Experimental Interpretation of FORC Diagrams by Magnetic X-Ray Microscopy

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Magnetic nanostructures, that are patterned on the length scale of the dipole and exchange interaction, have gained significant scientific interest in the past years [1]-[3]. They exhibit interesting new phenomena like artificial spin ice [3] and spin glass [4] and pairs of magnetic monopoles [5]. These nanostructures have great potential for technological applications in data processing and storage, and spintronics [1]-[3]. Additionally magnetic nanostructures can be used to realize magnonic crystals that are metamaterials with periodically alternating magnetic properties – similar to photonic crystals [2]. This periodic variation is achieved by creating holes in a magnetic host material to form a so-called antidot lattice. The introduction of the artificial antidot lattice changes the spin wave dispersion in the material and can be used to form a spin wave guide or filter [2]. To tune the spin wave dispersion, understanding the magnetization states and the static magnetic properties is of great importance. These static properties like the anisotropy, the coercivity and the orientation of the easy axes are determined by the hole size and distance, the antidot lattice symmetry and its orientation, and the magnetic host material [1]-[3].

Here, we follow two approaches to investigate the microscopic origin of these static magnetic properties: one is first-order reversal curves (FORC) that promise to gain microscopic information without the need for ultimate spatial resolution for the measurement [6, 7]. The separation of microscopic switching events is achieved by the acquisition of multiple minor loops [6]. Unfortunately, the direct interpretation of the experimental FORC distribution as a physically meaningful distribution of Preisach hysterons is not always possible [6]. Therefore, the second approach is scanning x-ray microscopy (SXM) with x-ray magnetic circular dichroism (XMCD) contrast that provides an actual nanoscopic image of the magnetization states. We showcase this using nano-scaled antidot lattices in both in-plane [8] and out-of-plane [9] magnetized materials. By combining the two approaches we can map the FORC density peaks to microscopically observable magnetization states and, thus, understand both the FORC distribution and the complex magnetization reversal processes of magnetic nanostructures.

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