MA 8: Magnetic Coupling Phenomena / Exchange Bias

Time: Monday 15:15–18:30 Location: HSZ 401

MA 8.1 Mon 15:15 HSZ 401

Exchange bias for a ferromagnetic film coupled to a spin glass — •Ulrich Nowak[1] and Klaus Usadel[2] — [1]Fachbereich Physik, Universität Konstanz — [2]Fachbereich Physik, Universität Duisburg-Essen

For a model system consisting of a ferromagnetic layer exchange coupled to a spin glass extensive Monte Carlo simulations are performed. For the spin glass the standard short range Gaussian model is used. Exchange bias is observed as a result of a frozen spin glass state. The exchange bias fields are calculated for different temperatures, cooling fields and thicknesses of the spin glass layer and the training effect is investigated. A major result of our simulations is that the bias field decreases with increasing strength of the cooling field in qualitative agreement with recent experiments.

MA 8.2 Mon 15:30 HSZ 401

Imaging of exchange bias in Co/FeMn bilayers on the nm length scale — •Florian Kronast, Joachim Schlichting, Florin Radu, Mishra Shrawan, and Hermann A. Dürr — Bessy, Helmholtz Zentrum Berlin, Germany

We investigated the magnetic interface coupling in Co/FeMn bilayers by photoemission electron microscopy (PEEM) in combination with magnetic circular dichroism (XMCD). Using a special sample holder with integrated micro-magnetic yoke we could apply magnetic fields up to 25mT during imaging, without significant reduction of the spatial resolution.

We studied the domain structure in the ferromagnetic Co layer and the arrangement of magnetic moments at the interface of the antiferromagnet as a function of applied magnetic field. Analyzing the local hysteresis loop of each pixel in the recorded images we could map local variations of exchange bias and coercitivity in the ferromagentic Co layer. We can correlate these local variations of exchange bias and coercitivity with the arrangement of magnetic moments at the ferromagnet / antiferromagnet interface.

MA 8.3 Mon 15:45 HSZ 401

Magnetic domain imaging of perpendicular exchange-coupled FM/AFM systems by soft x-ray holography — •Carsten Tieg[1], Erika Jiménez[2], Julio Camarero[2,3], Jan Vogel[4], Christophe Arm[5], Gilles Gaudin[5], Eric Gautier[5], Bernard Rodmacq[5], Bernard Dieny[5], and Rodolfo Miranda[2,3] — [1]ESRF, B.P 220, 38043 Grenoble, France — [2]Dpto. de Física de la Materia Condensada-UAM, 28049 Madrid, Spain — [3]IMDEA-Nanociencia, Campus UAM, 28049 Madrid, Spain — [4]Institut Néel-CNRS, 38042 Grenoble, France — [5]SPINTEC (CNRS/CEA) URA 2512, 38054 Grenoble, France

Magnetic domain imaging by soft x-ray holography was employed to investigate the exchange coupling phenomenon in layered systems composed of ferromagnetic (FM) $[Co/Pt]_n$ multilayers with perpendicular anisotropy and antiferromagnetic (AFM) IrMn and FeMn films. We have exploited both element selectivity and the ability to image in applied magnetic fields to follow the magnetization reversal along the hysteresis loop with sub-micrometer resolution. Our setup allows holographic imaging as well as absorption measurements by recording the transmitted intensity or the total electron yield signal. The sensitivity limits of this technique were explored by imaging the uncompensated moments in the AFM layer, which correspond to an equivalent thickness of about one monolayer only. Our domain images show that the uncompensated AFM moments are align parallel to the magnetization of the FM layer.

MA 8.4 Mon 16:00 HSZ 401

Oscillatory indirect exchange in adatom pairs and triplets — •Jens Wiebe[1], Lihui Zhou[1], Samir Lounis[2], Elena Y. Vedmedenko[1], Focko Meier[1], Peter H. Dederichs[2], Stefan Blügel[2], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg — [2]Institut für Festkörperfoschung and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich

Impurity spins in nonmagnetic metals induce an oscillatory spin-polarization in the conduction electrons, which mediates an alternately ferro- and anti-ferromagnetic coupling between two impurities. This "indirect magnetic exchange" is well known from layered systems investigated in the course of the discovery of the GMR effect and crucially depends on the atomic discreteness within the ferro- and the non-magnetic spacer layers [1]. Here, we measure the indirect exchange between two Co adatoms on a Pt(111) surface with distances of several lattice spacings and compare to calculations using the full-potential Korringa-Kohn-Rostoker method. We have straight experimental access to the exchange energies by measuring the magnetization of each adatom as a function of an applied magnetic field (single-atom magnetization curves [2]) and compare to Monte-Carlo simulations. Indeed, we observe a damped oscillatory behaviour with coupling strengths on the order of 0.1meV reproduced by the calculations. Additionally, we demonstrate magnetic frustration in adatom triplets with almost equilateral shape. [1] P. Bruno and C. Chappert, Phys. Rev. B 46, 261 (1992). [2] F. Meier et al., Science 320, 82 (2008).

MA 8.5 Mon 16:15 HSZ 401

Monte-Carlo Study of Hysteretic Properties of Atomic Pairs and Triplets — •Elena Y. Vedmedenko, Jens Wiebe, and Roland Wiesendanger — University of Hamburg, Jungiusstr. 11, 20355 Hamburg

It has been recently demonstrated that the thermodynamic behavior of single magnetic atoms, atomic pairs and triplets on conducting substrates, which often possess giant magnetic anisotropy, may be successfully described in the framework of the Langevin dynamics [1,2]. As the Langevin distribution can be very well reproduced by means of Monte-Carlo simulations we have studied the hysteretic properties of single atoms and their ensembles in the framework of this technique. For the atomic pairs and triplets coupled by RKKY-type exchange interactions the time-averaged and time-resolved magnetization curves on each individual atom have been investigated. We demonstrate that the hysteretic behavior is very sensitive to the type of interaction (ferromagnetic or antiferromagnetic) as well as to magnetic surrounding, and is determined by the field-dependent paramagnetic switching of individual moments. The occupancy of two energy minima depends on the above mentioned parameters and varies for different atoms. The time-averaged Monte-Carlo data mimic recent experiments performed by spin-polarized scanning tunneling microscopy and reveal very peculiar magnetization curves, unusual for macroscopic magnets.

[1] P. Gambardella et al., Science 300, 1130 (2003) [2] F. Meier, L. Zhou, J. Wiebe, R. Wiesendanger, Science 320, 82 (2008)

MA 8.6 Mon 16:30 HSZ 401

Thickness Dependence of the Antiferromagnetic Ordering Temperature in Ni/Fe_xMn_{1-x} Bilayers — •Miriam Stampe, Tobias Homberg, and Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

The ordering temperature of ultrathin single-crystalline antiferromagnetic (AFM) Fe_xMn_{1-x} layers is influenced by magnetic proximity effects due to a ferromagnetic overlayer. We have determined this ordering temperature T_{AFM} from the polar magneto-optical Kerr effect response of out-of-plane magnetized Ni overlayers (15 ML). Systematic investigations on the influence of the AFM layer thickness (6-10 ML) and composition ($0.4 < x < 0.6$) in these Ni/Fe_xMn_{1-x}/Cu(001) bilayers on T_{AFM} were performed. The ordering temperature is determined from the discontinuity in the temperature dependence of the coercive field. With increasing thickness, the ordering temperature rises, while the influence of the Fe_xMn_{1-x} composition is much smaller than in Co/Fe_xMn_{1-x}/Cu(001) bilayers [1].

[1] F. Offi et al., Phys. Rev. B 66, 064419 (2002)

Financial support by the DFG (KU1115/7-2) is acknowledged.

MA 8.7 Mon 16:45 HSZ 401

Training Induced Positive Exchange Bias in NiFe/IrMn Bilayers — •S. K. Mishra, F. Radu, H. A. Dürr, and W. Eberhardt — Albert-Einstein Str. 15, D-12489, Berlin, Germany

Positive exchange bias has been observed in the $Ni_{81}Fe_{19}/Ir_{20}Mn_{80}$ bilayer system via soft x-ray resonant magnetic scattering. After field cooling of the system through the blocking temperature of the antiferromagnet, an initial conventional negative exchange bias is removed after training i. e. successive magnetization reversals, resulting in a positive exchange bias for a temperature range down to 30 K below

the blocking temperature (450 K). This new manifestation of magnetic training effect is discussed in terms of metastable magnetic disorder at the magnetically frustrated interface during magnetization reversal.

MA 8.8 Mon 17:00 HSZ 401

Exchange bias in varied PtMn/CoFe systems — •Matthias Hawraneck[1,2], Wolfgang Raberg[1], Jürgen Zimmer[1], Klemens Prügl[1], Thomas Bever[1], and Lambert Alff[2] — [1]Infineon Technologies AG, Am Campeon 1-12, 85579 Neubiberg — [2]Institut für Materialwissenschaften, TU Darmstadt, Petersenstr. 23, 64287 Darmstadt

In magnetic spin valves, used e.g. in HDD read heads, the exchange bias (EB) is used to fix the magnetization of one layer, the so called "pinned layer". A very important requirement of spin valves in such applications is their stability with respect to temperature and magnetic field. At elevated temperatures interlayer diffusion degrades the spin valve [1]. In combination with temperature a magnetic field can influence the EB and thus the spin valve performance. We investigated the influence of various parameters in the PtMn deposition regarding the EB strength and stability. We observe that the gas flow at the sputtering process, the annealing temperature during the PtMn formation and the seed layer thickness show big influence on initial performance and stability.

[1] M. Hawraneck et. al., Appl. Phys. Lett. 93 012504 (2008)

MA 8.9 Mon 17:15 HSZ 401

Successive antiferromagnetic phase transitions in α-MnS probed by the exchange bias effect — •Pavel Borisov[1], Xi Chen[2], Andreas Hochstrat[1], and Wolfgang Kleemann[1] — [1]Angewandte Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Physics, South China University of Technology, Guangzhou, P.R. China

The exchange bias (EB) probe is applied to test the magnetic properties of a material with two successive antiferromagnetic (AF) phase transitions [1]. α-MnS has been claimed to reveal a second-order one at $T_{C1} = 152$ K and a discontinuous one at $T_{C2} = 129$ K. A cubic paramagnetic state (phase I) and a slightly rhombohedrally distorted fcc AF spin order (phase II) similar to that in NiO are observed at $T > T_{C1}$ and $T_{C2} < T < T_{C1}$, respectively. However, there was a debate about the spin structure below T_{C2} (phase III).

The EB effect of the heterolayer structure α-MnS(111)/Fe(1.5 nm)/Pt(3 nm) arises below T_{C1} and maximizes at T_{C2}, below which it vanishes steplike in parallel with a sudden increase of the coercive field of the Fe layer, H_C. EB recovers again below the second blocking temperature, $T_{B2} \approx 25$ K. The abrupt vanishing of H_{EB} and the step-like increase of H_C below T_{C2} comply with a first-order AF spin reorientation transition of α-MnS to phase III. The strong enhancement of H_C observed in the phase III corroborates the conjectured multi-k spin structure.

[1] X. Chen, A. Hochstrat, P. Borisov, W. Kleemann, submitted to Appl. Phys. Lett. (2008).

MA 8.10 Mon 17:30 HSZ 401

Influence of Rippled Substrate Morphology on the Interlayer Exchange Coupling in Fe/Cr/Fe Thin Films — •Michael Körner, Maciej Oskar Liedke, Thomas Strache, Siarhei Dzenisevich, Adrian Keller, Stefan Facsko, and Jürgen Fassbender — Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany

We have investigated the interlayer exchange coupling in Fe (4 nm)/Cr (x nm)/Fe (4 nm) thin film trilayers (x=0–5 nm) deposited on rippled armorphous silicon substrates. The substrate surface was periodically modulated (periods of 20 nm, 35 nm, and 50 nm) by Ar^+ ion erosion. The influence of the resulting surface and interface structure on the magnetic properties has been investigated by magneto-optical Kerr effect (MOKE). We found an orange peel type coupling, predicted by Néel's theory and, due to the morphology of the magnetic layers, a strong uniaxial magnetic anisotropy in the system.

This work is supported by DFG grant FA 314/6-1.

MA 8.11 Mon 17:45 HSZ 401

Role of interface alloying on the exchange bias in Fe/Cr bilayers — •Syed Rizwan Ali, Muhammad Bilal Janjua, Marian Fecioru-Morariu, Coen J. P. Smits, and Gernot Güntherodt — Physikalisches Institut (IIA), RWTH Aachen University, 52056 Aachen, Germany

Exchange bias (EB) in polycrystalline Fe/Cr bilayers has been investigated for either molecular beam epitaxy (MBE) grown or sputtered samples. The EB field (H_{EB}) in both series of samples changes its sign as a function of temperature. This zero crossing temperature (T_0) was found to increase with the thickness of the Cr layer. The positive part of the H_{EB} shows a maximum and then decreases with temperature up to the blocking temperature of the Cr film. The coercive field H_C was also found to vary in close correlation with H_{EB}, exhibiting a maximum near T_0. The results are explained by considering a chemically interdiffused Fe/Cr interface, where the interface alloying between Fe and Cr drives Cr into a spin glass (SG) phase. The interfacial exchange interaction between the SG and the ferromagnet is found to be responsible for the observed temperature dependence and sign change of H_{EB} in our samples. H_{EB} of samples containing the intentionally deposited Cr-Fe SG alloy underneath the Fe overlayer show all the features observed in our Fe/Cr bilayer samples, thereby corroborating our arguments.

MA 8.12 Mon 18:00 HSZ 401

Pinned and rotatable magnetic moments in the MnPd/Fe exchange bias system — •Sebastian Brück[1], Xiaosong Ji[2], Gisela Schütz[1], Kannan M. Krishnan[2], and Eberhard Goering[1] — [1]Max-Planck-Institut für Metallforschung, Heisenbergstrasse 3, D-70569 Stuttgart, Deutschland — [2]Dept. of Materials Science and Engineering, University of Washington, Seattle, USA

The element-specific magnetic structure of an epitaxially grown $Mn_{52}Pd_{48}$/Fe exchange bias system at the antiferromagnet/ferromagnet interface has been investigated by soft X-ray magnetic circular dichroism and resonant magnetic reflectivity. The magnetic reflectivity measurements were carried out at the UE56/2-PGM1 beamline at BESSY II using our newly developed UHV reflectometer [1]. A complex magnetic interfacial configuration, consisting of a 2-monolayer thick induced ferromagnetic region, and pinned uncompensated Mn moments that reach far deeper, is found in the antiferromagnet [2]. Proof for the direct relationship between the pinned Mn moments and the exchange bias loop shift is found from comparison of measurements parallel and perpendicular to the field cooling direction.

[1] S. Brück et al. *Rev. Sci. Instrum.* **79,** 083109 (2008)
[2] S. Brück et al. *Phys. Rev. Lett.* **101,** 126402 (2008)

MA 8.13 Mon 18:15 HSZ 401

Tuning exchange spring magnets by ion irradiation and annealing: X-ray investigations — Jürgen Fassbender[1], Jörg Grenzer[1], •Olga Roshchupkina[1], Y. Choi[2], J. S. Jiang[2], and S. D. Bader[2] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P. O. Box 51 01 19, 01314 Dresden, Germany — [2]Materials Science Division, Argonne National Laboratory, Argonne, Illinois 60439

The coupling effectiveness of the exchange spring effect can be influenced by the interface structure between hard and soft magnetic films. We have investigated the structural and magnetic properties of an Fe/Sm_2Co_7 exchange spring bilayer system after annealing and after low-energy ion irradiation. To study the interface properties X-ray reflectivity (XRR) measurements were carried out. From the XRR measurements it was shown that annealing influences the roughness of the layer surfaces causing an almost symmetrical broadening of the interfacial layers. Irradiation induces changes in the top three layers and the most pronounced effect upon irradiation is a change in electron density of the first two top layers and an interface broadening between Fe and Sm_2Co_7. In contrast annealing after irradiation triggers a material flow influencing the whole irradiated layers. The annealing afterwards therefore influences mainly the Fe layer by creating an Fe/Sm_2Co_7 intermixed region.