Magnetic domain mapping in Fe/SmCo spring magnets

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Introduction

Spring magnets are combinations of soft and hard magnetic materials. Such a combination results in a high-magnetic-energy product $(BH)_{max}$. In addition to this, the coupling between the soft and the hard material leads to an enhanced remanent magnetization and a reversible demagnetization curve due to the exchange interaction between the two materials [1]. These properties make spring magnets promising candidates for applications as permanent magnets. Technically, spring magnets are realized as multilayer structures [2]. Unfortunately, the spatial magnetic structure of buried layers in these multilayers is inaccessible to established methods like magnetic force microscopy. A new, polarized x-ray microprobe [3], developed at the Advanced Photon Source, may prove useful to explore the spatial structure of these materials.

Methods and Materials

The experiment was performed at the 1-ID insertion device beamline of the SRI-CAT. The linearly polarized beam from the undulator was circularly polarized by means of a Bragg phase retarder. Subsequently, the beam was focused using a Fresnel microzone plate in conjunction with an order-sorting pinhole. The focused beam was circularly polarized to better than 99%. The beam size, measured by knife-edge scans, was $3.04 \times 2.26\ \mu m^2$ (horizontally × vertically). The polarized flux in the focal spot was measured to be 5×10^7 photons/s.

Our sample was a (200 Å Fe / 800 Å SmCo) bilayer, grown on a 1 mm MgO substrate. The sample was coated with 50 Å Ag to protect against oxidation. SmCo was nominally deposited in the II-VII phase. Local deviations from the ideal stoichiometry cause Co surplus or shortage, leading to $SmCo_3$ or $SmCo_5$ phases [4].

The sample was scanned in two dimensions through the focused beam. Since the imperfect crystalline structure prevented measurements in diffraction geometry, we recorded the fluorescence yield from the sample after excitation at the Sm L3-edge (6.716 keV). To align the sample, a magnetic field of up to 0.8 Tesla could be applied parallel to the axis of easy magnetization.

Results

Since circularly polarized photons couple linearly to the magnetic moments in the scattering material, the normalized difference $(I^+-I^-)/(I^++I^-)$ of the observed intensities for opposite helicities of the incoming beam provides information about the magnitude of the magnetic moments in the scattering plane (see Figure 1).

Discussion

The axis of easy magnetization in SmCo films is defined by the stacking disorders induced by the I-III or I-V phases previously mentioned. Up to now it has been assumed that the magnetic domains in the SmCo layer align perpendicular to the stacking disorders. Contrary to this, our measurement shows that the magnetic domains align parallel to the axis of easy magnetization. Further experiments with a dedicated fluorescence setup will be performed to confirm this result.

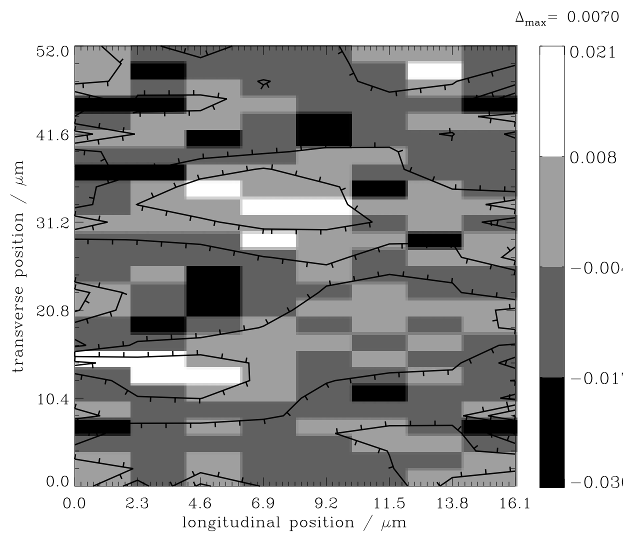

Figure 1: Two-dimensional scan of the Fe/SmCo spring magnet. The gray shade of each spot corresponds to the measured flipping ratio. To visualize spatial structures, the gray scale was strongly averaged. The axes' directions are given relative to the direction of the easy axis of magnetization. Clearly, stripes parallel to this axis can be identified.

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References

[1] E.F. Kneller and R. Hawig, *IEEE Trans. Mag.* **27**, 3588 (1991).
[2] E.F. Fullerton, J.S. Jiang, M. Grimsditch, C.H. Sowers, and S.D. Bader, *Phys. Rev. B* **58**, 12193 (1998).
[3] J. Pollmann, G. Srajer, J. Maser, J.C. Lang, C.S. Nelson, C.T. Venkataraman, and E.D. Isaacs, subm. to *Rev. Sci. Instrum*.
[4] M. Benaissa, K.M. Krishnan, E.F. Fullerton, and J.S. Jiang, *IEEE Trans. Mag.* **34**, 1204 (1998).