L-09

FORMATION AND TRANSFORMATION OF DOMAINS IN ANTIFERROMAGNETICALLY COUPLED MULTILAYERS

D.L. Nagy

KFKI Research Institute for Particle and Nuclear Physics, P.O.B. 49, H–1525 Budapest, Hungary

Antiferromagnetically (AF) coupled metallic multilayers (ML) have received much attention in recent years due to their relevance in fundamental science and magnetic recording technology alike. Both their plane-perpendicular and lateral magnetic structure can be efficiently studied by two closely related nuclear scattering techniques, viz. synchrotron Mössbauer reflectometry (SMR) and polarised neutron reflectometry (PNR). Here we present SMR and PNR studies of the magnetic-field-history-dependent formation and transformation of magnetic domains in a strongly AF-coupled epitaxial ML.

The orientation of the magnetisation of the ferromagnetic layers can be measured to a high accuracy by the specular intensity of the AF reflections. The room-temperature saturation field of the MgO(001)/[^{57}Fe(2.6 nm)/Cr(1.3 nm)]$_{20}$ ML of fourfold in-plane anisotropy was found to be H_S = 0.85 T and 1.05 T along the easy and hard axes, respectively. A bulk-spin-flop (BSF) transition took place when a magnetic field of 14 mT was applied along the easy axis in which the layer magnetisations actually lay [1]. The electronically forbidden AF reflections in specular SMR fully appeared or completely disappeared during the BSF transition [2]. In case of specular PNR, the AF reflection moved from the spin-flip to the non-spin-flip channel on BSF transition or vice versa [1,3].

The off-specular (diffuse) reflectivity probes the in-plane component q_x of the scattering vector and, consequently, reveals the in-plane correlation length of the scattering amplitude. In the first (kinematical) approximation, the q_x-scan width Δq_x at the AF Bragg peak (*i.e.*, at fixed q_z) is equal to the inverse of the in-plane correlation length ξ of the magnetisation, i.e., the 'size' of the AF domains: $\Delta q_x = 1/\xi$. Starting with a strongly AF-coupled ML in magnetic saturation and then gradually decreasing the field, two kinds of AF patch domains differing only in the sense of rotation of the magnetisation in their odd and even layers are spontaneously formed. On further decreasing the field and, thereby, increasing the domain-wall angle, the size of the domains is expected to spontaneously increase in order to decrease the domain-wall energy per unit area of the ML [4]. We observed this *domain ripening* both with SMR and PNR. At room temperature, irrespective of whether the field was applied along the easy or the hard magnetic axis, the native domain size of ξ = 370 nm did not change down to 200 mT while it spontaneously increased to ξ = 800 nm between 200 and 100 mT. No further increase of ξ was found down to remanence. The domain ripening was found to be an irreversible process (up to saturation) and was also followed by a characteristic change in the shape of the autocorrelation function of the magnetisation from Gaussian to Lorentzian. No ripening took place at T = 15 K, probably a consequence of the temperature dependence of the coercivity.

A dramatic increase of ξ from 800 nm to at least 5 μm, *i.e.*, a *coarsening* of the AF domains was observed in the same multilayer [3] both with SMR and with PNR when it passed the BSF transition provided that the external magnetic field was previously decreased from magnetic saturation to zero. This shows the key role of the in-plane magnetocrystalline anisotropy in the domain-coarsening process [3]. In contrast to ripening, a domain-wall-energy-driven and coercivity-limited process, the explosion-like coarsening is driven by the Zeeman and the anisotropy energies and is not associated with any long-range domain-wall movement. Akin to ripening, also coarsening was found to be irreversible as long as the applied field did not reach the saturation region.

We observed a novel *supersaturation memory effect* in the field history of the Fe/Cr ML. At room temperature, we had to apply no less then H_{SS} = 1.30 T in either easy or hard directions to erase the 'ripened' or 'coarsened' domain structure, i.e., to convert the ML domains into their native size and shape. We ascribe this effect to the magnetism of the Cr spacer. Indeed, the Cr exchange spring may 'remember' the sense of rotation of the Fe layer magnetisations even when the Fe layers are in full saturation. The extent of the supersaturation needed to erase the domain structure strongly increased at T = 15 K (H_S = 1.55 T, H_{SS} > 2.50 T in easy direction), supporting the role of the Cr magnetism.

A *spontaneous domain coarsening* induced by a 45° spin flop in a thick Fe/Cr/Fe trilayer in a decreasing field applied *exactly* along a hard axis was first observed using Kerr microscopy by Rührig *et al.* [5]. The domain structure after this peculiar transition consists of small (ripened) domains masked by large (coarsened) ones of mutually perpendicular magnetisation. The mechanism of the spontaneous domain coarsening is very similar to the mechanism of its BSF-induced counterpart. After a careful preparation of the periodic ML in a CEMS

polarimeter [6], we observed the 'Rührig state' with SMR. Indeed, as expected, the effective domain size along the hard direction parallel to the magnetic field last seen (ξ = 5 μm) significantly exceeded the effective domain size measured in the perpendicular hard direction (ξ = 2 μm).

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