ESRF	**Experiment title:** *Ion beam induced atomic displacements in periodic multilayers and consequent changes in properties*	**Experiment number**: **20-02-630**
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Report:

Ion irradiation causes many interesting changes in properties of multilayered systems. In multilayers showing giant magnetoresistance and antiferromagnetic coupling, e.g. Co/Cu multilayers, ion irradiation causes significant suppression of antiferromagnetic coupling [1]. Ion irradiation induced magnetization reorientation occurs in Co/Pt multilayers [2]. Even ferromagnetic behavior can be obtained by ion irradiation of nonmagnetic multilayers like Pt/C with Fe impurities [3]. Ion beam induced atomic displacement is responsible for these changes in properties. We have developed an analytical method combining X-ray standing wave (XSW) and X-ray reflectivity (XRR) techniques [4] and successfully used the method to study ion-beam induced microstructural changes in multilayers [5].

This combined XSW-XRR method was used to study ion-beam-induced structural changes in Ni/C multilayer systems and Si/Ni/Si double layers during the beamtime.

Laterally graded Ni/C multilayers (Ni-layer thickness fixed whereas C-layer thickness varied laterally) were fabricated on float glass substrates, by ion beam sputtering. The Ni/C multilayer samples used in this study were prepared at Nagoya University. The sample specifications are: N = 15 (the number of layer-pairs in the multilayer stack), d = 3.3 nm to 4.1 nm (multilayer period, i.e. the thickness of a Ni/C layer-pair). Different parts of a large sample (30 x 70) mm^2 were cut into strips with dimensions (30 X 5) mm^2. Then the virgin samples were irradiated with 2 MeV Cu^{2+} ions by rastering the ion beam on the five samples at fluences (ions/cm2) [1A (virgin, not implanted), 2B($1x10^{14}$), 3C($3x10^{14}$), 4D($5x10^{1}$), 5E($7x10^{1}$)] at Institute of Physics, Bhubaneswar, India. For comparison only 1 half of the sample surface was irradiated. The range of 2 MeV Cu ions in such Ni/C multilayers sample is about three times larger than multilayer film thickness.

Thus the implanted Cu ions are buried deep into the glass substrate passing through the multilayer stack, which is about 55 to 60 nm thick.

One virgin and all irradiated strips were analyzed with combined X-ray standing wave and X-ray reflectivity experiments at the ROBOL beam-line using 9.0 keV monochromatized X-rays.

We have measured ion beam induced expansion in the multilayer period as a function of ion fluence. Up to a certain dose we have observed mixing between Ni and C atoms across the interfaces. At higher doses demixing effect has been pronounced. This mixing-demixing phenomenon can be explained in terms of two competitive processes including ballistic and chemically guided atomic movements.

The pristine sample exhibits an enhanced diffuse signal caused by an almost perfect roughness correlation of the layer interfaces demonstrating an almost perfect superlattice. Figure 1 shows the reciprocal space map and the specular scattering of that sample. An enhancement of the diffusely scattered intensity can be observed at the position of the second satellite if the incidence or exit angle equals the value of the first one. The change of the reflectivity signal due to ion beam implantation can be seen in figure2; thickness oscillations are suppressed; the multilayer period increases, accordingly changed the X-ray standing wave signal.

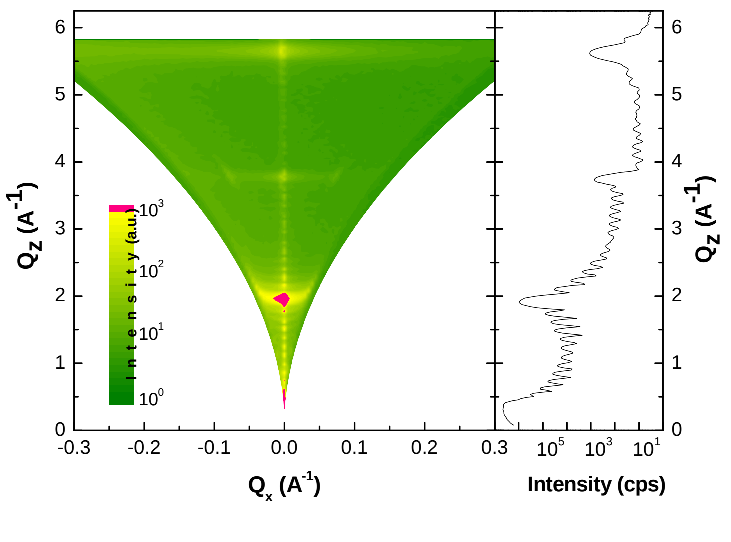

Figure 1: RSM and specular scattering of the not implanted sample

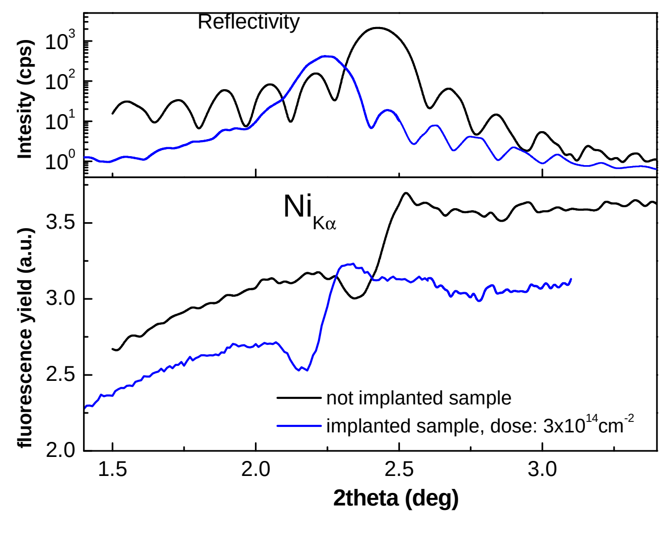

Figure2: Reflectivity and XSW signal around the first Bragg peak

References

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