MA 18: Magnetic Thin Films II

Time: Wednesday 15:15–19:15 Location: H3

MA 18.1 Wed 15:15 H3

Dzyaloshinskii-Moriya interactions due to internal strains in nanostructures: An ab-initio study — •Philipp Beck[1] and Manfred Fähnle[2] — [1]Institut für Theoretische und Angewandte Physik, Universität Stuttgart — [2]Max-Planck-Institut für Metallforschung, Stuttgart

Artificial nanostructures such as ferromagnetic thin films, multilayers, nanowires etc. often lack structural inversion symmetry, giving rise to a chiral asymmetry of the exchange couplings due to Dzyaloshinskii-Moriya interactions and to single-handed spin structures [1,2,3]. Thereby, one source for the structural symmetry breaking are internal strains originating from relaxation effects at free surfaces and interfaces or from lattice mismatches in epitaxial films. In the present contribution the strain-induced Dzyaloshinskii-Moriya interactions in iron are determined by a combination of the ab-initio density functional electron theory with a micromagnetic model.

[1] A.N. Bogdanov, U.K. Rössler, Phys.Rev.Lett. **87**, 037203 (2001).
[2] M. Bode et al., Nature **447**, 190 (2007).
[3] M. Heide, G. Bihlmayer, S. Blügel, Phys.Rev.B **78**, 140403 (2008).

MA 18.2 Wed 15:30 H3

Magnetic and microstructural properties of thin NdFeB based films and nanostructures — •Lars Bommer and Dagmar Goll — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart, Germany

The magnetic and microstructural properties of NdFeB and NdFeB/Fe thin films and nanostructures are presented. Samples with Cr buffer and protection layer (minimum thickness: $d = 50$ nm) have been produced by ion beam sputtering at elevated temperatures ($T_s = 700$ °C) using Al_2O_3 and MgO (001) single crystal substrates. Films deposited on Al_2O_3 substrates show c-axis growth in out-of-plane direction down to thicknesses of the NdFeB film of $d = 10$ nm with coercivities up to $\mu_0 H_c = 1$ T. The texture of films deposited on MgO (001) substrates is less pronounced and films below $d = 20$ nm show no hard magnetic behavior. For comparison, films were deposited at room temperature on Al_2O_3 and MgO (001) followed by post-annealing in Ar atmosphere (T_{pa} = 525-650 °C) leading to coercivities as high as $\mu_0 H_c = 1.2$ T but with isotropic behavior. By TEM images the grain structure of the NdFeB samples is studied. Bilayers of NdFeB ($d = 50$ nm) and Fe (d = 0-20 nm) show fully exchange coupled behavior. From the temperature dependence of the coercivity the microstructural parameters of all samples have been determined. Furthermore NdFeB periodical patterns were produced by means of electron beam lithography with dot sizes of 1000 nm and 500 nm, respectively.

MA 18.3 Wed 15:45 H3

Low Temperature FMR study of Ultra Thin Au/Fe/GaAs Samples — •Abdullah Kocbay[1], Ramazan Topkaya[1], Sinan Kazan[1], Bekir Aktas[1], Kubra Marhan[1], Bartek Kardasz[2], and Bret Heinrich[2] — [1]Gebze Institute of Technology, 41400 Gebze-Kocaeli, Turkey — [2]Simon Fraser University, British Columbia V5A 1S6, Canada

The interest in ultrathin magnetic multilayers has been steadily increasing since they are building blocks in spintronics applications such as data storage devices and magnetic random access memories. Molecular beam epitaxially grown Fe on GaAs(001) capped by Au overlayer with variable thickness had been investigated by ferromagnetic resonance (FMR) and vibrating sample magnetometer (VSM). FMR measurements were carried out using a Bruker X-Band EMX spectrometer with a microwave frequency of 9.5 GHz by sweeping the magnetic field from 0 to 2 kOe. The temperature dependence of FMR spectra was recorded from 5 K to 300 K. The samples were placed on the sample-holder in conventional in-plane geometries. (both DC and microwave magnetic fields always lie in the film plane). We have recorded the FMR data in the conventional in-plane geometry for some specific crystallographic axis such as static magnetic field were aligned parallel to the hard axis and easy axis of uniaxial magnetocrystalline anisotropy and 45 degrees from the hard axis respectively. Magnetization measurements of the samples were carried out using a physical property measurement system (PPMS) by Quantum Design.

MA 18.4 Wed 16:00 H3

Energy and angle dependent threshold photoemission magnetic circular dichroism from an ultrathin Co/Pt(111) film — •Kerstin Hild[1], Gerd Schönhense[1], Hans-Joachim Elmers[1], Takeshi Nakagawa[2], Toshihiko Yokoyama[2], and Peter Oppeneer[3] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]Institute for Molecular Science, The Graduate University for Advanced Studies Okazaki, Japan — [3]Department of Physics and Materials Science, Uppsala University, Sweden

Threshold photoemission magnetic circular dichroism (TPMCD) has recently been observed in one- and two- photon photoemission (1PPE [1] and 2PPE [2]). We report on measurements for ultrathin Co films with perpendicular magnetization grown on Pt (111) using ultrashort pulse lasers. Energy dependent TPMCD measurements reveal asymmetries, continuously increasing when approaching the photo threshold. At the threshold we obtain maximum values of 1.90 % for 1PPE and 12.8 % in the case of 2PPE. Angle dependent TPMCD measurements result in reduced asymmetry values for large incident angles following a cosine law in the case of 2PPE. The measured TPMCD asymmetries are compared to theoretical predictions based on local spin density calculations.

Funded by Carl-Zeiss-Stiftung and the Graduate School of Excellence MAINZ (Kerstin Hild) [1] T. Nakagawa and T. Yokoyama, Phys. Rev. Lett. 96, 237402 (2006). [2] K. Hild et al., Phys. Rev. Lett. 102, 057207 (2009).

MA 18.5 Wed 16:15 H3

Reversal mechanism of AF-coupled [Co/Pt]/Ir multilayers — •C. Bran[1,2], N.S. Kiselev[1], O. Hellwig[3], U. Wolff[1], A.N. Bogdanov[1], U.K. Rössler[1], L. Schultz[1], and V. Neu[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]IMPRS "Dynamical Processes in Atoms, Molecules and Solids", Nöthnitzer Str. 38 01187 Dresden, Germany — [3]San Jose Research Center, Hitachi Global Storage Technologies, 650 Harry Road, San Jose, CA 95120, USA

The magnetization reversal process in Co/Pt-based systems usually involves the formation of vertically correlated band domains resulting from a competition between ferromagnetic (FM) exchange, perpendicular anisotropy and dipolar energies. The reversal process can be modified by incorporating Ir spacer layers with appropriate thickness, which establishes an antiferromagnetic (AF) interlayer exchange coupling between blocks of Co/Pt layers. The magnetization processes of AF coupled $[(\mathrm{Co/Pt})_{X-1}/\mathrm{Co/Ir}]_4$ multilayers are investigated via MFM at room temperature by imaging the domain configuration in magnetic fields. The sample shows a new type of magnetization where FM band domains are present in the remanent state and effects of AF coupling appear in an intermediate field state, a magnetization path which has not been considered so far. The experimental results are compared quantitatively with a theoretical model developed for the investigated multilayers.

MA 18.6 Wed 16:30 H3

Epitaxial Growth of Ni on Si Substrate by DC Magnetron Sputtering — •Wolfgang Kreuzpaintner, Michael Störmer, Dieter Lott, Danica Solina, and Andreas Schreyer — GKSS Forschungszentrum Geesthacht, GmbH, Max-Planck-Straße 1, 21502 Geesthacht, Germany

The influence of the substrate temperature on the growth of highly textured Ni(111) and epitaxial Ni(200) with the epitaxial relationship Ni[100]||Si[110] and Ni(001)||Si(001) on hydrogen terminated Si(100) wafer substrates by means of direct current magnetron sputtering will be reported. To minimize crystal defect formation and in order to achieve a high quality epitaxial growth of Ni on Si a two step deposition process was developed whereby different deposition conditions were used for an initial nickel seed layer and the remaining nickel. In-plane and out-of-plane structural properties of the deposited films were investigated using x-ray scattering techniques whereas magneto-optical Kerr effect and neutron reflectometry were used to confirm their magnetic nature. Additionally, first results on the currently investigated epitaxial growth of Ni on Si with the Ni(111) in out-of-plane direction may be reported.

MA 18.7 Wed 16:45 H3

Effect of substrate morphology on magnetic anisotropy and domain-structure — •Stefan Rössler, Sebastian Hankemeier, Robert Frömter, and Hans Peter Oepen — Institute of Applied Physics, Hamburg, Germany

In contrast to single crystal silicon substrate, diamond has to be polished to achieve a plain surface. As a result polishing lines remain on the surface of the diamond. The lateral distance of these lines is about 100-200 nm and the height about 1-2 nm, respectively.

We have investigated the impact of these lines on the magnetic properties of a 20 nm Permalloy film. The surface texture of the substrate is replicated in the thin film. The magnetic properties have been investigated by means of magneto optical Kerr effect (MOKE) measurements. These measurements reveal a morphology induced anisotropy with an easy axis of magnetization parallel to the polishing lines.

We have investigated the impact of this anisotropy contribution on the domain structure of 5x5 μm^2 Permalloy squares by means of SEMPA. Due to the high symmetry of these structures they exhibit flux closure domain states, such as the diamond state or the Landau state. The Landau state consists of four triangle shaped domains with magnetizations parallel to the edges of the rectangles curling around a sharp core. It is shown, that the pair of domains with magnetization parallel to the direction of the easy axis are favored and therefore occupy a larger area than the other pair of domains. Thus the straight domain walls of the common Landau state become curved.

This work is supported by DFG via SFB 668.

MA 18.8 Wed 17:00 H3

(001) textured FePtCu thin films on amorphous SiO_2 substrates — •Christoph Brombacher[1], Christian Schubert[1], Patrick Matthes[1], Denys Makarov[1], Mireille Maret[2], Nathalie Boudet[3], and Manfred Albrecht[1] — [1]Chemnitz University of Technology, Institute of Physics, Germany — [2]Laboratory SIMAP, UJF, France — [3]Institute Néel, MCMF, France

In this study, 5 nm thick (001) textured and chemically ordered FePtCu films have been prepared via rapid thermal annealing of FePt(5 nm - x)/Cu(x) bilayers sputter-deposited at room temperature onto thermally oxidized Si substrates. The thickness x of the Cu film was varied between 0 nm and 1.2 nm resulting in a Cu content between 0 at.% and 27 at.% verified by RBS. The influence of both the annealing temperature and the Cu content on the magnetic properties was investigated by SQUID magnetometry and an uniaxial perpendicular magnetic anisotropy of up to 2 MJ/m^3 has been achieved. The magnetic analysis was complemented by MFM revealing the local magnetic domain configuration. Detailed structural investigations by XRD confirm the pronounced (001) texture and the existence of a high degree of $L1_0$-type long range order. In addition, the topography has been further investigated by SEM and AFM confirming that annealing to temperatures $T > 600°C$ leads to a distinct dewetting behavior of these thin films and the formation of small FePtCu grains. This phenomena correlates with a pronounced increase in coercivity.

This work was supported by the European project - TERAMAGSTOR (contract No. ICT-224001).

MA 18.9 Wed 17:15 H3

Induced Magnetic Anisotropy in Amorphous $Fe_{24}Co_{68}Zr_8$ Thin Films — •Yu Fu[1], Igor Barsukov[1], Marina Spasova[1], Hossein Raanaei[2], Björgvin Hjövarsson[2], and Michael Farle[1] — [1]Fakultät für Physik and CeNIDE, Universität Duisburg-Essen, Duisburg, Germany — [2]Department of Physics and Materials Science, Uppsala University, Uppsala, Sweden

Amorphous building blocks, due to their uniformity, are good candidates for TMR (tunnelling magnetoresistance) structures, for which the tailoring of magnetic anisotropy is a valuable aspect. Amorphous thin films Al/AlZr/$Fe_{24}Co_{68}Zr_8$(10 nm)/AlZr/Si and Al/AlZr/[$Fe_{24}Co_{68}Zr_8$(3 nm)/AlZr(3 nm)]$_2$/Si were grown using dc magnetron sputtering in the presence of an external magnetic field (growth field). The two magnetic layers of the latter sample were deposited in different directions of the growth field rotated by 90° to each other. By means of ferromagnetic resonance (FMR), a uniaxial anisotropy with the hard axis along the direction of the growth field was found in the single layer sample. The FMR spectra of the bi-layer reveal the superposition of 2 sets of angular dependences shifted by 90° to each other, indicating that the growth field has imprinted layer specific anisotropy in different layers. The temperature dependences of effective magnetization and uniaxial anisotropy have been evaluated from low-temperature FMR. The hysteresis loops of the single layer sample measured by SQUID show exchange bias which decreases with increasing temperature, suggesting the presence of an antiferromagnetic phase in the sample. Supported by DFG/SFB 491.

15 min. break

MA 18.10 Wed 17:45 H3

Investigation of soft-magnetic properties of thin FeCo films for contact-less temperature and strain sensor applications — •Claas Thede, Steffen Chemnitz, Iulian Teliban, Christoph Bechtold, and Eckhard Quandt — Christian-Albrechts-Universität zu Kiel

In magnetostrictive materials, magnetic properties like permeability or magnetization depend on the material's strain, which can be caused by e.g. mechanical stress. If the magnetostrictive material is combined with another material of different thermal expansion coefficient, temperature changes have a similar effect. Furthermore, the coercive field strength of ferromagnetic materials depends on temperature due to its effect on domain wall mobility.

Therefore, magnetostrictive phases can be used as sensors with remote readout capability for mechanical stress and, if the above condition is met, temperature. In order to integrate magnetostrictive sensor phases into other materials, a technique for highly selective detection of magnetic properties is needed, e.g. frequency mixing.

We present a sensor based on this technique with additional phase sensitivity, capable of parallel measurement of permeability, magnetic moment, and relative changes of coercive field strength. Application of the sensor with respect to functionalized coatings with wear-resistant properties and integrated magnetostrictive phases (FeCo) is discussed.

Founding by the DFG via the priority program 1299 "HAUT" is gratefully acknowledged.

MA 18.11 Wed 18:00 H3

Spin Reorientation Transition of Co/Au(111) induced by ion bombardment — •Moritz Bubek, Sabine Pütter, and Hans Peter Oepen — Angewandte Physik, Universität Hamburg, Jungiusstr 11, 20355 Hamburg, Germany

Due to surface contributions ultrathin Co/Au(111) films exhibit large magnetic anisotropies perpendicular to the surface. A thickness driven spin reorientation transition (SRT) can be observed by increasing the film thickness. In magnetic susceptibility measurements a pronounced peak was found during Co growth indicating the reorientation from out-of-plane to in-plane orientation of the magnetization [1].

In our experiment we studied the magnetic susceptibility during Co removal by sputtering with 800 eV Ar ions. Starting with films of 6 monolayers thickness and in-plane easy axis of magnetization we can again drive the system into a spin reorientation to end up with a perpendicular magnetization orientation.

This is surprising as ion bombardment modifies the surface morphology and causes surface roughness that in general decreases the surface anisotropy [2]. To control the impact of the ion bombardment on the surface structure we used low energy electron diffraction. We discuss the magnetic origin of the peak and compare the film thickness of the SRT for Co growth and removal.

[1] S. Pütter et al., Phys. Rev. B 64, 092409, (2001)
[2] P. Bruno, J. Phys. F 18, 1291, (1988)

MA 18.12 Wed 18:15 H3

Forcing ferromagnetism in Fe/Gd thin films via Cr interlayer — •Carolin Antoniak[1], Bernhard Krumme[1], Anne Warland[1], Frank Stromberg[1], Biplab Sanyal[2], Christian Praetorius[3], Kai Fauth[3], Olle Eriksson[2], and Heiko Wende[1] — [1]Fakultät für Physik and CeNIDE, Universität Duisburg-Essen (Germany) — [2]Department of Physics and Materials Science, Uppsala University (Sweden) — [3]Experimentelle Physik IV, Universität Würzburg (Germany)

Magnetic materials with a large saturation magnetic moment are used in many applications like e.g. write heads for computer hard disk drives. Since the rare earth metals are known for their large magnetic moments but low Curie temperatures, one may think of a rare earth/3d transition metal system to achieve a high saturation magnetic moment in combination with an enhanced Curie temperature caused by the coupling to the 3d transition element. As a prototype system, 13ML Gd on 15ML Fe was chosen. Since Fe and Gd spins tend to be aligned antiparallel, a ferromagnetic coupling between these compounds was

forced by a Cr interlayer. The spin alignment was measured by means of x-ray magnetic circular dichroism (XMCD) at the Fe $L_{3,2}$ and Gd $M_{5,4}$ absorption edges. While for a Cr interlayer thickness of 4ML an antiparallel alignment was obtained, 5ML Cr yield a parallel alignment of Fe and Gd spins as predicted by theory. Temperature dependent measurements of the XMCD at the Gd $M_{5,4}$ absorption edges indicate an enhanced Curie temperature due to the strong coupling to the Fe thin film. – Funded by BMBF(05ES3XBA/5) and DFG(SFB491).

MA 18.13 Wed 18:30 H3

Effect of the iron overlayer thickness on the first and second order anisotropy constants of a $(Co/Pt)_8$ multilayer film — •Matthias Hille, Daniel Stickler, André Kobs, Robert Frömter, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg

We studied the influence of Fe overlayers on the anisotropy constants K_1 and K_2 of a Co/Pt multilayer. Fe is deposited on a stack that consists of a 2 nm Pt covered $(Co_{0.7nm}/Pt_{2nm})_8$ multilayer, grown on a Pt seed layer (5 nm). From investigations of the magnetic microstructure via x-ray holography it is known that the iron causes a domain size reduction indicating changes of the anisotropy constants [1].
We used the magneto-optical Kerr effect to study the magnetization behavior. From the magnetization curves the anisotropy constants are determined. The uncoated multilayer has an out-of plane easy axis. Increasing the Fe thickness up to 4 nm reduces K_1 while K_2 remains nearly constant. Between 2 and 3 nm Fe thickness the magnetization changes from out-of-plane to a canted magnetization orientation. Additional Fe up to a thickness of 9 nm leads to a decrease of K_2 while K_1 exhibits only marginal changes and the magnetization remains canted. The influence of the Pt cap layer thickness which separates Fe from the Co/Pt multilayer is discussed.

[1] Stickler et al. - submitted to APL (2009)

MA 18.14 Wed 18:45 H3

Interdiffusion at a ferromagnetic/semiconductor interface: experiment and theory — •Anne Warland, Bernhard Krumme, Heike C. Herper, Claudia Weis, Carolin Antoniak, Frank Stromberg, Peter Entel, Werner Keune, and Heiko Wende — Fakultät für Physik und CeNIDE, Universität Duisburg-Essen

Fe_3Si on GaAs is a promising ferromagnet/semiconductor system due to the low lattice mismatch of 0.1% . For this system, spin injection at room temperature has been demonstrated. A detailed understanding and control of the interface properties is necessary for future spintronic applications. We prepared 80 Å thick Fe_3Si films on GaAs(001) and MgO(001). The film on MgO served as a reference for nearly perfectly ordered Fe_3Si. The magnetic properties of the films were investigated by means of X-ray magnetic circular dichroism (XMCD) spectroscopy. In addition, conversion electron Mössbauer spectroscopy (CEMS) measurements were carried out to characterize the chemical ordering and the structural properties of the films. In case of Fe_3Si/GaAs we obtained indications of an interdiffusion of substrate atoms at the interface [1]. We compare our experimental XAS and XMCD spectra with theoretically calculated spectra, which allow to disentangle the different contributions from the inequivalent Fe sites. In order to study the interdiffusion effects in detail, SPR-KKR calculations introducing different contents of Ga have been performed. –Supported by DFG(SFB491) and BMBF(05ES3XBA/5)

[1] B. Krumme et al., Phys. Rev. B **80**, 144403 (2009)

MA 18.15 Wed 19:00 H3

MOKE spectroscopy of FePtCu thin films with perpendicular magnetic anisotropy — •Michael Fronk, Lars Smykalla, Christoph Brombacher, Christian Schubert, Manfred Albrecht, and Georgeta Salvan — Chemnitz University of Technology

Since the uniaxial magnetic anisotropy of FePt in its chemically ordered $L1_0$ phase can reach 10 MJ/m^3 FePt is considered to be a promising material for future magnetic storage devices. In this work $Fe_{52}Pt_{48}$(5 nm – x)/Cu(x) bilayers have been sputter deposited at room temperature onto thermally oxidized Si wafers and afterwards annealed to various temperatures between 450°C and 800°C under N_2 atmosphere using a commercial rapid thermal annealing (RTA) setup. The RTA procedure leads to the formation of a ternary FePtCu alloy with pronounced perpendicular magnetic anisotropy. The dependence of both the coercivity and remanence extracted from polar MOKE hysteresis loops at 1.96 eV on the annealing temperature will be discussed with respect to the initial Cu thicknesses of 0.5 nm and 0.9 nm. In addition, MOKE-spectroscopy in the energy range between 1.7 eV and 5.5 eV was performed and a clear dependence on the initial Cu thickness and the annealing temperature is found. In some of the spectra the main spectral feature at around 2 eV exhibits a fine structure, which could be caused by the coexistence of the two crystalline phases and/or by the presence of defect sites.