MA 7: Micromagnetism/Computational Magnetics

Time: Monday 17:00–18:30 Location: H10

MA 7.1 Mon 17:00 H10

Application of exchange coupled composite layers for magnetic recording — Helmut Kronmüller and •Dagmar Goll — MPI für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

High-density recording systems require magnetic bits with large magnetocrystalline anisotropy to guarantee thermal stability. However, the large magnetic fields required for magnetization reversal cannot be afforded by conventional write heads. Therefore, composite exchange coupled spring systems of soft and hard magnetic layers are used to reduce the switching field. The reversal of magnetization in this case takes place in two steps: A nucleation process in the soft layer and a depinning process for the displacement of a domain wall (dw) into the hard layer thus inducing full switching of the exchange coupled system. The nucleation and depinning fields are calculated analytically on the basis of the continuum theory of micromagnetism. It is shown that the nucleation fields decrease according to a $1/D^2$ law with increasing thickness D of the soft layer and in general remain smaller than the depinning fields of the dws. For longitudinal recording the depinning field is that of a Bloch wall whereas for perpendicular recording we deal with a Néel wall. The Bloch wall depinning field is found to be of the order of 1/4 of the ideal nucleation field of the hard phase. The Néel wall depinning field depends on the relative values of the spontaneous polarizations of the hard and soft phase and may be larger or smaller than the depinning field of the Bloch wall.

MA 7.2 Mon 17:15 H10

Current-induced high-frequency normal modes in single-crystalline Fe nanodisks — •A. Kakay, R. Hertel, and C. M. Schneider — Institut für Festkörperforschung IFF-9 "Elektronische Eigenschaften", Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

The magnetization dynamics in a single-crystalline Fe nanodisk (diameter: 150 nm, thickness: 4 nm) driven by a spin-polarized current flowing perpendicular to the plane has been studied by means of micromagnetic simulations. The micromagnetic simulations have been performed with a finite-element algorithm based on the Landau-Lifshitz-Gilbert equation including Slonczewski's torque term. The magnetic excitations are induced by a spin-polarized current. At current densities between 4-6$\times 10^{11}$ A/m^2, two pronounced peaks can be observed in the Fourier spectra. A spatial Fourier filtering shows that the lowest frequency peak (12.2 GHz) arises from a magnetic mode localized at opposite sides of the nanodisk. The main peak at 15.7 GHz represents a macrospin oscillation. In addition, well-defined and more complicated normal modes are observed in a frequency range around 22 GHz. Our simulations show that spin-polarized currents can induce stationary, non-uniform high-frequency normal modes, similar with those reported on the magnetization dynamics created by external field pulses. The occurrence of these normal modes emphasizes the need for a full-scale micromagnetic approach. The influence of the Oersted field (created by the current flowing through the sample) on the high-frequency normal modes will also be discussed.

MA 7.3 Mon 17:30 H10

Influence of spin waves on the dynamics of magnetization processes — •Sebastian Macke, Dagmar Goll, and Gisela Schütz — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart, Germany

Spin wave influenced switching of the magnetization of thin Co and permalloy films is studied by micromagnetic simulations. Therefore standing spin waves are superimposed on the magnetization configuration in the ground state. The dependence of magnetization reversal is analyzed for variable frequencies and phases with amplitudes up to 30°. Most spin waves cause an increase of the switching time but not all of them. The variation of switching times depends strongly on the external field. In the field range in which the switching time increases a significant dependence on the spin wave phase is oberserved. Thermally excited spin waves with Bose-Einstein distribution reduce the saturation magnetization by the well-known Bloch $T^{3/2}$ -law. In order to take care of the role of the spectrum of spin waves the effect of a discrete number of spin waves with different frequencies is determined quantitatively.

MA 7.4 Mon 17:45 H10

Switching magnetic vortices on the picosecond timescale — Riccardo Hertel, •Sebastian Gliga, and Claus M. Schneider — Institut für Festkörperforschung IFF-9 "Elektronische Eigenschaften", Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

Magnetic vortices are naturally occurring structures in confined-geometry ferromagnetic materials: regions where the magnetization curls around a perpendicularly magnetized core. Highly stable, the core has until now been assumed to behave like a rigid structure. Only very recently has it been shown that the core could easily be switched by applying an in-plane magnetic pulse [1].

In this study, we present the dynamics of vortex core reversal using three-dimensional micromagnetic simulations based on finite-elements. The simulations show that a single suitable in-plane magnetic pulse of intermediate strength (ca. 70 mT) can be used to reverse the orientation of a vortex core. We found that this process is mediated by the creation and annihilation of a vortex-antivortex pair in the sample. We have systematically studied the influence of the field pulse strength and duration and found that it is possible to trigger the core reversal with ultrafast pulses (as short as 5 ps). The simulations predict that for very strong pulses, the core switches multiple times.

We find that the magnetization dynamics is driven by the exchange field, which allows the magnetization reversal process to unfold on the picosecond time scale, making it faster than any field-driven magnetization reversal process previously known from micromagnetic theory.

[1] B. Van Waeyenberge et al., Nature **444**, 461 (2006)

MA 7.5 Mon 18:00 H10

Magnetization Dynamics during Vortex-Antivortex Annihilation — •R. Hertel and Claus M. Schneider — Institut für Festkörperforschung IFF-9 "Elektronische Eigenschaften", Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

Magnetic vortices and antivortices in thin-film elements can annihilate, resulting in a homogeneous magnetization. Both, the vortex and the antivortex contain a small core magnetized perpendicular to the film plane [1]. The direction of the magnetization of the core is called the polarization. A detailed description of the magnetization dynamics of vortex-antivortex annihilation processes is obtained by micromagnetic finite-element simulations based on the Landau-Lifshitz-Gilbert equation. As an example to study such an annihilation process, we simulated the dynamic domain structure conversion in a 100 × 100 × 10 nm^3 Permalloy element from a cross-tie structure to a single vortex structure. The simulations show that, depending on the relative polarization of the vortex-antivortex pair, the annihilation process is either a continuous transformation of the magnetic structure or it involves the propagation of a micromagnetic singularity (Bloch point) causing a burstlike emission of spin waves (exchange explosion) [2].

[1] Shinjo et al. Science 289, 930 (2000).
[2] R. Hertel and C.M. Schneider, PRL 97, 177202(2006).

MA 7.6 Mon 18:15 H10

Ferromagnetic resonance in ordered magnetic particle systems — •Peter Majchrák[1,3], Zdeněk Frait[2], Ján Dérer[1], Eva Kováčová[1], Vasil Šmatko[1], and Ivo Vávra[1] — [1]Institute of Electrical Engineering SAS, Bratislava, Slovakia — [2]Institute of Physics, AS CR, Na Slovance 2, Prague Czech Republic — [3]on leave at Institute of Physics, AS CR, Na Slovance 2, Prague Czech Republic

Microwave properties of arrays of circular FeSi dots were studied by ferromagnetic resonance (FMR) technique in wide range of frequencies from 17GHz to 70GHz. All of the dots had the radius 2 - 3 μm, thickness 40 nm, and were arranged into square array with 4 μm dot period. In the case of perpendicular magnetization (in field up to 28 kG) multiple resonance peaks were observed below the main FMR peak. Quantitative description of the observed multiresonance FMR spectra is given using the dipolar intradot interactions, and also the inhomogeneity of the intradot static demagnetization field in the nonellipsoidal dot is taken into account. In the next part of the contribution there are presented the results of FMR measurements performed on the superlattice of iron nanoparticle layers.