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Size-dependent magnetization curves of individual iron nanoparticles at finite temperatures

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Magnetic nanoparticles show a variety of novel magnetic phenomena when compared to the respective bulk materials, mostly due to the effect of the surface and interface on the magnetic interactions and to critical magnetic length scales such as domain wall width and exchange length. For instance the size may determine whether a particle is in a single domain state or whether it will show a non-collinear spin structure [1]. A related aspect concerns magnetic switching processes in a nanoparticle. For sufficiently small structures it is assumed that the magnetic reversal occurs as a coherent rotation of the atomic spins at T = 0 K. However, at finite temperatures thermal excitations may disturb the ferromagnetic spin order and thus lead to complex reversal modes [2]. These modes are not only relevant for the quasi-static properties of the particles, but also determine their dynamical response to external stimuli.

We have used photoemission electron microscopy (PEEM) together with x-ray magnetic circular dichroism (XMCD) to detect the magnetization curves of individual Fe nanoparticles at room temperature, cf. Fig. 1. By varying the particle size we observe the transition from superparamagnetic fluctuations to stable ferromagnetic order at a particle size of about 12 nm. Applying a magnetic field allows us to record magnetization curves of the particles in both, the superparamagnetic and the ferromagnetic state, as well as in the transition regime. We compare these data with the predictions of conventional macro spin theory and discuss the role of thermal excitations and non-collinear spin structures on the magnetization reversal.

references:
[1] A. Fraile-Rodriguez et al., Phys. Rev. Lett. 104, 127201 (2010).
[2] S. Krause et al., Phys. Rev. Lett. 103, 127202 (2009).

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