Wednesday Afternoon, November 6, 2002

Magnetic Interfaces and Nanostructures
Room: C-205 - Session MI-WeA

Magnetization Dynamics
Moderator: S.E. Russek, NIST, Boulder

2:00pm **MI-WeA1 Investigation of Magnon Generation by a dc Current through a Point Contact/Magnetic Multilayer Junction**, ***W.H. Rippard***, *M.R. Pufall, T.J. Silva*, National Institute of Standards and Technology

We have studied the spin-momentum transfer (SMT) effect with mechanical point contacts and several types of magnetic multilayers, exhibiting both ferromagnetic (FM) and antiferromagnetic (AF) exchange-coupling. Electron spins flowing though a magnetic multilayer transfer angular momentum between the individual layers. At sufficiently high current densities, the resultant spin torque is large enough to induce magnetization dynamics.[1-5] Previous work using point contacts has shown that there is an abrupt step in the dc resistance, and corresponding peak in dV/dI, when the current reaches a critical value Ic. The linear dependence of Ic on applied magnetic field suggests a correlation with magnon generation. Earlier data were obtained from AF coupled films, with fields applied perpendicular to the film. In our measurements, we have explored a variety of parameters. We found that spin-momentum transfer is a robust effect, occurring for a wide range of experimental conditions. SMT-related phenomena are observed for both in-plane and out-of-plane fields, for AF exchange-coupled multilayers grown at both the 1st and 2nd GMR maxima, and for FM-coupled multilayers. Also, the dependence of Ic on field can vary substantially from contact to contact. Peaks in dV/dI can persist (albeit with reduced magnitude) down to zero applied field for AF-coupled samples. Multiple peaks can also occur, implying multiple excitation modes. For FM-coupled multilayers the SMT effects have large ~0.5 W steps in the dc resistance at the critical current, implying the onset of surprisingly large excitations. The persistence of SMT down to zero applied field suggests application of SMT as a novel high-frequency oscillator.

[1] M. Tsoi et al., Phys. Rev. Lett. 80, 4281 (1998)
[2] L. Berger, Phys. Rev. B 54, 9353 (1996)
[3] J. C. Slonczewski, J. Magn. Magn. Mater. 159, L1 (1996)
[4] J. A. Katine, et al., Phys. Rev. Lett. 84, 3149 (2000)
[5] E. B. Myers, et al., Science 285, 867 (1999).

2:20pm **MI-WeA2 Mechanical Detection of Ferromagnetic Resonance in Micron-size YIG Disk**, ***V. Charbois***, *O. Klein,* C.E.A. Saclay, France, *V.V. Naletov*, Kazan State University, Russia

We present room temperature measurements by Magnetic Resonance Force Microscopy (MRFM) of the ferromagnetic resonance (FMR) spectra on a normally magnetized YIG disk (with thickness 4.75µm and radius 80µm). The analysis of the influence of the tip for different probe-sample separation h led us to distinguish two cases. In the weak coupling regime, when the bias field generated by the tip is smaller than a few hundred Gauss, the prominent change is a shift of the entire spectrum to lower applied fields as h decreased. The result can be quantitativelly understood within the framework of the Damon and Eshbach model. In the strong coupling regime, the additional inhomogenous field produced by the tip can be used to localize new magnetostatic modes underneath the probe[2] (this allows local spectroscopy to be performed). However, in the case of YIG, the spatial extension of these modes is limited to 4µm. Simultaneous measurements of FMR both by standard susceptibility and mechanical detection demonstrate the higher sensitivity of MRFM[1] and its ability to measure smaller sample (in this case the spectroscopic response of the entire sample is obtained). Imaging of the magnetostatic modes can be performed by taking advantage of the localized probe. Ideally one should work at small h (to achieve high spatial resolution) with a tip producing a weak stray field (e.g. a tip coated with a thin film of ferromagnetic material). The last advantage of this technique is that it is sensitive to the longitudinal magnetization and thus it provides information complementary to conventional microwave susceptibility measurements.

[1] V.Charbois, V.V.Naletov, J.Ben Youssef and O.Klein, J.Appl.Phys 91, 7337 (2002).
[2] V.Charbois, V.V.Naletov, J.Ben Youssef and O.Klein, to be published in Appl.Phys.Lett. (June 24th issue)

2:40pm **MI-WeA3 Spin Wave Dynamics in Structured Magnetic Media**, ***S.O. Demokritov***, University Kaiserslautern, Germany **INVITED**

Spin waves are the fundamental dynamic eigen-modes of a magnetic system. The knowledge of the spin-wave properties in the small-amplitude limit is mandatory to understand the dynamic properties of a magnetic system in general. This presentation covers the recent results obtained on spin wave excitations in arrays of magnetic elements using Brillouin light scattering spectroscopy (BLS). Confinement of spin waves in magnetic elements leads to dramatic changes of the spin wave dispersion and density of states. The observed lateral quantization of spin wave modes in an element is one consequence of the confinement. The quantization conditions are determined by the stripe width, and by the boundary conditions at the lateral edges of the stripe. It is shown, that these conditions result in an effective "pinning" of a purely dipolar nature due to the inhomogeneity of the dynamic internal field near the stripe edges. An additional analysis of the BLS-intensity as a function of the transferred wavevector provides information on the mode profiles. According to the scattering theory from confined modes, the BLS-intensity of a given mode is determined by the Fourier-components of the mode profile. Thus, light scattering can be used as a "Fourier-microscope" and can provide information on the distribution of the dynamic magnetization in the elements with the resolution better than 200 nm. Another striking effect of magnetic confinement is a strongly inhomogeneous static internal magnetic field in the element. This inhomogeneity creates potential wells for spin waves near the edges of the elements. The size of the wells is much smaller than the lateral size of the element. The dynamic magnetic susceptibility in the well shows a strong maximum, causing a localization of low frequency spin wave modes in the well, which is experimentally confirmed using BLS-Fourier-microscope.

3:20pm **MI-WeA5 Spin Wave Excitations by Low Energy Electrons in Fe**, ***M.R. Vernoy***, *H. Hopster, D.L. Mills*, University of California, Irvine

A new spectrometer for spin polarized electron energy loss spectroscopy (SPEELS) has been constructed. The spectrometer is based on 127° cylindrical sectors as monochromator and analyzer, with the analyzer being rotatable for angle dependent measurements. A standard GaAs negative-electron-affinity photoemitter source is coupled to the monochromator and provides spin polarized electrons with polarization values around 25 %. SPEELS measurements were performed on thick (several 100 Å) epitaxial Fe films grown in situ on GaAs(100) substrates. The Fe films were remanently magnetized by a magnetic field pulse and SPEELS spectra were taken with the incoming beam polarization parallel or antiparallel to the magnetization. The primary energy used was 20 eV and an energy resolution of 25 meV (FWHM) was achieved. Strong spin asymmetries are detected in the energy loss spectrum. In addition to the well known Stoner excitation spectrum at high energies there is a distinct loss structure at small energies (100-300 meV) due to spin wave excitations. This spin wave energy loss structure has a highly asymmetric shape with a sharp onset around 100 meV, a maximum around 165 meV and a tail extending out to 350 meV. This peak shape can be explained by excitation of a continuum of bulk spin waves due to the non-conservation of q-perpendicular in the excitation process. We shall present comparison between the measured spectra and model calculations which employ a very simple description of the excitation process, and a Heisenberg model to describe spin waves at the crystal surface.

3:40pm **MI-WeA6 Dynamical Investigation of Transient Magnetic Anisotropy in $Ni_{80}Fe_{20}$**, ***R. Lopusnik****, *J.P. Nibarger, T.J. Silva, Z. Celinski*, National Institute of Standards and Technology

The values of static and dynamic uniaxial anisotropy in thin permalloy films are anomalously different by a factor of 2. The dynamic response of different thickness films are measured with a pulse inductive microwave magnetometer. The time-resolved precessional response was measured as a function of the applied bias field varying from 0 to 8 kA/m. The frequency range varies from 700 MHz to 3 GHz. Spectroscopic analysis of the data yields quantitative information about the intrinsic gyromagnetic properties of the films. The observed dependence can be fitted to high precision with the Kittel formula for ferromagnetic resonance to extract anisotropy field H_k, the spectroscopic factor g etc. The static anisotropy field value was obtained by a quasi-static measurement of a hysteresis loop along the magnetic hard axis. In this case, the saturation field corresponds to the anisotropy field of the sample. To understand this effect, variable angle measurements were performed for several different orientations of the uniaxial anisotropy with respect to the applied bias field. For each angle the value of the dynamical anisotropy was obtained. The angular dependence of the anisotropy can be fitted to a cosine function, but with an additional angle-independent offset field of ~400 A/m. The modulation amplitude of the fitted cosine function is equal to the static anisotropy field value of ~320 A/m. Both the cosine amplitude and angle-independent offset are found to

* Falicov Student Award Finalist

be independent of film thickness below 100 nm. We interpret the constant offset field as a transient component of the magnetic anisotropy that only affects dynamical response at time scales below 10 ns. Similar behavior has been observed using magneto-optical methods.[1] In these recently reported studies, an initial fast response of the magnetization was followed by very slow increase over a much longer time scale. We will discuss possible explanations, including non-linear dynamics and eddy currents.

[1] M. Bauer, R. Lopusnik, J. Fassbender, B. Hillebrands, J. Bangert, and J. Wecker, J. Appl. Phys. 91, 543 (2002); M. Pufall and T. Silva, IEEE Trans. Mag. 38, 129 (2002)

4:00pm **MI-WeA7 A New Equation for Magnetization Dynamics Based Upon Transverse Relaxation Processes**, ***T.J. Silva***, *R. Lopusnik*, *J.P. Nibarger*, National Institute for Standards and Technology, *T. Gerrits*, University of Nijmegen, The Netherlands

We present a new equation for magnetodynamic response, derived from the Bloch-Bloembergen formulation for spin relaxation phenomena. The new equation is vectorial and adapted for all possible field geometries. The longitudinal and transverse relaxation rates are constrained to insure conservation of the magnetization. As such, the new equation is amenable to finite-element micromagnetic simulations. Subject to the constraint of constant magnetization, the longitudinal relaxation rate cannot be constant during free induction decay in unbiased ferromagnetic films. However, if the transverse relaxation rate is held constant, the resulting equation is of the Landau-Lifshitz form but with an additional dependence of the damping term on longitudinal field. The field dependence strongly renormalizes the relaxation times for thin films in small bias fields such that MHz transverse relaxation rates for undressed excitations can result in nanosecond damping times in a thin film geometry. Such strong renormalization allows for a significant contribution by weak spin-orbit effects to the overall damping of precessional excitations in thin film structures. Inverse field dependence for the damping parameter in thin films is predicted by the new equation, in agreement with recent data obtained by inductive and optical methods.[1] In addition, highly viscous response is predicted when the magnetization is subject to large magnetic field pulses along the hard axis of uniaxial anisotropy films, also in agreement with recent observations of metastable states in homogeneous Permalloy films.[2] Implications for device performance and data storage applications will be discussed.

[1] T. J. Silva, T. M. Crawford, IEEE Trans. Magn. 35, 671 (1999).
[2] P. Kabos, S. Kaka, S. E. Russek, T. J. Silva, IEEE Trans. Magn. 36, 3050 (2001).

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