MA 13: Magnetic Materials

Time: Monday 15:00–19:30 Location: H 0112

MA 13.1 Mon 15:00 H 0112

Comparison of x-ray and electron holography using the example of thin magnetic films — •Stefanie Frömmel, Erik Gührs, Tore Niermann, Michael Lehmann, and Stefan Eisebitt — IOAP, Technische Universität Berlin, Germany

We investigated and compared basic principles, prospects and limitations of both electron- and x-ray holography in off-axis geometry for magnetic domain imaging. A Co/Pt multilayer film served as a sample with perpendicular magnetic anisotropy. There are several methods to display magnetic structures in thin films. In the soft x-ray regime we used the x-ray magnetic circular dichroism (XMCD) as contrast mechanism. XMCD investigations were carried out in Fourier transform holography (FTH) geometry with a sample-integrated mask, which provided apertures for object and reference beam. In transmission electron holography we utilized the Aharonov-Bohm effect to generate magnetic contrast. An electrostatic biprism was employed to let the object and reference beam interfere coherently. Advantages and disadvantages of both approaches with respect to spatial resolution and quantitative magnetization determination are discussed.

MA 13.2 Mon 15:15 H 0112

Femtosecond infrared and x-ray annealing of magnetic multilayers — •Stefan Schaffert, Jan Geilhufe, Christian Günther, Jyoti Mohanty, Bastian Pfau, and Stefan Eisebitt — IOAP, Technische Universität Berlin, Germany

We have studied the influence of single and multi-shot femtosecond annealing of magnetic Co/Pt multilayers using infrared and x-ray pulses. Prior to annealing the multilayers have been demagnetized using in-plane or out-of-plane external magnetic fields thus conditioning stripe or maze domain patterns with magnetization normal to the sample surface. We performed annealing series employing a Ti:Sa Laser at 800 nm at different fluences and observed irreversible changes in the average domain size.
We compare the optical annealing experiments with results obtained by annealing identical samples with high-power shots of the free-electron Laser FLASH at Hamburg operating at 20.8 nm wavelength, e.g. the cobalt M absorption energy. The thermally induced changes were investigated with respect to the magnetic anisotropy (via MOKE) and the resulting domain patterns (via MFM).

MA 13.3 Mon 15:30 H 0112

Domain-structure-induced giant magneto-impedance of iron whiskers — •Matthäus Langosch, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D-66041, Saarbrücken, Germany

Specific contributions to the giant magneto-impedance (GMI) effect, especially those being due to domain wall motion, should further be investigated in order to better understand this interesting effect. For this purpose, soft magnetic materials were studied at low frequencies leading mainly to contributions of domain wall motion. These are not relevant to the effect at high frequencies as normally applied. Iron single crystals (iron whiskers) were grown as specific samples to investigate the GMI effect with AC currents up to 100 kHz. The magnitude of the currents was large enough to modify the whiskers' domain structure by the Oersted fields. We give an overview not only of the impedance components obtained but also of the magnitude and the phase of the effective circumferential permeability. The latter is obtained through calculations based on the standard skin effect formalism and on the experimental data. We further discuss relevant domain configurations, domain wall motions and their relations to the applied longitudinal magnetic field, the AC current magnitude and its frequency.

MA 13.4 Mon 15:45 H 0112

Magneto-impedance of Permalloy nanowires — •Saleh Getlawi, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P.O. Box 151150, D-66041, Saarbrücken, Germany

The magneto-impedance (MI) effect was studied extensively on amorphous wires, ribbons, and on multilayer thin films. This effect involves huge changes of the complex impedance of soft magnetic materials upon applying an external magnetic field. In this contribution we discuss the MI effect of Permalloy nanowires. Nanowires with a length of 20 micrometer and a width of 300 nm were prepared by electron beam lithography (EBL) and focused-ion-beam (FIB)-based methods. The nanowires were placed into a microwave transmission line consisting of two gold microstrip lines with 50 ohm characteristic impedance. The impedance of the Permalloy nanowire has been measured up to 3 GHz within a field up to 30 mT. When the frequency is far above the ferromagnetic resonance (FMR), the obtained impedance change is less than 1% due to the small effective permeability.

MA 13.5 Mon 16:00 H 0112

Giant Magnetoimpedance Effect in Composite Wires with Insulating Layer — •Ralf Betzholz[1], Haibin Gao[1], Zhenjie Zhao[2], and Uwe Hartmann[1] — [1]Institute of Experimental Physics, Saarland University, P.O.Box 151150, D-66041 Saarbrücken, Germany — [2]Department of Physics, East China Normal University, 3663 Zhongshan North Road, 200062 Shanghai, P.R. China

Composite wires with a three-layered structure were analysed with respect to the giant magnetoimpedance (GMI) effect. The composite wire samples consist of a copper core, a silicon dioxide insulating layer and an outer Permalloy shell. The GMI effect refers to a huge change in the complex impedance upon the application of a static external magnetic field. The samples were prepared by RF magnetron sputtering and their GMI behaviour was analysed experimentally as well as theoretically. In the theoretical analysis a model for the composite wire impedance was developed by solving Maxwell's equations to obtain the field distribution in every layer and by linearising the Landau-Lifschitz-Gilbert equation in order to establish an expression for the permeability tensor in the ferromagnetic shell. The dependency of the impedance on the applied field strength and the driving current frequency was measured and the experimental results were compared with the theoretical model.

MA 13.6 Mon 16:15 H 0112

Magnetic order and quantum criticality in single-crystalline $NbFe_2$ — •Sven Friedemann[1], Max Hirschberger[1,2], Megan Stanley[1], William J Duncan[1], Andreas Neubauer[2], Thomas Bauer[3], Robert Küchler[3], Alexander Steppke[3], Luis Pedrero[3], Manuel Brando[3], Christian Pfleiderer[2], and F Malte Grosche[1] — [1]Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, UK — [2]Physik Department E21, TU München, 85748 Garching, Germany — [3]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

The low-temperature band magnet $NbFe_2$ can be tuned by varying pressure, magnetic field or composition, providing an attractive candidate system for investigating quantum criticality in a transition metal compound. Near the composition-tuned quantum critical point, $NbFe_2$ displays signatures of Fermi liquid breakdown in the electronic heat capacity $\Delta C \sim -T \ln T$ and in the resistivity $\Delta\rho \sim T^{3/2}$ at low temperature T. Our data on high-quality single crystals confirm the existence of a non-ferromagnetic phase via distinct transition anomalies in the field dependence of the entropy. This presumed spin-density-wave phase envelops the lower-lying ferromagnetic phase in most parts of the composition–field–temperature phase diagram. The associated transition temperature can be suppressed with a transverse magnetic field ($\perp c$). Consequently, transverse field is identified as a further tuning parameter, which leads to a direct transition from the ferromagnetic to a field-induced paramagnetic state. In the vicinity of this quantum phase transition, we observe a suppression of Fermi liquid behaviour.

MA 13.7 Mon 16:30 H 0112

Coercivity enhancement in nanocrystalline NdFeB hot pressed magnets by means of DyF_3 — •Simon Sawatzki[1], Martina Moore[1], Juliane Thielsch[1], Ludwig Schultz[1], and Oliver Gutfleisch[2,1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]TU Darmstadt, Institute of Material Science, Petersenstrasses 23, D-64287 Darmstadt, Germany

In order to address the strategic resource problems related to permanent magnet's development for electro motors the specific modification of the grain boundary by the heavy rare earth Dy is a possible solution. For that reason the magnets have been prepared by means of hot pressing Nd-rich melt-spun ribbons of MQU-F type. The treatment

with DyF_3 powder was done in two ways: (a) by coating the compact magnet with DyF_3 and subsequent annealing and (b) by mixing DyF_3 with the melt-spun powder and subsequent hot pressing at 725°C. Permagraph measurements have been carried out to characterize the magnetic properties whereas the microstructure was investigated with high-resolution scanning electron microscopy.

The coating and annealing, route (a), was shown not be useful as diffusion of Dy out of the dried slurry on to top of the magnet into the volume was very limited. Route (b) however results in magnets with optimized coercivities in dependency of the fluoride concentration. The most promising stoichiometry contains 1.15 wt% Dy and leads to an improvement in coercivity of 10 % compared to the unmodified hot compacted magnet with a largely unchanged remanence.

MA 13.8 Mon 16:45 H 0112

Effect of Ti Doping on the magnetic and structural properties of LaCrO3 — •Patrick Reuvekamp[1], Reinhard K Kremer[1], Fereidoon S. Razavi[2], and Alexander Schindler[3] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [2]Department of Physics, Brock University, St. Catharines, Ontario, L2S 3A1, Canada — [3]NETZSCH-Gerätebau GmbH, Wittelsbacherstrasse 42, D-95100 Selb, Germany

We report on the preparation as well as the structural and magnetic characterization of titanium doped lanthanum chromium oxides. Heat capacity, magnetic susceptibility, XRD and EPR were used to characterize the polycrystalline samples of $LaCr_{1-x}Ti_xO_3$ (x = 0,0.1,0.2). $LaCrO_3$ undergoes a structural phase transition at $T_{st} \sim 560$ K and canted antiferromagnetic order below $T_N \simeq 290$ K. In contrast to reports in literature, Ti doping reduces T_{st} and decreases T_N to ~ 230 K.

MA 13.9 Mon 17:00 H 0112

Terahertz Spectroscopy of Overdoped Manganites — •F. Fischgrabe[1], V. Moshnyaga[1], T. Zhang[2], L. Kadyrov[3], E. Zhukova[3,6], B. Gorshunov[3,6], V. Torgashev[4], K. Velebit[5,6], U. Pracht[6], and M. Dressel[6] — [1]I. Physikalisches Institut, Universität Göttingen, Germany — [2]Institute of Solid State Physics, Chinese Academy of Sciences, Hefei, China — [3]Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia — [4]Faculty of Physics, Southern Federal University, Rostov on Don, Russia — [5]Institut of Physics, Zagreb, Croatia — [6]I. Physikalisches Institut, Universität Stuttgart, Germany

Highly doped manganites $La_{1-x}Ca_xMnO_3$ with the composition $0.5 < x < 1$ are synthesized as ceramic samples and epitaxial films on MgO. Using a coherent source terahertz spectrometer, the dynamical conductivity and dielectric permittivity spectra are measured in the spectral range from 8 cm^{-1} to 48 $cm^{-}1$ and at temperatures from 5 K to 300 K. In the samples with $x \approx 0.5$ an insulator to metal phase transition is seen while cooling below $\approx 80K$ whose origin could be caused by coexistence of ferromagnetic metallic and anti-ferromagnetic insulator phases. For commensurate calcium contents (x=1/2, 2/3) strong resonances at terahertz frequencies are seen and ascribed to acoustic phonons that become optically active due to Brillouin zone folding accompanying changes in crystal lattice (as seen for x=3/4 in [1]). Incommensurate doping result in broad absorptions due to acoustic phonons density of states.

1. T. Zhang et al. Physical Review B 81, 125132 (2010).

15 min. break

MA 13.10 Mon 17:30 H 0112

The Hourglass and Charge-Stripe Order of La(5/3)Sr(1/3)CoO(4) — •Paul Freeman[1,2], Sean Giblin[3], Prabhakaran Dharmalingam[4], Peter Babkevich[4,5], Eugen Weschke[1], Enirco Schierle[1], and Andrew Boothroyd[4] — [1]Helmholtz-Zentrum Berlin, Berlin, Germany. — [2]Institut Laue-Langevin, Grenoble, France. — [3]ISIS Facility, RAL, Didcot, U.K. — [4]Oxford University, Oxford, U. K.. — [5]Laboratory for Neutron Scattering, Paul Scherrer Institut, Villigen, Switzerland.

The universal hourglass magnetic excitation spectrum in hole doped cuprates has reopened the debate on the importance of charge stripe order and cuprate superconductivity[1]. While the incommensurate ordered phase of the cuprates strongly resemblances that of charge ordered La(2-x)Sr(x)NiO(4+delta)[2], the magnetic excitation spectrum does not[1,3]. We however observe that the magnetic excitation spectrum of charge stripe ordered La(5/3)Sr(1/3)CoO(4) has an hourglass dispersion that can be understood within a charge stripe model[2,4].

In this contribution we present our combined neutron scattering, μSR and resonant soft x-ray diffraction studies of charge stripe ordered La(5/3)Sr(1/3)CoO(4). Studying the magnetism on different length and timescales, while providing the first direct evidence of charge-stripe ordering in La(2-x)Sr(x)CoO(4).

[1] S. M. Hayden, et. al. , Nature 429, 531 (2004); J. M. Tranquada, , et. al., Nature 429, 534 (2004). [2] J. M. Tranquada et al. Nature 375, 561 (1995). [3] H. Woo et. al. Phys. Rev. B 72, 064437 (2005). [4] A. T. Boothroyd, et. al., Nature 471, 341 (2011).

MA 13.11 Mon 17:45 H 0112

Surface magnetism of RuO2 (110): implications for electrocatalysis — Chang-Ming Fang[1], •Engin Torun[1], Gilles A de Wijs[1], and Robert A de Groot[1,2] — [1]Radboud University Nijmegen, Institute for Molecules and Materials, Heyendaalseweg 135, 6525 AJ, Nijmegen, The Netherlands. — [2]Laboratory of Chemical Physics, Zernike Institute of Advanced Materials, Nijenborgh 4, NL-9747 AG Groningen, The Netherlands.

Chemical reactions, where one of the reactants is magnetic, are slow because of the violation of the conservation of angular momentum. Production of hydrogen by electrolysis of water can be considered as an archetype example of such reactions: practically all losses occur in the production of magnetic oxygen. Anodes with a relatively low overvoltage (a measure of the losses) are based on the ruthenium-dioxide (110) surface. First-principles electronic structure calculations reported here show that this surface itself carries magnetic moments, which is a rare situation for 4d metals and their compounds, and it is the only surface of low index to do so. This surface enables the production of oxygen conserving angular momentum.

MA 13.12 Mon 18:00 H 0112

Low-temperature X-ray diffraction experiments on magnetocaloric La(Fe,Si)$_{13}$ - compounds — •Anja Waske[1], Lars Giebeler[1], Maria Krautz[2], Konstantin Skokov[2], and Oliver Gutfleisch[2] — [1]IFW Dresden, Institute of Complex Materials, P.O. Box 270116, D-01171 Dresden — [2]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden

Materials exhibiting the magnetocaloric effect could one day be the basis of a new magnetic cooling concept for consumer use, replacing conventional refrigeration technology. Since the magnetocaloric effect relies on a strong change of magnetization with temperature, usually these materials are employed close to a magnetic transition (e.g. FM to PM). Currently, most of the research in this field is dedicated to materials which undergo a structural transition that couples to the magnetic phase transition. In this way, large entropy changes and hence a large magnetocaloric effect can be achieved. However, very little is known about how the structural and the magnetic transition interact. Here, we report on low-temperature X-ray diffractometry experiments on magnetocaloric La(Fe,Si)$_{13}$ with varying Si content. By comparing the volume changes caused by the structural transition with the magnetocaloric properties, a close relation between structure and magnetism is revealed.

MA 13.13 Mon 18:15 H 0112

Study of the mechanisms of the Thermal Decomposition reaction in the magnetocaloric system La(Fe,Si,Co)$_{13}$ — •Konrad Löwe[1], Jian Liu[1], Hossein Sepehri-Amin[2], Kazuhiro Hono[2], Matthias Katter[3], and Oliver Gutfleisch[4,1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]NIMS, 1-2-1 Sengen, Tsukuba 305-0047 Japan — [3]Vacuumschmelze GmbH u Co. KG, Grüner Weg 37, 63450 Hanau, Germany — [4]TU Darmstadt, Institute for Materials Science, Petersenstr. 23 64287 Darmstadt, Germany

We report on the influence of the Co content in the magnetocaloric system La(Fe,Si,Co)$_{13}$ on the Thermal Decomposition (TD) reaction. In the course of the reaction, the magnetocaloric La(Fe,Si,Co)$_{13}$ phase reversibly decomposes into α-Fe(Co,Si) and the intermetallic LaFeSi phase, thus greatly enhancing the mechanical properties and therefore the machinability of the compound. The addition of Co significantly speeds up the reaction kinetics. The optimum temperature range for the TD was determined to be 973 - 1073 K, whereas the lower and upper limit lies at 873 K and 1173 K, respectively. With electron microscopy a pearlitic microstructure (lamellae) has been found in the decomposed state, indicating a eutectoid-type phase reaction. The thickness of the lamellae is about 20-30 nm in $LaFe_{12}Si$ and decreases with increasing Co content. Also the pearlite seems to be more ordered with addition of Co. 3DAP measurements show the enrichment of Co

in both the α-Fe(Co,Si) and the LaFeSi lamellae. We conclude that the addition of Co somehow changes the pearlitic growth mechanisms, which is the main reason for the greatly enhanced TD kinetics.

MA 13.14 Mon 18:30 H 0112

Mechanisms of enhanced orbital dia- and paramagnetism: Application to the Rashba semiconductor BiTeI — •Giulio Albert Heinrich Schober[1,2,3], Hiroshi Murakawa[4], Mohammad Saeed Bahramy[4], Ryotaro Arita[1,4], Yoshio Kaneko[5], Yoshinori Tokura[1,3,4,5], and Naoto Nagaosa[1,3,4] — [1]Department of Applied Physics, University of Tokyo, Tokyo 113-8656, Japan — [2]Institute for Theoretical Physics, University of Heidelberg, D-69120 Heidelberg, Germany — [3]Cross-Correlated Materials Research Group (CMRG), ASI, RIKEN, Wako 351-0198, Japan — [4]Correlated Electron Research Group (CERG), ASI, RIKEN, Wako 351-0198, Japan — [5]Multiferroics Project, Exploratory Research for Advanced Technology (ERATO), Japan Science and Technology Agency (JST), c/o Department of Applied Physics, University of Tokyo, Tokyo 113-8656, Japan

We study the magnetic susceptibility of a layered semiconductor BiTeI with giant Rashba spin splitting both theoretically and experimentally to explore its orbital magnetism. Apart from the core contributions, a large temperature-dependent diamagnetic susceptibility is observed when the Fermi energy E_F is near the crossing point of the conduction bands, while the susceptibility turns to be paramagnetic when E_F is away from it. These features are consistent with first-principles calculations, which also predict an enhanced orbital magnetic susceptibility with both positive and negative signs as a function of E_F due to band (anti)crossings. Based on these observations, we propose two mechanisms for an enhanced paramagnetic orbital susceptibility.

MA 13.15 Mon 18:45 H 0112

An effective quantum parameter for strongly correlated metallic ferromagnets — •Bhaskar Kamble[1] and Avinash Singh[2] — [1]Institut fuer Theoretische Physik III, Ruhr Universitaet Bochum, 44801 Bochum, Germany — [2]Department of Physics, Indian Institute of Technology Kanpur, 208016, India

The correlated motion of electrons in multi-orbital metallic ferromagnets is investigated in terms of a realistic Hubbard model with N-fold orbital degeneracy and arbitrary intra- and inter-orbital Coulomb interactions U and J using a Goldstone-mode-preserving non-perturbative scheme. An effective quantum parameter $'\hbar' = \frac{U^2+(N-1)J^2}{(U+(N-1)J)^2}$ is obtained which determines, in analogy with $1/S$ for quantum spin systems and $1/N$ for the N-orbital generalized Hubbard model, the strength of correlation-induced quantum corrections to magnetic excitations. The rapid suppression of this quantum parameter with Hund's coupling J, especially for large N, provides fundamental insight into the phenomenon of strong stabilization of metallic ferromagnetism by orbital degeneracy and Hund's coupling. This approach is illustrated for the case of ferromagnetic iron and the half-metallic Heusler alloy Co_2MnSi. For realistic values of iron, the calculated spin stiffness and Curie temperature values obtained are in quantitative agreement with measurements. Significantly, the contribution of long wavelength modes is shown to yield a nearly $\sim 25\%$ reduction in the calculated Curie temperature.

MA 13.16 Mon 19:00 H 0112

The effect of magnetism on strength and structural stability in ferromagnetic metals — •Mojmír Šob[1,2,3] and Martin Zelený[3,4] — [1]Central European Institute of Technology, CEITEC MU, Masaryk University, Brno, Czech Republic — [2]Department of Chemistry, Faculty of Science, Masaryk University, Brno, Czech Republic — [3]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Brno, Czech Republic — [4]COMP/Department of Applied Physics, Aalto University School of Science, Aalto, Finland

We report on a strong effect of magnetism on ideal tensile strength in iron, cobalt and nickel. In nickel, the ferromagnetic (FM) modification is distinctly stronger than the nonmagnetic (NM) modification, about 1.6x for uniaxial compression along the [001] direction and for biaxial tension in the (001) plane and about 1.1x for uniaxial compression along the [111] direction and for biaxial tension in the (111) plane. On the other hand, in cobalt, the FM modification is considerably weaker than the NM modification, about 0.33x for uniaxial compression along the [001] direction and for biaxial tension in the (001) plane and about 0.60x for uniaxial compression along the [111] direction and for biaxial tension in the (111) plane. NM iron is not stable wrt tetragonal deformation and is slightly (1.09x) stronger in uniaxial tension along the [111] direction. All these effects are explained on the basis of analysis of changes in the electronic structure when magnetic order is lost.

MA 13.17 Mon 19:15 H 0112

Ultrasound investigations of intrinsic and extrinsic non-stationary field-driven processes in spin ice — •S. Erfanifam[1], S. Zherlitsyn[1], J. Wosnitza[1], R. Moessner[2], O.A. Petrenko[3], G. Balakrishnan[3], and A.A. Zvyagin[2,4] — [1]Hochfeld-Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden, Germany — [2]Max-Planck Institut für Physik komplexer Systeme, D-01187 Dresden, Germany — [3]University of Warwick, Coventry CV4 7AL UK — [4]B.I. Verkin Institute for Low Temperature Physics and Engineering, Kharkov, 61103, Ukraine

The elastic properties of spin-ice material Dy2Ti2O7 has been studied for different longitudinal and transverse acoustic-modes in a temperature range from 20 mK to 300 K and magnetic fields applied along various crystallographic directions. The sound velocity and the sound attenuation exhibit a number of anomalies versus magnetic field at temperatures below the "freezing" temperature of approximately 500 mK. Most notable are peaks in the sound velocity, which exhibit two distinct regimes: an intrinsic (extrinsic) one in which the data collapse for different field-sweep rates when plotted as function of field strength (time). The intrinsic regime involves the release of Zeeman energy from spins, the extrinsic one, transfer of energy out of the sample. Additionally a sharp drop in the sound velocity can be seen at B = 1.25 T. This can indicate a 1st-order phase transition from the low-density to the high-density monopole state. We discuss our observations in context of the emergent quasiparticles which govern the low-temperature dynamics of the spin-ice.