MA 24: Magnetic Imaging and Scattering Techniques

Time: Wednesday 9:30–12:15 Location: H22

MA 24.1 Wed 9:30 H22

Specular reflection from Ir(001) as efficient electron spin filter — •D. Kutnyakhov[1], P. Lushchyk[1], A. Fognini[2], D. Perriard[2], M. Kolbe[1], K. Medjanik[1], E. Fedchenko[1], S.A. Nepijko[1], H.J. Elmers[1], G. Salvatella[2], C. Stieger[2], R. Gort[2], T. Bähler[2], T. Michlmayer[2], Y. Acremann[2], A. Vaterlaus[2], F. Giebels[3], H. Gollisch[3], R. Feder[3], C. Tusche[4], A. Krasyuk[4], J. Kirschner[4], and G. Schönhense[1] — [1]Institut für Physik, Univ. Mainz — [2]Lab. für Festkörperphysik, ETH Zürich, Switzerland — [3]Universität Duisburg-Essen — [4]MPI für Mikrostrukturphysik, Halle

A novel spin polarimeter is described that can transport a full image by making use of k-parallel conservation in low-energy electron diffraction from an Ir(001)-surface, extending our previous work on W(001) [1, 2]. This spin-filter crystal provides a high analyzing power combined with a *lifetime* in UHV of a full day. For specular reflection at 45° scattering angle we found a good working point at 37eV scattering energy that shows a broad maximum of 5eV usable width. A second one at about 10eV exhibits a narrower profile <1eV but much higher figure of merit. A relativistic layer-KKR SPLEED calculation shows good agreement with measurements. The asymmetry function (Sherman function) reaches values of 0.7 which considerably reduces the significance of spurious asymmetries. The novel detector has been used in a time-resolved experiment in the femtosecond region at the free-electron laser FLASH at DESY. [1] C. Tusche et al., APL 99 (2011) 032505; [2] M. Kolbe et al., Phys. Rev. Lett. 107 (2011) 207601

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MA 24.2 Wed 9:45 H22

Universal correlated velocity and domain wall spin structure oscillations probed by direct dynamic imaging — •Mohamad-Assaad Mawass[1,2], André Bisig[2,3,4], Amelie Axt[1], Martin Stärk[3,4], Christoforos Moutafis[3,4], Jan Rhensius[3,4], Matthias Noske[2], Markus Weigand[2], Tolek Tyliszczak[5], Bartel Van Waeyenberge[6], Hermann Stoll[2], Gisela Schütz[2], and Mathias Kläui[1,3,4] — [1]Johannes Gutenberg-Universität Mainz, Germany — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [3]Paul Scherrer Institut, Villigen, Switzerland — [4]Universität Konstanz, Germany — [5]Advanced Light Source, LBNL, Berkeley, USA — [6]Ghent University, Ghent, Belgium

Magnetic memory, sensing and logic devices based on the motion of magnetic domain walls (DWs) rely on the precise control of the position and the velocity of individual magnetic DWs. Varying DW velocities have been predicted to result from intrinsic effects, such as oscillating DW spin structure transformations and extrinsic pinning due to imperfections. We use direct dynamic imaging of the nanoscale spin structure to investigate these predictions, revealing universal oscillating domain wall motion. As the origin, the oscillating magnetostatic energy reservoir is identified, which scales with the DW velocity. Imaging wall motion in rings with varying width, we correlate the velocity with the wall energy revealing wall inertia. This inertia also explains our observation of extrinsic pinning-dominated DW propagation at low velocities, while we are able to achieve reproducible wall motion for fast walls that overcome defect-pinning.

MA 24.3 Wed 10:00 H22

Imaging of magnetic domains in TbCo alloys with magnetic circular dichroism in two-photon photoemission electron microscopy — •Markus Rollinger[1], Pascal Melchior[1], Philip Thielen[1,2], Sabine Alebrand[1], Ute Bierbrauer[1], Christian Schneider[1], Stéphan Mangin[3], Mirko Cinchetti[1], and Martin Aeschlimann[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany — [3]Institut Jean Lamour, Université de Lorraine, France

We use magnetic circular dichroism in two-photon photoemission to image the magnetic domains of TbCo thin films with a photoemission electron microscope (PEEM). With a Time-of-flight analyzer we perform time- and energy-resolved measurements with a spatial resolution of only a few tens of nanometers. As excitation source, we use the second harmonic (3,1eV photon energy) of a Ti:sapphire oscillator. The two-photon-photoemission process delivers a distinctively visible magnetic circular dichroism, whose strength depends strongly on the kinetic energy of the observed photoemitted electrons.

We present a detailed analysis of the energy-resolved PEEM dichroism spectra and explain the origin of the observed effect. These results open the way to the investigation of all-optical control of the magnetization in high-anisotropy rare earth-transition metal alloys [1] by means of energy- and time-resolved PEEM.

[1] S. Alebrand et al., Applied Physics Letters 101, 162408 (2012)

MA 24.4 Wed 10:15 H22

Domain structure in the vicinity of a spin reorientation transition — •Maciej Dabrowski[1], Andreas K. Schmid[2], Marek Przybylski[1,3], and Jürgen Kirschner[1,4] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [2]National Centre for Electron Microscopy, Lawrence Berkeley National Laboratory, Berkeley, USA — [3]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Kraków, Poland — [4]Naturwissenschaftliche Fakultät II, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

There are two non-equivalent magnetization directions in the sample plane if ferromagnetic thin films are grown on stepped (001) surfaces. Moreover, there are additional terms to the anisotropy energy due to the steps, which cause the magnetization to tilt differently from the film plane if the in-plane magnetization orientation is kept perpendicular to the steps or along the steps. The thickness driven spin reorientation transition (SRT) for Fe films grown on a stepped surface of Ag(001) was studied by spin-polarized low energy electron microscopy (SPLEEM). Direct imaging of magnetic domains and local magnetization orientation was performed using three orthogonal spin polarizations of the incident electron beam. While the Fe film thickness increases, stripe domains expand and align perpendicular to the step edges. Our experiment demonstrates that as soon as the magnetization starts to tilt from the sample plane, a discontinuous in-plane SRT occurs and the magnetization prefers to be oriented perpendicular to the step edges.

MA 24.5 Wed 10:30 H22

Domain pattern breakup in mesoscopic structures studied with x-ray microscopy — Stephanie Stevenson, Christoforos Moutafis, Laura Heyderman, Christoph Quitmann, and •Jörg Raabe — Paul Scherrer Institut, 5232 Villigen, Switzerland

We report on the modification of the ground state domain pattern in $Ni_{81}Fe_{19}$ square islands due to RF excitation as monitored by scanning transmission x-ray microscopy at the PolLux beamline of the Swiss Light Source. A sinusoidal continuous wave field is applied via a stripline to excite the magnetisation of structures with physical dimensions in the micrometer range, fabricated at the Laboratory for Micro- and Nano-technology (LMN) at the Paul Scherrer Institute. During the RF excitation, a breakup of the domain configuration into a metastable state occurs. This metastable state returns to the ground state when the excitation is removed. Micromagnetic simulations and experiment agree that the domain breakup nucleates from a high amplitude motion of the domain walls. Directly visualising such metastable states provides insight into the tailoring of RF excitations for vortex core reversal and domain reorientation processes.

MA 24.6 Wed 10:45 H22

Magnetic dichroism in angle-resolved hard x-ray photoemission from amorphous Gd-Fe films — •Hans-Joachim Elmers[1], Andrei Gloskovskii[2], Gerd Schönhense[1], Alisa Chernenkaya[1], Katerina Medjanik[1], Mirko Emmel[1], and Gerhard Jakob[1] — [1]Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany — [2]Deutsches Elektronen-Synchrotron, Experimental Physics and Materials Science, Germany

The bulk sensitivity of hard x-ray photoelectron spectroscopy (HAXPES) in combination with circularly polarized radiation of the P09 beamline at PETRA III enables the investigation of the magnetic properties of capped films. We have determined the temperature dependence of the magnetic dichroism in the Fe 2p and in the Gd 3d states in amorphous Gd-Fe films. The magnetic dichroism reflects the stronger temperature dependence of Gd moments compared to Fe moments according to atomistic models. We resolved the exchange splitted Gd 3d5/2 sub states and found a significant temperature dependence of the splitting which is attributed to a temperature dependent exchange energy. Funded by COMATT.

MA 24.7 Wed 11:00 H22

Magneto-mechanical coupling of nickel nanorods with an elastic matrix studied by magneto-optical transmission measurements — •Christoph Schopphoven, Philipp Bender, Andreas Tschöpe, and Rainer Birringer — Universität des Saarlandes, Saarbrücken

The rotation of ferromagnetic nickel nanorods in a soft-elastic hydrogel matrix was investigated by magnetic field-dependent optical transmission of linearly polarized light. Nickel nanorods with an average diameter of 23nm and an average length of 125nm were prepared by pulsed electrodeposition of nickel into porous AAO-templates. Dissolution of the alumina layer in dilute NaOH with polyvinylpyrrolidone(PVP) added for steric stabilization and subsequent separation and purification resulted in a stable aqueous solution. The microstructure of the nanorods was characterized by electron microscopy and the magnetic properties were obtained through magnetization measurements. These rods were dispersed into gelatin sols at 60°C and cooled to room temperature. During gelation a homogeneous field was applied to align the rods in field direction. The rods were rotated by applying a field perpendicular to their orientation and the resulting rotation angle was determined through optical transmission measurements. These experimental results were used to calculate the shear modulus of the gelatin matrix and the energy transferred into elastic deformation of the hydrogel matrix.

MA 24.8 Wed 11:15 H22

Scanning probe magnetic field imaging with a single spin sensor — •Dominik Schmid-Lorch, Thomas Häberle, Friedemann Reinhard, and Jörg Wrachtrup — 3. Physikalisches Institut und Forschungszentrum SCoPE, Universität Stuttgart, Germany

We work on a novel magnetic field sensor that is based on the nitrogen-vacancy (NV)-color center in diamond. The electron spin structure of the NV-center allows us to perform optically detected electron spin resonance (ESR) measurements, which can be made sensitive to the ambient magnetic field. Mounted to the tip of an AFM, these atomic-sized color centers promise an even higher spatial resolution than the MFM [1] while reducing back-action on the sample to a minimum.

I present the principles of this technique as well as benchmark measurements on magnetic microstructures. Furthermore I compare the performance of different electron spin resonance (ESR) protocols used for magnetic imaging.

Applications of this technique are detection and imaging of single electron spins [2] and small nuclear spin ensembles.

[1] G. Balasubramanian et al., Nature Vol 455, 648-651 (2008)
[2] M.S. Grinolds et al., arXiv:1209.0203v1 (2012)

MA 24.9 Wed 11:30 H22

Magnetic small–angle neutron scattering of two–phase bulk ferromagnets — •Dirk Honecker and Andreas Michels — Laboratory for the Physics of Advanced Materials, University of Luxembourg, Luxembourg

Based on micromagnetic theory we have derived analytical expressions for the magnetic small–angle neutron scattering cross section of a two–phase ferromagnet. The approach – valid close to magnetic saturation – provides access to several features of the spin structure such as perturbing magnetic anisotropy and dipolar stray fields. The micromagnetic SANS model inherently explains the 'clover–leaf' type angular anisotropies, which were previously observed for several nanostructured magnetic materials. Analysis of experimental neutron data of an iron–based soft magnetic nanocomposite yields information on the exchange–stiffness constant as well as on the anisotropy and dipolar fields.

MA 24.10 Wed 11:45 H22

Local symmetries and their effect on resonant magnetic scattering in $YMn_{2-x}Fe_xO_5$ — •Sven Partzsch[1], Enrico Schierle[2], Jorge E. Hamann-Borrero[1], Eugen Weschke[2], Taichi Matsuda[3], Hiroki Wadati[3], Stuart B. Wilkins[4], Dmitri Souptel[1], Bernd Büchner[1], and Jochen Geck[1] — [1]IFW Dresden — [2]HZB Berlin — [3]University of Tokyo — [4]BNL Upton

Resonant magnetic x-ray scattering (RMXS) is a powerful experimental photon-in/photon-out probe to study the magnetic structure in an element specific way. The RMXS of a free atom is known and, in fact, this is very often used [1]. However, when a scatterer is embedded in a solid additional effects need to be considered [2].

We derive the scattering matrix of the Fe2 sites of $YMn_{2-x}Fe_xO_5$ at the Fe $L_{2,3}$ edge from azimuth scans. The principle axes of the scattering matrix are strongly energy dependent because of the orthorhombic space group, the magnetic moments pointing in all three crystallographic directions and the strong anisotropic ligand field of the square pyramids.

[1] J. P. Hannon et al., PRL, 61, 1245 (1988)
[2] M. W. Haverkort et al., PRB, 82, 094403 (2010)

MA 24.11 Wed 12:00 H22

Multiple ordering phenomena in the magnetic metal $SrCo_6O_{11}$ — •Sven Partzsch[1], Taichi Matsuda[2], Hiroki Wadati[2], Enrico Schierle[3], Eugen Weschke[3], Shintaro Ishiwata[2], Yoshinori Tokura[2], Bernd Büchner[1], and Jochen Geck[1] — [1]IFW Dresden — [2]University of Tokyo — [3]HZB Berlin

$SrCo_6O_{11}$ has a layered hexagonal crystal structure and is a novel type of giant magnetoresistance system [1]. So far magnetic structures were studied only by powder neutron diffraction measurements [2], which revealed an $a \times a \times 3c$ superstructure, consistent with the $1/3$ magnetization plateau.

In this study we used single crystals of this material and performed resonant soft x-ray scattering (RSXS) to obtain more detailed magnetic structures. RSXS measurements were performed at the UE46-PGM1 beamline of BESSY II. At the Co L_3 edge we observed the $L = 2/3$, 1, $4/3$ and $3/2$ reflections in agreement with the neutron data [2]. But in addition there are reflections which can be decomposed into $L = 4/5$, $5/6$, and $6/7$. This points to the "devil's staircase" theoretically obtained from the simple axial next nearest neighbor Ising model.

[1] S. Ishiwata et al., Phys. Rev. Lett. 98, 217201 (2007)
[2] T. Saito et al., J. Magn. Magn. Mater. 310, 1584 (2007)