MA 3 Spin-Dependent Transport Phenomena I

Time: Monday 10:15–13:00 Room: HSZ 103

MA 3.1 Mon 10:15 HSZ 103

Characterisation of ion beam sputtered Fe/MgO/Fe magnetic tunnel junction — •Alexandra Steeb, Henning Dassow, Diana Rata, Franz-Josef Köhne, Daniel Bürgler, and Claus M. Schneider — Institute for solid state research, Electronic Properties, Research Centre Jülich

The tunnel magnetoresistance effect (TMR) in magnetic tunnel junctions (MTJs) is the key to developing magnetoresistive random-access-memory. In single-crystal Fe/MgO/Fe MTJs prepared by MBE a TMR up to 180% at room temperature was measured [1]. The sputtered polycrystalline CoFe/MgO/CoFe MTJs exhibit TMR values of up to 220% at room temperature [2]. We report on Fe/MgO/Fe trilayers prepared by ion beam sputtering in ultra high vacuum conditions. Using the crystalline GaAs substrate the trilayers grow epitaxially as confirmed by LEED. We work with 300Å Fe/25Å MgO/100Å Fe samples, the MgO layer is sputtered directly from a MgO target. With XPS we proved, that there is no FeO between the Fe and MgO layers. To apply an exchange bias on the upper Fe layer, an antiferromagnetic layer FeMn is deposited on the trilayer. After post-annealing 1h@250°C we found a typically exchange bias field of 50 mT. First TMR measurements on this single crystalline TMR structures will be presented.

[1] S. Yuasa et al. Nature Materials 3, 868 (2004)
[2] S. Parkin et al. Nature Materials 3, 862 (2004)

MA 3.2 Mon 10:30 HSZ 103

Magnetic tunnel junctions with MgO barriers — •Volker Drewello, Xinli Kou, Jan Schmalhorst, Andy Thomas, and Günter Reiss — Bielefeld University, Nano Device Group, 33615 Bielefeld

Recently, there has been much excitement about the high tunneling magnetoresistance (TMR) values observed in magnetic tunnel junctions (MTJs) with crystalline magnesium oxide (MgO) barriers. These MTJs show vary large TMR values compared to those with amorphous aluminum oxide barriers.

We have investigated the TMR in MTJs with MgO barriers and several different electrode materials. The MTJs are prepared at ambient temperature in our DC magnetron sputtering chamber with a base pressure of 1.0×10^{-7} mbar. In this process the lower electrode is covered with a thin layer of Magnesium (Mg) to prevent oxidation during the sputtering of MgO. Then, the latter is directly sputtered on the Mg layer.

The different FM/Mg/MgO/FM layer systems show TMR values of up to about 120% depending on the electrode material. Furthermore, the thickness of the Mg and the MgO layers as well as the annealing temperature have been optimized yielding high TMR ratios. The results are compared with standard Alumina junctions.

MA 3.3 Mon 10:45 HSZ 103

Ab initio calculations of spin-dependent tunneling conductance in Fe/FeCo/MgO/Fe: Role of the interfaces — •Daniel Wortmann[1], Jussi Enkovaara[1,2], and Stefan Blügel[1] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, Germany — [2]CSC – Scientific Computing,Espoo, Finland

Magnetic tunneljunctions based on epitaxially grown MgO are currently the most promising system for magnetoelectonic applications like magnetic random access memory cells. Record high tunneling magnetoresistance values at room temperature have been achieved in such junctions [1]. We will present *ab initio* calculations of electron tunneling in Fe/MgO based tunneljunctions with the focus on the details of the interface structure and its influence on the tunneling conductance. In particular we will show the differences which can be expected between a pure Fe/MgO/Fe junction and a Fe/Co/MgO/Fe system in which one or two monolayers of Co have been added at the interface as well as a Fe/FeCo/MgO/Fe junction in which a two-dimensional FeCo alloy is present at the interface. The calculations are carried out within the density-functional theory with the full-potential linearized augmented plane wave (FLAPW) method. The novel embedded Green function method enables us to treat semi-infinite junctions and to calculate the spin-dependent conductance[2].

[1] S. Yuasa *et al.*, Nature Materials **3**, 868 (2004); and S. Parkin *et al.*, *ibid*, 862 (2004)
[2] D. Wortmann, H. Ishida, and S. Blügel, Phys. Rev. B **65**, 165103 (2002); *ibid* **66**, 075113 (2002)

MA 3.4 Mon 11:00 HSZ 103

Noncollinear interface magnetism in Fe/FeO/MgO/Fe tunnel junctions: Effect on ballistic transport. — •Bogdan Yavorsky and Ingrid Mertig — Martin-Luther-Universität Halle-Wittenberg, Fachbereich Physik, Fachgruppe Theoretische Physik, D-06099, Halle, Germany

On the basis of *ab initio* total energy calculations made within the screened Korringa-Kohn-Rostoker method we discuss the possibility of formation of noncollinear magnetic structures near the FeO layer in the Fe/FeO/MgO/Fe tunnel junction. The competition between intrinsic antiferromagnetism of iron oxide and ferromagnetism of pure iron was shown to result in stabilization of an intermediate tilted configuration at the interface. Variation of the angle of tilting θ causes significant changes in the ballistic conductance of the junction. In particular, at $\theta \approx 75°$ the local density of states of Fe in the FeO layer has an interface state which forms a resonance of the conductance.

MA 3.5 Mon 11:15 HSZ 103

Co_2FeSi an alternative for the Co_2MnSi Heusler electrode integrated in magnetic tunnel junctions — •Daniel Ebke[1], Ning-Ning Liu[1], Marc Sacher[1], Jan Schmalhorst[1], Günter Reiss[1], and Andreas Hütten[2] — [1]Universität Bielefeld, Universitätsstrasse 25, D-33615 Bielefeld, Germany — [2]Forschungszentrum Karlsruhe GmbH, Institut für Nanotechnologie, Hermann-von-Helmholtz-Platz 1, D-76021 Karlsruhe, Germany

Recently, we have shown that the tunnel magnetoresistance of magnetic tunnel junctions containing the half metallic Heusler alloy Co_2MnSi as lower magnetic electrode is limited to about 108% TMR-effect at 20K. This can be associated with the oxygen affinity of the Mn resulting in a MnSiOx- enriched layer at the tunnel barrier. To avoid this step like barrier we have started to integrate another Heusler alloy, Co_2FeSi, as a magnetic electrode which is very promising due to its high Curie temperature of 1100K. In this presentation the evolution of the TMR-effect amplitude at room temperature is discussed as a function of preparation conditions and the width of the AlOx-tunnel barrier. We will present XAS measurements revealing the Vanadium diffusion through the Co_2FeSi layer deteriorating the atomic order at the Co_2FeSi/AlOx-interface. Thus, to enhance the TMR-effect MgO was tested as a new seed layer so as to avoid the Vanadium. In addition, multilayered Heusler electrodes consisting of $\{Co_2MnSi_{xnm}/Co_2FeSi_{xnm}\}_N$ have been prepared to increase the atomic ordering of the Co_2FeSi compound. The resulting TMR-effect amplitudes will be shown as a function of temperature and will be discussed in combination with magnetic and XRD measurements.

MA 3.6 Mon 11:30 HSZ 103

Characteristics of the half-metallic character of Co_2MnSi Heusler alloy — •Ning-Ning Liu[1], Daniel Ebke[1], Marc Sacher[1], Jan Schmalhorst[1], Günter Reiss[1], and Andreas Hütten[2] — [1]Fakultät für Physik, Universität Bielefeld, D-33615 Bielefeld, Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe GmbH, Hermann-von-Helmholz-Platz 1, D-76021 Karlsruhe, Germany

Co_2MnSi is an attractive material to be used as magnetic electrode in magnetic tunnel junctions (MTJs). This is due to the half metallic character predicted by band structure calculation and to its high Curie temperature of 986K, indicating the potential for future magnetoelectronic and spintronic applications. A tunnel magnetoresistance (TMR) of currently 108% at 20K has been achieved, and is associated with a Co_2MnSi spin polarization of 70%. The corresponding room temperature value of TMR is 42%. A new technique has been used in order to relay on a wedge shaped AlOx tunnel barrier. The current limitation to achieve larger TMR has been identified as a direct consequence of the oxygen affinity of the Co_2MnSi - Heusler element Mn. Dependences of annealing temperatures, different oxidation times, and additional interlayers between heusler alloy and tunnel barrier on the TMR behavior have been investigated and will be discussed in detail.

MA 3.7 Mon 11:45 HSZ 103

How many crystalline interface layers are necessary to create high TMR? — •Christian Heiliger, Peter Zahn, and Ingrid Mertig — Martin Luther University, FB Physik, FG Theorie, D-06099 Halle, Germany

Recent experiments [1-3] based on epitaxially grown Fe/MgO/Fe samples shed light on the subject of tunneling magnetoresistance (TMR). First of all, the obtained TMR ratios exceed the predictions by Julliere's model. Second, the measured bias voltage characteristic shows features which could be related to the electronic structure of the system. The high crystallinity of the samples [1-3] seemed to be the reason. New experiments [5], however, demonstrate that even amorphous electrodes attached to a crystalline MgO barrier show a TMR of more than 230%. The question that is addressed in this talk is: How many crystalline metal layers close to the interface are necessary to obtain high TMR?

A screened Korringa-Kohn-Rostoker (KKR) method based on density functional theory was applied to calculate the electronic and magnetic structure of the different junctions self-consistently. The Landauer conductance of planar junctions was calculated using the Baranger-Stone scheme by means of Green's functions in the limit of coherent tunneling.

The results demonstrate that only a few crystalline ferromagnetic layers cause a significant spin-polarisation and TMR.

[1] J. Faure-Vincent et al., Appl. Phys. Lett. **82**, 4507 (2003)
[2] S. Yuasa et al., Nature Materials **3**, 868 (2004)
[3] S.S.P. Parkin et al., Nature Materials **3**, 862 (2004)
[4] K. Tsunekawa et al., Appl. Phys. Lett. **87**, 072503 (2005)

MA 3.8 Mon 12:00 HSZ 103

Tunneling Magneto Resistance in Co-Fe-B/Al-Ox Magnetic Tunnel Junctions — •Oliver Schebaum[1], Andy Thomas[1], Hubert Brückl[2], and Günter Reiss[1] — [1]Bielefeld University, Nano Device Group, Universitätsstrasse 25, 33615 Bielefeld — [2]ARCS research GmbH, Division "Nano System Technology", Tech Gate Vienna, Donau-City-Strasse 1, 1220 Vienna, Austria

We investigated the effect of Co-Fe-B as the free and the pinned magnetic layer in magnetic tunnel junctions (MTJs). The lower electrode was exchange-bias coupled to MnIr and Al-Ox was used as a tunnel barrier. The samples were prepared by dc/rf-magnetron sputtering in a UHV chamber with a base pressure of 1×10^{-7} mbar. The metallic Aluminum was oxidized utilizing electron cyclotron plasma oxidation in a pure Oxygen.

We measured the influence of different B compositions of the electrodes using sputter-targets with 5% and 12% of B [Co 70%/Fe 25%/B 5%; Co 62%/Fe 26%/B 12%]. Furthermore, we optimized the samples yielding high TMR ratios by varying the thickness of the Al-Ox barrier.

The TMR effect of the samples prepared with a 5% B target decreased (38% @ RT) compared with standard MTJs consisting of Co-Fe and Ni-Fe electrodes (52% @ RT). However, the 12% B electrodes raised the TMR ratio to 72% at RT when reducing the Al thickness (before oxidation) to 1.2nm (compared to 1.4nm in our standard MTJs). Low temperature measurements showed a TMR value of 114% at 21K and possible explanations for this behavior are discussed.

MA 3.9 Mon 12:15 HSZ 103

Interfacial microstructure of Fe/AlOx/Fe-magnetic tunnel junctions in high resolution — •Holger Schmitt[1], Jens Ellrich[1], and Horst Hahn[1,2] — [1]Forschungszentrum Karlsruhe GmbH, Institute for Nanotechnology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany — [2]Technische Universität Darmstadt, Joint Research Laboratory Nanomaterials, Petersenstrasse 23, 64287 Darmstadt, Germany

Tunneling Magneto Resistance (TMR) systems were prepared by deposition of a Ta-buffered Fe-AlO_x-Fe-trilayer on a thermally oxidized Silicon wafer. In order to investigate the influence of the different Fe-oxides on the TMR effect, a ^{57}Fe tracer was deposited at the lower barrier interface. Using Conversion Electron Mössbauer Spectroscopy (CEMS) the chemical, structural and magnetic changes were followed from the as-prepared state and after several annealing steps. The nuclear probe technique can resolve different phases at the interface with submonolayer resolution. In addition, Transmission Electron Microscopy and X-Ray Reflectivity have been applied to complete the insight into the interfacial structure and to correlate to magnetoresistance of the trilayers. The results indicate the formation of a spinel-like phase and a spinel (Hycernite), in expense of the pure iron oxide Fe_2O_3, produced by a slight overoxidation of the barrier during its preparation. The changes at the interface are correlated to the changes of the TMR effect during annealing.

MA 3.10 Mon 12:30 HSZ 103

Induced magnetic anisotropy effects on the transport properties of magnetic tunnel junctions — •Voicu Popescu and Hubert Ebert — Department Chemie/Physikalische Chemie, University of Munich, Butenandtstr. 5-13, 81377 Munich, Germany

We report results of calculations on the electronic, magnetic and transport properties of Fe/GaAs/Fe and Fe/GaAs/Au/Fe magnetic tunneling junctions (MTJs) that have been obtained using the tight-binding Korringa-Kohn-Rostoker Green function method in a spin-polarised fully relativistic formulation (TB-SPR-KKR). This approach, by coupling the electron spin and orbital degrees of freedom, allows one to properly account for the changes induced in the electronic transport when different magnetic configurations, e.g., in-plane and out-of-plane, are considered.

Recent experimental work on MTJs based on diluted magnetic semiconductors have shown that, while keeping the orientation of the magnetisation in the plane of the junction but varying its azimuthal angle, a measurable dependence of the resistance with respect to this angle can be observed. This phenomenon is now commonly termed as Tunneling Anisotropic Magnetoresistance (TAMR).

We have performed analogous theoretical investigations on MTJs based on metallic (ferromagnetic or non-magnetic) leads. Our results show that a similar dependence is obtained also for such systems and it can be related to the spin-orbit coupling induced magnetic anisotropy at the metal/semiconductor interface. This, in turn, is shown to vary for different terminations (As or Ga) of the semiconductor, revealing the role of the covalent bonding at the interface.

MA 3.11 Mon 12:45 HSZ 103

Anisotropic magnetoresistance and spin-valve effect in all-metal mesoscopic spin-valve devices — •Alexander van Staa, Ulrich Merkt, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Jungiusstraße 11, 20355 Hamburg

Only in a few experiments all-electrical spin injection and detection in normal metal structures has been demonstrated [1]. We investigate all-metal lateral spin-valve devices with and without tunneling barriers. The devices consist of two permalloy electrodes and an interconnecting aluminum strip. The micromagnetic behavior of the device has been imaged with a magnetic-force microscope in external magnetic fields at room temperature. During a single cooling cycle at temperatures between 2 and 120 K we have measured the anisotropic magnetoresistance of both electrodes and the magnetoresistance of the entire device. In the latter we can clearly identify the contributions of the anisotropic magnetoresistance and the mesoscopic spin-valve effect [2].

[1] F.J. Jedema, M.S. Nijboer, A.T. Filip, and B.J. van Wees, Phys. Rev. B **67**, 085319 (2003).
[2] A. van Staa, C.M.S. Johnas, U. Merkt, and G. Meier, Superlatt. Microstruct. **37**, 349 (2005); A. van Staa and G. Meier, submitted (2005).