ESRF	**Experiment title:** **Coherent scattering from CoSi$_2$ nano wires embedded in a Si crystal** ***Structural investigations of grain growth induced by focused ion beam irradiation in thin magnetic films**	**Experiment number**: SI/1915
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Report:

We planned to investigate CoSi$_2$ nanostructures using coherent radiation. These structures are embedded in a Si matrix just below the surface. We were not able to identify a coherent scattering signal.
During the beam time another series of nanostructures created by irradiation with different fluences of Ga$^+$ ions using a focused ion beam source were investigated.
The aim of this experiment was to study the structure of magnetic metallic films after irradiation. We would like to understand the degradation of magnetic properties in terms of lattice changes due to the incorporation of Ga$^+$ ions into the permalloy during irradiation.
A 50nm thick permalloy layer (Ni$_{80}$Fe$_{20}$) irradiated with different fluences of Ga$^+$ ions was chosen for the investigations of grain size and microstrain. Previous studies have demonstrated that FIB irradiation of thin metallic films could induce significant grain growth and therefore modify magnetic properties[1-2].

Focused ion beam irradiation can be used as a tool for creation of magnetic nanostructures. In order to use FIB irradiation as a tool for nano-structuring of magnetic materials one has to solve several technological challenges. Irradiation with 30keV Ga$^+$ ions requires high doses up to 2000μC/cm^2, leading to irradiation times of about 5 up to 98 hours for the area size of 0.4x0.4mm^2. As a result due to the small irradiated areas produced by FIB irradiation XRD measurements were carried out using a 1μm focused beam.

Figure 1 shows rocking curves of the (111) permalloy reflection of samples irradiated with different ion fluences (analogous measurements that were carried out with the optimized X-ray labotratory setup with a beam size of 200μm are in a good agreement with the ones obtained with the synchron source). For our measurements we have used a line detector (position sensitive detector). As a result each rocking curve was supported by a set of 2θ values which the line detector was covering. The 2θ range covered by the line detector allows one to estimate strain by comparing the lattice parameter of irradiated and non-irradiated areas; one can also estimate the crystallite size. From the rocking curve measurements we found out that fluences up to 1000μC/cm^2 modify the material and induce the crystalline growth (from 13nm for the non-irradiated sample up to 22nm for the sample irradiated with 1000μC/cm^2), whereas larger fluences completely destroy the crystalline structure. Additionally two in-plane rotation measurements for the non-irradiated sample and for the sample irradiated with a dose of 1000μC/cm^2

were obtained as shown on figure 2 and 3 respectively. Figures 2 and 3 clearly demonstrate the texturing of the material after irradiation.

As mentioned prevously higher fluences destroy the crystalline structure. For the samples irradiated with 4000μC/cm^2 and 6000μC/cm^2 no diffraction measurements were possible. The only possibility to measure these samples was small angle X-ray scattering. On the figure 4 a sample surface scan at fixed 2θ and θ values is demontrated (2θ=2.5°, θ=1.25°). Both areas irradiated with 4000μC/cm^2 and 6000μC/cm^2 were created on the same sample. The strong peak corresponds to the reflected beam. On the right-hand side of the map one can observe the Yoneda wing (line highlighted in white), which gives the information about the surface roughness. One can see two areas with a higher intensity in contrast to other positions along the wing. These areas correspond to the irradiated ones. From this measurement one can conclude that high doses cause a strong roughening of the surface.

Our investigations let us propose two competitive processes: irradiation leads to a further material crystallization that could improve the magnetic properties, but the irradiation leads as well as to an incorporation of Ga$^+$ ions that causes degradation of the magnetic properties.

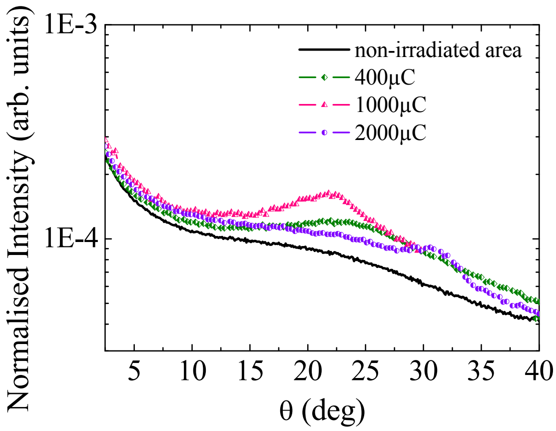

Figure 1. Rocking curves of the (111) $Ni_{80}Fe_{20}$ reflection of samples irradiated with different ion doses.

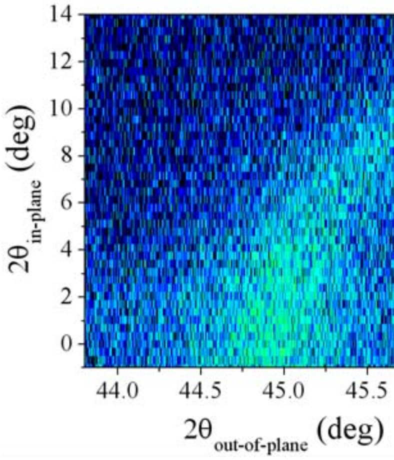

Figure 2. In-plane rotation measurement of the (111) $Ni_{80}Fe_{20}$ reflection of the non-irradiated sample.

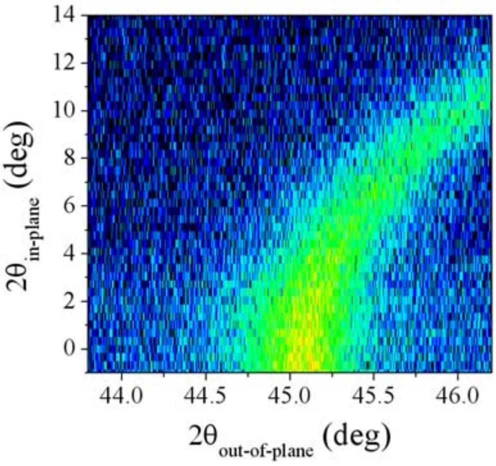

Figure 3. In-plane rotation measurement of the (111) $Ni_{80}Fe_{20}$ reflection of the sample irradiated with 1000μC/cm^2 dose.

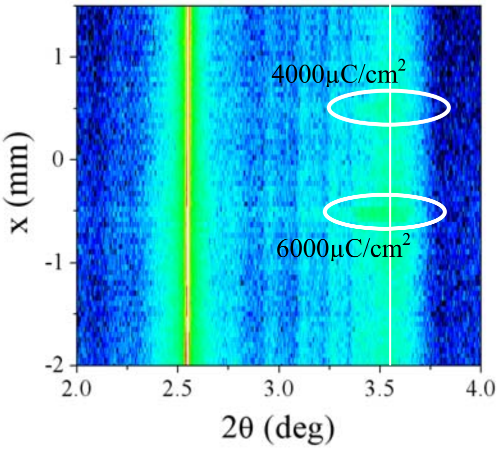

Figure 4. Sample scan at fixed 2θ=2.5° and θ=1.25° values of the sample irradiated with 4000μC/cm^2 and 6000μC/cm^2 dose.

References

[1] C.M. Park and J. A. Bain., J. of Appl. Phys. 91, 6830 (2002).
[2] W.M. Kaminsky et al., Appl. Phys. Lett. 78, 1589 (2001).
[3] O. Roshchupkina, J. Grenzer, M. Fritzsche, J. Fassbender, DPG Regensburg 2010, DS 36.2.