MA 4: Magnetic Coupling Phenomena/ Exchange Bias

Time: Monday 11:00–13:15 Location: H22

MA 4.1 Mon 11:00 H22

The origin of exchange bias, Observation of pinned orbital moments at iron L2,3 in FeMn/Co — •Patrick Audehm[1], Sebastian Brück[2], Gisela Schütz[1], and Eberhard Goering[1] — [1]Max Planck Institute for Metals Research, Heisenbergstrasse 3, 70569 Stuttgart, Germany — [2]University of Würzburg, Physikalisches Institut. IV Am Hubland, D-97074 Würzburg, Germany

The exchange anisotropy was discovered by Meiklejohn and Bean in 1956. Since then there have been many attempts to model the behavior of a system with exchange bias effect. Exchange bias (EB) results in a shift of the hysteresis loop and secondly in an increase of the coercive field. We investigated a widely studied EB-system, consisting of polycrystalline iron (Fe)-manganese (Mn) as an antiferromagnet and cobalt as a ferromagnet. We used X-ray magnetic circular dichroism (XMCD) and x-ray resonant magnetic reflectivity (XRMR) at the Fe L2,3 and Mn L2,3 edges, simultaneously performed in surface sensitive total electron yield (TEY) and bulk sensitive total fluoresence yield (TFY) at room and low temperatures. For the first time, we measured pinned magnetic Fe moments in iron-manganese. Mn shows nearly no XMCD effect, while the Fe provides a sizeable signal from the rotatable moments and a very small (about 0.7 per mill of the total signal) signal from the pinned uncompensated moments. According to the well established sum rules of XMCD the non-rotatable Fe L2,3 edge spectra reveal nearly pure orbital character. These results suggest a different view on the origin of exchange bias, based on locally loaded spin-orbit-coupling, and new possibilities understanding the origin of EB.

MA 4.2 Mon 11:15 H22

Antiferromagnetic coupling in Fe/Si/Fe structures with interfacial Co "dusting" — •Rashid Gareev[1], Matthias Buchmeier[2], Matthias Kiessling[1], Georg Woltersdorf[1], and Christian Back[1] — [1]Uni Regensburg, Universitätsstrasse 31, 93053 Regensburg — [2]Uni Münster, Corrensstraße, 48149 Münster

Epitaxial Fe/Si/Fe structures demonstrate strong antiferromagnetic coupling (AFC) reaching 8mJ/m2 and resonant-type tunnelling magnetoresistance (TMR) [1]. A promising way to increase spin polarization is to insert Co *dusting* layers at interfaces [2]. We present AFC in Fe/Co/Si/Co/Fe epitaxial structures with 0.2 nm-thick Co *dusting* layers and different thickness of Si spacer. We extracted AFC from fitting experimental FMR data as well as from the MOKE hysteresis. The AFC is near 0.1mJ/m2 with the maximum of coupling near 2.0 nm of spacer thickness. For spacers thinner than 1.7 nm coupling is ferromagnetic indicating an increased inter-diffusion. Temperature dependence of magnetization above T0~50K corresponds to the Bloch*s law characteristic for spin-wave parameters of iron films. We revealed regions with different temperature dependence of AFC. Below T0~50K and above T~100K saturation field and, accordingly, coupling strength show increase with decreasing temperature. In the intermediate region coupling is not stable. We relate observed features to formation of interface magnetic iron-cobalt silicides with Tc~50K. This work is supported by the project DFG 9209379.[1]. R.R. Gareev et al: JMMM 240, 235 (2002), APL 81, 1264 (2002), JAP 93, 8038 (2003), APL 88, 172105 (2006); [2]. Y. Wang et al, APL 93, 172501 (2008).

MA 4.3 Mon 11:30 H22

Effect of re-entrant spin glass transition on the exchange bias in Fe/Cr bilayers — •Syed Rizwan Ali[1], Muhammad Bilal Janjua[1], Dieter Lott[2], Marian Fecioru-Morariu[1], Coen J. P. Smits[1], and Gernot Güntherodt[1] — [1]Physikalisches Institut (IIA), RWTH Aachen University, 52056 Aachen, Germany — [2]GKSS Forschungszentrum, 21502 Geesthacht, Germany

The exchange bias (EB) field H_{EB} in polycrystalline Fe/Cr bilayers is found to exhibit sign reversal and enhancement at low temperature due to competing ferromagnetic and antiferromagnetic interfacial couplings. The interface roughness as examined by x-ray reflectivity is considerably large indicating significant alloying at the Fe/Cr interface. Our results indicate that the interface alloying drives Cr into an Fe-cluster spin glass (SG) phase. After field cooling below the SG transition temperature the Fe clusters give a net ferromagnetic coupling to the adjacent Fe layer and hence result in an enhanced negative H_{EB}. With increasing temperature the net ferromagnetic interfacial coupling progressively decreases as the alloy undergoes a temperature-driven re-entrant SG-to-antiferromagnet phase transition. Thereafter, antiferromagnetic interfacial coupling between the uncompensated Cr moments and the Fe layer dominates. This yields the temperature driven sign reversal of H_{EB}. The H_{EB} of samples containing the intentionally deposited $Cr_{1-x}Fe_x$ SG-alloy underneath the Fe layer show all the features observed in our nominal Fe/Cr bilayer samples, thereby confirming our arguments.

MA 4.4 Mon 11:45 H22

Influence of ferromagnetic–antiferromagnetic coupling on the antiferromagnetic ordering temperature in Ni/Fe_xMn_{1-x} bilayers — •Miriam Stampe, Paul Stoll, Tobias Homberg, Kilian Lenz, and Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

We present a detailed study on epitaxial bilayers made up of ferromagnetic (FM) Ni and antiferromagnetic (AFM) Fe_xMn_{1-x} layers. The AFM ordering temperature (T_{AFM}) and the coupling at the interface of FM and AFM layer are deduced from polar magneto-optical Kerr effect measurements at different temperatures. The enhancement of coercivity for samples with different Fe_xMn_{1-x} layer thickness, Fe concentration and FM–AFM interface roughness reveals that T_{AFM} only depends on the layer thickness. The FM–AFM coupling strength is determined by the Fe concentration of the Fe_xMn_{1-x} layer and the interface roughness, but as the measurement series clearly show, these do not affect the ordering temperature. The different behaviour of our out-of-plane measurements compared to earlier results for in-plane magnetization [1,2] leads us to the assumption that the spin structure in Fe_xMn_{1-x} is distorted from the 3Q structure in bulk material, depending on the magnetization direction of the adjacent FM layer.

[1] F. Offi *et al.*, Phys. Rev. B **66**, 064419 (2002).
[2] K. Lenz *et al.*, Phys. Rev. Lett. **98**, 237201 (2007).
Financial support by the DFG (KU1115/9-1) is acknowledged.

MA 4.5 Mon 12:00 H22

Ab initio exchange constants for the Heisenberg model — •Adam Jakobsson[1,2], Stefan Blügel[1], Marjana Ležaić[1], and Biplab Sanyal[2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Department of Physics and Materials Science, Uppsala University, Box 530, SE-75121 Uppsala, Sweden

Ab initio total energies of spin spirals in selected metals and insulators have been mapped to Heisenberg Hamiltonian in order to extract the exchange constants as well as Curie temperatures through a Monte Carlo algorithm. The full potential linearized augmented plane wave code `FLEUR` [1] was employed. A comparison is made between extracting exchange constants from a set of Fourier transforms and a least square fit to total energies. The calculations of total energy differences are approximated by the use of Andersen's force theorem. The validity and the precision of the calculations are discussed. For strongly correlated systems such as MnO a Hubbard U is applied and additional attention is required when the force theorem is used. The benchmark materials bcc Fe, fcc Ni and rock salt MnO are covered. Fe is a metal and has long ranged interactions with Ruderman-Kittel-Kasuya-Yosida behaviour. In contrast the insulator MnO has mainly short ranged interactions. For Ni longitudinal fluctuations of magnetic moments are substantial. Finally we discuss a Hamiltonian with higher order terms and the influence they might have on magnetism of some compounds.
[1] www.flapw.de

MA 4.6 Mon 12:15 H22

Magnetic and transport properties of spin-valve elements based on iron oxide nanoparticles — •Giovanni Andrea Badini Confalonieri[1], Philipp Szary[1], Maria Jose Benitez[1,2], Durga Mishra[1], Matthias Stadlbauer[1], Frank Brüssing[1], Matthias Feyen[2], Anhui Lu[2], Oleg Petracic[1], and Hartmut Zabel[1] — [1]Experimentalphysik IV, Ruhr-Universität Bochum, D-44780 Bochum — [2]Max-Planck Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr

Spin-valve elements based on magnetic nanoparticles are prepared by a combination of self-organization, ion etching and thin film growth.

Highly monodisperse magnetic iron oxide nanoparticles are prepared by a chemical synthesis route, suspended in a toluene solution and spin coated on a Si substrate to form a well ordered self-assembled hexagonal close-packed monolayer. A Co bias-layer is evaporated on top of the nanoparticles after ion milling. Several cases are investigated: biasing via an unoxidized Co layer or via an exchange bias CoO layer. Surface characterisation is performed by means of Scanning Electron Microscopy and Atomic Force Microscopy. The magnetic characterisation presented includes field-cooling/zero-field cooling M(T) curves and magnetic hysteresis curves, in the temperature range from 15 K to 380 K, as well as surface magnetic properties studies by means of Magneto Optic Kerr Effect and Magnetic Force Microscopy. The transport properties of the spin-valve devices are measured by conventional four-probe technique. The effect of the device geometry on the magnetic and transport properties will be discussed.

MA 4.7 Mon 12:30 H22

Perpendicular FePt-based exchange-coupled composite media — •Denys Makarov[1], Jehyun Lee[2], Christoph Brombacher[1], Christian Schubert[1], Markus Fuger[2], Dieter Suess[2], Josef Fidler[2], and Manfred Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Institute of Solid State Physics, Vienna University of Technology, A-1040 Wien, Austria

To increase storage density in magnetic recording, FePt alloys in the $L1_0$ phase are under study as promising candidates for a recording layer [1]. However, due to the strong magnetic anisotropy, the magnetic field required to reverse the magnetization of the media may become higher than the field provided by a recording head. To solve this issue, the concept of exchange-coupled composite (ECC) media was suggested to reduce the switching field of a hard magnetic layer [2].

We fabricated ECC media which consisted of a hard FePtCu alloy film and a softer $[Co/Pt]_N$ multilayer stack both revealing an out-of plane easy axis of magnetization. We demonstrated that the switching field could be efficiently reduced by increasing the thickness of the soft magnetic layer and by tuning the interlayer exchange coupling. These studies were supported by theoretical modeling revealing the relevant factors to reduce the switching field of the hard layer which are important for future media design.

[1] D. Makarov et al., J. Appl. Phys. 103 (2008) 053903.
[2] D. Suess et al., Appl. Phys. Lett. 87 (2005) 012054.

MA 4.8 Mon 12:45 H22

Magnetization in a epitaxial $[Fe/Cr/Co/Cr]_{20x}$ spin valve system — •Frank Brüssing[1], Boris Toperverg[1], Kirill Zhernenkov[1], Maximilian Wolff[1], Hartmut Zabel[1], Katharina Theis-Bröhl[2], Carsten Wiemann[3], Alexander Kaiser[3], and Claus M. Schneider[3] — [1]Department of Physics, Ruhr-University Bochum — [2]University of Applied Sciences Bremerhaven — [3]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH

Magnetic heterostructures containing different magnetic layers, such as Co and Fe, are essential elements for modern spintronic devices. As a model system we have chosen $[Co/Cr/Fe/Cr(100)]_{20x}$ epitaxial superlattices with spin valve properties. The thicknesses of the Fe and Co layers were adjusted such that their magnetization magnitudes are roughly equal. The quality of the layering and the epitaxial relationship were verified via x-ray methods. Via PEEM and PNR the ground state and the magnetization reversal were studied. In this work we mainly focused on the magnetic correlation between Co and Fe mediated by Cr spacer layer and its dependence on the Co bcc-hcp martensitic transition. The alignment between neighboring Co and Fe layers can be recognized via intensity variations of the superlattice Bragg peaks, which are different for odd and even orders. For a certain thickness of the Co and Fe layers in the as grown state additional half-order peaks can be recognized, which indicate a spiral like magnetic ordering in the sample. A combination of the magnetic anisotropy of the different layers and interlayer exchange coupling is most likely the reason for the spiral state. This project was supported by the DFG via SFB491.

MA 4.9 Mon 13:00 H22

Magnetic circular dichroism in the angular distribution of electrons emitted from buried layers observed by hard X-ray photoelectron spectroscopy. — •G. Stryganyuk[1], E. Ikenaga[2], X. Kozina[1], S. Ouardi[1], T. Sugiyama[2], N. Kawamura[2], M. Suzuki[2], K. Kobayashi[3], K. Inomata[4], M. Yamamoto[5], C. Felser[1], and G.H. Fecher[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany — [2]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan — [3]National Institute for Materials Science, SPring-8, Hyogo, Japan — [4]NIMS, Tsukuba 305-0047, Japan — [5]Hokkaido University, Sapporo, Japan

This work reports on measurements of the magnetic dichroism in photoemission from core levels and valence band of magnetised buried thin films. The high bulk sensitivity of hard X-ray photoelectron spectroscopy allows to study the magnetic multilayers. High resolution photoelectron spectroscopy was performed with an excitation energy of $h\nu = 7.938$ keV. The circularly polarised photons were produced by an in-vacuum phase retarder at undulator BL-47XU beamline of SPring-8. The experiments were performed on exchange biased magnetic layers covered by insulators of 1 nm to 3 nm thickness. Two types of structures were used with the MnIr (10 nm) exchange bias layer either on top or below the ferromagnetic layer.

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