# MA 22: Spin Dynamics / Spin Torque III

Time: Thursday 9:30–12:45 Location: H10

**Invited Talk** MA 22.1 Thu 9:30 H10

**Tailoring the spin functionality of a hybrid metal-organic interface by means of alkali metal doping** — •Mirko Cinchetti, Sabine Neuschwander, Jan-Peter Wüstenberg, Alexander Fischer, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany

Doping of organic semiconductors (OSCs) has proven to be an efficient strategy to adjust their electronic properties for implementation in organic-based electronic devices. The recent success in the application of OSCs for spintronics raises the fundamental question if doping can be used as well to tailor the functionality of hybrid metal-organic interfaces, and thus to control the high spin injection efficiency achievable in OSC. We employ a recently developed purpose-made technique based on spin resolved two-photon photoemission spectroscopy [1] to study the influence of alkali doping (Cs and Na) on the spin functionality of the interface between a thin cobalt film and the organic semiconductor copper phthalocyanine (CuPc). We find two alkali-induced effects. First, alkali atoms act as impurities and increase the spin-flip probability for the electrons crossing the interface (detrimental effect). Second, they allow to enhance the efficiency of spin-injection at an arbitrary energy above the Fermi level of the cobalt (intrinsic effect). We show that the intrinsic effect dominates over the detrimental one, giving rise to the possibility to actively tailor the spin functionality of the considered hybrid interface by changing the doping concentration.

[1] M. Cinchetti et al., Nature Materials 8, 115-119 (2009)

MA 22.2 Thu 10:00 H10

**Critical Current for Switching the Magnetization of Quasistable Nano-Islands Using SP-STM** — •Stefan Krause, Gabriela Herzog, Anika Emmenegger, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

Spin-polarized scanning tunneling microscopy (SP-STM) has been demonstrated to be capable for manipulating the superparamagnetic switching behavior of nano-islands, using the spin torque and Joule heating of elevated spin-polarized tunnel currents [1]. The question arises whether SP-STM can also be used to manipulate static magnetic nanostructures, thereby opening perspectives for future data storage technologies based on SP-STM.

In our experiment, an individual thermally quasistable nano-island consisting of about 40 iron atoms on a W(110) surface has been addressed using a magnetic probe tip. Sweeping the spin-polarized tunnel current between tip and sample from the nA to the $\mu$A regime allows for switching the island's magnetization back and forth, depending on the bias polarity. The critical current for switching the magnetization back and forth is discussed in terms of the current sweep rate, and numerical simulations supporting the experimental findings are presented. The local current density necessary for switching the magnetization is found to be comparable to that used in experiments on nanopillar devices [2].

[1] S. Krause *et al.*, Science **317**, 1537 (2007).
[2] G. D. Fuchs *et al.*, Appl. Phys. Lett. **85**, 1205 (2004).

MA 22.3 Thu 10:15 H10

**Optimum tunnel barrier thickness for spin torque memory devices** — •Santiago Serrano-Guisan[1], W. Skowronski[2], N. Liebling[1], J. Wrona[2], M. Czapkiewicz[2], T. Stobiecki[2], J. Langer[3], B. Ocker[3], G. Reiss[4], and H.W. Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116, Braunschweig, Germany — [2]AGH University of Science and Technology, Department of Electronics, Al. Mickiewicza 30, 30059 Krakow, Poland — [3]Singulus, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany — [4]Bielefeld University, Department of Physics, P.O. Box 100131, 33501 Bielefeld, Germany

We study the influence of the exchange coupling strength $J_{FP}$ between the free and the reference layer magnetization on the precessional magnetization dynamics in CoFeB/MgO/CoFeB based magnetic tunnelling junction stacks with different MgO barrier thickness (tMgO) by pulse inductive microwave magnetometry (PIMM). From PIMM data the field dependent precession frequency f and the effective Gilbert damping $\alpha$ as well as their respective dependence on tMgO are derived. For tMgO $<$ 0.76 nm the strong $J_{FP}$ inhibits reversal of the free layer. However, for a thickness range 0.85 nm $>$ tMgO $>$ 0.76 nm free layer reversal is possible and a relative low damping $\alpha \approx 0.017 \pm 0.003$ is found with no significant barrier thickness dependence. For such relatively low $\alpha$, a low current density spin torque reversal is expected as it scales linearly with $\alpha$. Additionally, the large TMR ratios (larger than 150%) and small RA products (2-4 $\Omega\mu m^2$) occurring in this thickness range make it optimum for ST memory applications

MA 22.4 Thu 10:30 H10

**Spin-transfer torque experiments on magnetic disks near the vortex regime** — •Volker Sluka, Daniel Bürgler, and Claus Schneider — Institute of Solid State Research, Research Center Jülich, Jülich, Germany

In thin magnetic disks vortex states appear as ground states of magnetization as a result of the interplay between exchange interaction and dipolar energy. The vortex structure can be divided into two regions. The magnetization basically lies in the disk plane while possessing a circular shape, thereby closing the flux and minimizing the stray field. In the center of this pattern referred to as the vortex core region however, this would lead to a strong build-up of exchange energy. Therefore in this part the magnetization points out of plane, defining the vortex polarity. In this work nano-pillars containing two single crystalline Fe disks close to the vortex regime have been prepared. The structures are processed from MBE grown layers and have diameters of roughly 150 nm. The 30 and 15 nm thick disks are seperated by a non-magnetic spacer (Ag, 6 nm). DC and HF measurements are performed to investigate the nano-pillar's response to external fields and pulsed / constant currents.

MA 22.5 Thu 10:45 H10

**Spin shot noise and spin torque dynamics** — •Jacek Swiebodzinski[1], Alex Kamenev[2], Thomas Dunn[2], Daniela Pfannkuche[3], and Alexander Chudnovskiy[3] — [1]Theoretische Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Physics, University of Minnesota, Minneapolis, Minnesota 55455, USA — [3]I. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany

Investigations of noise in nano-scale devices are indispensable in any use-oriented consideration and - at the same time - a broad and fascinating field from the basic-researcher's point of view. In this theoretical contribution we investigate the role of spin shot noise in spin torque dynamics of mono-domain ferromagnets. Spin shot noise is a consequence of the discreteness of angular momentum transfer and present in any spin torque experiment. At low temperatures it gives the dominant contribution to magnetization noise. Unlike its thermal counterpart the nonequilibrium noise displays a dependence on the relative orientation of the ferromagnets forming the magnetic junction. We address the question of spin torque switching by applying a generalized Fokker-Planck approach that models switching rates with the help of an effective temperature in the Arrhenius factor. We show that the spin shot noise leads to a renormalization of the effective temperature. The details of the renormalization depend on the geometry of the system. In particular, the nonequilibrium noise may lead to the occurrence of "cold" and "hot" trajectories of the magnetization vector with respect to the noise intensity.

MA 22.6 Thu 11:00 H10

**Local spin-transfer torque within narrow domain walls** — •Stellan Bohlens and Daniela Pfannkuche — I. Institut für Theoretische Physik

In mesoscopic ferromagnets, a domain structure that consists of regions in which the magnetization points in different spatial directions is energetically more favorable than a monodomain. The individual domains are separated by domain walls, where the magnetization changes continuously. A current traversing such a non-collinear magnetization texture exerts a spin-transfer torque on the local magnetization. A consistent theory of spin-transfer torque and spin transport that is also applicable for narrow domain walls is still missing and its impacts are not assessable to date.

We present a theoretical formulation of electron and spin transport that allows for the derivation of the local spin-transfer torque in general magnetization textures. The framework provides the microscopic derivation of transport coefficients that were treated so far as phenomenological parameters in the theory of the spin-transfer torque. [1] We apply our formalism to a Bloch wall and calculate the spatially resolved spin-transfer torque. In the case of narrow domain walls it turns out that the treatment of coupled charge and spin transport offers startling insight into fascinating physics in an intermediate transport regime that comprises diffusive charge transport and ballistic spin transport at the same time.

[1] S. Zhang and Z. Li, Phys. Rev. Lett. 93, 127204 2004

MA 22.7 Thu 11:15 H10

**Non-adiabatic spin transfer torque investigated using thermally activated magnetic domain walls in permalloy wires** — •Matthias Eltschka[1], Mathias Wötzel[1,2], Takeshi Kasama[2], Jan Rhensius[1,3], Stephen Krzyk[1], Laura Heyderman[3], Rafal Dunin-Borkowski[2], Ulrich Nowak[1], and Mathias Kläui[1] — [1]Fachbereich Physik, Universität Konstanz, Universitätsstraße 10, 78457 Konstanz, Germany — [2]Center for Electron Nanoscopy, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark — [3]Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

The understanding of the interplay between spin-polarized currents and magnetization as well as the determination of the spin torque terms are of scientific interest and essential for many proposed applications.

Using transmission electron microscopy we investigate thermally activated domain walls (DWs) jumping back and forth between two pinning sites in permalloy wires at room temperature. The motion is of pure thermal origin without the influence of external magnetic fields or electron currents. Considering the DW as a quasi particle in a local potential with two metastable states we show that this DW movement can be described by an Arrhenius law. Subsequently, we investigate the change of the local potential by constant currents which are far below the threshold values needed for DW propagation and do not induce significant heating. Based on a 1D description of the spin transfer torque effect and the Arrhenius law we derive the non-adiabatic coefficient $\beta$ for a transverse and a vortex DW.

MA 22.8 Thu 11:30 H10

**Heat assisted Spin Torque Switching of Nanomagnets by SP-STM** — •Gabriela Herzog, Stefan Krause, Anika Emmenegger, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

Recently it has been shown that spin-polarized scanning tunneling microscopy (SP-STM) can be applied to manipulate magnetization switching of individual thermal agitaded nano-islands by the injection of elevated spin-polarized tunnel currents [1].

The open question remained whether it is possible to manipulate the static magnetization of nanostructures with a SP-STM. We demonstrate the capability of current-induced magnetization switching of quasistable nanostructures. Therefore in-plane magnetized uniaxial Fe monolayer nano-islands on W(110) were prepared. Using spin-polarized tunnel current pulses originating from the microscope tip the magnetization of individual nano-islands is switched reliably and reversibly. We find the current pulse length to be of crucial importance for magnetization reversal, and by changing pulse polarity we ascertain the roles of both Joule heating and spin torque.

[1] S. Krause *et al.*, Science **317**, 1537 (2007).

MA 22.9 Thu 11:45 H10

**Spin torque and waviness in magnetic multilayers: a bridge between Valet-Fert theory and quantum approaches** — •Valentin Rychkov[1,3], Simone Borlenghi[1], Henry Jaffres[2], Albert Fert[2], and Xavier Waintal[1] — [1]Nanoelectronics group, Service de Physique de l'Etat Condensé, CEA Saclay F-91191 Gif-sur-Yvette Cedex, France — [2]Unité Mixte de Physique CNRS-Thales, Route départementale 128, 91767 Palaiseau Cedex and Université Paris-Sud 91405, Orsay, France — [3]Institut fuer Theoretische Physik und Astrophysik Universitaet Wuerzburg Am Hubland D-97074 Wuerzburg Germany

We develop a simple theoretical framework for transport in magnetic multilayers, based on Landauer-Buttiker scattering formalism and Random Matrix Theory. A simple transformation allows one to go from the scattering point of view to theories expressed in terms of local currents and electrochemical potential. In particular, our theory can be mapped onto the well established classical Valet Fert theory for collinear systems. For non collinear systems, in the absence of spin-flip scattering, our theory can be mapped onto the generalized circuit theory. We apply our theory to the angular dependance of spin accumulation and spin torque in non-collinear spin valves.

MA 22.10 Thu 12:00 H10

***Ab initio* calculation of the spin torque in all metallic spin valves and magnetic tunnel junctions** — •Frank Freimuth, Daniel Wortmann, and Stefan Blügel — Institut für Festkörperforschung, & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

We present calculations of the current perpendicular to the plane (CPP) spin torque for the all metallic spin valves Co/Cu/Co, Fe/Ag/Fe and Fe/Au/Fe and for MgO-based magnetic tunnel junctions. Compared to the Co/Cu/Co spin valve the Fe/Ag/Fe and Fe/Au/Fe spin valves are characterized by a much larger asymmetry of the angular dependence of the torque. In the case of Fe/Au/Fe we investigate the influence of spin-orbit coupling on the spin torque. Special attention is given to the dependence of the torque on the thicknesses of the free magnetic layer and the interlayer. For MgO-based magnetic tunnel junctions we discuss the dependence of the spin torque on the magnetic lead material and the bias-dependence of the torque. Our calculations are based on an order-N implementation of the full-potential linearized augmented-plane-wave method `FLEUR` (www.flapw.de) within the Green function embedding formalism.

MA 22.11 Thu 12:15 H10

**Multi-macro spin simulations of opto-magnetic switching** — •Stefan Gerlach[1], Denise Hinzke[1], Thomas Ostler[2], Roy W. Chantrell[2], and Ulrich Nowak[1] — [1]University of Konstanz, 78457 Konstanz, Germany — [2]University of York, York YO10 5DD, U. K.

The ultrafast manipulation of the magnetization with the aid of femtosecond laser pulses promises to become a real alternative to writing techniques where magnetic field pulses are used in addition to laser heating. It was recently demonstrated [1] that a 40 fs, circularly polarized laser pulse is able to reverse the magnetization on a picosecond time scale as if the laser pulse acts as an equally short magnetic field pulse with a polarization dependent direction caused by the so-called inverse Faraday effect.

To investigate the opto-magnetic magnetization reversal, we use Landau-Lifshitz-Bloch (LLB)-based multi-macro spin simulations [2] for extended systems with up to $4 \times 10^6$ macro-spins ($10\ \mu m \times 10\ \mu m$) where the exchange coupling as well as the dipolar interaction is taken into account. Furthermore, we assume a Gaussian temperature profile in order to model a realistic laser spot and to explore the size of a stable opto-magnetically reversed area after excitation. We will show and discuss results of the magnetization evolution of thin films and compare with recent experiments [3].

[1] C. D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007) [2] N. Kazantseva et al., Phys. Rev. B 77, 184428 (2008) [3] K. Vahaplar et al., Phys. Rev. Lett. 103, 117201 (2009)

MA 22.12 Thu 12:30 H10

**Numerical investigation of opto-magnetic switching** — •Denise Hinzke[1], Stefan Gerlach[1], Thomas Ostler[2], Roy W. Chantrell[2], and Ulrich Nowak[1] — [1]Universität Konstanz, 78457 Konstanz — [2]University of York, York YO10 5DD, U. K.

Ultrafast magnetisation dynamics has been extensively studied recently as a possibility to improve the storage density as well as the writing speed in magnetic data storage. It was demonstrated [1] that a 40 fs, circularly polarised laser pulse is able to reverse the magnetisation. One possible explanation is that the laser pulse acts as an equally short magnetic field pulse pointing along the direction of light caused by the so-called inverse Faraday effect [2].

We perform single macro-spin simulations [3] within the framework of the Landau-Lifshitz-Bloch equation recently derived by Garanin [4]. One of our findings consistent with experimental results is that field pulse durations as short as 250 fs can be sufficient to reverse the magnetisation [5]. Furthermore, we found that the magnetisation switching is via a linear pathway [6] without any precession.

[1] C. D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007) [2] A. V. Kimel et al, Nature (London) 435, 655 (2005) [3] N. Kazantseva et al, Phys. Rev. B 77, 184428 (2009), [4] D. A. Garanin, Phys. Rev. B 55, 3050 (1997), [5] K. Vahaplar et al, Phys. Rev. Lett. 103, 117201 (2009) [6] N. Kazantseva et al, Europhys. Lett. 81, 27004 (2008)