MA 8: Spin Excitations and Spin Torque

Time: Monday 9:30–12:30 Location: H23

MA 8.1 Mon 9:30 H23

Impact of Atomic Structure on the Magnon Dispersion Relation: Fe(111)/Au/W(110) and Fe(110)/W(110) — •Tzu-Hung Chuang[1], Khalil Zakeri[1], Arthur Ernst[1], Leonid M. Sandratskii[1], Pawel Buczek[1], Yu Zhang[1], Huajun Qin[1], Waheed Adeagbo[2], Wolfram Hergert[2], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Seckendorff-Platz 1, D-06120 Halle, Germany

We present a combined experimental and theoretical study of the correlation between the atomic structure and magnon energies in ultrathin Fe films. High wave-vector magnon excitations in a 2 monolayer (ML) Fe(111) film grown in an fcc-like stacking on 2ML Au/W(110) are probed by spin-polarized electron energy loss spectroscopy. The results are compared to the ones of a bcc-like film directly grown on W(110). It is found that the magnon energies in Fe(111)/Au/W(110) are lower than the ones in Fe(110)/W(110). Our calculations confirm the experimental results revealing a strong dependency of exchange interaction on the atomic structure. In the Fe/Au/W structure, it is observed that the intralayer exchange interactions increase with increasing distance between Fe atomic layers. This effect can be understood based on the complexity of the electronic structure and the contribution of different orbitals to the hybridization and exchange interaction [1].

[1] T.-H. Chuang, Kh. Zakeri, A. Ernst, L. M. Sandratskii, P. Buczek, Y. Zhang, H. J. Qin, W. Adeagbo, W. Hergert, and J. Kirschner, Phys. Rev. Lett. **109**, 207201 (2012).

MA 8.2 Mon 9:45 H23

Strong magnon softening in tetragonal FeCo compounds: An *ab initio* many-body perturbation theory study — •Ersoy Sasioglu, Christoph Friedrich, and Stefan Blügel — Peter Grünberg Institut and Institute forAdvanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Magnons play an important role in fast precessional magnetization reversal processes serving as a heat bath for dissipation of the Zeeman energy and thus being responsible for the relaxation of magnetization [1]. Employing *ab initio* many-body perturbation theory [2] within the framework of the full-potential linearized-augmented plane-wave (FLAPW) method [3], we have studied the magnon spectra of the tetragonal FeCo compounds considering three different experimental c/a ratios, c/a =1.13, 1.18, and 1.24 corresponding to FeCo grown on Pd, Ir, and Rh, respectively. We find that for all three cases the short-wave-length magnons are strongly damped and tetragonal distortion gives rise to a significant magnon softening. The magnon stiffness constant D decreases almost by a factor of two from FeCo/Pd to FeCo/Rh. The combination of soft magnons together with the giant magnetic anisotropy energy suggests FeCo/Rh to be a promising material for perpendicular magnetic recording applications.

[1] K. Baberschke, physica status solidi (b) **245**, 174 (2008).
[2] E. Şaşıoğlu, A. Schindlmayr, C. Friedrich, F. Freimuth, and S. Blügel, Phys. Rev. B **81**, 054434 (2010).
[3] http://www.flapw.de

MA 8.3 Mon 10:00 H23

Imaging of spin transfer torque induced magnetization reversal — •Matthias Buhl[1], Jochen Grebing[1], Sebastian Wintz[1], Jörg Raabe[2], Jürgen Fassbender[1], and Artur Erbe[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Paul Scherrer Institut, Villigen, Switzerland

Setting the magnetic state of nanostructures can be used for durable information storage. For future applications, this process needs to be developed towards true nanoscale dimensions in order to keep up the miniaturization speed of modern nanoelectronic components. Therefore, new concepts for controlling the state of nanomagnets are currently in the focus of research in the field of nanoelectronics. Here, we demonstrate the magnetic characterization of purely metallic nanopillars placed on a lead that conducts a spin-polarized current at room temperature. The structures are fabricated by means of electron beam lithography. Spin diffusion across the metal-metal (Cu to CoFe) interface between the pillar and the lead causes spin accumulation in the pillar, which may then be used to set the magnetic orientation of the pillar. Reproducible switching of the magnetization of the pillar is observed by direct imaging via scanning transmission x-ray microscopy (STXM).

MA 8.4 Mon 10:15 H23

Spin Torque Ferromagnetic Resonance in MgO-based Magnetic Tunnel Junctions — •Yuriy Aleksandrov[1,2], Alina M. Deac[1], Kerstin Bernert[1,2], Ciaran Fowley[1], Volker Sluka[1], Ewa Kowalska[1], Jürgen Lindner[1], and Jürgen Fassbender[1,2] — [1]HZDR, Dresden, Germany — [2]TU Dresden, Dresden, Germany

Spin polarized currents can exert a torque on a ferromagnetic layer‘s magnetic moment leading to switching or steady-state precession. Spin-torque driven ferromagnetic resonance (ST-FMR) is a unique method to measure the magnetic anisotropy, saturation magnetization and damping in a nanoscale structure. ST-FMR can also be used to determine the bias dependence of spin-transfer torques in magnetic tunnel junctions [1- 3]. For different values of applied RF power and DC bias, we swept the RF frequency from 1 to 15 GHz and measured the resulting mixing voltage across our MgO-based tunnel junctions. Not only the low-frequency fundamental mode was observed, but also a higher order mode. We find that the mixing voltage peak shifts with applied DC-field and increases with RF power. Finally, we separate the field-like torque contribution from that of the in-plane spin-transfer torque and determine their bias dependence.

[1] A. Deac et al., Nature Phys. 4, 803 (2008).
[2] H. Kubota et al., Nature Phys. 4, 37 (2008).
[3] J. C. Sankey et al., Nature Phys. 4, 67 (2008).

MA 8.5 Mon 10:30 H23

Minimizing the Fano factor of spin shot noise in a nano-oscillator — •Jacek Swiebodzinski — Theoretische Physik, Universität Duisburg-Essen and CENIDE, 47048 Duisburg, Germany

A spin polarized current may transfer angular momentum to a free ferromagnet resulting in the celebrated spin-torque phenomenon. If its amplitude and direction are fine-tuned in such a way that the magnetic damping is compensated for, the microscopic torque may lead to an undamped steady-state precession of the magnetization vector in sufficiently small samples. The linewidth of such a nano-oscillator is a result of thermal and non-thermal sources of noise. A prominent source of non-equilibrium noise in spin-torque systems is the spin shot noise [1]. It is a consequence of the discreteness of the angular momentum transfer and as such present in every spin-torque experiment. Here, we introduce the Fano factor of the spin shot noise. For a spin-torque nano-oscillator we calculate the voltage dependence of the Fano factor and show that there is an optimal precession angle at which the Fano factor is minimized [2]. In particular at low temperatures, where the spin shot noise constitutes a dominant contribution to magnetization noise, our findings are of practical importance for an efficient operation of nano-oscillators.

[1] A. L. Chudnovskiy, J. Swiebodzinski, and A. Kamenev, Phys. Rev. Lett. **102**, 066601 (2008).
[2] J. Swiebodzinski, Phys. Scr. **T151**, 014024 (2012).

MA 8.6 Mon 10:45 H23

Thermally Excited Ferromagnetic Resonance in MgO-based Magnetic Tunnel Junctions — •Ewa Kowalska[1], Yuriy Aleksandrov[1,2], Kerstin Bernert[1,2], Ciaran Fowley[1], Volker Sluka[1], Jürgen Lindner[1], Jürgen Fassbender[1,2], and Alina Deac[1] — [1]HZDR, Dresden, Germany — [2]TU Dresden, Dresden, Germany

Spin polarized currents can exert a so-called spin-transfer torque to the magnetic moment of a ferromagnetic layer. One application of this phenomenon is the spin torque nano-oscillator (typically an MgO-based magnetic tunnel junction (MTJ)) which can act as a tunable microwave emission source. However, a more detailed understanding of the spin-torque physics is needed. For example, the spin torque bias dependence of the two spin torque components (in-plane and field-like) is still widely discussed in the community [1]. We present results for MgO-MTJs obtained by thermally excited ferromagnetic resonance (TE-FMR). With the help of TE-FMR, the bias dependence of the two spin-transfer torques can be determined from the peak position and linewidth [2]. Microwave measurements were carried out in the frequency range of 1-9 GHz at positive and negative magnetic fields and for different dc current values. Analyzing this data, we could separate the in-plane and field-like spin torque components and determine their bias dependence.

[1] M. H. Jung et al., PRB 81, 134419 (2010).
[2] A. Deac et al., Nature Phys. 4, 803 (2008).

15 min. break

MA 8.7 Mon 11:15 H23

Concentration dependence of the tunnel magnetoresistance and spin-transfer torque in FeCo/MgO/FeCo tunnel junctions — •Christian Franz, Michael Czerner, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University, Giessen, Germany

We investigate magnetic tunnel junctions with $Fe_{1-x}Co_x$ alloys as magnetic layers and a MgO barrier. We calculate *ab initio* the tunnel magnetoresistance (TMR) and spin-transfer torque (STT) for zero and finite bias voltage and analyze their dependence on the concentrations. We describe the transport processes using a non-equilibrium Green's function method, which was implemented in a KKR method. The FeCo alloys are described by the coherent potential approximation (CPA). In the CPA calculations we incorporate non-equilibrium vertex corrections. The alloy scattering, which is included in the CPA description, leads to a broadening of the bands. As a result, we find that in the voltage dependence of TMR and STT resonant features are smeared out for finite concentrations. For zero bias the TMR shows only a weak concentration dependence for intermediate concentrations but a strong enhancement towards the pure components. At a finite bias of 0.54 V we find that the TMR strongly decreases with the Co concentration. The investigation of the concentration dependence of the STT shows that, while the interlayer exchange coupling decreases with the Co concentration, the linear bias dependence of the in-plane-torque is independent of the concentration. Thus our results favour high Fe concentrations in order to obtain a high TMR and STT.

MA 8.8 Mon 11:30 H23

Perpendicular anisotropy in CoFeB/MgO - based magnetic tunnel junctions — •Vladyslav Zbarsky[1], Marvin Walter[1], Maria Mansurova[1], Christian Leutenantsmeyer[1], Tim Eggebrecht[1], Karsten Rott[2], Günter Reiss[2], Rashid Gareev[3], Tae Hee Kim[4], and Markus Münzenberg[1] — [1]I. Physikalisches Institut, Universität Göttingen, — [2]Physikalisches Institut, Universität Bielefeld — [3]Physikalisches Institut, Universität Regensburg — [4]Department of Physics, Ewha Womans University Korea

The reduction of the switching current density is important for spin-transfer torque based MRAM and predicted for the magnetic tunnel junctions (MTJs) with perpendicular magnetic anisotropy (PMA). The first experiments show that the thicknesses of CoFeB and MgO layers are crucial for the out-of-plane magnetic behaviour. In this context, samples with a CoFeB thickness gradient were fabricated and MOKE measurements as well as electrical characterization carried out. For CoFeB layers below 1.3 nm a perpendicular anisotropy is observed. On those samples, MTJs with 155 nm diameter show STT with a very low switching current density of $2 \cdot 10^5$ A/cm^2. Samples with higher CoFeB thickness show a change of magnetic behaviour from out-of-plane to in-plane easy axis. To investigate the influence of the MgO interface, a thin Co layer is inserted at one of the MgO interfaces and its influence on the magnetic anisotropy is studied.

MA 8.9 Mon 11:45 H23

Fabrication of CoFeB|MgO|CoFeB magnetic tunneljunctions with ultrathin barriers for thermal spin transfer torque — •Johannes Christian Leutenantsmeyer[1], Marvin Walter[1], Vladyslav Zbarsky[1], Patrick Peretzki[2], Henning Schuhmann[2], Michael Seibt[2], Karsten Rott[3], Günter Reiss[3], Andy Thomas[3], and Markus Münzenberg[1] — [1]I. Phys. Inst., Universität Göttingen — [2]IV. Phys. Inst., Universität Göttingen — [3]Thin Films and Physics of Nanostructures, Universität Bielefeld

Thermal spin-transfer torque (T-STT) describes the combination of the spin-transfer torque effect with the spin-caloric magneto-Seebeck effect. Here, thermally excited electrons are used to manipulate the magnetization of a magnetic tunneljunction (MTJ). Calculations have been performed in 2011 [1] suggesting a switching T-STT at temperature gradients in the order of 10 K in MTJs with 3 monolayer (ML) MgO barriers. The effect is suitable for storage application, enhancing the energy efficiency of those devices.

We have fabricated CoFeB/MgO MTJs with 3 ML MgO barriers and reasonable interface roughness. For different deposition parameters (in particular MgO growth temperature), the quality of the interface was studied via quantitave HR-TEM analysis. Characterization shows a TMR-effect of up to 55% in nanoscaled junctions. Also spin-transfer torque was observed in 4 ML junctions. MTJs with 4 ML MgO and perpendicular magnetization anisotropy (PMA) show ultra low switching currents (0.2 MA/cm^2), making PMA MTJs suitable for T-STT.

[1] Jia et al., PRL **107** 176603, 2011

MA 8.10 Mon 12:00 H23

Current induced domain wall nucleation and motion in an out-of-plane magnetized CoFeB-MgO nanowire — •Tomek Schulz[1], Tim Zacke[1], Su-Jung Noh[1], Berthold Ocker[2], Capuciné Burrowes[3], Dafiné Ravelsona[3], and Mathias Kläui[1] — [1]Instute of Physics, Johannes Gutenberg-Universität Mainz, Germany — [2]Singulus Technologies AG, Kahl am Main, Germany — [3]Institut d'Electronique Fondamentale, Universite Paris-sud, France

For read-out of a racetrack device, an appropriate material compositions that is compatible with high TMR MgO barriers has been developed. We report on transport measurements on a magnetic nanowire structure consisting of a Ta/CoFeB/MgO/Ta-multilayer with a perpendicular magnetization anisotropy. By applying single short current pulses through a gold wire on top of the nanowire it is possible to nucleate domain walls only by the generated Oersted field. After the nucleation, we investigated the properties of this multilayer stack for current induced domain wall motion and found very low propagation fields.

MA 8.11 Mon 12:15 H23

Current induced Domain Wall Motion in Rashba nanowires — •Martin Stier[1], Reinhold Egger[2], and Michael Thorwart[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg — [2]Institut für theoretische Physik, Heinrich-Heine-Universität, D-40225 Düsseldorf

We consider the current-induced motion of a Bloch domain wall in an thin ferromagnetic nanowire with strong Rashba spin-orbit coupling. By including intrinsic and extrinsic relaxation mechanisms, we calculate the full nonadiabatic spin torque. In particular, we show that a nonadiabatic local magnetic Rashba field $\mathbf{H}_R$ arises which can become large for small dampings β. Our theory predicts that with increasing spin-orbit coupling strength, domain wall motion progresses from purely translatory to oscillatory dynamics. For pulsed currents, depending on the pulse length, rich behavior is found, including wall motion *against* the current direction and a strong enhancement of the wall velocity.