MA 12: Spindependent Transport I

Time: Tuesday 10:15–13:00 Location: H22

MA 12.1 Tue 10:15 H22

Spin-valve effect and spin precession in lateral all-metal spin-valve devices — •Jeannette Wulfhorst, Alexander van Staa, Ulrich Merkt, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Jungiusstrasse 11, 20355 Hamburg (Germany)

The efficiency of electronic devices could be improved drastically by the use of spin polarized currents. Important properties like the spin precession and the spin-diffuson length can be analyzed with the help of lateral spin valves. At low temperatures and with an applied external magnetic field we examine spin valves which consist of two ferromagnetic permalloy electrodes and an aluminum strip either with or without integrated aluminum oxide tunnel barrier. A tunnel barrier can enlarge the spin polarization of the injected current [1]. Due to the shape anisotropy the electrodes are quasi-single domain and can be oriented parallel or antiparallel in an external magnetic field. To obtain the coercive fields of the electrodes we have measured the anisotropic magnetoresistance of both. The nonlocal spin-valve effect is determined by using the first electrode to inject a spin polarized current into the aluminum strip and to detect it with the aid of the other electrode [2]. With an out-of-plane external magnetic field spin precession, i.e. the Hanle-effect, is observed and fitted with the model used in Ref. [1]. We estimate a spin diffusion length in aluminum of 329 ± 19 nm.

[1] F.J. Jedema et al., Nature **416**, 713 (2002)
[2] A. van Staa and G. Meier, Physica E **31**, 142 (2006)

MA 12.2 Tue 10:30 H22

Transport properties of magnetic tunnel junctions with the quaternary Heusler alloy $Co_2Mn_{0.5}Fe_{0.5}Si$ — •Daniel Ebke[1], Jan Schmalhorst[1], Andreas Hütten[1], Günter Reiss[1], Benjamin Balke[2], and Claudia Felser[2] — [1]Thin Films and Nanostructures, Department of Physics, Bielefeld University, 33501 Bielefeld, Germany — [2]Institute for Inorganic and Analytical Chemistry, Johannes Gutenberg University, 55099 Mainz, Germany

Due to the half metallic character predicted by band structure calculations and because of the high Curie temperature the Heusler alloys Co_2MnSi and Co_2FeSi are promissing canditates for spintronic applications. Both alloys, as well as a multilayered Heusler electrode, have been integrated sucessfully into magnetic tunnel junctions (MTJs) in the past. In case of the multilayered electrode TMR ratios of more than 110% can be observed at 20K and about 40% at RT, respectively. Recently, Balke et al have shown band structure calculations for the quaternary Heusler alloy $Co_2Mn_{1-x}Fe_xSi$ and found a shift of the Fermy energy from the top of the valence band to the bottom of the conduction band with a increase of the Fe concentration. To enhance the TMR ratio for Heusler alloys at room temperature as well, we have integrated the Heusler alloy $Co_2Mn_{0.5}Fe_{0.5}Si$ into MTJs as the bottom electrode. We will present the resulting TMR effect amplitudes in dependence of preparation conditions and the thickness of the AlO_x barriere. The temperature dependence of the TMR ratio will be discussed in combination with magnetic and XRD measurements.

MA 12.3 Tue 10:45 H22

Temperature dependence of resistance and TMR in MgO based tunnel junctions — •Volker Drewello, Andy Thomas, and Günter Reiss — Bielefeld University, Universitätsstraße 25, 33615 Bielefeld

In magnetic tunnel junctions the widely used Alumina barriers are more and more replaced with MgO, which shows much higher TMR rates. While Alumina based junctions show quite big temperature dependence of the conductance in parallel magnetic state, it is commonly observed that this tendency is much smaller in MgO junctions.

We have prepared MgO based tunnel junctions with CoFeB electrodes. The junctions show TMR of over 140% at room temperature, which increases by a factor of 1.4 when temperature is decreased to 12 K. The parallel resistance however only changes by 8% so that the chance of the TMR is mainly the change of the anti parallel resistance. This behavior is also observed in MgO junctions with higher TMR and different electrode materials [1, 2].

Different existing models for the TMR temperature dependence of these junctions are discussed. We will see that that these can describe the MgO junctions temperature dependence but the physical meaning of the parameters used remains unclear. Therefore, we will present a modified model with convincing results.

[1] S.S.P. Parkin et. al., Nat. Mat. **3**, 862 (2004)
[2] T. Ishikawa et. al., Appl. Phys. Lett. **89**, 192505 (2006)

MA 12.4 Tue 11:00 H22

Electronic structure of Fe/MgO_x interfaces studied by photoemission — •Martina Müller, Frank Matthes, and Claus Schneider — Institut für Festkörperforschung, Forschungszentrum Jülich, D-52428 Jülich, Germany

Ferromagnet/insulator (FM/I) systems have experienced a long-term interest by providing fundamental insights in the physics of spin-dependent transport. A critical factor concerns the electronic structure of the FM/I boundary which is considered to act decisive on the tunneling spin-polarization. Whereas the interface of nearly stoichiometric Fe/MgO systems is well characterized, the interaction mechanisms with off-stoichiometric MgO_x barriers remain concealed so far.

We present results on modifications of the Fe(001) $3d$ electronic structure at Fe/MgO_x interfaces resulting from variations of the MgO_x stoichiometry. Spin- and angle-resolved photoemission spectroscopy experiments have been performed at low photon energies (< 40eV) at the beamline U250-PGM of the storage ring DELTA (Germany). Fe(001)/GaAs samples have been prepared under UHV conditions covered with ultrathin MgO_x layers. Their degree of oxidation was monitored via Mg $2p$ core-level shifts. We found a noticeable dependence of the magnitude of the interfacial spin-polarization P on the MgO_x degree of oxidation. P is strongly enhanced for oxygen-deficient MgO_x overlayers, whereas it drops down in case of an oxygen excess at the interface. We ascribe these findings to well-defined chemical bonding mechanisms between the Fe $3d$ and O $2p$ electronic states, thereby taking into account the particular occupancy of the MgO_x lattice sites.

MA 12.5 Tue 11:15 H22

Spin Polarization at the Co / MgxO1-x interface: the influence of interface stoichiometry — •Frank Matthes[1], Liu-Niu Tong[2], Martina Müller[1], and Claus M. Schneider[1] — [1]Institute of Solid State Research, Research Centre Jülich, 52425 Jülich, Germany — [2]Institute of Material Science and Engineering, Anhui University of Technology, Ma-An-Shan, 243002, Anhui, China

One decisive factor for the functionality of single crystalline magnetoresistive tunnelling junctions, like Fe/MgO/Fe or Co/MgO/Co, are the spin transport properties through the interface between ferromagnet and isolator. In this study, we extended our earlier studies of Fe/MgO to the Co/MgO system, because i) the affinity to form oxides at the interface should be less compared to Fe/MgO , ii) theoretically, a higher tunnelling magnetoresistive ratio is predicted and iii) we want to compare the results of both systems. We modified the interfacial bonding conditions by precisely controlling the amount of oxygen offered during growth of MgO. Utilizing spin polarized valence band photoemission spectroscopy, we studied the electronic band structure of bct Co and monitor its modification upon the coverage with MgO layers of different stoichiometries. Upon coverage with MgO of correct stoichiometry, we determined an unexpected attenuation of the spectral weight for transitions originating from $\Delta 5$ spin down initial states. The oxygen deficiency in MgO caused a positive increase in the measured spin polarization. Analogue observations existing in the Fe/MgO system lead to the assumption that similar mechanism is responsible for the observed effects in both systems.

MA 12.6 Tue 11:30 H22

FIB-structured nanoconstrictions for the study of domain wall magnetoresistance — •Daniel Stickler[1], Robert Frömter[1], Holger Stillrich[1], Yun Zhou[2], Genhua Pan[2], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg , Germany — [2]CRIST, Faculty of Technology, University of Plymouth, Plymouth, Devon PL4 8AA, UK

Several fundamentally and technologically interesting physical effects emerge when spin polarized currents in a ferromagnet pass through a laterally confined domain wall. We pursue different approaches for the fabrication of suitable structures for domain wall pinning which are based upon direct FIB (Focused Ion Beam) structuring. Our FIB is operating under ultrahigh vacuum condition. While the lateral resolution for imaging is 6 nm, the smallest structures written so far are 20nm. First results on 70 nm wide constrictions in a current in plane (CIP) geometry are presented. The experiments have been performed in a homogenous external field. Specifically shaped magnetic pads are used as a spin reservoir for injection. In 3 nm Ta / 8 nm NiFe / 3 nm Ta multilayers characteristic jumps in the magneto resistance (MR) are found which indicate the controlled injection of a domain wall into the constriction. We have also investigated the magneto resistance in a current perpendicular to plane (CPP) geometry. A cobalt point contact (smaller than 30 nm) has been fabricated by filling a pinhole milled into a silicon-nitride membrane. Financial support by the EU via EU04-586 "BMR" is gratefully acknowledged.

MA 12.7 Tue 11:45 H22

Current induced domain wall motion and domain wall transformations observed with XMCDPEEM — •Lutz Heyne, Dirk Backes, Markus Laufenberg, Mathias Kläui, and Ulrich Rüdiger — Universität Konstanz, 78457 Konstanz

While current-induced domain wall motion (CIDM) has been known theoretically [1] as well as experimentally, only recently controlled current-induced motion of single domain walls has been observed.

In this work we investigate CIDM in zig-zag permalloy wires of different dimensions. To image the magnetization configuration, x-ray magnetic circular dichroism photoemission electron microscopy (XMCDPEEM) is used. By imaging the magnetization contribution we can estimate an average domain wall (DW) velocity and directly observe spin-torque induced transformations of the internal DW structure.

In thick wires we observe a spin-torque induced nucleation and annihilation of magnetic vortices. The velocity is found to be directly correlated to these transformations [2]. Depending on the wire dimensions, several DW configurations are stable. A periodic transformation of the DW under current from vortex to transverse and vice versa is predicted by theory [3]. In a wire where both configurations can coexist we succeeded to image different DW configurations after the current pulses in agreement with theory, we also saw intermediate states, showing the actual transformation from transverse to vortex walls.

[1] C.H. Marrows, Adv. Phys. **54** 585 (2005).
[2] M. Kläui, *et al.*, Appl. Phys. Lett. **88**, 232507 (2006).
[3] A. Thiaville *et al.*, Europhys. Lett. **69**, 990 (2005);

MA 12.8 Tue 12:00 H22

Epitaxial $Co_2Cr_{0.6}Fe_{0.4}Al$ thin films and magnetic tunneling junctions — •Andres Conca, Martin Jourdan, Christian Herbort, and Hermann Adrian — Institut für Physik, Johannes Gutenberg University, Staudinger Weg 7, 55128 Mainz, Germany

The full-Heusler compound $Co_2Cr_{0.6}Fe_{0.4}Al$ (CCFA) is expected to be a half metal, i.e. to show a 100% spin polarization at the Fermi energy. This property, together with the relatively high Curie temperature (800K) and the soft magnetic behaviour make CCFA a promising candidate for implementation in spinelectronic devices.

Magnetic tunneling junctions were deposited using epitaxial CCFA thin films as ground electrode with AlOx as barrier and Co as counter electrode. The use of an Fe buffer layer on MgO(100) induces the growth of highly ordered CCFA films with smooth surface even at low deposition temperatures, as proved by XRD, TEM and in-situ STM investigations. The CCFA films were additionally annealed at different temperatures up to 600°C. The dependence of the TMR ratio on the annealing temperature was studied. A maximum TMR ratio of 40.5% was measured from which a spin polarization of 54% is deduced by the Jullière model. Possible correlations between the TMR ratio and the surface properties, as observed with STM and RHEED, are discussed.

Alternatively, epitaxial CCFA films were also grown directly on $MgAl_2O_4(100)$ and $Al_2O_3(110)$. A comparison with the results on MgO substrates is shown.

MA 12.9 Tue 12:15 H22

Inverted spin polarization of Heusler alloys — •Andy Thomas[1], Dirk Meyners[1], Daniel Ebke[1], Ning-Ning Liu[1], Jan Schmalhorst[1], Guenter Reiss[1], and Andreas Huetten[1,2] — [1]Bielefeld University, Thin films and nanostructures, Germany — [2]Research Center Karlsruhe, Institute for Nano-technology, Germany

We prepared magnetic tunnel junctions with different Heusler compound electrodes and investigated the transport properties of these devices. The most striking feature of these structures is the inversion of the tunnel magnetoresistance (TMR) effect at certain bias voltages.

We use this feature to present a magnetic logic concept that overcomes the limitations of field programmable logic arrays while having a 50% smaller unit cell then conventional TMR designs. To reach that the negative TMR effect is used as an additional degree of freedom. This might be possible in other spintronic devices.

Band structure calculations give the theoretic explanation of the negative TMR.

MA 12.10 Tue 12:30 H22

On the asymmetry of the inelastic tunneling spectra on magnetic materials — •Albert F. Takács[1], Timofey Balashov[1,2], Wulf Wulfhekel[1,2], Jürgen Kirschner[2], Markus Däne[3], Arthur Ernst[2], and Patrick Bruno[2] — [1]Physikalisches Institut, Universität Kalrsuhe (TH), Wolfgang-Gaede Str. 1, 76131 Karlsruhe — [2]MPI für Mikrostrukturphysik, Weinberg 2, 06108 Halle — [3]Martin-Luther-Universität Halle-Wittenberg, Fachbereich Physik, 06099 Halle

Inelastic tunneling spectroscopy (ITS) is a valuable tool to study excitations in metallic systems. We have applied ITS to investigate low lying magnetic excitations. For tunneling between a non-magnetic tip and a ferromagnet, the excitations were found to be asymmetric with respect to the Fermi energy.

For Fe(001) magnon creation was found predominantly for tunneling into the ferromagnet, while for opposite bias the excitation is much weaker. For fcc Co(001) strong magnon excitations were found for both positive and negative bias. Using *ab-initio* calculations of the spin-polarised DOS of the ferromagnets we show that this asymmetry is related to the spin-polarisation of the ferromagnet. This effect has strong implications for the efficiency of the spin transfer effect used in switching of MRAM cells.

MA 12.11 Tue 12:45 H22

Magneto-transport hysteresis loop of a single nanostructure — •Guillemin Rodary, Sebastian Wedekind, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120, Halle (Saale), Germany

We have studied morphological, electronic and magnetic properties of a single cobalt nano-island by means of spin-dependent scanning tunneling microscopy (SP-STM) at 7K and under a high magnetic field (7T). Two monolayer high triangular Co islands are grown on Cu(111) surface at room temperature and are then imaged by STM at low temperature. Scanning tunneling spectroscopy reveals spin polarized states of the nano-islands [1]. In contrast to previous studies using the field variation of images contrast to obtain a magnetic hysteresis loop [2], we directly record the apparent topology change with magnetic field variation at a single point. This method allows to understand the magnetic properties of a single nano-object, as the coercitive field or the switching behavior. The magneto-transport hysteresis curve obtained is explained from a tunnel magnetoresitance standpoint. We discuss the precise method to obtain such measurement with a STM in comparison to solid state spin electronic experiments, specially artifacts that have been isolated.

[1] L. Diekhöner, M. A. Schneider, A. N. Baranov, V. S. Stepanyuk, P. Bruno and K. Kern, Phys. Rev. Lett. 90, 236801 (2003).
[2] O. Pietzsch, A. Kubetzka, M. Bode and R. Wiesendanger, Science 292, 2053 (2001).