Coarsening of Antiferromagnetic Domains: the Key Role of Magneto-crystalline Anisotropy[1]

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Experimental and theoretical study of the magnetic domain structure of an antiferromagneticaly coupled MgO(001)/[^{57}Fe(26 Å)/Cr(13 Å)]$_{20}$ superlattice is presented [1]. Synchrotron Mössbauer reflectometric (SMR) and polarized neutron reflectometric (PNR) maps show micrometer-size (2.6 μm) primary domain formation as the external field decreases from full saturation ($H \gg H_{\mathrm{sat}} \approx 0.9\,\mathrm{T}$). From this primary domain state a secondary domain state forms with majority presence of (order of magnitude) larger[2] (> 16.5 μm) and minority presence of smaller (2.6 μm) domains when passing a spin-flop transition[3] ($H_{\mathrm{sf}} = 13\,\mathrm{mT}$) from field-parallel to field-perpendicular direction. This domain coarsening is illustrated on Fig. 1 and Fig. 2 cited from [1].

A simple two dimensional Monte-Carlo calculation is presented in [2] on the transition from primary domain state to secondary domain state of the multilayter. By applying simple first neighbour domain formation rules both the primary and the secondary AF domain formation can be followed with results being in fair accordance to already available Kerr-microscopic results on Fe/Cr trilayers [3].

The presented model in accordance with the PNR and SMR measurements gives a new insight into the nature of the domain transformation and lifts a controversy in the literature by showing that the condition for domain coarsening 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 minute AF domain-wall energy to shape the domain structure. Out of this equilibrium the Zeeman energy or the anisotropy energy whichever is greater stabilizes the actual domain structure.

References

[1] D. L. Nagy *et al.*, submitted to Phys. Rev. Lett (May 29, 2001)

[2] M. Major, L. Bottyán, D. L. Nagy, to be published

[3] M. Rührig *et al.*, Phys. Status Solidi A **125**, 635 (1991)

[4] K. Temst *et al.*, Physica B **276–278** , 684 (2000)

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[1] A shortened preprint of a paper submitted to Phys. Rev. Lett. [1].

[2] Due to the finite experimental resolution only a lower limit can be given.

[3] In remanence, the magnetization vectors of the Fe layers in an antiferromagnetically coupled superlattice with fourfold in-plane anisotropy point in an easy direction (Fe{010} or Fe{100}). Releasing the external field from saturation along an easy axis, the magnetizations settle solely in the perpendicular easy direction. As observed by PNR [4] and SMR [5], an irreversible spin-flop transition takes place when a moderate magnetic field is applied within the easy axis in which the layer magnetizations actually lay. At a given spin-flop field H_{sf}, the layer magnetizations jump into the perpendicular easy axis. This alignment is retained in remanence and on further field cycles until the sample is turned with the magnetizations parallel to the field.

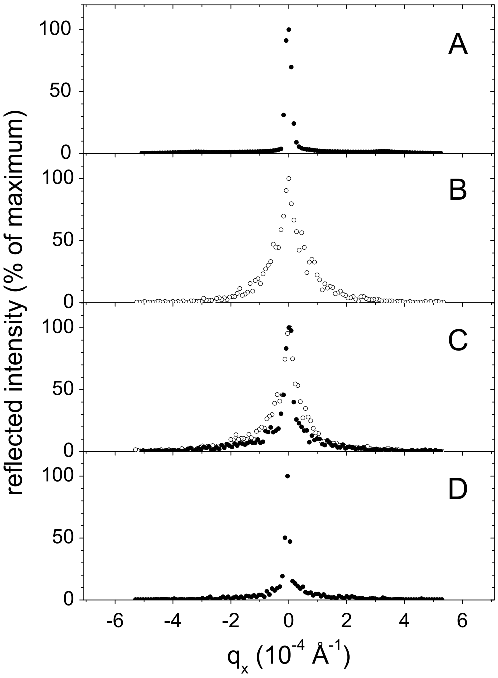

Figure 1: Off-specular prompt X-ray and SMR ω-scans. Reflected intensity vs. scattering vector component $q_x = 2k\Theta\,(\omega - \Theta)$ of a $\mathrm{MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]_{20}}$ multilayer at the AF Bragg-reflection ($\Theta = 0.4°$) measured in zero external magnetic field: A) prompt reflectivity, not being dependent on magnetic field prehistory, B–D) delayed reflectivity, B) following saturation in 4.07 T, C) following exposure to 13 mT parallel to the magnetizations (open circles: non-flipped domains, full circles: flipped domains), D) following exposure to a field of 35 mT.

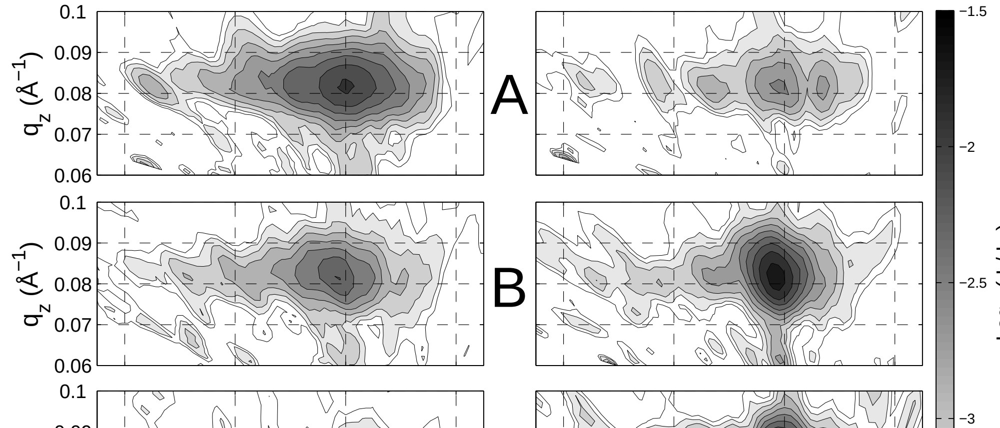

Figure 2: Normalized neutron reflectivity maps. Polarized neutron intensity scattered specularly and off-specularly by a $\mathrm{MgO(001)/[^{57}Fe(26Å)/Cr(13Å)]_{20}}$ multilayer in a magnetic field of A) 7 mT, B) 14.2 mT and C) 35 mT in R^{--} (left side) and in R^{-+} (right side) channels as a function of the scattering vector components q_x and q_z.