MA 38: MagneticThin Films I

Time: Thursday 9:30–13:00 Location: H 0112

MA 38.1 Thu 9:30 H 0112

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

Amorphous magnetic thin films are good candidates for designing new spintronic devices, due to their lack of inhomogeneity caused by crystalline defects or lattice strain at the interfaces. An amorphous $Co_{68}Fe_{24}Zr_8$(3 nm)/$Al_{70}Zr_{30}$(3 nm)/$Co_{68}Fe_{24}Zr_8$(3 nm) trilayer structure was investigated using in-plane and out-of-plane angular dependent ferromagnetic resonance at different frequencies. By deconvoluting the resonance lines and fitting the angular dependences of the resonance field, it was proved that the uniaxial magnetic anisotropy of each $Co_{68}Fe_{24}Zr_8$ layer can be tailored independently and arbitrarily by applying an external magnetic field during film deposition. The magnetic anisotropy constants of the $Co_{68}Fe_{24}Zr_8$ layers are nearly identical. Furthermore, the magnetic layers act independently upon each other due to the absence of interlayer coupling. This work was supported by the Deutsche Forschungsgemeinschaft (DFG), SFB 491 and the Swedish Research Council.

MA 38.2 Thu 9:45 H 0112

Temperature driven oscillatory magnetic anisotropy in ultrathin ferromagnetic films — Maciej Dabrowski[1], •Marek Przybylski[1], Marek Cinal[2], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Institute of Physical Chemistry of the Polish Academy of Sciences, Kasprzaka 44/52, 01-224 Warsaw, Poland

In ultrathin ferromagnetic films, quantum well states (QWS) are expected to contribute to the magnetic anisotropy energy (MAE) when the spread of the Fermi function ($\sim 4 \cdot k_B T$) is much smaller than the energy difference between the two states of each QWS pair contributing to the MAE. The magnetic anisotropy should therefore exhibit a strong temperature dependence for film thicknesses for which the pairs of QWS contribute to the MAE ($d = d_0 + n \cdot L$). The result is an oscillatory magnetic anisotropy at low temperatures only. The oscillation period L is determined by the wave vector of the bulk d-band corresponding to the QWS crossing Fermi level, and thus allows to identify the electronic states which contribute to the MAE.

Such temperature effects on the MAE is shown and discussed for *fcc*-Co films on vicinal surfaces of Cu(001) and for *bcc*-Fe films on vicinal surfaces of Au(001).

MA 38.3 Thu 10:00 H 0112

Morphology and magnetism of MnSi thin films — •Josefin Engelke, Tommy Reimann, Dirk Menzel, and Stefan Süllow — IPKM, TU Braunschweig, Germany

MnSi exhibits an intriguing magnetic behavior with a helimagnetic ground state below 29 K and field induced conical and ferromagnetic order. Thin MnSi films are prepared using molecular beam epitaxy in ultra high vacuum. MnSi thin films can be grown on Si(111) due to a small lattice misfit of 3% between the $\sqrt{3}x\sqrt{3}R30$ reconstructed Si surface and MnSi in $< 111 >$ direction. We report on the influence of the preparation method on the morphology of the MnSi films. Two different growth procedures are compared, one of which is an alloying process of a deposited Mn layer on the Si substrate, where heating enforces a reaction forming MnSi. Alternatively, films have been grown by codeposition of Mn and Si. A structural characterization using RHEED, AFM and TEM reveals that the codeposition technique generally improves the film quality. Magnetization measurements show that the ordering temperature is dependent on the film thickness and reaches values up to 40 K.

MA 38.4 Thu 10:15 H 0112

Magnetic properties of epitaxial $Nd_{(1-x)}Pr_xCo_5$ thin films grown on Al_2O_3(0001) — •Stephan Zimmermann, Marietta Seifert, Ludwig Schultz, and Volker Neu — IFW Dresden, Institute for Metallic Materials, P.O. 270116, 01171 Dresden, Germany

A series of epitaxial $Nd_{(1-x)}Pr_xCo_5$ thin films was prepared by pulsed laser deposition and systematically studied as a function of Pr/RE content x (RE – rare earth). As known from previous studies, the hexagonal and isostructural systems $NdCo_5$ and $PrCo_5$ posses a strong magnetocrystalline anisotropy with an uniaxial easy direction parallel to the c-axis at room temperature. For lower temperatures both materials undergo a spin reorientation transition, however into an easy cone and easy plane state for $PrCo_5$ [1] and $NdCo_5$ [2], respectively. In this work we focus on the spin reorientation of the solid solution $Nd_{(1-x)}Pr_xCo_5$. To achieve a perpendicular anisotropy, the films were grown on a Ru buffered Al_2O_3(0001) substrate. Structural measurements have proven the epitaxial growth with one single variant and also indicate successful formation of the $RECo_5$ phase, independent of the Pr/RE content x. Hystereses measured at different temperatures reveal a characteristic change of easy direction and were also used to evaluate the anisotropy constants of second and forth order K_1 and K_2. Furthermore the temperature dependence of the domain structure was investigated for selected samples by magnetic force microscopy.

[1] Patra A.K. et al, PRB 75, 184417 (2007)
[2] Seifert M. et al, JAP 107, 09A711 (2011)

MA 38.5 Thu 10:30 H 0112

An amorphous model system for the 2D XY universality class — •Andreas Liebig[1], Panagiotis Korelis[2], Martina Ahlberg[2], Manfred Albrecht[1], and Björgvin Hjörvarsson[2] — [1]Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 20 Uppsala, Sweden

We present a study on the magnetic properties of thin (15 Å) amorphous $Fe_{89}Zr_{11}/Al_{78}Zr_{22}$ layers in low fields (below 7 mT) around the apparent ordering temperature (140 K). Despite the thickness of 15 Å, the ordering transition is in excellent agreement with the finite 2D XY model, with a Kosterlitz-Thouless temperature of 134.6 ± 0.1 K. A comparison to crystalline systems, for which the crossover to three dimensional behavior is observed for far thinner layers, is made.

Significant polarizability above the ordering temperature is observed, resulting from large-scale magnetic correlations. These long-range correlations are a inherent feature of the 2D XY universality class. A simple model allows the quantification of these correlations.

MA 38.6 Thu 10:45 H 0112

X-ray Magnetic Linear Dichroism in reflection at the 2p and 3p edges of antiferro-magnetic MnNi and NiO — •Marc Tesch[1], Markus Gilbert[1], Hans-Christoph Mertins[1], Daniel Bürgler[2], Claus Schneider[2,3], and Peter Oppeneer[4] — [1]FH Münster, Stegerwaldstr. 39, D-48565 Steinfurt — [2]FZ Jülich GmbH, Peter Grünberg Inst. (PGI-6), D-52425 Jülich — [3]Fakultät f. Physik and CeNIDE, Uni Duisburg-Essen, D-47048 Duisburg — [4]Depart. of Physics, Uppsala Uni., Box 530, S-751 21 Uppsala, Sweden

Antiferromagnetic (AFM) materials find key applications in novel spintronic devices. Typically, AFM layers are embedded in a stack of non-magnetic and ferro-magnetic layers. Therefore, a probing-depth sensitive, element-specific experimental technique, which can discriminate signals from ferro- and antiferro-magnets, is needed for their investigation. X-ray magnetic linear dichroism (XMLD) in reflection is most suited for this purpose as proven for the 2p edges in grazing incidence [1]. We present XMLD spectra of AFM layers of MnNi and NiO at the Mn and Ni 3p edges, respectively, and compare them with spectra at the corresponding 2p edges, obtained at DELTA. Due to the increased reflectivity at low energy 3 p edges, XMLD spectra could be taken from grazing up to normal incidence that show clear and large magnetic signals. The data are discussed with respect to the electronic structures and are compared with ab-initio calculated XMLD spectra.

[1] P.M. Oppeneer et al. Phys. Rev. B 67, 052401 (2003)

MA 38.7 Thu 11:00 H 0112

Analysis of anisotropy constants for $Co_{50}Fe_{50}$ and Fe films investigated by MOKE — •Timo Kuschel[1], Jaroslav Hamrle[2], Jaromir Pistora[2], Kesami Saito[3], Subrojati Bosu[3], Yuya Sakuraba[3], Koki Takanashi[3], Henrik Wilkens[1], and Joachim Wollschläger[1] — [1]Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49069 Osnabrück, Germany — [2]Department of Physics, VSB - Technical University of Ostrava, 17. listopadu 15, 70833 Ostrava-Poruba, Czech Republic — [3]Institute for Materials Research

(IMR), Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai 980-8577, Japan

Differently prepared $Co_{50}Fe_{50}$ and Fe films on MgO(001) are investigated by vectorial magnetometry via magnetooptic Kerr effect (MOKE). Measurements using s- and p-polarized incident light and an external magnetic field either parallel or perpendicular to the incidence plane of light are performed. Additionally, different in-plane orientations of the crystalline samples with respect to the external magnetic field are analyzed.

The cubic and the uniaxial magnetic anisotropy constant as well as the domain wall pinning energy are determined using the classic Stoner-Wohlfarth model. The $Co_{50}Fe_{50}$ films show a decreasing domain wall pinning energy with increasing annealing temperature due to fewer defects in the film. The analysis of the Fe film measurements reveal a decreasing domain wall pinning energy for films with increasing lateral crystallite size obtained by grazing incidence x-ray diffraction (GIXRD). This can also be explained by fewer defects in the film.

15 min. break

MA 38.8 Thu 11:30 H 0112

$Fe_{100-x}Ga_x$ for magnetostrictive applications: from thin films to nanowires — •Diana Iselt[1], Alexander Funk[1,2], Heike Schlörb[1], and Ludwig Schultz[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]TU Dresden, Faculty of Mechanical Engineering, 01062 Dresden

Magnetostrictive materials are of high interest for electromagnetic sensing and actuating devices. A promising candidate to overcome the mechanical limitations of Terfenol-D is $Fe_{100-x}Ga_x$ with 15 to 25 at.% Ga, which exhibits high mechanical strength and low saturation fields. For sensor applications an efficient, scalable preparation routine is required for thin film and nanowire fabrication.

A suitable deposition process for Fe-Ga alloy thin films has been developed using electrochemical pulse plating [1]. By optimizing the deposition parameters such as electrolyte composition, deposition potential, deposition time and pulse sequences, homogeneous thin films with low oxygen content and tunable texture have been prepared. These deposition conditions are used to prepare highly ordered nanowires with high aspect ratios in nanoporous templates. Results of the structural and magnetic characterization of the nanowires will be presented and discussed.

[1] D. Iselt, U. Gaitzsch, S. Oswald, S. Fähler, L. Schultz, H. Schlörb, Electrochim. Acta 56 (2011) 5178.

MA 38.9 Thu 11:45 H 0112

$Fe_{32}Co_{44}Hf_{12}N_{12}$/TiN multilayer coatings for non-contact high frequency sensor applications — •Kathrin Krüger, Klaus Seemann, Harald Leiste, Michael Stüber, and Sven Ulrich — Karlsruhe Institute of Technology (KIT), Institute for Applied Materials (IAM-AWP), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

In mechanical engineering the use of wear resistant PVD coatings is well established to enhance the durability of tools and components. In order to avoid interruptions of the working flow, a contactless observation of the wear state of surfaces and coatings would be beneficial. With regard to the dependence of ferromagnetic magnetization on temperature or strain, a wear resistant coating with an embedded ferromagnetic phase is realized as a potential functional thin film sensor and wear resistant material. In this study the ferromagnetic properties of FeCoHfN layers were combined with the mechanical properties of TiN layers in $Fe_{32}Co_{44}Hf_{12}N_{12}$/TiN multilayer coatings to simultaneously develop and tailor the magnetic and mechanical properties.

In order to investigate the effect of interfaces and individual layer thickness on the ferromagnetic high frequency permeability and on selected mechanical properties, the number of bilayers was varied systematically while keeping the total thickness and the ratio of the single layer thicknesses constant. It will be shown that the material selection and the specific multilayer design provide good magnetic softness and cut-off frequencies above 2 GHz. Low residual stresses and high hardness values, similar to the hardness of TiN, can be achieved.

MA 38.10 Thu 12:00 H 0112

Structural characterisation of exchange biased thin film systems with Grazing Incidence X-ray Diffraction — •Markus Meyl and Arno Ehresmann — Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

Exchange biased thin film systems are structurally characterised by Grazing Incidence X-ray Diffraction (GIXRD) realized with the X-ray Guinier thin film goniometer Huber G 653. This goniometer uses the Guinier process, which is based on the Seemann-Bohlin geometry. In the latter geometry the line focus of the X-ray tube, the surface of the sample and the detector entrance slit are located on a constant focussing cylinder. To improve the Seemann-Bohlin geometry for thin film measurements, the Gunier process uses a focussing monochromator between the X-ray tube and the thin film system for achieving strictly monochromatic X-rays. The angle of incidence between the incident X-rays and the surface of the sample is very small (0° - 10°) to achieve a large effective distance in the thin films and thereby higher diffraction intensities. As a consequence the Guinier thin film Goniometer is especially suitable for analysing thin polycrystalline films on crystalline or amorphous substrates. From the diffraction spectrum the lattice parameters, the indices of the atomic planes and the crystallite sizes can be calculated. Exemplary results of exchange biased thin film systems will be presented with a focus on crystallite sizes.

MA 38.11 Thu 12:15 H 0112

Structural and magnetic dynamics of a laser induced phase transition in FeRh — •Federico Pressacco[1], Simon O. Mariager[2], Eduardo Mancini[1], Andrin Caviezel[2], Ekaterina Vorobeva[2], Paul Beaud[2], Steven L. Johnson[2], Chris Milne[3], Eric Fullerton[4], Robert Feidenhans'l[5], Christoph Quitmann[2], Gerhard Ingold[2], and Christian H. Back[1] — [1]Universität Regensburg, 93053 Regensburg, Deutschland — [2]SLS, Paul Scherrer Institute, 5232 Villigen, Switzerland — [3]Ecole Polytechnique Federal Lausanne, 1015 Lausanne, Switzerland — [4]University of California, San Diego, La Jolla, CA 92093-0401, USA — [5]Niels Bohr Institute, University of Copenhagen, 2100 Kobenhavn, Denmark

The FeRh compound shows an extraordinary onset of a net magnetization with the increase of temperature starting from a antiferromagnetic room temperature ground state. The effects of the transition can be detected also in a change of the structural order accompanied with a isotropic volume expansion of about 1 percent. We used time-resolved x-ray diffraction and magnetic optical Kerr effect to study the laser induced antiferromagnetic to ferromagnetic phase transition in FeRh. The structural response is given by the nucleation of independent domains (t1=30 ps). This is significantly faster than the average magnetic response (t2=100 ps) which is given by the subsequent domain realignment. X-ray diffraction shows that two phases co-exists on a short time scale. We present a simple model that, assuming a simultaneous nucleation of structural and magnetic domains, accounts well both dynamics on a sub-nanosecond time scale.

MA 38.12 Thu 12:30 H 0112

Magneto-optical coupling in ferromagnetic thin films investigated by VMOGE — •Kahming Mok[1], Camelia Scarlat[1], György J. Kovacs[1], Lin Li[2], Vitaly Zviagin[1], Jeffrey McCord[3], Manfred Helm[1], and Heidemarie Schmidt[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [2]State Key Laboratory of Nuclear Physics and Technology, Peking University, China — [3]Institute of Materials Science, University of Kiel, Germany

We investigated the magneto-optical coupling in ferromagnetic thin films (Fe, $Ni_{20}Fe_{80}$, Co, $Ni_{80}Fe_{20}$, Ni) in the spectral range from 300 to 1100 nm. We performed Mueller matrix ellipsometry measurements in a magnetic field of arbitrary orientation and magnitude up to 400 mT at room temperature with a set-up vector-magneto-optical generalized ellipsometer (VMOGE). We extracted the magneto-optical dielectric tensor ε^{MO} of the ferromagnetic thin films under saturated in-plane magnetization conditions. The off-diagonal elements of the ε^{MO} depend on the net spin polarization and the electronic band structure of the magnetized material. For ferromagnetic Fe, Co, and Ni, the converted ε^{MO} agrees well with reported experimental optical conductivity data. With additional measurements on the magnetization of the ferromagnetic thin films, we extracted the magnetic field independent magneto-optical coupling constant **Q**, which is a useful parameter for characterization of magneto-optical materials.

Reference: K. Mok *et al.*, Phys. Rev. B **84**, 094413 (2011)

MA 38.13 Thu 12:45 H 0112

The importance of beyond-Heisenberg interactions in ferromagnetic metal/antiferromagnetic oxides interfaces — •Valerio Bellini[1], Gustav Bihlmayer[2], Franca Manghi[1,3], and

Stefan Blügel[1] — [1]CNR - Istituto di Nanoscienze - S3, Modena, Italy — [2]Peter Grünberg Institut (PGI-1) and IAS-1, Forschungszentrum Jülich, Jülich, Germany — [3]Dipartimento di Fisica, Università di Modena and Reggio Emilia, Modena, Italy

We present a density functional theory investigation of transition metal (TM) monolayers, i.e. Fe, Co, and Ni, on NiO(001). By means of the constrained local moment approach implemented in the FLEUR code [1], we analyze the possibility of attaining a perpendicular spin-flop canted state of the Ni spin moments with respect to the TM moments at the Ni layers close to the interface. In order to interpret the observed behaviors within a localized spin model Hamiltonian approach, beyond-Heisenberg, i.e. biquadratic terms, have to be necessarily taken into account. The competition between the different interactions at the interface determines whether the spin-flop state is the magnetic ground state of the systems across the series [2]. In light of our theoretical results, we give a possible interpretation of recent XMLD experiments [3,4] on these interfaces, in terms of Ni uncompensated spins originating from a reduced Ni layer at the interface, and mediating the coupling between the TM and the NiO spins. [1] Ph. Kurz, et al., Phys. Rev. B 69 024415 (2004). [2] V. Bellini, et al., to be submitted (2011). [3] G. van del Laan, et al., Phys. Rev. B 83, 064409 (2011). [4] S. Mandal, et al., Europhys. Lett. 95, 27006 (2011).