ESRF	**Experiment title:** Antiferromagnetic domain structure transformations in magnetic multilayers by Synchrotron Mössbauer Reflectometry	**Experiment number**: SI-962
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Report:

In subsequent experiments previously performed at ID18 we have measured SMR ω-scans of an MgO(001)/[^{57}Fe(26Å)/ Cr(13Å)]$_{20}$ multilayer (ML) at the antiferromagnetic (AF) reflections in order to probe the correlation length parallel to the scattering vector q_x. The following cases were examined:

a) releasing the magnetic field (along either the in-plane easy or hard axis) from saturation to remanence (‘domain ripening’ (DR) leading from the native domain state (NDS) to the SDS) [1,2], and

b) increasing the field from zero to a relatively small value, H_{BSF}, parallel to the easy axis in which the layer magnetizations had previously been aligned (domain coarsening (DC) on bulk spin-flop, (BSF) leading from the SDS to a large domain state (LDS)) [3,4]. We have shown [2,3,5] that the anisotropy plays an important role in the domain transformation. The average patch domain size after DR was interpreted through a simple model, which fits the experimental data rather well [2]. DR is a domain-wall-energy-driven process limited by the coercivity of the Fe layers the latter acting as a ‘friction’ against the movement of the plane-perpendicular domain walls.

The DR, i.e., the spontaneous irreversible growth of the domain size while the field is decreasing from saturation turned out to result in a sudden change of the shape of the off-specular peak [6]. Indeed, the shape of the off-specular peak was Gaussian above the DR and exponential below it. Consequently, the autocorrelation function of the magnetisation is Gaussian and Lorentzian above and below the DR, respectively.A spontaneous domain coarsening induced by a 45° spin flop was observed.

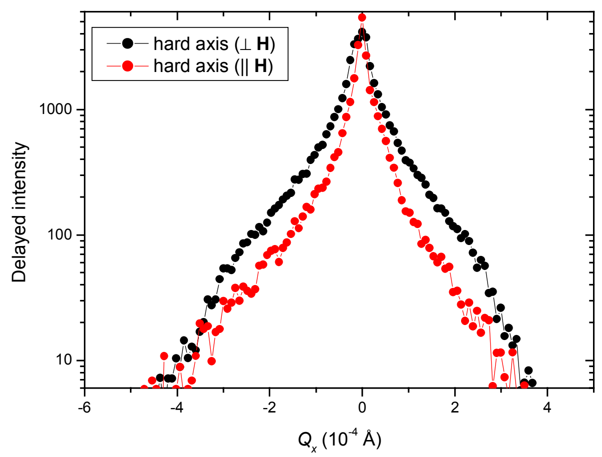

Fig. 1 Observed narrower and wider SMR ω-scans (smaller width corresponding to larger in-plane domains and *vice versa*) in the same state of the MgO(001)/[^{57}Fe(26Å)/ Cr(13Å)]$_{20}$ superlattice measured in zero external field parallel and perpendicular to the direction of the hard axis field last seen by the sample. For explanation see text.

Both DC [4] and DR [6] can be used to study the fascinating 'supersaturation domain memory effect' (SDME). We found on the Fe/Cr ML, that the LDS of Fe retained up to well above the saturation field $H_S \approx 1.0$ T inferred from either the magnetization and Kerr loops or from the field dependence of the SMR AF peak intensity. In fact, at room temperature the native domains only retained in a field as high as $H_{SS} = 1.30$ T. The effect was tentatively ascribed to the exchange spring of the atomic AF Cr spacer.

Two specific problems related to the AF domain structure were addressed in the present experiment:

1) observation of the Rührig state [7] and
2) clarifying the role of Cr magnetism in the SDME.

1. The MgO(001)/[Fe(2.6nm)/Cr(1.3nm)]$_{20}$ anti-ferromagnetically (AF) coupled epitaxial superlattice (SL) sample of four-fold in-plane crystal anisotropy was carefully magnetized in exact hard direction. Preparation and adjustment was made in the home laboratory using Mössbauer polarimetry.

The resulting domain structure in remanence, first described by Rührig et al. [7] consists of four kinds of small domains of mutually perpendicular magnetization along the easy directions. The small domains assemble in large groups so that the net magnetization of the large groups is parallel or antiparallel to the field seen by the SL, i.e., a coarsening in the field-parallel magnetization takes place while in the perpendicular direction small domains are seen. The observed difference in the diffuse scattering widths in the two perpendicular hard directions in Fig. 1 supports the formation of this peculiar "Rührig state".

2. The role of Cr magnetism in SDME found a strong support in the present experiment. Indeed, as shown in Fig. 2., the size of the SDME significantly increased when the temperature was decreased to T = 15 K (H_S =1.55 T, 2.50 T < H_{SS} < 4.07 T along the easy direction), a fact supporting the role of the Cr spacer magnetization. Besides, as seen in Fig. 2., the Gaussian shape of the diffuse scattering peak retained in remanence, i.e., no DR took place at this low temperature, probably a consequence of the temperature dependence of the Fe layer coercivity (in a fully compensated ML there is no way to measure this latter quantity by magnetometry). Unfortunately, in course of that experiment no time was left for investigating the temperature dependence of either the supersaturation field H_{SS} or the DR. However, the knowledge of these data is imperative for checking the exchange-spring model of the SDME and of the coercivity-limited domain-wall-motion model of the DR.

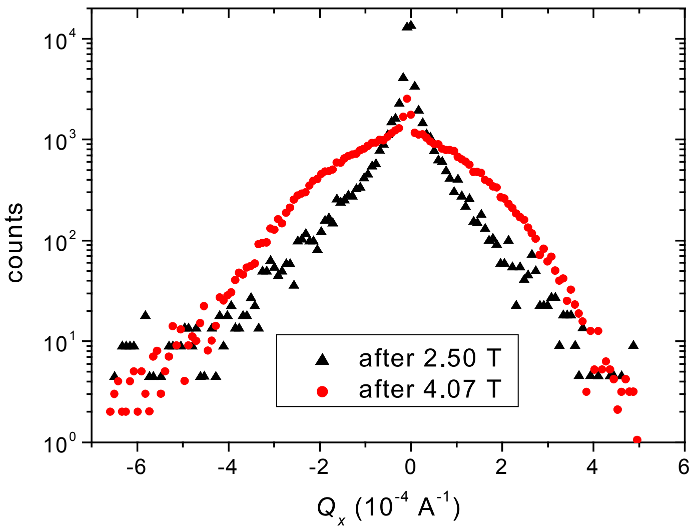

Fig. 2. Change of the shape of the SMR ω-scans in an MgO(001)/[^{57}Fe(26Å)/ Cr(13Å)]$_{20}$ multilayer at T = 15 K after releasing the external field from 2.50 T and 4.07 T applied along an easy direction. Previously the sample passed the bulk-spin-flop-induced domain coarsening. The saturation magnetic field of the sample inferred from magnetization data is H_S = 1.0 T.

References

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