ESRF	**Experiment title:** Magnetization Dynamics in ^{57}Fe Nanostructure Patterns During Growth (Proposal reference number 31097)	**Experiment number**: HC-822
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Report:

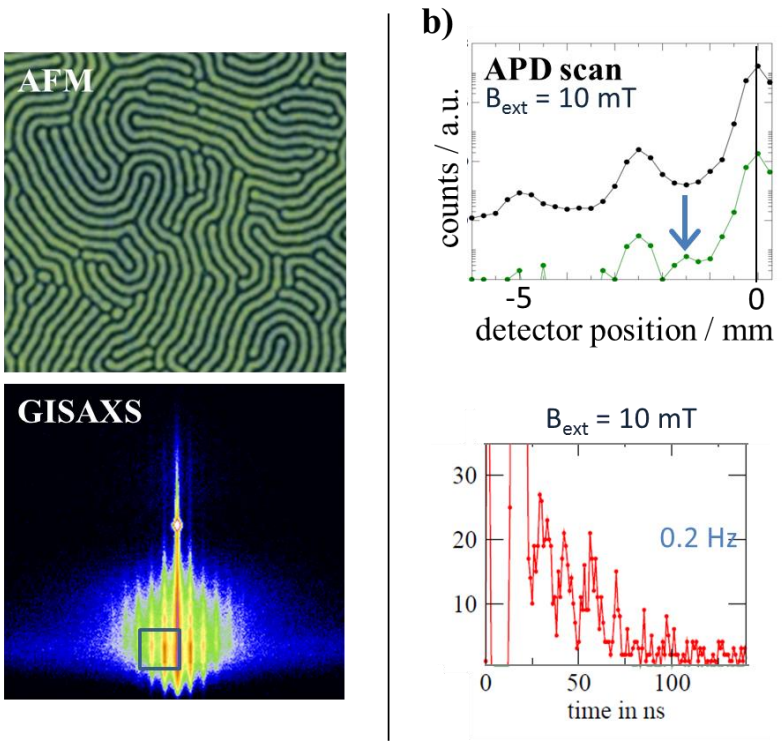
We investigated the structural growth and magnetic evolution of ^{57}Fe nanostructure samples by in-situ Grazing Incidence Small Angle X-ray Scattering (GISAXS) and Nuclear Forward Scattering (NFS). These nanostructures were prepared by sputter deposition onto laterally structured templates: A) microphase separated diblock copolymer film with chemical lateral surface structure, B) nanofaceted α-Al_2O_3 substrate with topographical lateral surface structure. The lateral magnetic domain structure of the samples was studied by Grazing Incidence Nuclear Small Angle X-Ray Scattering (GINSAXS).

A) ^{57}Fe nanowires on microphase separated diblock copolymer film

^{57}Fe nanowires were prepared by sputter deposition onto a microphase separated PS-b-PMMA diblock copolymer template. In this template, isotropic lamellar domains of PS and PMMA are expressed at the film surface. Pronounced selective wetting of ^{57}Fe on PS leads to an agglomeration of ^{57}Fe exclusively on the PS domains. Thus, well-separated isotropic ^{57}Fe nanowires with a width of approx. 100 nm are produced (see AFM micrograph in Fig. 1a)). ^{57}Fe was deposited in several steps; after each step a GISAXS pattern (see Fig 1a)) and a NFS time spectrum were recorded to relate the stage of nanowire growth with the magnetic state. After the ferromagnetic state had been established, a magnetic field was applied parallel to the incoming x-ray beam to induce magnetic reversal. The aim of the experiment was to determine the type of magnetic reversal by analysis of the nuclear resonant GISAXS signal. The APD was scanned horizontally through the scattering pattern, thus recording the distribution of

the time integrated nuclear GISAXS signal in q_y (see Fig. 1b), the box in the GISAXS pattern marks the region of interest for the APD scan). If antiparallel magnetization orientation in adjacent nanowires occurs, one expects purely nuclear resonant superstructure GISAXS peaks in the scattering pattern at half the q_y value of the structural GISAXS peaks, as the period for parallel magnetization orientation is doubled. The electronic signal (black curve) shows peaks corresponding to the structural periodicity of the sample. The NFS signal (green curve) exhibits an additional peak indicating the occurrence of a magnetic superstructure with antiparallel magnetization orientation in the sample. The time spectrum (see Fig. 1b)) recorded at the superstructure peak is indeed characteristic for parallel alignment of magnetic moments.

Figure 1



B) Patterned hardmagnetic ^{57}Fe film on nanofaceted α-Al_2O_3 substrate

A continuous hardmagnetic ^{57}Fe film with alternating stripelike regions of different thicknesses was prepared by sputter deposition onto a nanofaceted α-Al_2O_3 substrate: The sputtering source was positioned at 90° with respect to the long axes of the facets and at 45° with respect to the macroscopic sample surface. This resulted in different deposition rates of the sputtered ^{57}Fe atoms, i.e. different film thicknesses, for the facet surfaces facing the sputtering source and for the facet surfaces being avert from the source (see Fig. 2a). Because the surface of the sample is completely faceted, there is no central specular scattering rod in the GISAXS pattern, but two tilted scattering rods (see Fig. 2b): one on the left half of the scattering pattern from the left facet surfaces (thick regions of ^{57}Fe film), and one on the right half of the scattering pattern from the right facet surfaces (thin regions of ^{57}Fe film). The tilt angles of the scattering rods correspond to the angles enclosed between the facet surfaces and the macroscopic sample plane. Thickness oscillations on the individual scattering rods correlate with the respective film thicknesses on the left and right facet faces. A weak specular reflection is left, but otherwise all x-ray photons impinging on the left resp. right facet

surfaces are scattered to the left resp. right scattering rod – including the resonantly scattered photons. The ^{57}Fe film was deposited in several steps; after each step a GISAXS pattern and three NFS time spectra (thin regions, thick regions, specular position) were recorded. In this way, the magnetic evolution of different parts of a magnetically heterogeneous sample could be observed in-situ depending on the film thickness in the respective regions (see Fig. 3): By placing an APD detector at the positions marked in the GISAXS patterns, it was possible to separately detect the NFS signal from the thin and thick regions of the ^{57}Fe film in the two tilted scattering rods, as shown in Fig. 3b. The specular reflection contains a mixed NFS signal from both the thin and the thick regions.

These experiments on planar nanowire arrays and on faceted thin films demonstrate the feasibilty of employing GINSAXS as a method to elucidate the lateral magnetization structure of nanostructured and/or heterogeneous samples.

Figure 2

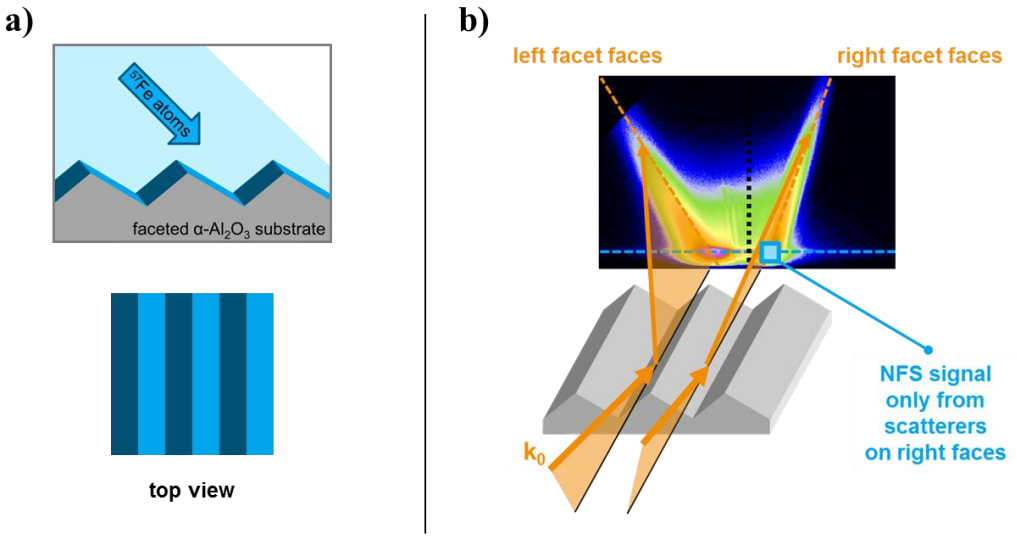


Figure 3