Experimental report

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Proposal: **TEST-2984** **Council:** 4/2018

Title: Structural defects in Si single crystals

Research area:

This proposal is a new proposal

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Samples: Si

Instrument	Requested days	Allocated days	From	To
IN3	5	5	23/10/2018	25/10/2018
			24/07/2019	27/07/2019

Abstract:

Experimental Report IN3 experiment:

Background:

High-energy radiation induces clusters of point defects in solid state materials and these clusters modify material properties. For instance, indirect measurements showed that the capture cross-sections for electrons and holes become similar. A model of cluster with such property was proposed [1], and the present project aims to check, if it can apply for Si. The cluster internal structure has never been observed directly. Attempts to do it by HRTEM or using X-rays were not successful since these techniques induce cluster transformations similar to annealing or introduce additional defects.

Experiment:

For this reason, we planned to investigate the formation and annealing of Si defect clusters with the help of thermal neutron diffraction. Due to the low kinetic energy, thermal neutrons should act as a non-destructive probe to analyze the hadron generated clusters.

The experiment was performed on IN3 with incident and scattered wave vectors of k_i=k_f=2.662Å. A graphite filter was used after the sample to filter higher harmonics from the monochromator. In order to achieve best angular resolution, monochromator and analyzer were horizontally flat and 20' collimation was used before and after the sample. We only used the central analyzer blade to restrict the natural divergence further, and to avoid ambiguous signals due to scattering of several analyzer blades. With this setup we achieved an angular resolution of FWHM= $(0.22\pm0.01)^\circ$, as seen by the solid black line in Fig.1. Due to the use of an analyzer any scattering from the sample was restricted to an energetic window of $\pm$ 0.8 meV.

The sample had a cuboid shape with W x H ~ 6 x 10 mm^2 and a thickness of 4 mm. It is of the same type as used for the detectors at LHC, CERN. It was fixed into a Vanadium container and put inside a furnace.

From simulations we expected that the clusters should have 10^2 to 10^3 A size and manifest as Lorentzian tails around the central nuclear Bragg reflections (with Gaussian shape). Due to the high symmetry of Si, only few peaks were accessible in the angular range of IN3 with k_i=2.662 A^{-1}. For the temperature ramp we restricted our measurements to the most intense (111) reflection.

In a previous test time on IN3 we measured rocking curves and 2-2θ scans at room temperature on non-irradiated samples (blue points, Fig.1). The samples were irradiated in the following in the TRIGA nuclear reactor with a neutron fluence 10^{16} cm^{-2}. On one of the irradiated samples we performed rocking curves again at room temperature, 380°C and 500°C, with an annealing time of several hours at this temperature. The sample was cooled down and re-measured at RT in the following. The different rocking curves are shown in Fig.1. The centers have been shifted to correct for the lattice expansion and intensities scaled to the same monitor.

Lorentzian tails are clearly observed at all temperatures. After comparison of measured intensities at different temperatures with calculated Bose-factors for energy transfers < 1meV, we concluded that these tails are dominated by phonon scattering of the acoustic branches, which are picked up by the analyzer due to the limited energetic resolution.

Comparing of the Bragg peak halfwidth of the non-irradiated with the irradiated and annealed sample showed that the width in the non-irradiated sample of sigma=(0.1355 ± 0.0001)°, is slightly lower than the width of the irradiated sample of sigma=(0.1368 ±0.0003)°. This might be explained by a reduction of disordered region due to annealing. The difference was bigger than two standard errors.

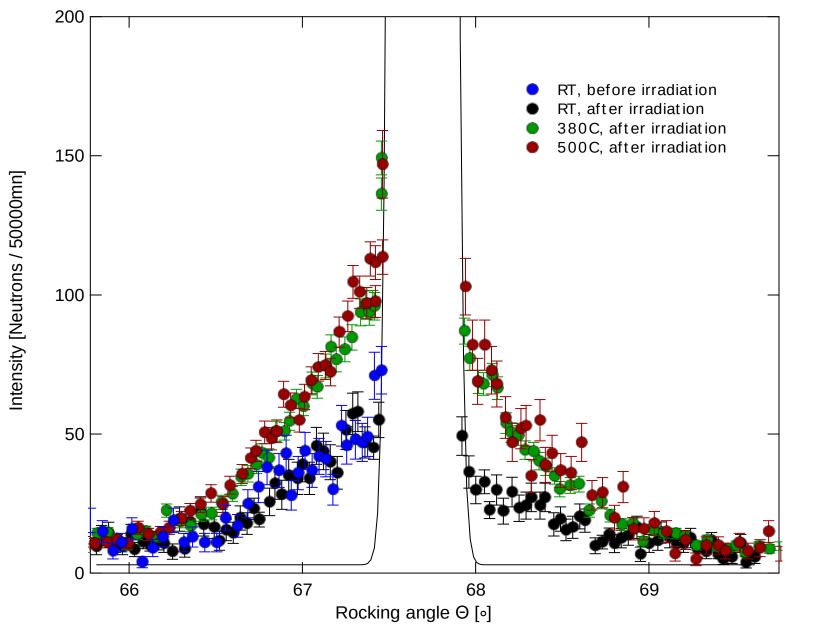

Fig.1: Rocking curve around the Si (111) reflections at different temperatures, before and after irradiation. The solid line is a Gaussian fit to the RT data (after irradiation).

Literature

[1] E.Zasinas, J.Vaitkus. 26 RD 50 Workshop, Santander, Spain.

http://www.cern.ch/rd/50/.