ESRF	**Experiment title:** History-dependent magnetic domain structures in coupled multilayers studied by off-specular synchrotron Mössbauer reflectometry	**Experiment number**: SI-735
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Report:

In our proposal, we suggested to study the domain formation and the domain coarsening in a Fe/FeSi multilayer with a motivation to clarify the role of the magnetic structure of the spacer. In fact, in our previous experiment SI-618 [Report SI-618] it was found that the secondary domain state created in a Fe/Cr multilayer after the bulk-spin-flop transition retains up to fields well above the saturation field inferred from the field dependence of the AF reflection. We tentatively ascribed this ‘supersaturation memory effect’ to the exchange spring of the Cr spacer. If this is correct, the effect should not appear in antiferromagnetically coupled multilayers with non-magnetic spacers like B2 FeSi.

Unfortunately, we have not been able to complete the planned experiment. Although previous polarised neutron reflectometry data taken on similar Fe/FeSi samples of fourfold in-plane magnetocrystalline anisotropy [H.J. Lauter, V. Lauter-Pasyuk, private communication] showed broad diffuse scattering, i.e., small primary domains in remanence, in the present experiment we could only observe specular scattering. By careful magnetic anisotropy analysis of the Fe/FeSi sample showed an unexpected, almost uniaxial anisotropy with an axis tilted by about 20° to the MgO [100] axis. This was probably due to the special geometry, which had to be used during the MBE growth of this sample, for technical reasons. In the meanwhile, these restrictions in the MBE chamber have been removed and new Fe/FeSi multilayers with fourfold magnetic anisotropy are available.

Further elaborating our earlier studies (SI-618, [1-4]) at the ID18 of ESRF off-specular SMR was used for studying the history-dependent domain structure of antiferromagnetically coupled metallic multilayers. In the present study the domain size evolution in MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]$_{20}$ was followed as the external magnetic field is reduced from a large value and the layer magnetizations of the magnetic superlattice relax in their mostly antiparallel alignment in remanence.

The sample was placed in a superconducting split coil mounted on a one-circle goniometer at ID18. Spectra were taken at (290±1) K in various decreasing transversal magnetic fields in the range of 1T to 0, in steps of 0.1 T. The off-specular scattering was measured on the 1/2–order (antiferromagnetic) superlattice reflection at 2Θ=0.80°. At a fixed 2Θ, the number of prompt and that of the time integrated delayed photons were recorded as a function of grazing incidence angle ω in the range of 0 to 2Θ. A few selected scans are displayed in Figure 1. The off-specular scattering is plotted as a function of q_x, the longitudinal in-plane component of the scattering vector. Decreasing the field from the saturation region, the AF peak gradually appears with increasing intensity.

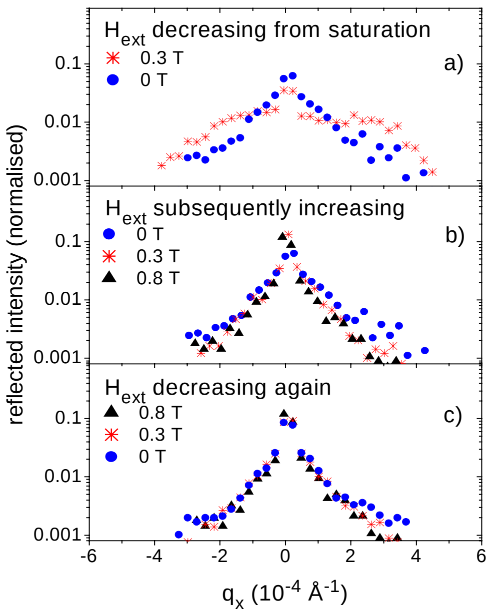

Figure 1 Off-specular SMR scans of a MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]$_{20}$ ML in external fields parallel to an easy axis. In a field of 0.3 T decreasing from saturation to remanence, the in-plane AF domain size is about ξ = 0.5 μm, which increases to ξ = 2.6 μm in remanence. No further change is observed on increasing or decreasing the field without saturating the ML again.

Down to H_{ext} = 0.4 T, no peak was observed. At H_{ext} = 0.3 T, the peak width is characteristic of an average domain size of $\xi \approx$ 500 nm. On decreasing the field to 0, the domain size increased to ξ = 2.6 μm (Fig. 1/a). (The increase of the size of certain domains at the expense of the surrounding smaller domains shows close similarities to the Ostwald ripening process in crystal growth, therefore we use the term ‘ripening’ for this type of domain evolution.) Domain ripening is an irreversible process: the average domain size no longer changes in increasing (Fig. 1/b) or decreasing field (Fig. 1/c) below saturation. Immediately after their formation, the domain size is expected to be equal to the lateral structural correlation length of the multilayer (terrace length, ≤ 50 nm). However, in remanence we observe a few μm-sized domains. The driving force of such a spontaneous change of the domain size in decreasing field is the domain-wall energy.

Whether the domains are driven to decrease or to increase in size, depends on the scaling law of the domain-wall density. For inclusions (one type of AF domain surrounded by a ‘sea’ of other type) the domain wall density scales with $\propto \xi$ (ξ is the size of the domain in consideration), therefore inclusions tend to decrease. For nested domains (e.g. a chessboard domain pattern), however, the domain wall density scales with $\propto 1/\xi$, consequently, such patterns tend to increase. Domain evolution is limited by the coercivity. This determines ξ_c, the critical domain size in remanence: $\xi_c = \frac{A_{ex}\pi^2/l + lK/4}{2\pi M \mu_0 H_c}$, with $l = (\pi/2)(A_{ex} t_{Fe}/J)^{1/2}$, A_{ex}, l, K, M, H_c, t_{Fe} and J being the exchange constant of the bulk ferromagnetic material, the domain-wall width, the magnetocrystalline anisotropy constant, the moment per unit area, the coercivity, the thickness of the individual magnetic layers and the interlayer coupling, respectively. Using the parameters of the particular film, 2 Oe < H_c < 30 Oe corresponds to 0.6 μm < ξ_c < 8.4 μm. Evaluation of the results is in progress [5].

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