ESRF	**Experiment title:** Spin-flop and related domain structure evolution in magnetic superlattices by Synchrotron Mössbauer Reflectometry	**Experiment number**: SI-847
Beam line: ID18	**Date of experiment**: from: 19.02.03. to: 24.02.03.	**Date of report**: 28.02.03
Shifts: 15	Local contact(s)**: Rudolf Rüffer**	*Received at ESRF:*

Names and affiliations of applicants (* indicates experimentalists):

László Bottyán*, László Deák, Márton Major, Dénes Lajos Nagy*, Edit Szilágyi*, KFKI Research Institute for Particle and Nuclear Physics, P. O. Box 49, H-1525 Budapest, Hungary

Bart Croonenborghs*[1], Veerle Vanhoof*[1], André Vantomme[1], Kristiaan Temst[2], [1]Instituut voor Kern- en Stralingsfysica / [2]Lab. Vaste-stoffysica en Magnetisme, Katholieke Univ., Celestijnenlaan 200D, B-3001 Leuven, Belgium

Olaf Leupold, ESRF, BP 220, F-38043 Grenoble Cedex, France

Report:

In our proposal, we suggested to study the "supersaturation memory effect" observed in our previous experiment SI-618 [1] in a Fe/Cr multilayer (ML). Indeed, it was found that the secondary (large) domain state created in a Fe/Cr ML after the bulk-spin-flop transition retains up to fields well above the saturation field inferred from the field dependence of the AF reflection. The effect was tentatively ascribed to the exchange spring of the Cr spacer. Two possible experimental approaches to support this reasoning are: a) to perform analogous studies on antiferromagnetically (AF) coupled MLs with non-magnetic spacers like B2 FeSi and b) to destroy or to change the magnetic properties of the Cr spacer in an Fe/Cr ML by changing the temperature.

Furthermore, we suggested to observe the spontaneous spin-flop-induced coarsening of AF domains after the domain ripening, the latter being the spontaneous, pinning-limited spontaneous growth of the domain size in decreasing field [2]. Such a coarsening is expected a) in MLs with uniaxial magnetic anisotropy, in decreasing magnetic fields parallel to the easy axis and b) in MLs with fourfold magnetic anisotropy, in decreasing magnetic fields parallel to the hard axis.

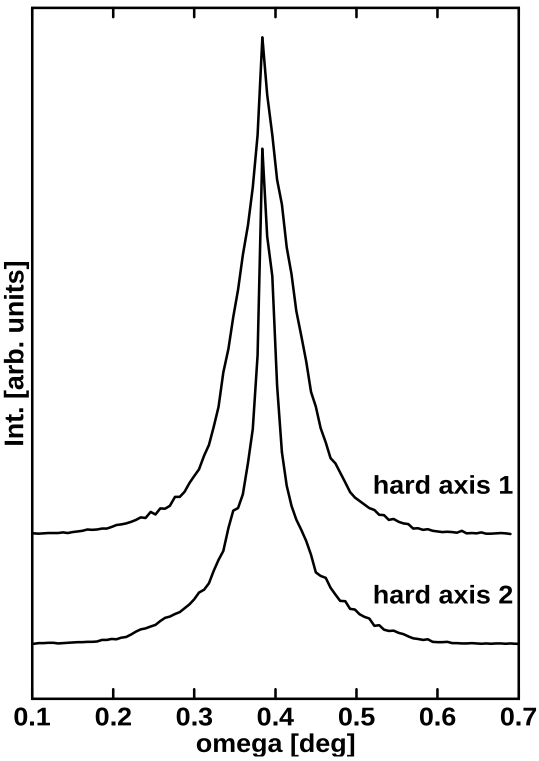

Figure 1. Off-specular SMR scans of a $MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]_{20}$ ML at remanence measured along two perpendicular hard directions after releasing a saturating external magnetic field applied parallel to hard axis 1. Note the significant difference in the width of the diffuse peaks.

Unfortunately, two unexpected experimental problems prevented us from performing the originally planned experiments supporting the exchange-spring model of the "supersaturation memory effect". First, although the Fe/FeSi ML showed a pronounced AF Bragg peak and also diffuse scattering due to small domains could be observed at this reflection, for so far unclear reasons, we have not been able to observe a spin-flop-induced domain coarsening in this sample. Second, due to a failure in the cryogenic system of the variable temperature insert of the cryostat "George" on the ID18 beamline, it turned out to be impossible to perform any of the planned temperature-dependent measurements this time.

Nevertheless, we performed detailed Synchrotron Mössbauer Reflectometry (SMR) studies on an MgO(001)[^{57}Fe(26Å)/Cr(13Å)]$_{20}$ ML that had been extensively investigated, under different experimental conditions, in previous SMR experiments [1–6]. We obtained new and strong support of the existence of the "supersaturation memory effect" and of its independence on the magnetisation of the Fe layers. Furthermore, we observed for the first time the spontaneous spin-flop-induced domain coarsening in decreasing magnetic field along the hard magnetic axis of a coupled ML of fourfold magnetic anisotropy.

The sample was placed at horizontal position in the superconducting split coil of the cryostat George mounted on a tilt stage at ID18. Around the vertical axis, the sample was manually oriented with an accuracy and reproducibility of about 1° making use of laser light reflection on a mirror attached to the sample rod. $\Theta/2\Theta$- and ω-scans were taken at 300 K in various transversal magnetic fields or in remanence. The off-specular scattering was measured on the 1/2-order (AF) superlattice reflection at $2\Theta=0.78°$.

The spontaneous domain coarsening induced by a 45° spin flop is shown in Fig. 1. This peculiar structure, first described by Rührig et al. [7] consists of small domains masked by large ones of mutually perpendicular magnetisation of the two kinds of domains so that (with respect to the original field direction) parallel and perpendicular large and small domains are seen, respectively. The observed difference in the diffuse scattering width supports the formation of the "Rührig state".

The "supersaturation" in the easy direction was observed [1] between the easy-direction saturation field of 0.85 T and 1.35 T where the primary small-domain state recovered. In the hard direction an increased saturation field 1.05 T was found (no AF reflection was observed above this field value) followed by a "supersaturation" region up to 1.35 T where the small-domain state recovered (cf. Fig. 2). Note that in the hard direction the domain ripening rather than the domain coarsening was used to detect the field value where the small-domain state recovered. The same values of the "supersaturation" fields in the easy and hard directions of different saturation field values supports the existence of the domain memory effect above the saturation of the Fe-layer magnetizations.

In addition, we have determined the magnetic-field dependence of the AF reflection and the average domain size as a function of the decreasing external magnetic field (ripening) in the hard direction.

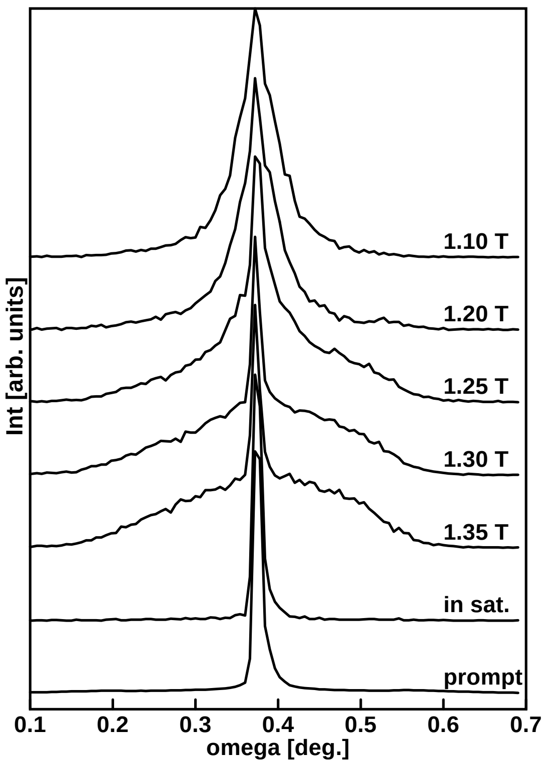

Figure 2. Off-specular SMR scans of an MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]$_{20}$ ML measured along one of the hard directions. A magnetic field was applied along the perpendicular hard axis. The upper five scans were measured in H_{ext} = 0.5 T released from the value indicated in the figure. The two lower scans show the residual delayed and prompt reflectivity in magnetic saturation, respectively.

References

1. Report SI-618.
2. Report SI-735.
3. D.L Nagy, L. Bottyán, L. Deák, M. Major, Acta Phys. Polon. A **100,** 669 (2001).
4. 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, Phys. Rev. Lett. **88,** 157202 (2002).
5. D.L. Nagy, L. Bottyán, L. Deák, B. Degroote, J. Dekoster, O. Leupold, M. Major, J. Meersschaut, R. Rüffer, E. Szilágyi, A. Vantomme, Hyp. Int. **141/142,** 459 (2002).
6. D.L. Nagy, L. Bottyán, L. Deák, B. Degroote, O. Leupold, M. Major, J. Meersschaut, R. Rüffer, E. Szilágyi, J. Swerts, K. Temst, A. Vantomme, Phys. Stat. Sol. A **189,** 591 (2002).
7. M. Rührig, R. Schäfer, A. Hubert, R. Mosler, J.A. Wolf, S. Demokritov, P. Grünberg, Phys. Stat. Sol. A **125**, 635 (1991).