ESRF	**Experiment title:** Exchange bias by implantation of N ions in Co thin films and subsequent annealing	**Experiment number**: HC-1586
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Report:

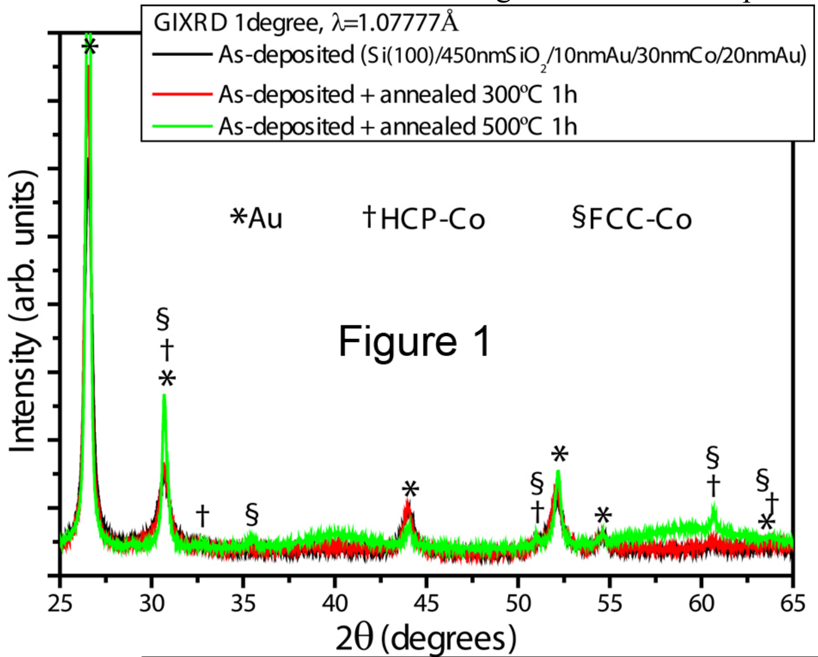
This proposal was aimed at investigating the structural evolution by synchrotron X-ray diffraction (XRD) of N-implanted Co thin films with a uniform N-depth profile as a function of the implantation fluence (i.e., amount of incorporated N) and annealing temperature.

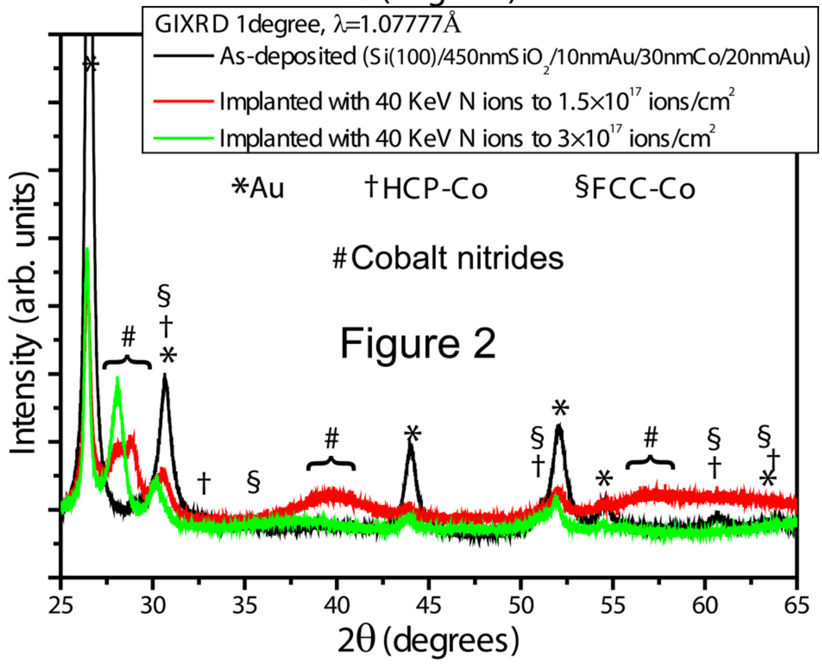
The samples were prepared by molecular beam epitaxy and consist of a Au capping layer (20 nm)/Co layer (30 nm)/Au buffer layer (10 nm)/SiO_2 (450 nm)/substrate Si (100). 40 keV N ions and fluences of 1×10^{16}, 5×10^{16}, 1×10^{17}, 1.5×10^{17}, 2×10^{17} and 3×10^{17} ions/cm^2 were used to implant the samples. Then, in order to promote thermal activation and thus atomic diffusion, the samples were annealed in vacuum (pressure < 1×10^{-8} mbar) at different temperatures, such as 300ºC or 500ºC, for 1 hour (the heating and cooling rates were set to be 5ºC/min to avoid any type of quenching related effects).

Annealing of the as-implanted samples results in low-temperature exchange bias properties which are mainly ascribed to the interfacial exchange interaction between the formed antiferromagnetic cobalt nitrides and the ferromagnetic Co matrix upon field cooling.

For this purpose, we performed room temperature synchrotron XRD with a radiation wavelength of 1.07777Å in both $\theta/2\theta$ and grazing incidence (GI) configurations for each of the samples. The used experimental conditions were the following: A 2θ angular range between 10 and 70 degrees, a step size of 0.005 degrees, a dwell time of 0.5 s/step and an incident incoming angle of 1 degree for the GIXRD measurements.

As can be seen in Figure 1, the annealing procedure at 500ºC of the as-deposited sample (Si(100)/450nmSiO_2/10nmAu/30nmCo/20nmAu) results in sharp and intense diffraction peaks, evidencing a significant crystallite growth and a pronounced structural relaxation of the Au and Co phases. Interestingly, no traces of CoO peaks are observable. Thus, within the detection limits of synchrotron XRD, we might rule out the Co/CoO interaction as the origin of the low-temperature exchange bias properties of the implanted and subsequent annealed systems.





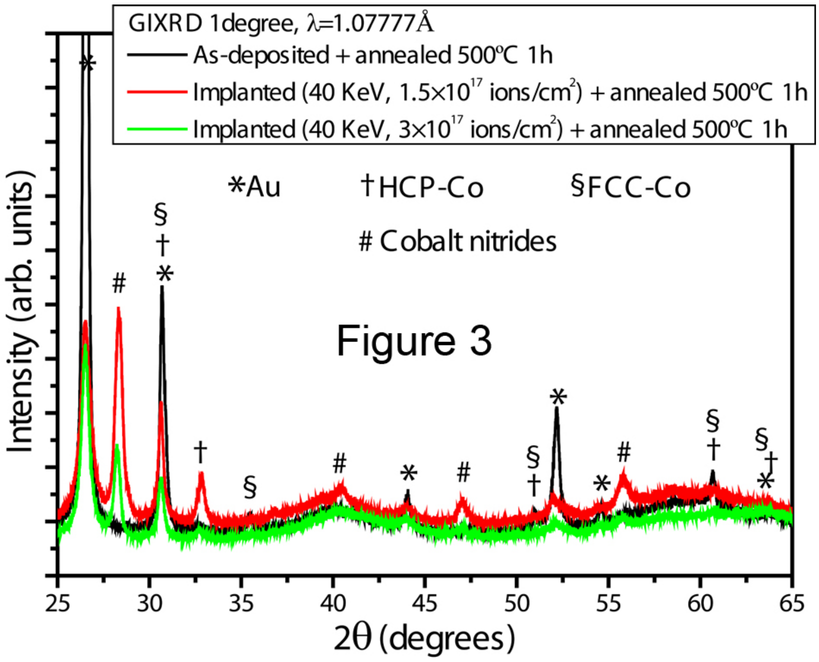


Figure 2 shows the GIXRD patterns of two as-implanted samples (1.5×10^{17} and 3×10^{17} ions/cm^2) together with the diffractogram of the as-deposited sample. The implantation leads to a pronounced reduction and a broadening of the Au peaks as a result of the structure refinement of the Au phase. The Au XRD peaks shift towards lower angles with implantation fluence, indicating a lattice cell expansion of the Au structure. Only weak traces of Co XRD peaks are visible, confirming the nanostructure character of the Co phases and their reduction in quantity due to the formation of new phases. In fact, other XRD peaks than Co and Au are also visible, suggesting the formation of N containing phases. These peaks are very broad and are consistent with a variety of cobalt nitrides. Since CoN_x can be stable in a wide range of compositions, these peaks might comprise more than one phase or certain phases with deficiencies in stoichiometry. The lack of well-defined cobalt nitrides both in structure and composition might explain why the as-implanted samples do not show exchange bias properties.

Figure 3 shows the patterns of two implanted samples (1.5×10^{17} and 3×10^{17} ions/cm^2) annealed at 500ºC. The thermal activation results in a better definition of the abovementioned cobalt nitrides peaks.

In conclusion, the preliminary interpretation of the results suggests that the low temperature exchange bias properties of the implanted and subsequently annealed samples might be ascribed to the interaction between antiferromagnetic cobalt nitrides and the Co matrix. Now, we will continue working on these results. We will also consider the possible formation of gold nitrides and we will further structurally investigate these systems by transmission electron microscopy. Moreover, we will also perform line-profile analysis of the patterns by Rietveld refinement with the aim to further shed light on the structural characteristics of the new phases formed after implantation and annealing.