MAGNETIC SWITCHING (SYMS)

Jointly organized by
Magnetism (MA)
Low Temperature Physics (TT)
Thin Films (DS)

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OVERVIEW OF INVITED TALKS AND SESSIONS

(lecture room HSZ 04)

Invited Talks

SYMS 1.1	Mon	15:00	(HSZ 04)	**Manipulation of magnetization by spin transfer: switching, microwave generation**, Albert Fert, O. Boulle, V. Cros, M. Elsen, J. Grollier, A. Hamzic, H. Jaffrés, M. AlHajDarwish, J. Bass, H. Kurt, W. P. Pratt, J. Barnas, I. Gimtra, I. Weymann, R. Giraud, G. Faini, A. Lamaitre
SYMS 1.2	Mon	15:45	(HSZ 04)	**Spin-torque effects in single-crystalline Fe nanomagnets and nanopillars**, Daniel E. Bürgler, Henning Dassow, Ronald Lehndorff, Matthias Buchmeier, Peter A. Grünberg, Claus M. Schneider
SYMS 1.3	Mon	16:15	(HSZ 04)	**Current-induced spin-transfer torque and spin dynamics in spin-valve structures**, Jozef Barnas, Martin Gmitra, Vitaly Dugaev, Albert Fert
SYMS 2.1	Mon	17:00	(HSZ 04)	**Spin-Hall effect in a two-dimensional electron system**, Peter Schwab, Michael Dzierzawa, Roberto Raimondi, Cosimo Gorini
SYMS 2.2	Mon	17:20	(HSZ 04)	**Submicrometer ferromagnetic logic gates**, Russell Cowburn
SYMS 2.3	Mon	17:50	(HSZ 04)	**Spin torque: wall dynamics in nanowires vs. switching in nanopillars**, Jacques Miltat, André Thiaville
SYMS 2.4	Mon	18:20	(HSZ 04)	**Interactions between domain walls and spin currents**, M. Klaeui, M. Laufenberg, D. Backes, P.-O. Jubert, R. Allenspach, A. Bischof, L. Vila, C. Vouille, G. Faini, U. Ruediger

Sessions

SYMS 1	**Magnetic Switching I**	Mon 15:00–16:45	HSZ 04	SYMS 1.1–1.3
SYMS 2	**Magnetic Switching II**	Mon 17:00–18:50	HSZ 04	SYMS 2.1–2.4

Sessions

– Invited Talks –

SYMS 1 Magnetic Switching I

Time: Monday 15:00–16:45 Room: HSZ 04

Invited Talk SYMS 1.1 Mon 15:00 HSZ 04

Manipulation of magnetization by spin transfer: switching, microwave generation — •Albert Fert[1], O. Boulle[1], V. Cros[1], M. Elsen[1], J. Grollier[1], A. Hamzic[1], H. Jaffrés[1], M. AlHajDarwish[2], J. Bass[2], H. Kurt[2], W. P. Pratt[2], J. Barnas[3], I. Gimtra[3], I. Weymann[3], R. Giraud[4], G. Faini[4], and A. Lamaitre[4] — [1]Unité Mixte de Physique CNRS/Thales, 91767 Palaiseau, France — [2]Michigan State University, East Lansing, MI, USA — [3]Poznan University, Poland — [4]LPN/CNRS, Marcoussis, France

The magnetization of a ferromagnetic body can be manipulated without applying any magnetic field, only by transferring some quantity of spin angular momentum from a spin-polarized electrical current. The first part of the lecture introduces the concept of spin transfer and describes basic experiments we performed on pillar-shaped metallic pillars and tunnel junctions. Specific experiments giving more insight on the microscopic mechanism will also be presented, for example experiments in which the switching currents can be inverted by the introduction of impurities with selected spin dependent scattering cross-section. The second part of the talk summarizes the theoretical model developed for the calculation of the spin torque and its application to several problems: inversion or tuning of the switching currents by impurity scattering, generation of microwave oscillations at zero field, etc. I will conclude with some work on the problem of the synchronization of spin transfer oscillators, an important challenge for the future applications to microwave generation.

Invited Talk SYMS 1.2 Mon 15:45 HSZ 04

Spin-torque effects in single-crystalline Fe nanomagnets and nanopillars — •Daniel E. Bürgler, Henning Dassow, Ronald Lehndorff, Matthias Buchmeier, Peter A. Grünberg, and Claus M. Schneider — Institut für Festkörperforschung und cni - Center of Nanoelectronic Systems for Information Technology, Forschungszentrum Jülich GmbH

We report on current-induced magnetization switching (CIMS) and microwave excitations in single-crystalline Fe nanomagnets and nanopillars. Fe(14)/Cr(0.9)/Fe(10)/Ag(6)/Fe(2) [thicknesses in nm] multilayers are prepared by molecular beam epitaxy. The middle Fe layer is magnetically hardened due to AF interlayer coupling across the Cr spacer. The topmost Fe layer is decoupled and acts as free layer. Nanomagnets and nanopillars with diameters of about 150 nm are patterned by optical and e-beam lithography. The CPP-GMR is 2.6% at RT and 5.6% at 4 K. Clearly different GMR curves for the field along the easy and hard axes of Fe(001) indicate the single-crystalline nature of the nanostructures. Hysteretic CIMS occurs at current densities larger than 2×10^7 A/cm^2. The critical current density and the switching behavior are different for the field applied along easy and hard axes. In nanopillars, CIMS appears for both current polarities and is related to the switching of the top or middle Fe layer, respectively, and to the different spin scattering asymmetries of Fe/Cr and Fe/Ag interfaces. High-frequency spectroscopy reveals magnetic GHz excitations in the nanomagnets with a rich dependence of the excitation frequency on the DC current, field strength and direction, again with clearly different easy and hard axis behaviors.

Invited Talk SYMS 1.3 Mon 16:15 HSZ 04

Current-induced spin-transfer torque and spin dynamics in spin-valve structures — •Jozef Barnas[1,2], Martin Gmitra[1], Vitaly Dugaev[3], and Albert Fert[4] — [1]Department of Physics, Adam Mickiewicz University, Poznan, Poland — [2]Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland — [3]Instituto Superior Tecnico, Lisbon, Portugal — [4]Unite Mixte de Physique CNRS/THALES, Orsay, France

A unified description of the current-perpendicular-to-plane giant magnetoresistance (CPP-GMR) and current-induced magnetic switching (CIMS) in spin-valve structures has been worked out in terms of a macroscopic model. The description is based on the classical spin diffusion equation for the distribution function and on the relevant boundary conditions for the longitudinal and transverse components of the spin current. The description explains experimentally observed correlations between normal/inverse CPP-GMR and normal/inverse CIMS.

Time evolution of the CIMS and spin dynamics due to spin-transfer torque have been analyzed in terms of a macrospin model by solving the relevant Landau-Lifshitz-Gilbert equation. Current-induced transition to steady precessional modes in zero magnetic field has been found in some asymmetrical structures. Conditions for the occurrence of such precessional modes and the relevant phase diagram have also been found.

SYMS 2 Magnetic Switching II

Time: Monday 17:00–18:50 Room: HSZ 04

Invited Talk SYMS 2.1 Mon 17:00 HSZ 04

Spin-Hall effect in a two-dimensional electron system — •Peter Schwab[1], Michael Dzierzawa[1], Roberto Raimondi[2], and Cosimo Gorini[2] — [1]Universität Augsburg, Germany — [2]Università di Roma Tre, Italy

In a two-dimensional electron gas with spin-orbit coupling an electric field can generate spin currents and spin polarization. We study the problem using the method of quasiclassical Green's functions. In the clean limit we establish a connection between the spin-Hall conductivity and a Berry phase in momentum space. For disordered systems we calculate spin currents and spin accumulation numerically for a strip connected to a voltage source. Universal spin currents are found in the short-time dynamics, leading to a spin-Hall spin polarization near the edges of the strip.

Invited Talk SYMS 2.2 Mon 17:20 HSZ 04

Submicrometer ferromagnetic logic gates — •Russell Cowburn — Blackett Physics Laboratory, Imperial College London, Prince Consort Road, London SW7 2BW, UK

Spintronics, in which both the spin and charge of electrons are used for logic and memory operations, promises an alternative route to traditional semiconductor electronics. A complete logic architecture can be constructed that uses planar magnetic wires less than a micrometer in width. Logical NOT, logical AND, signal fan-out and signal cross-over elements each have a simple geometric design and can be integrated together into one circuit. An additional element for data-input allows information to be written to domain wall logic circuits. Working nanocircuits comprising all of these logic elements will be described, as well as a proposal for a new ultrahigh density data storage device based on domain walls circulating in 3-dimensional magnetic networks (Science 309, 1690, 2005).

Invited Talk SYMS 2.3 Mon 17:50 HSZ 04

Spin torque: wall dynamics in nanowires vs. switching in nanopillars — •Jacques Miltat and André Thiaville — Laboratoire de Physique des Solides, Univ. Paris-Sud and CNRS, ORSAY, France

Spin transfer induced switching in nanopillars may be viewed as an efficient process mainly due to the existence of a parametric pumping phase preceeding switching. Thus, a minute torque combined to the micromagnetic response of the nanoelement allows for switching at relatively low current densities. Spin pressure may also induce wall motion in ferromagnetic nanowires. Assuming current polarization adiabaticity and full transfer of angular momentum to the local magnetization, the usual spin torque term translates into $-\left(\vec{u}\cdot\vec{\nabla}\right)\vec{M}$, where $\vec{u}$ represents a velocity vector proportional to the current density and impinging electrons polarization. Unfortunately, according to the adiabatic theory, walls in nanowires, be it of the Transverse or Vortex type, are found to move only for current densities about one order of magnitude larger than experimental values. Also, wall structures are found to transform continuously during motion, a phenomenon directly linked to the so-called Walker velocity limit. A better agreement between theory and experiment may be achieved via the introduction of an additional torque term, the origin of which remains unclear at this stage. It is anticipated that theory and experiments might be best compared under pulsed current conditions, special attention being paid to the displacement of a depinned wall during the time necessary for a structure transition at a specified current density.

Invited Talk SYMS 2.4 Mon 18:20 HSZ 04

Interactions between domain walls and spin currents — •M. Klaeui[1], M. Laufenberg[1], D. Backes[1], P.-O. Jubert[2], R. Allenspach[2], A. Bischof[2], L. Vila[3], C. Vouille[3], G. Faini[3], and U. Ruediger[1] — [1]Fachbereich Physik, Universitaet Konstanz, D-78457 Konstanz — [2]IBM Research, Zurich Research Laboratory, CH-8803 Rueschlikon — [3]LPN - CNRS, Route de Nozay, F-91460 Marcoussis

A promising novel approach for switching magnetic nanostructures is current-induced domain wall propagation (CIDP) where due to a spin torque effect, electrons transfer angular momentum to a head-to-head domain wall and thereby push it in the direction of the electron flow without any externally applied fields. We use magnetoresistance measurements and spin polarized scanning electron microscopy to directly observe domain wall propagation in-situ in ferromagnetic nanostructures induced by current pulses [1]. We determine the propagation distances as a function of pulse height and pulse length as well as the critical current densities, where domain propagation sets in as a function of temperature. High resolution microscopy allows us to image the nanoscale spin structure of the walls after injection of currents and shows that the current modifies the spin structure dramatically [1]. Comparison to recent theoretical description [2] yields qualitative agreement on some aspects of domain wall transformation, whereas the theories do not reproduce the observed strong temperature dependence of the spin torque effect [2].

[1] M. Klaui et al., Phys. Rev. Lett. 94, 106601 (2005), Phys. Rev. Lett. 95, 26601 (2005); [2] A. Thiaville et al., Europhys. Lett. 69, 990 (2005); G. Tatara et al., Appl. Phys. Lett. 86, 252509 (2005);