MAGNETIZATION DYNAMICS OF THIN FILMS AND NANOSTRUCTURES USING X-RAYS AND MAGNETO-OPTICS

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Magnetization reversal dynamics at nanosecond timescales is an important subject for many technological applications of magnetic materials. In magnetic recording industry, the fast magnetization reversal in storage media and read heads is primordial to guarantee a high data transfer rate. Read and write speeds are today of the order of 300-400 MHz and are not limited by the magnetization reversal times. As these times will evolve towards the GHz regime, limitations due to magnetization reversal speeds can be expected.

The atomic scale magnetization dynamics is governed by the Landau-Lifschitz-Gilbert equation of motion and damping. The spatial and time scales for which this model can be applied are determined by the domain wall width (some hundreds of nanometers at most) and the paramagnetic relaxation time (tens of picoseconds). In that case, coherent rotation of all the spins in the system is possible. Above these scales, the reversal is thermally activated, consisting of nucleation of small reversed domains and domain wall propagation.

We have studied the thermally activated magnetization dynamics in different systems, in particular exchange coupled Co/NiO bilayers and NiFe/Cu/Co trilayers. We have used both laboratory (Kerr measurements) and synchrotron based (XMCD, PEEM) techniques to study these systems, for sweep rates of the magnetic field (dH/dt) ranging from 1 Oe/s to several GOe/s, combining classical electromagnets and specially developed copper microcoils. The Kerr measurements allow the determination of the macroscopic coercivity as a function of field sweep rate, while XMCD measurements can be used to separate the contributions of the different layers to the magnetization dynamics. Time-resolved Kerr microscopy and PEEM allow the different reversal processes to be visualized.

Phenomenological models taking into account both domain wall motion and nucleation processes [1,2] predict a logarithmic increase of the coercive field with the applied field sweep rate. The activation volume - the magnetization volume that switches for a single activation event - and the relaxation time can be obtained from measurements of H_C vs. dH/dt. In general, different linear rates of change of H_C vs. ln(dH/dt) are found for low and high sweep rates. The two regimes are dominated respectively by domain wall motion (low dH/dt) and nucleation processes (high dH/dt). The value of dH/dt for which the change of regime takes place strongly depends on the system under study.

For the Co/NiO bilayers, measurements of the magnetization dynamics allow information to be obtained on the activation volume as a function of Co thickness as well as the F/AF coupling strength as a function of NiO thickness. XMCD measurements emphasize the role of the NiO uncompensated moments on the reversal.

For the trilayers, the different reversal modes have a crucial influence on the coupling between the two magnetic layers. Nanosecond resolved XMCD measurements show that the coupling can be very different in quasi-static and dynamic regimes. The coupling disappears when nucleation becomes dominant over domain wall propagation in the magnetization reversal. Time-resolved PEEM measurements indicate that the reversal at high sweep rates is indeed dominated by nucleation, and micromagnetic simulations were performed to elucidate the influence of the reversal mode on the coupling.

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[2] B.Raquet, R.Mamy, and J.C.Ousset, Phys.Rev.B **54**, 4128 (1996).