanted sample is lower than that of the reference silicon (inset in Fig. 2). These findings indicate that (i) DXS from defects is sufficiently high in spite of the small thickness probed by the beam, (ii) the implant defects are of interstitial type and (iii) an atomic displacement occurs in the defect surrounding matrix, leading to a Debye-Waller factor induced reduction of the 220 structure factor.

The net DSX from defects is obtained by subtracting the tail intensities of the reference silicon from those of the implanted sample. This intensity can be elaborated according to the classical theories of DXS [2]. The symmetric part of the angular distribution of DXS is plotted in Fig. 3, which shows that the extrapolation

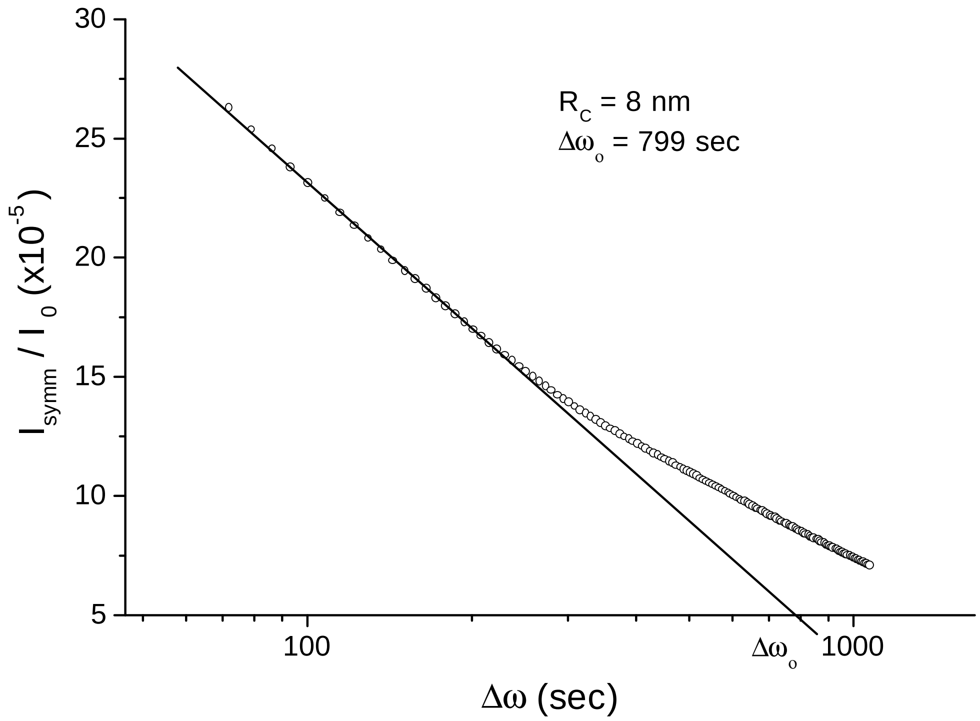


Fig. 3. Symmetric part of DXS *vs* sample rotation angle. From the intercept of the straight line on the angular axis, the cluster radius is obtained.

to zero intensity of the linear trend in the small angle region gives an intercept $\Delta\omega_o$ = 799 arc s, from which a defect cluster radius R_c = 8 nm is obtained. Though referred to the size of the cluster distortion field and not to actual cluster size, this value seems somewhat overestimated if we consider the penetration depth of X-rays and the 10 nm thickness of the implanted layer [3]. However, these preliminary measurements made on March past confirmed that investigation of implanted layers as thin as 10 nm is possible. This drew the interest of Dr. H. Metzger, new responsible of ID01 beamkine, who recently performed similar DXS measurements [4,5] on B implanted silicon at 32 keV energy, where the damaged layers were thicker than ours by more than a factor of ten. Therefore, a cooperation was agreed with Dr. Metzger and Dr. A. Mazuelas (second scientist at ID01 beamline) having further DXS experiments on ultra-low energy B implanted silicon as the objective, in the framework of a FET (Future Emerging Technologies) European Research Program, whose proposal is being submitted to EC.

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