Quantitative MFM – probing magnetization structures on the nanoscale

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Magnetic force microscopy (MFM) has established its place as an extremely valuable method for the investigation of magnetic microstructures on the nanometer scale. Its rather simple principle of sensing the sample's stray field above its surface makes it a robust but yet sensitive and highly resolving method with little demand on sample surface preparation. Beyond being a purely qualitative imaging technique, quantitative MFM has the capability to locally measure the stray fields and eventually provide quantitative input data for a reconstruction of the underlying magnetization structure. It requires a full calibration of the imaging properties of the used MFM tip and the most general approach is through the determination of the so-called tip transfer function (TTF) in Fourier space [1-3]. Applying a calibrated tip transforms MFM signals into true stray field values on the nanometer scale, which for certain applications is already the desired quantity. Reconstructing the magnetization structure from the stray field landscape is an ill-posed inversion problem, which needs additional knowledge on the sample. Here, micromagnetic simulations can help by providing valid initial magnetization models.

As one of several qMFM examples, we present the peculiarities of stripe domains in an epitaxial CoFeC film with biaxial texture and strain-induced perpendicular magnetic anisotropy. The Kerr micrograph of the sample shows the large basic in-plane domains along the two FeCoC [110] in-plane easy directions. The MFM measurements resolve the perpendicular magnetization modulation in the form of so-called stripe domains parallel to the underlying in-plane magnetization. A quantitative MFM analysis allows determining the amplitude of the perpendicular magnetization component, and together with micromagnetic simulations, can probe the 3-dimensional magnetization structure of such vortices and vertices as shown below.

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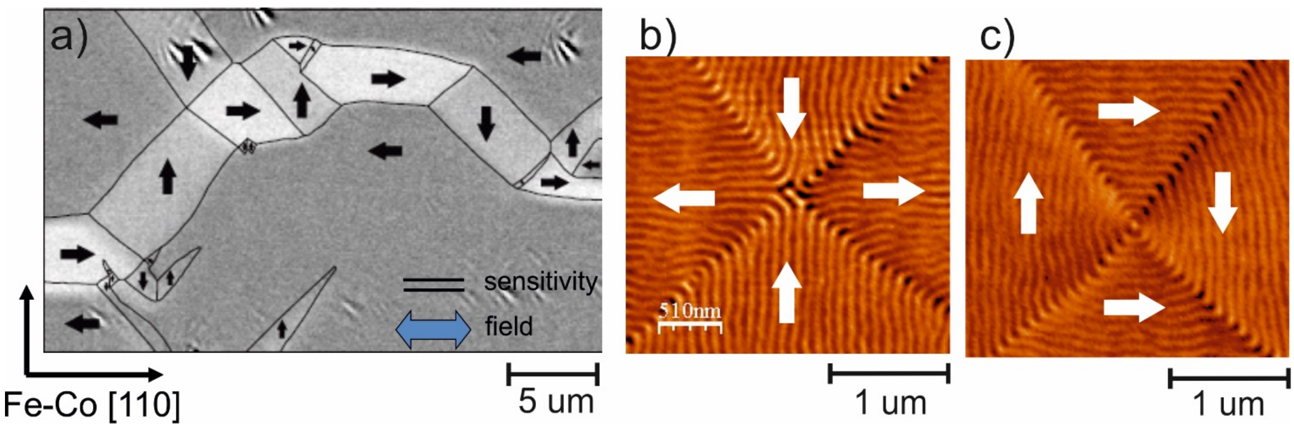

[1] Hug *et al*. JAP'98, [2] Vock *et al*. APL'14, [3] Panchal *et al.* Sci. Rep.'17