# Application of the EBS NRS nanobeam in thin-film magnetism

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Submicron magnetic structure of laterally patterned thin films is a key issue in magnetic recording and spintronic devices. Kerr microscopy and magnetic force microscopy have no or very limited sensitivity for antiferromagnetic (AF) heterostructures and buried magnetic layers. Nuclear resonance scattering (NRS) of synchrotron radiation (SR) proved to be an efficient complementary technique to these methods, at least for $^{57}$Fe NRS. So far, only grazing-incidence NRS of SR (a.k.a. synchrotron Mössbauer reflectometry, SMR) has been used in studying thin-film magnetism. In this approach, in-plane correlation of the magnetisation is mapped by the shape of the diffuse scatter of the longitudinal plane-parallel component $q_x$ of the scattering vector. The method yields information in the reciprocal (momentum) space only so that no individual objects in the direct space can be identified and, in case of $^{57}$Fe SMR, it is practically limited to the correlation length range of about 200 nm to 2 μm. In this presentation the feasibility of submicron and micrometre magnetic microscopy on thin films using the EBS NRS nanobeam will be analysed.

Scanning magnetic microscopy with NRS needs to be performed in forward-scattering geometry. Transmission of 500 μm thick Si, MgO or sapphire substrates is in the range of 0.25–0.30. To have an effective resonant thickness of unity, about 50–60 nm $^{57}$Fe is needed; the exact value depends on the Lamb–Mössbauer factor.

Strongly AF-coupled Fe-Cr multilayers show two kinds of domain transformation. Domain coarsening [1] is associated with a bulk spin-flop of the AF domain magnetisation that leads to a sudden increase of the domain size from about 800 nm to at least 5 μm, an indirect conclusion drawn from off-specular SMR experiments [1]. This process can be directly followed by the EBS NRS nanobeam using its linear polarisation. In contrast, scanning magnetic microscopy of the so-called ripening process, i.e. the spontaneous increase of the primary domains in decreasing magnetic field from about 300 nm to about 800 nm would need special samples with additional isotope periodicity, tilting the sample and applying circularly polarised radiation.

The evolution of magnetism on a curved nano-surface shows a varied picture, as indirectly concluded from grazing-incidence NRS experiments [2]. Using the EPS NRS nanobeam, the vortices on the top and the magnetisation alignment at the side of the nanospheres, respectively, can be visualized. In principle, similar experiments may be feasible on skyrmions [3], as well.

Finally, the non-focussed beam of 50 μm horizontal width may be efficiently applied in grazing-incidence NRS experiments on magnetic thin films with varying marker layer position in the horizontal transverse direction [4].

**References**
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