MA 37: Spin Dependent Transport Phenomena

Time: Thursday 15:15–19:45 Location: HSZ 403

MA 37.1 Thu 15:15 HSZ 403

Spin-polarized tunneling through $SrTiO_3$ and $BaTiO_3$ barriers — •Daniel Wortmann and Stefan Blügel — Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

With the increased experimental control in growing transition-metal oxides in thin films of high quality, the fabrication of tunneljunctions containing e.g. $SrTiO_3$ and $BaTiO_3$ barriers became possible. Such junctions can be viewed as the prototype of new oxide-electronic devices employing the rich physics of transition-metal oxides for novel functionalities. In particular the large dielectric response of e.g. $SrTiO_3$ or even the ferroelectricity of $BaTiO_3$ can be exploited for innovative tunneling setups.

We present *ab initio* calculations of spin-polarized transport in tunneljunctions with magnetic $SrRuO_3$ leads and $SrTiO_3$ and $BaTiO_3$ insulating barriers. These calculations have been performed within the FLAPW method as implemented in the Jülich `FLEUR` code (www.flapw.de) and utilize the newly developed linearly scaling Green-function method that will presented in another presentation of this conference [1]. Detailed studies of the electronic structure of the barrier, i.e. of their complex bandstructure, will be presented demonstrating that these materials form significantly more complex barriers than simple oxides like MgO.

Support from the SPP-1243 of the DFG is gratefully acknowledged.
[1] F. Freimuth, D. Wortmann, S. Blügel, *Embedding based order-N implementation of the FLAPW method*

MA 37.2 Thu 15:30 HSZ 403

***Ab initio* study of antiferromagnetic Cr interlayers in Fe/MgO/Fe junctions** — •Peter Bose[1], Peter Zahn[1], Ingrid Mertig[1], and Jürgen Henk[2] — [1]Martin Luther University Halle-Wittenberg, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

One important issue for spintronics applications is the ability to tune the tunnel magnetoresistance (TMR) ratio, for example by insertion of metallic buffers into Fe/MgO/Fe tunnel junctions. Promising candidates are antiferromagnetic chromium interlayers which are intensively investigated experimentally and thus lend themselves support for a theoretical investigation.

We show by first-principles electronic-structure and transport calculations that the desired increase of the TMR ratio is not achieved. Instead, a strong exponential decay with Cr thickness is observed. Further, the conductances—and so the TMR ratio—oscillate with a period of 2 monolayers, which can be traced back to the layerwise antiferromagnetic structure of bcc Cr(001). A detailed analysis of layer-resolved and symmetry-decomposed spectral densities reveals that the electronic transport is mainly determined by the Cr/MgO interface.

MA 37.3 Thu 15:45 HSZ 403

Electronic Transport Properties of Magnetic Tunnel Junctions at High Temperatures — •Markus Meinert, Jan Schmalhorst, Daniel Ebke, Andy Thomas, and Günter Reiss — Department of Physics, Bielefeld University, Germany

In this contribution the results of electronic transport measurements on magnetic tunnel junctions (MTJs) at high temperatures will be presented. Two types of magnetic tunnel junctions were invesigated. First, junctions based on the half-Heusler alloy CoMnSb with a Curie-temperature of about 500K. And second, CoFeB/MgO/CoFeB junctions, which were characterized *in-situ* during an annealing process and after a conventional annealing.

The evolution of the TMR effect with temperature and bias voltage of the CoMnSb based junctions will be discussed as well as the temperature dependence of the TMR effect and the resistance of CoFeB/MgO/CoFeB-junctions.

MA 37.4 Thu 16:00 HSZ 403

ZnO-based magnetic tunnel junctions — •Shengqiang Zhou[1], Qingyu Xu[2], L. Hartmann[3], A. Muecklich[1], M. Helm[1], G. Biehne[3], H. Hochmuth[3], M. Lorenz[3], M. Grundmann[3], and H. Schmidt[1] — [1]Forschungszentrum Dresden-Rossendorf, Bautzner Landstraße 128, 01328 Dresden — [2]Southeastern University, Nanjing 211189, China — [3]Universität Leipzig, Linnéstraße 5, 04103 Leipzig

Spin-polarized tunnel magnetoresistance (TMR) effects occur when two ferromagnets are separated by a thin insulator. The resistance of the tunneling current changes with the relative magnetization orientation of the magnetic bottom and top electrode. The research is fuelled by the demanding of magnetoresistive random access memory (MRAM) devices. Novel MRAM cells are based on magnetic tunnel junctions with current-induced switching. It has been shown that semiconductors need a current pulse for switching which is two orders of magnitude smaller in comparison to metals [1]. In this talk, we report the clearly observed tunneling magnetoresistance at 5 K in magnetic tunnel junctions with Co-doped ZnO as the bottom electrode and Co as the top electrode prepared by pulsed laser deposition and thermal evaporation [2], respectively. Spin-polarized electrons were injected from Co-doped ZnO to the crystallized Al2O3 separation layer and tunnelled through the amorphous part of the Al2O3 barrier. Our studies demonstrate the spin polarization in Co-doped ZnO and its possible application in future ZnO-based spintronics devices. [1] M. Yamanouchi et al., Nature 428, 539 (2004). [2] Q. Xu et al., Phys. Rev. Lett. 101, 076601 (2008).

MA 37.5 Thu 16:15 HSZ 403

Hot electron transport in thin bcc FeCo spin valves - Room temperature Magnetocurrent exceeding 1200% — Christoph Kefes, •Emanuel Heindl, Johann Vancea, and Christian Back — Department of Physics, University of Regensburg, 93040 Regensburg, Germany

We use the tip of a scanning tunneling microscope to create a nonequilibrium unipolar electron distribution in a metal layer and measure the subsequent perpendicular ballistic hot electron transport through thin single crystalline metallic spin valves by employing ballistic electron emission microscopy (BEEM). By variation of the thickness of one of the ferromagnetic layers we can determine the spin dependent attenuation lengths which reflect the bulk hot electron transport along the [100]-axis of the bcc FeCo-layers. While the minority spin attenuation length is found to be energy independent and about 0.8 nm, the majority spin attenuation length is about 6 times larger within the measured energy interval of 1.3 up to 2 eV above the Fermi level. Consequently, a magnetocurrent effect exceeding 1200 % accompanied by a monotonic bias voltage behavior is observed at room temperature.

MA 37.6 Thu 16:30 HSZ 403

Temperature dependent non local spin precession in lateral all-metal spin valves — •Jeannette Wulfhorst, Andreas Vogel, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

All-metal spin-valve devices are studied to determine spin-dependent effects in normal metals. The non local spin-valve effect has been measured with spin-valve devices consisting of permalloy, copper or aluminum, and aluminumoxide. With a perpendicular external magnetic field the Hanle effect, i.e. spin precession of the electrons injected into a normal metal, is observed [1]. Transport measurements at various temperatures have been performed. Spin-dependent phenomena, namely the non local spin-valve effect and spin precession, are observed. A theoretical description of spin-dependent transport is presented including spin diffusion, spin relaxation, spin precession, and tunnel barriers. From the comparison of the experimentally observed spin precession to the theoretical description, we obtain a spin-relaxation time of 78 ps and a spin-relaxation length of 703 nm in aluminum. In copper a spin-relaxation time of 68 ps and a spin-relaxation length of 2571 nm are determined.

[1] A. van Staa, J. Wulfhorst, A. Vogel, U. Merkt, and G. Meier, Phys. Rev. B **77**, 214416 (2008)

MA 37.7 Thu 16:45 HSZ 403

Time dependent dielectric breakdown in Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions. — •Ayaz Arif Khan, Jan Schmalhorst, Karsten Rott, Andy Thomas, and Günter Reiss — Thin films and physics of Nano structures Department of Physics, Bielefeld university, P. O. Box 100131, 33501 Bielefeld germany.

The reliability of magnetic tunnel junctions (MTJs) is a key issue for their application in sensing or storing devices. We have investigated the time dependent dielectric breakdown in Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions deposited on thermally oxidized silicon wafers and focused on its dependence on the barrier thickness(1.8 to 4nm), junction area, polarity of the applied voltage, ramp speed and annealing temperature. Measurements with positive and negative polarities are carried out by a voltage ramp method. The junctions with an area from 15×15 to $25 \times 25\mu m^2$ were patterned using laser lithography process, leading to a tunneling magneto resistance (TMR) up to 174% with a 1.8 nm thick barrier. It is found that the TMR decreases with increasing barrier thickness and a 4 nm thick barrier shows no TMR at room temperature. The observed intrinsic failure due to voltage stress-induced degradation of an insulator is characterized by an abrupt decrease in resistance at the breakdown voltage. The junction studied show an average DC breakdown voltage from 1.72 to 3.48 V depending on barrier thickness and on polarity of the applied voltage.The breakdown voltage increases linearly with the MgO thickness and the resistance area product increases from $96k\Omega\mu m^2$ to $461M\Omega\mu m^2$ in this investigated thickness range.

MA 37.8 Thu 17:00 HSZ 403

Examination of manipulation of domain walls by pure diffusive spin currents — •Andreas Lörincz[1], Dennis Ilgaz[1], Lutz Heyne[1], Jan Rhensius[1,2], Stephen Krzyk[1], Mathias Kläui[1], Laura J. Heyderman[2], and Ulrich Rüdiger[1] — [1]Universität Konstanz, 78462 Konstanz — [2]Paul Scherrer Institut, 5232 Villigen, Schweiz

Non local spin valves (NLSV) have drawn much attention over the last years, due to their physical porperties and behaviour as well as the perspective of application in different ultra-low power dissipation devices. The advantage of the NLSV is the ability to examine purely the effects of spin currents without contributions from charge currents, which entail Joule heating.

By separating the charge current from the spin current we can study the effects of spin current absorption by a ferromagnet with a domain wall. Using transport measurements at variable temperature, we determine the domain wall depinning properties as a function of the spin accumulation. We then compare the effect to Oersted field-induced domain wall depinning [1].

References: [1] D. Ilgaz et al., Appl. Phys. Lett. 93, 132503 (2008)

MA 37.9 Thu 17:15 HSZ 403

Magnetoresistance effects of Co/Pt layered structures — •André Kobs, Simon Hesse, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

We have investigated the current in plane (CIP) magnetoresistance (MR) of Co/Pt single and multilayers at room temperature. In case of multilayers with 4 fold repetition, the Pt interlayer thickness has been varied from 1 nm to 10 nm with a fixed Co thickness of 0.7 nm (perpendicular magnetization). In case of single layers, the Co thickness has been varied between 0.5 nm (perpendicular magnetization) and 5 nm (in plane magnetization). The MR of the samples has been measured in three different geometries, with the magnetic field applied in plane parallel and perpendicular to the current direction, respectively, as well as perpendicular to the film plane (out of plane geometry). In all geometries the anomalous Hall effect (AHE), which is sensitive to the perpendicular component of magnetization, has been measured simultaneously. In contradiction to the anisotropic MR (AMR) of bulk materials we find, that the perpendicular in plane saturation resistance is significantly smaller than the perpendicular out of plane resistance. For Co single layers the opposite effect was found [1]. In case of samples with perpendicular magnetization, antisymmetric peaks at the fields of magnetization reversal occur [2].

[1] W. Gil et al., Phys. Rev. B **72**, 134401, (2005)
[2] X. M. Cheng et al., Phys. Rev. Lett. **94**, 017203 (2005)

15 Min. break

MA 37.10 Thu 17:45 HSZ 403

Magnetoresistance of iron thin films on facetted Al_2O_3-substrates — •Sebastian Mooser and Martin Jourdan — Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

Al_2O_3(100) substrates are annealed at high temperatures in air which results in a facetted surface. A layer of iron is deposited via molecular beam epitaxy. The deposition temperature, the thickness, the angle of the beam respective to the sides of the facets as well as the annealing process after the deposition are varied. The shape of the facets is analysed via in-situ STM and ex-situ AFM after Al-capping, respectively. The growth of iron on facetted Al_2O_3 is analysed via four-circle-diffractometry. Finally, the resistance depending on the applied magnetic field is measured at different temperatures. A change in resistance up to 0.5% has been achieved yet. A possible morphological origin of the observed magnetoresistance is proposed. Small iron grains building sorts of nano-wires give rise to the resistance being dependent on the applied magnetic field.

MA 37.11 Thu 18:00 HSZ 403

Current induced resistance change of magnetic tunnel junctions — •Patryk Krzysteczko[1], Xinli Kou[1,2], Karsten Rott[1], Andy Thomas[1], and Günter Reiss[1] — [1]Thin Films and Physics of Nanostructures, Bielefeld University, 33615 Bielefeld, Germany — [2]School of Physical Science and Technology, Lanzhou Universuty, Lanzhou, China

Ultra-thin magnetic tunnel junctions with low resistive MgO tunnel barriers are prepared to examine their stability under large current stress. The devices show magnetoresistance ratios of up to 110 % and an area resistance product of down to 4.4 $\Omega\mu m^2$. If a large current is applied, a reversible resistance change is observed, which can be attributed to two different processes during stressing and one relaxation process afterwards. Here, we analyze the time dependence of the resistance and use a simple model to explain the observed behavior. The explanation is furter supported by numerical fits to the data in order to quantify the timescales of the involved phenomena.

MA 37.12 Thu 18:15 HSZ 403

Resistance of domain walls in epitaxial Fe wires on GaAs(110) — •Christoph Hassel[1], Florian M. Römer[1], Nathalie Reckers[1], Sven Stienen[1], Florian Kronast[2], Günter Dumpich[1], and Jürgen Lindner[1] — [1]Fachbereich Physik, AG Farle, CeNIDE, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Bessy GmbH, Berlin

From epitaxial Fe films grown on GaAs (110) wires of different widths are prepared using electron beam lithography and Ar sputtering. Since the coercive field of longitudinally magnetized wires depends on the width of the wires, it is possible to pin a domain wall at the transistion between a smaller and a wider wire. The resistance of this domain wall is measured and contains contributions from the anisotropic magnetoresistance (AMR) and the domain wall resistance. Micromagnetic calculations are performed to study the structure of the domain wall and estimate contributions of the AMR. Furthermore, a magetic force microscope tip is used to create a different number of domain walls in transversally magnetized wires in a controlled way. The additional resistance contribution due to the presence of the domain walls is measured and the contributions from AMR are estimated by micromagnteic calculation. This work is financially supported within the SFB 491.

MA 37.13 Thu 18:30 HSZ 403

Transport through Single Molecule Magnets with Magnetic Field and Polarized Electrodes — •Nikolaos P. Konstantinidis[1,2,3] and Maarten R. Wegewijs[1,2,3] — [1]Institut für Theoretische Physik A, Physikzentrum, RWTH Aachen, 52056 Aachen, Germany — [2]Institut für Festkörperforschung-Theorie III, Forschungszentrum Jülich, Leo-Brandt-Strasse, 52425 Jülich, Germany — [3]JARA-Fundamentals of Future Information Technology

We investigate transport through single molecule magnets (SMMs) contacted by non-colinear magnetic and non-magnetic electrodes in the single electron tunneling regime. We show that an external magnetic field splits the negative differential conductance (NDC) that originates in weakly allowed spin-transitions between states in different charge sectors. The resulting current oscillations as a function of the applied voltage depend on the direction of the magnetic field relative to the easy axis of the molecule. We also show how Berry-phase interference appears as crossing and anticrossing lines in conductance maps in magnetic field and applied voltage. We analyze the detailed dependence of the current on the electrode polarizations and the arbitrary angles with each other and the easy axis of the SMM.

MA 37.14 Thu 18:45 HSZ 403

Femtosecond spin dynamics induced by ballistic transport of spin-polarized carriers in Au/Fe/MgO(001) — A. Melnikov[1], I. Razdolski[2], T. Wehling[3], A. Lichtenstein[3], E. Papaioannou[1], Ch. Rüdt[1], P. Fumagalli[1], O. A. Aktsipetrov[2], and •U. Bovensiepen[1] — [1]Freie Universität Berlin, Fachbereich Physik, 14195

Berlin, Germany — [2]Physics Department, Moscow State University, Moscow, 119992, Russia — [3]Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany

Scattering of hot carriers can be studied by ballistic electron microscopy. Here, we present a complementary approach using femtosecond laser pulses in a pump-probe experiment. We demonstrate an all-optical back-pump front-probe scheme to analyze the transport of spin-polarized hot carriers through Au/Fe/MgO(001). We excite hot carriers in 15 nm thick Fe by absorption of an 800 nm laser pulse. The spin-polarized hot carriers propagate subsequently at the Fermi velocity through the layer stack. A time-delayed second laser pulse generates its optical second harmonic (SH) in reflection at the opposite Au surface. We monitor the SH intensity as a function of pump-probe delay for opposite Fe magnetization directions, which facilitates an analysis of the spin and carrier propagation through Au. From the observed transfer time and its broadening we conclude that the carriers propagate ballistically for 50 nm Au and diffusively for 100 nm. Interestingly, the magneto-optical signal changes its sign after 500 fs, which is discussed in terms of local spin reorientation and different propagation velocities for minority and majority carriers.

MA 37.15 Thu 19:00 HSZ 403

Hall effect and electronic structure of half metallic $Co_2Fe_xMn_{1-x}Si$ films — •Gerhard Jakob[1], Horst Schneider[1], Enrique Vilanova[1], Stanislav Chadov[2], Gerhard Fecher[2], and Claudia Felser[2] — [1]Institute of Physics, Johannes Gutenberg-University, 55099 Mainz, Germany — [2]Institute of Anorganic and Analytical Chemistry, Johannes Gutenberg-University, 55099 Mainz, Germany

Half metals are defined by the existence of an energy gap at the Fermi energy for one spin direction. Keeping half metallicity at room temperature requires not only a large gap but also the Fermi energy to be far away from the band edges. As a model system we chose the system $Co_2Fe_xMn_{1-x}Si$, where the Fermi energy was calculated to move from the valence band edge of the minority states to the conduction band edge with increasing x. On high quality laser ablated epitaxial films we observe a sign change of the normal and anomalous Hall effect with doping. The experiments are discussed in comparison to band structure calculations done in the LSDA+U scheme.

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MA 37.16 Thu 19:15 HSZ 403

Spin-filtering in thin magnetic insulator barriers: EuO — •Martina Müller[1,2], Guo-Xing Miao[1], and Jagadeesh S. Moodera[1] — [1]Francis Bitter Magnet Laboratory, Massachusetts Institute of Technology, Cambridge, USA — [2]Institute of Solid State Research, Research Center Jülich, Jülich, Germany

The magnetic insulator Europium Oxide (EuO) has been recognized as a promising material for the generation of highly spin-polarized currents. Its spin-filtering property is due to exchange splitting of the conductance band below the ferromagnetic transition temperature T_c. Especially challenging is to achieve sizable magnetic ordering and exchange splitting in thin (< 6 nm) EuO films, which is the thickness regime of spin-filter tunnel barriers.

In this work, we studied the magnetic and transport properties of 1 – 6 nm EuO films to explore their spin filtering efficiency. We found the EuO thickness being one of the primary factors scaling the Curie temperature T_c and the onset of the metal-insulator transition. We show, that the reduced magnetic ordering at interfaces due to structural and chemical intermixing becomes particularly relevant in the low thickness regime. Current-voltage measurements of EuO-based tunnel junctions showed a strongly bias-dependent, two-step Fowler-Nordheim-type tunneling characteristics. Moreover, we could determine an exchange splitting of ϕ=0.5 eV of the conduction band (CB) of 4nm EuO barriers by fully electrical means. The results show a direct correlation of the temperature-dependent change of the CB height with the EuO magnetic state.

MA 37.17 Thu 19:30 HSZ 403

Measurement of the spin polarisation of Co_2FeSi with Andreev reflection point-contact spectroscopy — •Samuel Bouvron[1], Michael Marz[1], Gernot Goll[1], and Claudia Felser[2] — [1]Physikaliches Institut, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität, 55099 Mainz, Germany

With a theoretical spin polarisation P of 100 % at the Fermi level, a Curie temperature of 1100 K and a high magnetic moment of $6\,\mu_B$, the ferromagnetic Heusler alloy Co_2FeSi exhibits advantageous properties for magnetoelectronic or spin-electronic devices. Spin polarisation measurements were performed on polycrystalline and single-crystalline Co_2FeSi and $Co_2FeAl_{1-x}Si_x$ samples, using Andreev reflection spectroscopy in ferromagnet/superconductor (F/S) point contacts which were realized with the needle-to-anvil method with a mechanical control of a superconductive Pb tip. Analyses of the conductance spectra were carried out by the Cuevas modell, which is based on the Landauer-Büttiker formalism with spin dependent transmission coefficients $\tau_{\uparrow(\downarrow)}$ with $P = (\tau_\uparrow - \tau_\downarrow)/(\tau_\uparrow + \tau_\downarrow)$. The extracted polarisation was lower than expected from band-structure calculations, the maximal measured value being 56 %. A decrease of the polarisation both with increasing size of the contact and increasing potential barrier at the F/S interface hints at possible origins of the reduced current spin polarisation among which spin-orbit scattering in the contact region [1] is the most prominent candidate.

[1] M. Stokmaier *et al.*, Phys. Rev. Lett. 101, 147005 (2008)