Angular dependent magnetization reversal modes in Co-films with in-plane uniaxial anisotropy

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Magnetization reversal and the associated phenomenon of hysteresis are key aspects of ferromagnetic materials. The hysteresis property specifically is of great interest in fundamental science but also for modern technology, such as for the application in magnetic storage devices, for instance, that rely on hysteresis as the non-volatile information preservation mechanism. While the significance of the hysteresis phenomenon is mirrored by a vast scientific literature, some features remain still unexplained and are subject to scientific disagreement. One of such topics of active scientific discourse is the existence of criticality upon fine-tuning of magnetic disorder, which has been proposed theoretically [1]. Within this scientific approach, the magnetization M versus field H hysteresis loop itself becomes critical and undergoes a non-equilibrium second order phase transition from a discontinuous *M(H)* curve with a sample sized magnetization jump to a smooth curve with many intermediate states [1]. It is believed that this kind of criticality has been experimentally observed in thin and therefore effectively two dimensional Co-films [2], even though theoretical predictions indicate that this type of critical point should actually not occur in two dimensional systems.

In this work, we have studied the angular dependence of the magnetization reversal in thin Co-films with in-plane uniaxial anisotropy. The underlying idea of this experiment is that by changing the orientation of the applied field, we change the effectiveness of the magnetic disorder already present in the material due to the partial misalignment of its crystallographic grains. This approach could then allow a continuous tuning of the “effective disorder” in our samples, and hereby provide an alternative experimental pathway to test for criticality of magnetization loop hysteresis in a two dimensional system. In order to grow in-plane uniaxial films with a suitable level of weak crystalline disorder, we have deposited the previously reported [3] epitaxial sequence Ag(110)/Cr(211)/Co(10$\underline{1}$0) on top of Si (110) single crystal substrates by means of ultra high vacuum (UHV) sputter deposition. Certain aspects of magnetization reversal have already been studied in these systems but the angular dependence of magnetization reversal modes and criticality have not been addressed [4].

The experimental characterization of our samples has been done by means of a home-built magneto-optical Kerr effect set up, which allows for a high-resolution of sample alignment with respect to the magnetic field orientation. With this set-up, hysteresis loops where measured for different angles of the applied field in the range from 0º to 60º as measured from the easy axis, with an angular resolution of 0.2º. Furthermore, a high field amplitude resolution of 0.1 Oe was utilized to allow for a very detailed study of the magnetization reversal. In our experiments, no multi-loop signal averaging was done to avoid a smearing out of possibly sharp features in the reversal regime, hereby setting very high requirements for the signal-to-noise ratio of our experimental set-up. Measured *M(H)*–curves demonstrate a clear change of loop shape as one changes the applied field angle θ from the easy axis towards the hard axis. Figure 1 shows a clear distinction between the sharp loop measured at small θ and the continuous curve at higher angles. Figure 2 shows this behavior even more clearly by means of $M(\theta,H)$ color maps for both branches of the loop. For small angles, the magnetization switches from positive saturation to negative saturation, or vice versa, with almost perfect abruptness, indicated by the sharp transition range from red to blue near the coercive field. For larger values of θ, intermediate magnetization states become increasingly more relevant as denoted by the white and yellow areas in both maps.

Moreover, the high resolution of our experiment in field and angle of the applied field will also permit a detailed quantitative determination of the nature of this qualitative behavioral change, an aspect that is currently under investigation.

References

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Figures

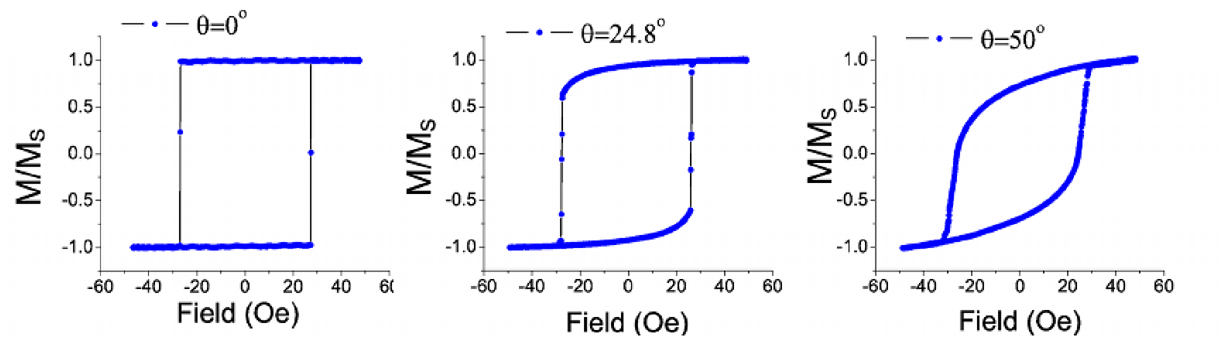

Figure 1: Hysteresis loop curves for different in-plane orientations of the applied field, as characterized by the angle from the easy axis for θ. While the reversal is very sharp at and near the easy axis, the behavior transitions into a smooth curve as the field orientation moves towards the hard axis.

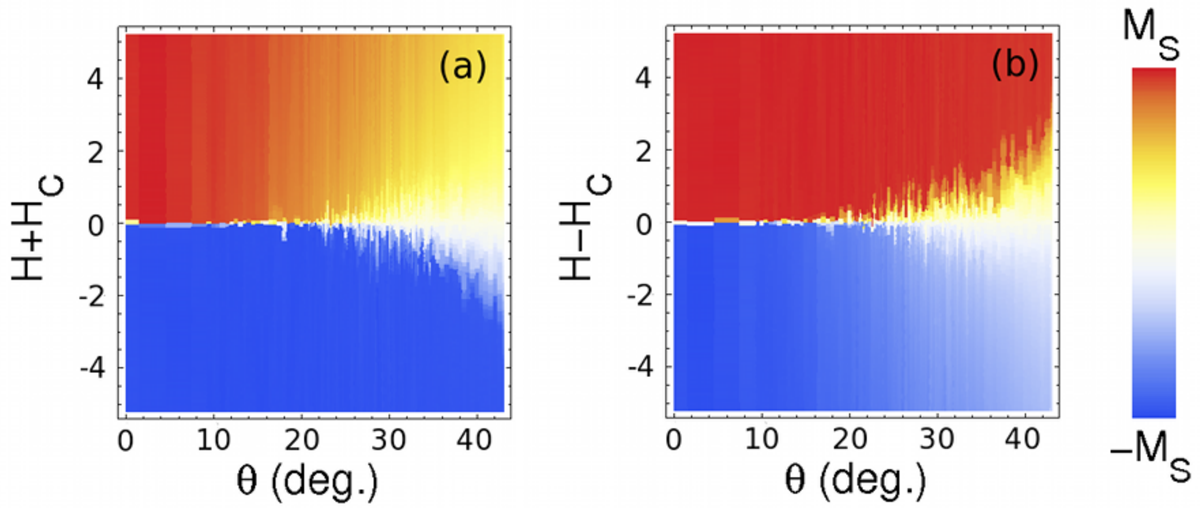

Figure 2: Color-coded magnetization M(θ,H) maps for (a) the decreasing field branch and (b) the increasing field branch of hysteresis loops, measured on a Co-film with in-plane uniaxial anisotropy.