ESRF	**Experiment title:** **Observation of the Coarsening of Antiferromagnetic Domains in a Magnetic Superlattice by Synchrotron Mössbauer Reflectrometry**	**Experiment number**: SI-618
Beamline: ID18	**Date of experiment**: from: 06.12.00 to: 09.12.00	**Date of report**: 28.02.01
Shifts: 9 shifts	**Local contact(s)**: R. Rüffer, O. Leupold	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

Name: **László BOTTYÁN*, Márton MAJOR*, Dénes Lajos NAGY***
Address: KFKI Research Institute for Particle and Nuclear Physics,
P.O. Box 49, H-1525 Budapest, Hungary

Name: **Guido LANGOUCHE, Johan MEERSSCHAUT,**
Address: Instituut voor Kern- en Stralingsfysica, Katholieke Universiteit Leuven,
Celestijnenlaan 200D, B-3001 Leuven, Belgium

Name: **Olaf LEUPOLD*** (also local contact)
Address: Nuclear Resonance Group, ESRF, BP 220, F-38043
GRENOBLE CEDEX, France

Report:

As a further step towards better understanding spin-flop, finite stacking and domain transformation phenomena in antiferromagnetically (AF) coupled multilayers by Synchrotron Mössbauer Reflectrometry (SMR), a project referred to as 'Direct Observation of Surface Spin Flop Transitions in Magnetic Superlattices', we used off-specular SMR to study how spin-flop phenomena influence the domain structure in a MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]$_{20}$ superlattice.

The sample was placed in the variable temperature insert of a superconducting split-coil cryostat which was mounted on a one-circle goniometer. All spectra were taken at (290±2) K and in zero magnetic field after the magnetic field history as described below. The off-specular scattering was measured on the first order AF reflection at an angle of $2\Theta = 0.80°$. The number of prompt photons from electronic scattering and the time integrated number of delayed photons from the nuclear resonant scattering process were recorded as a function of the angle of grazing incidence ω in the range from 0 to 2Θ. The off-specular scattering is shown in Fig. 1 as a function of the longitudinal in-plane component q_x of the scattering vector.

First the sample was saturated along the Fe[100] easy direction by an external field of 4.07 T. The photon wave vector **k** was perpendicular to the [100] easy direction such that after switching off the magnetic field the layer magnetisation was in the [010] easy direction, i.e., parallel/antiparallel to **k**. The specular reflection appeared on the prompt reflectivity scan (Fig. 1A). However, no specular reflection but a broad diffuse shoulder was observed on the SMR ω-scan (Fig. 1B). The sample was rotated by 90° so that the magnetisation was perpendicular to **k** and the AF reflection disappeared. Having applied an increasing magnetic field along the [010] easy direction, i.e., perpendicular to **k**, the intensity of the AF reflection recovered in the range of 12–16 mT indicating the spin flop. Fig. 1C shows two ω scans taken in mutually perpendicular orientations of the sample following an exposure to 13 mT, i.e., in the state of a partial spin-flop. While the not-yet-flipped part shows the broad diffuse shoulder only, a strong specular scattering is observed on the flipped part. On completely passing the spin-flop transition, i.e. after an exposure to 35 mT, the ω scan is dominated by the specular scattering (Fig. 1D). Finally, following a repeated exposure to 4.07 T the ω-scans became identical with that shown in Fig. 1B i.e., the specular reflection again disappeared from the SMR ω-scan.

The pure diffuse delayed reflectivity in Fig. 1B shows that a small domain state (SDS) is formed on decreasing the external magnetic field and is retained in zero field. The correlation length ξ of the AF domains can be estimated from the width of the diffuse shoulders. Supposing an exponential autocorrelation function for the domain magnetisation, $\xi \approx 2.6$ μm is deduced from the broad diffuse SMR shoulders, i.e. in the SDS. The presence of a narrow specular reflection after passing the spin-flop transition shows the appearance of large domains. In this large-domain state (LDS) only a lower limit for ξ ($\xi > 16.5$ μm) can be given, due to the finite angular resolution of 2Θ.

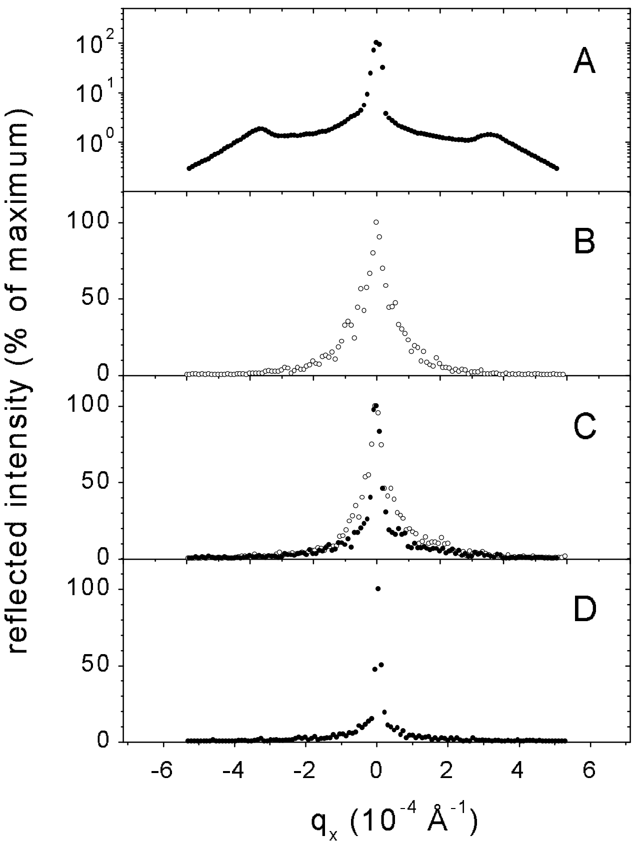

Fig. 1. Off-specular prompt X-ray and SMR scans plotted vs. the scattering vector component q_x of a MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]$_{20}$ multilayer at the AF Bragg-reflection (Θ = 0.4°) measured in zero external magnetic field: A) prompt reflectivity which does not depend on magnetic field history, B–D) delayed reflectivity, B) following saturation in 4.07 T, C) following exposure to 13 mT parallel to the magnetisation (open circles: non-flipped domains, full circles: flipped domains), D) following exposure to 35 mT.

One would expect that the SDS develops when decreasing the field from all values above the saturation field. This is not the case. It was found that the LDS retains up to fields well above the saturation field of 0.9 T as inferred from the magnetic field dependence of the AF reflection. The SDS only recovers in 1.35 T. This ‘supersaturation memory effect’ needs further investigations.

In conclusion, we observed the magnetic-field-history dependent AF domain structure of a coupled Fe/Cr superlattice by off-specular SMR. It was found that releasing the field from full saturation in an easy direction results in a SDS. However, large size patch domains are formed from these primary small domains on passing the spin-flop transition. This gives a new insight into the nature of the domain coarsening transition by showing that its condition is not the equilibrium of the Zeeman energy with the domain wall energy, but *the equilibrium of the Zeeman energy with the anisotropy energy*. It is only this equilibrium that permits the much smaller domain wall energy to shape the domain structure. Out of this equilibrium the Zeeman energy or the anisotropy energy whichever is greater will stabilise the already existing domain structure.

Reference

D.L. Nagy, L. Bottyán, B. Croonenborghs, L. Deák, B. Degroote, J. Dekoster, H.J. Lauter, V. Lauter-Pasyuk, O. Leupold, M. Major, J. Meersschaut, O. Nikonov, A. Petrenko, R. Rüffer, H. Spiering, E. Szilágyi, submitted for publication