# Magnetism Division
# Fachverband Magnetismus (MA)

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## Overview of Invited Talks and Sessions

(lecture rooms HSZ 04, HSZ 401, HSZ 403, HSZ 103, and HSZ 101 (Wednesday); Poster P1A and P1B)

### Invited Talks

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|---|---|---|---|---|
| MA 1.1 | Mon | 10:15–10:45 | HSZ 04 | **Exciting magnetism : inelastic scanning tunneling spectroscopy on magnetic nanostructures** — •Wulf Wulfhekel |
| MA 6.1 | Mon | 14:00–14:30 | HSZ 04 | **Symmetry dependent spin injection from Fe/MgO in single crystal based magnetic tunnel junctions** — •Michel Hehn, Fanny Greullet, Julien Bernos, Coriolan Tiusan, Christine Bellouard, Francois Montaigne, Daniel Lacour, Marc Alnot, Yuan Lu, Gwladys Lengaigne, David Halley, Wolfgang Weber |
| MA 6.2 | Mon | 14:30–15:00 | HSZ 04 | **Magnetic imaging at the limits of space and time** — •Thomas Eimüller, Wei He, Jie Li, Min-Sang Lee, Björn Redeker, Stefan Buschhorn |
| MA 12.1 | Tue | 9:30–10:00 | HSZ 04 | **Electron theory of fast and ultrafast dissipative magnetization dynamics** — •Manfred Fähnle, Daniel Steiauf, Jonas Seib |
| MA 16.1 | Wed | 9:30–10:00 | HSZ 04 | **Nonlinear optics on spin-spiral multiferroics** — •Thomas Lottermoser |
| MA 22.1 | Wed | 14:00–14:30 | HSZ 04 | **Quantum Transport through Single Molecular Magnets** — •Herbert Schoeller |
| MA 29.1 | Thu | 9:30–10:00 | HSZ 04 | **Quantum information processing with electron spin resonance** — •Arzhang Ardavan |
| MA 34.1 | Thu | 14:00–14:30 | HSZ 04 | **The biophysics of geomagnetic-field reception in animals** — •Michael Winklhofer |
| MA 34.2 | Thu | 14:30–15:00 | HSZ 04 | **Micromagnets for multispectral magnetic resonance imaging** — •Gary Zabow, Stephen Dodd, John Moreland, Alan Koretsky |
| MA 39.1 | Fri | 10:15–10:45 | HSZ 04 | **Magnon gases and condensates** — •Burkard Hillebrands |

### Topical Talks of the Focused Session: Spin Transport and Coherence in Emerging Materials

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| MA 28.1 | Wed | 14:45–15:15 | HSZ 101 | **Gate-tunable magnetic exchange and giant g-factor fluctuations in InAs nanowire quantum dots** — Szabolcs Csonka, Lukas Hofstetter, Frank Freitag, •Christian Schönenberger, Thomas S. Jespersen, Martin Aagesen, Jesper Nygard |
| MA 28.2 | Wed | 15:15–15:45 | HSZ 101 | **Spin transport theory in carbon-based materials** — •Reinhold Egger |
| MA 28.3 | Wed | 15:45–16:15 | HSZ 101 | **Visualizing heat transport in quantum magnets** — Marian Otter, Dmitry Fishman, Viktor V. Krashnikov, Maxim S. Pshenichnikov, Romualt Saint-Martin, Alexander Revcolevschi, •Paul H.M. van Loosdrecht |

### Invited talks of the joint symposium SYSC

See SYSC for the full program of the Symposium.

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| SYSC 1.1 | Wed | 9:30–10:00 | BAR SCHÖ | **Optical Pumping of Nuclear Spins in Semiconductor Quantum Dots** — •X. Marie, B. Urbaszek, T. Amand, O. Krebs, A. Lemaître, P. Voisin, B. Eble, C. Testelin, M. Chamarro |
| SYSC 1.2 | Wed | 10:00–10:30 | BAR SCHÖ | **Dyakonov-Perel' Spin-Dynamics in GaAs Quantum Wells** — •Richard Harley |
| SYSC 1.3 | Wed | 10:30–11:00 | BAR SCHÖ | **Quantum dot spins in optical microcavities** — •Rudolf Bratschitsch |
| SYSC 1.4 | Wed | 11:00–11:30 | BAR SCHÖ | **Spin relaxation in quasi-one-dimensional electron systems: transition from 2D to 1D** — •Alexander Holleitner |
| SYSC 1.5 | Wed | 11:30–12:00 | BAR SCHÖ | **Triggering phase-coherent spin packets by pulsed electrical spin injection across an Fe/GaAs Schottky barrier** — •Bernd Beschoten |
| SYSC 1.6 | Wed | 12:00–12:30 | BAR SCHÖ | **Quantum Spin Hall Effect in HgTe Quantum Well Structures** — •Hartmut Buhmann |

## Invited talks of the joint symposium SYAI

See SYAI for the full program of the Symposium.

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| SYAI 1.1 | Thu | 15:00–15:30 | SCH 251 | **Insights and Progress in Density Functional Theory** — Paula Paula Mori-Sanchez, Aron Cohen, •Weitao Yang |
| SYAI 1.2 | Thu | 15:30–16:00 | SCH 251 | **Quasiparticle energy calculations in a new light: from defects in semiconductors to the $f$-electron challenge** — •Patrick Rinke |
| SYAI 1.3 | Thu | 16:00–16:30 | SCH 251 | **LDA+DMFT approach to excitations spectrum in Half-Metallic Ferromagnets** — •Alexander Lichtenstein |
| SYAI 1.4 | Thu | 17:00–17:30 | SCH 251 | **Insight and prediction of material properties from ab initio calculations of electronic excitations** — •Lucia Reining, Matteo Gatti, Ralf Hambach, Christine Giorgetti |
| SYAI 1.5 | Thu | 17:30–18:00 | SCH 251 | **Local excitations in strongly interacting charge-transfer insulators: Frenkel excitons within TD-LDA+$U$ and strong coupling theory** — •Wei Ku |
| SYAI 1.6 | Thu | 18:00–18:30 | SCH 251 | **Electron tunneling and transport at molecular junctions** — •Roberto Car |

## Sessions

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| MA 1.1–1.1 | Mon | 10:15–10:45 | HSZ 04 | **Invited Talk Wulfhekel** |
| MA 2.1–2.9 | Mon | 11:00–13:15 | HSZ 04 | **Spin-Dynamics / Spin-Torque I** |
| MA 3.1–3.9 | Mon | 11:00–13:15 | HSZ 401 | **Magnetic Half Metals and Oxides** |
| MA 4.1–4.9 | Mon | 11:00–13:15 | HSZ 403 | **Surface Magnetism I** |
| MA 5.1–5.9 | Mon | 11:00–13:15 | HSZ 103 | **Electron Theory of Magnetism** |
| MA 6.1–6.2 | Mon | 14:00–15:00 | HSZ 04 | **Invited Talks Hehn / Eimüller** |
| MA 7.1–7.15 | Mon | 15:15–19:15 | HSZ 04 | **Spin-Dynamics/ Spin-Torque II** |
| MA 8.1–8.13 | Mon | 15:15–18:30 | HSZ 401 | **Magnetic Coupling Phenomena / Exchange Bias** |
| MA 9.1–9.7 | Mon | 15:15–17:00 | HSZ 403 | **Surface Magnetism II** |
| MA 10.1–10.7 | Mon | 17:15–19:00 | HSZ 403 | **Magnetic Imaging** |
| MA 11.1–11.15 | Mon | 15:15–19:15 | HSZ 103 | **Magnetic Materials** |
| MA 12.1–12.1 | Tue | 9:30–10:00 | HSZ 04 | **Invited Talk Fähnle** |
| MA 13.1–13.60 | Tue | 10:15–13:00 | P1A | **Poster Ia: Electron Theory (1); Magnetic Imaging (2,3); Thin Films (4-25); MSMA (26-33); Magn. Semiconductors (34-42); Magn. Half Metals and Oxides (43-60)** |
| MA 14.1–14.25 | Tue | 10:15–13:00 | P1B | **Poster Ib: Magnetic Materials (1-14); Micro Magnetism/Computational Mag. (15-17); Surface Magnetism (18-22); Spin Structures/Phase Transitions (23-25)** |
| MA 15 | Tue | 14:00–16:15 | HSZ 04 | **ThyssenKrupp Dissertationspreis der AG Magnetismus** |
| MA 16.1–16.1 | Wed | 9:30–10:00 | HSZ 04 | **Invited Talk Lottermoser** |
| MA 17.1–17.10 | Wed | 10:15–12:45 | HSZ 04 | **Magnetic Thin Films I** |
| MA 18.1–18.11 | Wed | 10:15–13:00 | HSZ 401 | **Spin Structures and Magnetic Phase Transitions** |
| MA 19.1–19.10 | Wed | 10:15–12:45 | HSZ 403 | **Micro Magnetism / Computational Magnetism** |
| MA 20.1–20.2 | Wed | 12:45–13:15 | HSZ 403 | **Micro- and Nanostructured Magnetic Materials I** |

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|---|---|---|---|---|
| MA 21.1–21.11 | Wed | 10:15–13:00 | HSZ 103 | **Magnetic Shape Memory Alloys I** |
| MA 22.1–22.1 | Wed | 14:00–14:30 | HSZ 04 | **Invited Talk Schoeller** |
| MA 23.1–23.14 | Wed | 14:45–18:15 | HSZ 04 | **Magnetic Thin Films II** |
| MA 24.1–24.17 | Wed | 14:45–19:15 | HSZ 401 | **Magnetic Semiconductors** |
| MA 25.1–25.17 | Wed | 14:45–19:15 | HSZ 403 | **Micro- and Nanostructured Magnetic Materials II** |
| MA 26.1–26.7 | Wed | 14:45–16:30 | HSZ 103 | **Magnetic Shape Memory Alloys II** |
| MA 27.1–27.4 | Wed | 16:45–17:45 | HSZ 103 | **Spin Electronics / Spininjection in Heterostructures** |
| MA 28.1–28.8 | Wed | 14:45–17:45 | HSZ 101 | **Focused Session: Spin Transport and Coherence in Emerging Materials** |
| MA 29.1–29.1 | Thu | 9:30–10:00 | HSZ 04 | **Invited Talk Ardavan** |
| MA 30.1–30.11 | Thu | 10:15–13:00 | HSZ 04 | **Spin-Dynamics / Spin-Torque III** |
| MA 31.1–31.11 | Thu | 10:15–13:00 | HSZ 401 | **Magnetic Particles and Clusters I** |
| MA 32.1–32.9 | Thu | 10:15–12:30 | HSZ 403 | **Magnetic Thin Films III** |
| MA 33.1–33.10 | Thu | 10:15–12:45 | HSZ 103 | **Bio- Molecular Magnetism** |
| MA 34.1–34.2 | Thu | 14:00–15:00 | HSZ 04 | **Invited Talks Winklhofer / Zabow** |
| MA 35.1–35.16 | Thu | 15:15–19:30 | HSZ 04 | **Spin-Dynamics / Spin-Torque IV** |
| MA 36.1–36.12 | Thu | 15:15–18:15 | HSZ 401 | **Magnetic Particles and Clusters II** |
| MA 37.1–37.17 | Thu | 15:15–19:45 | HSZ 403 | **Spin Dependent Transport Phenomena** |
| MA 38.1–38.16 | Thu | 15:15–19:30 | HSZ 103 | **Multiferroics** |
| MA 39.1–39.1 | Fri | 10:15–10:45 | HSZ 04 | **Invited Talk Hillebrands** |
| MA 40.1–40.108 | Fri | 11:00–14:00 | P1A | **Poster II: Bio- and Molecular Magnetism (1-9); Magnetic Coupling Phenomena/Exchange Bias (10-15); Magnetic Particlicles and Clusters (16-29); Micro and Nanostructured Magnetic Materials (30-51); Multiferroics (52-64); Spin Injection in Heterostructures (65-67); Spin-Dyn./Spin-Torque (68-93); Spindependent Transport (94-108)** |

## Annual General Meeting Magnetism Division

Mittwoch 18:30–19:30 HSZ 04

- Bericht des Vorsitzenden
- ICM 2009 und Satelliten
- Verschiedenes

# MA 1: Invited Talk Wulfhekel

Time: Monday 10:15–10:45 Location: HSZ 04

**Invited Talk** MA 1.1 Mon 10:15 HSZ 04

**Exciting magnetism : inelastic scanning tunneling spectroscopy on magnetic nanostructures** — •Wulf Wulfhekel — Physikalisches Institut, Universität Karlsruhe (TH), Germany

When passing an electric current through a magnetic material, magnetic excitations can be created. In these inelastic scattering events, the spin of a hot electron of the current may be flipped and angular momentum is transferred to the magnetic system. Energy is required for such excitations, making inelastic scanning tunneling spectroscopy (ISTS) the method of choice to study these excitations in nanoscale metallic systems [1]. We have successfully applied ISTS to investigate the nature and size of the inelastic spin-torque effect in bulk Fe samples and Co films [2], to obtain magnon dispersions and life times in thin Mn, Co and Ni films with precision similar to neutron scattering [3] and to measure the magnetic anisotropy of single Co and Fe atoms and clusters on Pt(111) [4].

[1] T. Balashov et al., Phys. Rev. Lett. 97, 187201 (2006), [2] T. Balashov et al., Phys. Rev. B 78, 174404 (2008), [3] C.L. Gao et al., Phys. Rev. Lett. 101, 167201 (2008), [4] T. Balashov et al., submitted

# MA 2: Spin-Dynamics / Spin-Torque I

Time: Monday 11:00–13:15 Location: HSZ 04

MA 2.1 Mon 11:00 HSZ 04

**Magnon dispersion and life times of thin Ni films studied with inelastic scanning tunneling spectroscopy** — •Toyo Kazu Yamada[1], Nicolai Urban[1], Timofey Balashov[1], Albert Takács[1], Pawel Buczek[2], Leonid Sandratskii[2], Arthur Ernst[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Universität Karlsruhe, Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany — [2]Max-Plank-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Ni films of thickness between 4 and 12 monolayers were grown epitaxially on a Cu(100) substrate. Using inelastic scanning tunneling spectroscopy at 4 K magnons in the Ni film were studied. In the thin films, the magnons are confined and thus quantized along the surface normal. For a film of $n$ momolayres, $n$ magnon modes normal to the surface are expected. In the experiments these modes appear as peaks in the inelastic tunnelling spectra. By measuring the peak position and widths the magnon energies and lifetimes can be obtained. The observed lifetimes strongly depend on the momentum of the magnons in agreement with non-adiabatic dynamic susceptibility calculations.

MA 2.2 Mon 11:15 HSZ 04

**One-dimensional YIG film based magnonic crystals** — •Andrii V. Chumak, Alexander A. Serga, and Burkard Hillebrands — FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, Germany

Scattering of backward volume magnetostatic spin waves (BVMSW) from a one-dimensional magnonic crystal was experimentally studied. The crystal was produced by etching of a periodic groove array on a surface of a single crystal yttrium-iron-garnet ferrite film. We demonstrate that in the BVMSW configuration the one-dimensional magnonic crystal shows excellent spin-wave signal rejection of more than 30 dB. It was found that the optimal groove depth (ensuring that the loss in the transmission band inserted by the array is smaller than 5 dB) is approximately 10% of the film thickness. The rejection efficiency and the frequency width of the rejection bands increase with increasing groove depth.

A theoretical model based on the analogy of a spin-wave film waveguide with a microwave transmission line was used to interpret the obtained experimental results.

Financial support by the DFG within SE 1771/1-1 is acknowledged.

MA 2.3 Mon 11:30 HSZ 04

**Ways to magnonic crystals: Studies with femtosecond pump-probe technique** — •Benjamin Lenk, Jakob Walowski, Andreas Mann, Henning Ulrichs, Gerrit Eilers, and Markus Münzenberg — I. Physikalisches Institut, Universität Göttingen

The propagation of surface modes on thin Nickel films is investigated with all optical pump-probe experiments. Laser pulses with a duration of 60 fs from a Ti:Sa mode-coupled laser system are used for optical excitation (pump pulse) as well as observation of the subsequent magnetic relaxation taking place in the pico- and nanosecond regime (probe pulse). The time dependent magnetization curves $M(t)$, are recorded using the time-resolved magneto-optical Kerr effect (TRMOKE) in different external fields $0\,\mathrm{mT} \leq \mu_0 H \leq 150\,\mathrm{mT}$.

The behaviour of the different precessional modes observed (exchange-dominated perpendicular standing spin waves, dipole-dominated surface modes, and uniform precession) changes when going from a continuous to a periodically structured surface. The different mode wave vectors can be numerically determined from $\nu(H)$. Structuring the thin films with matching periodicity induces drastic changes in the mode frequency observed, indicating the interaction of the periodic modification with the propagating modes excited with the laser pulse.

Research is supported by *DFG Schwerpunkt SPP 1133: "Ultrafast magnetization processes"*.

MA 2.4 Mon 11:45 HSZ 04

**Pumping free Bose-Einstein condensate of magnons** — •Alexander A. Serga[1], Vitaliy I. Vasyuchka[1,2], Christian Sandweg[1], Andrii V. Chumak[1], Timo Neumann[1], Gennadiy A. Melkov[2], and Burkard Hillebrands[1] — [1]FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]National Taras Shevchenko University of Kiev, Ukraine

A free evolution of a Bose-Einstein condensate (BEC) of parametrically injected magnons after shutdown of a pumping microwave field was studied by means of time-resolved Brillouin light scattering spectroscopy in a tangentially magnetized yttrium-iron-garnet film at room temperature. The light scattered by the primary magnon group, which was parametrically excited near the frequency of ferromagnetic resonance, and by the BEC of magnons at the bottom of spin-wave spectrum was detected and analyzed in the time domain.

A pronounced and sharp (by a factor of 10 during 30 ns) intensity jump of the BEC of magnons above its equilibrium value has been detected just after the external pumping source was switched off. This jump was accompanied by the fast nonlinear decay of the primary magnon group with the relaxation time of 60 ns. The subsequent decay of the BEC of magnons is much slower and is characterized by the relaxation time of 800 ns. The discovered surge is interpreted as an increase in scattering efficiency of the parametrically injected magnons to the Bose-Einstein condensate in absence of pumping.

Financial support by the DFG (SFB/TRR 49) and by the Ukrainian Fund for Fundamental Research (No. 25.2/009) is acknowledged.

MA 2.5 Mon 12:00 HSZ 04

**Spatial handling of Bose-Einstein condensate of magnons** — •Oleksandr Dzyapko, Vladislav E. Demidov, and Sergej O. Demokritov — Institut für Angewandte Physik, Westfälische Wilhelms-Universität Münster, Münster, Deutschland

After the experimental observation of Bose-Einstein condensation (BEC) of atoms and quasi-particles manipulating the condensate as a single whole and the study of interaction between two or more condensates are of particular interest. However, experimental results only for atomic condensate were reported. Recently discovered room temperature BEC of magnons driven by a microwave pumping [1] opens a new way for manipulation of condensates of quasi-particles. Here we demonstrate a way to create simultaneously two condensates of magnons separated in space and report the study of their spatial evolution using the space- and time-resolved Brillouin light scattering spectroscopy. Two separate condensates were created along the opposite edges of a microstrip resonator, which has a width of 500 mkm. The

presented results show that, whereas the spatial separation between the condensates is determined by the width of the resonator, the width of each condensate depends on the applied microwave pumping power. Thus, varying the power and the width of the resonator one can handle the dimensions and the separation of the condensates which gives a convenient tool for realization of a magnon Josephson junction.

1. S.O. Demokritov, V.E. Demidov, O. Dzyapko, G.A. Melkov, A.A. Serga, B. Hillebrands, and A.N. Slavin, Nature 443, 430 (2006).

MA 2.6 Mon 12:15 HSZ 04

**Spin-wave signal recovering under influence of multipulse parametric pumping** — •Sebastian Schäfer, Volker Kegel, Alexander A. Serga, and Burkard Hillebrands — FB Physik und Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We have studied the storage and parametrically stimulated recovery of microwave signals in a tangentially magnetized yttrium-iron-garnet (YIG) ferrite film. The microwave signal carried by a packet of magnetostatic surface spin waves (MSSW) is stored due to the excitation of dipolar-exchange standing spin-wave modes across the film thickness. A recovered MSSW packet appears in the film as a result of parametric amplification of one of these standing modes [1]. The recovery delay time as well as the duration and amplitude of the recovered signal are mostly controlled by the power of the pumping signal. Here we report on the behaviour of the spin-wave system under influence of multiple pumping pulses applied per one MSSW signal pulse. We demonstrate the ability of a multiple recovery process and discuss the dependence of its characteristics on the time interval between pumping pulses. Financial support by the DFG (SFB/TRR 49) is acknowledged.

[1] A.A. Serga, A.V. Chumak, A. Andre, G.A. Melkov, A.N. Slavin, S.O. Demokritov, and B. Hillebrands, PRL 99, 227202 (2007).

MA 2.7 Mon 12:30 HSZ 04

**Oersted field influence on three-magnon-scattering processes in nanopoint contact spin-valves** — •F. Ciubotaru[1], H. Schultheiss[1], A.A. Serga[1], X. Janssens[2], M. van Kampen[2], L. Lagae[2], B. Leven[1], A.N. Slavin[3], and B. Hillebrands[1] — [1]FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]IMEC, Leuven, Belgium — [3]Oakland University, Rochester, MI, USA

Using Brillouin light scattering microscopy we have investigated the spin-wave emission from a point contact spin-valve structure driven by a combined microwave and dc current. The spin waves irradiated into a free Py layer by an 80 nm point contact were studied for several applied microwave frequencies and powers with and without influence of dc current We report on observation of several nonlinear effects, namely the generation of higher harmonics (2f, 3f) as well as spin-wave modes with a half-integer factor (0.5f, 1.5 f) relative to the driving microwave frequency f. These modes are associated with three-magnon-scattering processes. The appearance of the 0.5f mode presents a clear threshold behavior as a function of the applied microwave power. Moreover, the threshold shows a strong nonlinear dependence on the dc current. The threshold power was calculated within three-magnon-scattering theory taking into account the influence of the Oersted field created by the dc current. The theoretical and experimental results agree and show that the threshold properties of 0.5 mode are controlled by the Oersted field. Support from EC-MRTN SPINSWITCH (MRTN-CT-2006-035327) is gratefully acknowledged.

MA 2.8 Mon 12:45 HSZ 04

**Interaction of spin-wave envelope solitons with potential barriers and wells** — •Ulf-Hendrik Hansen, Vladislav E. Demidov, and Sergej O. Demokritov — Institute for Applied Physics, University of Muenster, Corrensstr. 2-4, 48149 Muenster, Germany

The interaction of nonlinear waves with potential barriers and wells has recently attracted a strong interest, since it is believed that the tunneling-associated dynamics of nonlinear wave-packets in complex potentials can bring a new important knowledge to the physics of universal nonlinear phenomena [1]. Spin waves in thin ferromagnetic films are uniquely positioned as a flexible and convenient model nonlinear system. Recently it was demonstrated that linear spin waves can tunnel through a potential barrier, formed by an inhomogeneity of the static magnetic field [2]. Here we report an experimental study of interaction of nonlinear spin-wave packets, propagating in yittrium iron garnet films, with magnetic potential barriers and wells. We have found that the nonlinearity in the system causes a noticeable modification of this interaction in comparison to the linear case. The strongest modification is observed under conditions, where spin-wave envelope solitons are formed. Our findings show that for the case of potential barriers the solitons demonstrate an enhanced tunneling. Moreover, the nonlinear enhancement of the interaction was found to be stronger for potential wells, which was associated with its resonant character.

[1] O. Morsch and M. Oberthaler, Rev. Mod. Phys. 78, 179 (2006).
[2] S.O. Demokritov et al., Phys. Rev. Lett. 93, 047201 (2004).

MA 2.9 Mon 13:00 HSZ 04

**New 2D approach to the k-vector sensitivity in the Brillouin light scattering spectroscopy** — •Christian W. Sandweg, Vitaliy I. Vasyuchka, Alexander A. Serga, and Burkard Hillebrands — FB Physik und Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

An important step towards the understanding of the behavior of magnon gases and condensates in thin magnetic films will potentially allow one to determine the exact spectral positions of spin-wave excitations through experimental recognition of their frequencies and wave vectors. For the investigation and characterization of energy transfer processes initiated in a magnon gas by parametric excitation, an instrument capable of detecting and resolving the whole range of magnon wave vectors occurring during these processes is required. Here we report on our progress towards achieving this goal by varying the angle of incident light with respect to the orientation of magnetization. The distinct improvement of our approach is expanding this k-vector sensitivity to two dimensions so that spin-wave wavevectors oriented both parallel and perpendicular to the external field can be resolved and measured. The functionality of this setup is demonstrated by showing the results for (a) directly excited spin waves near the ferromagnetic resonance and (b) for magnons at the lowest energy state of a parametrically driven magnon gas in yttrium-iron-garnet ferrimagnetic film.

## MA 3: Magnetic Half Metals and Oxides

Time: Monday 11:00–13:15 Location: HSZ 401

MA 3.1 Mon 11:00 HSZ 401

**Magneto-optical study of $Co_2$-based Heusler compound thin films** — •Simon Trudel, Jaroslav Hamrle, Oksana Gaier, Thomas Sebastian, and Burkard Hillebrands — FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

$Co_2$-based Heusler compounds are promising materials for spintronic applications due to their predicted half-metallicity, their high Curie temperatures, and their tunable magnetic properties with respect to composition.

In this presentation, we will present our recent results on the magnetic characterization of $Co_2$-based Heusler compound thin films using magneto-optical probes such as magneto-optical Kerr effect (MOKE) and Brillouin light scattering (BLS) spectroscopy.

In our MOKE investigations, we particularly focus on the amplitude of the longitudinal (LMOKE) and quadratic MOKE (QMOKE) signals. We find that for several $Co_2$-based Heusler alloys, the QMOKE signal is remarkably strong. This points to an important contribution from second-order (and higher) spin-orbit interaction in this family of materials.

Using BLS spectroscopy, we find that the exchange constant of $Co_2$-based compounds depends on their composition. In particular, the exchange constant and the spin-wave exchange stiffness increase with the concentration of valence electrons.

Financial support from DFG FG559 “Neue Materialien mit hoher Spinpolarization”is gratefully acknowledged.

MA 3.2 Mon 11:15 HSZ 401

**Surface properties of Co based full Heusler alloys** — •Jan-Peter Wüstenberg, Sabine Neuschwander, Alexander Fischer, Martin Aeschlimann, and Mirko Cinchetti — Department of

Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin Schrödingerstr. 46, 67663 Kaiserslautern, Germany

Half metallic Heusler compounds are promising candidates for spintronics applications due to their predicted minority spin gap at the Fermi energy. Unfortunately, the proof of half metallicity at the surface is still missing. In this contribution we present spin resolved low energy photoemission data as well as results from LEED and Auger spectroscopy of several Co based full Heusler alloys. The influence of a thin MgO tunneling barrier and small coverages of the organic semiconductor copper-phthalocyanine (CuPC) on the surface spin polarization is discussed and compared to results of the free Heusler surface.

MA 3.3 Mon 11:30 HSZ 401

**Investigation of the metal-insulator transition in a thin manganite film by STM/STS** — •Christin Kalkert, Vasily Moshnyaga, Bernd Damaschke, and Konrad Samwer — I. Phys. Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

The colossal magnetoresistance (CMR) effect in manganite thin films is accompanied by a metal to insulator transition (MIT) in these samples. In this work a thin film of (La1-0.375Pr0.375)0.7Ca0.3MnO3 was grown by the metal-organic aerosol deposition technique on MgO substrates and investigated by transport measurements and scanning tunnelling microscopy (STM) and spectroscopy (STS) as a function of temperature. With these techniques we were able to compare the local electronic properties of the film with the global transport behavior. We observed an electronic phase separation at low temperatures and in the vicinity of the MIT. The metallic conductivity at low temperatures can be attributed to a double exchange mechanism while the insulating regions can be interpreted by a charge ordered high temperature phase.

This work is supported by DFG via SFB 602, TPA2 and the Leibniz program

MA 3.4 Mon 11:45 HSZ 401

**Correlation effects in p-electron magnets: the case of $RbO_2$** — •Roman Kováčik and Claude Ederer — School of Physics, Trinity College Dublin, Dublin 2, Ireland

The development of spintronics in recent years has triggered a need for new materials such as half metallic (HM) ferromagnets. HM materials with 2p-magnetism were proposed from electronic structure calculations, e.g. $Rb_4O_6$ [1]. However, recent measurements indicate that $Rb_4O_6$ is a magnetically frustrated system that exhibits spin-glass-like behavior in a magnetic field [2]. This discrepancy was attributed to inadequate treatment of the molecular states within the local spin density approximation (LSDA). This assumption was supported by calculations for $RbO_2$, known to be an insulating antiferromagnet, which turns out to be HM in LSDA as well. According to [2], this outcome could not be corrected within LDA+U even for $U = 13.6\,\mathrm{eV}$.

We present results of LDA+U calculations for $RbO_2$, which show that, when allowing the system to reduce its symmetry, an orbitally polarized insulating state is favored for $U > 2\,\mathrm{eV}$, consistent with experiment. Furthermore, we discuss an alternative treatment of on-site correlations in $RbO_2$, using an effective tight-binding model corresponding to a molecular orbital basis, which is constructed via maximally localized Wannier functions. In this case, the insulating state is obtained for significantly lower $U > 0.5\,\mathrm{eV}$. In addition, we discuss a possible orbital ordering driven by correlation effects.

[1] J. J. Attema *et al.*, J. Am. Chem. Soc. **127**, 16325 (2005).
[2] J. Winterlik *et al.*, J. Phys. Condens. Matter **19**, 1 (2007).

MA 3.5 Mon 12:00 HSZ 401

**Photolitchemically deposited amorphous iron(III) oxide exhibiting room-temperature ferromagnetism** — •Simon Trudel[1,2] and Ross H. Hill[1] — [1]4D LABS and Department of Chemistry, Burnaby, BC, Canada — [2]Now at FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

There is great interest in the study of new materials that exhibit useful ferromagnetic properties, while they are expected to be non-magnetic. A surprising example is amorphous iron oxide ($a$-$Fe_2O_3$), for which room temperature ferromagnetism (FM) has never been reported.

Thin films of $a$-$Fe_2O_3$ were prepared using a photochemical deposition method that allows direct patterning, without the use of photoresists. This method relies on light-induced decomposition of Fe(III) 2-ethylhexanoate, which can be spin-coated as high-quality thin films. Upon exposure to light, the precursor decomposes, yielding $a$-$Fe_2O_3$. The $a$-$Fe_2O_3$ thin films were found to exhibit FM at room temperature. Prior to this work, no magnetic amorphous iron oxide had previously been reported (*J. Phys. Chem. B* **111** (2007) 4003).

The FM in these films can be tuned by changing the preparation conditions, and complete deactivation of the FM can be achieved by changing the deposition temperature. The oxidation state and coordination of the Fe centers in $a$-$Fe_2O_3$ were detemined using X-ray absorption spectroscopy. It will be shown this route to amorphous magnetic oxide materials is general, and that $a$-$Cr_2O_3$ and $a$-$CoFe_2O_4$ also exhibit unprecedented room-temperature FM.

MA 3.6 Mon 12:15 HSZ 401

**Phase transition and anomalous low temperature ferromagnetic phase in a $Pr_{0.6}Sr_{0.4}MnO_3$ single crystal** — •Sahana Roessler[1], Steffen Wirth[1], Frank Steglich[1], S Harikrishnan[2], C. M. Naveen Kumar[2], Suja Elizabeth[2], H. L. Bhat[2], and Ulrich Karl Roessler[3] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnizer Straße 40, 01187, Dresden, Germany — [2]Department of Physics, Indian Institute of Science, Bangalore 560012, India — [3]IFW Dresden, Postfach 270016, D-01171 Dresden, Germany

We report on the specific heat, electrical and magnetic properties of a $Pr_{0.6}Sr_{0.4}MnO_3$ single crystal. This compound is ferromagnetic and metallic below 300 K. The critical properties of the ferromagnetic transition investigated by static magnetic measurements, resistivity and specific heat display a continuous phase transition with the critical exponents belonging to those of the Heisenberg universality class. However, below a structural transition at $T_S \sim 60$ K, the field dependence of magnetization ($M$-$H$) loops display anomalous behavior, with the virgin curve lying outside the subsequent $M$-$H$ cycles. The coercivity of these $M$-$H$ loops is found to be close to zero. The hysteretic transformation and irreversible magnetization processes below $T_S$ is explained by phase separation between the orthorhombic and monoclinic ferromagnetic phases. Magnetic fields apparently drive modifications in these phase-separated microstructures which suggests a high magnetic anisotropy of the monoclinic phase.

MA 3.7 Mon 12:30 HSZ 401

**Magnetism without magnetic impurities in oxides ZrO2 and TiO2** — •Frantisek Maca[1], Josef Kudrnovsky[1], Vaclav Drchal[2], and Georges Bouzerar[2,3] — [1]Institute of Physics ASCR, Praha, Czech Republic — [2]Institut Néel, CNRS, Grenoble, France — [3]Institut Laue Langevin, Grenoble France

We perform a theoretical study of the magnetism induced in transition metal dioxides ZrO2 and TiO2 by substitution of the cation by a vacancy or an impurity from the groups 1A or 2A of the periodic table, where the impurity is either K or Ca.

In the present study both supercell and embedded cluster methods are used. It is demonstrated that the vacancy and the K-impurity leads to a robust induced magnetic moment on the surrounding O-atoms for both the cubic ZrO2 and rutile TiO2 host crystals. The presence of an impurity band close to the top of the valence band is a precursor for the appearance of magnetism in dioxides.

[1] F. Maca, J. Kudrnovsky, V. Drchal, and G. Bouzerar, Appl. Phys. Lett. 92, 212503 (2008).

MA 3.8 Mon 12:45 HSZ 401

**Effect of strain and magnetic interaction parameters in $Fe_2O_3$-$FeTiO_3$ heterostructures** — •Hasan Sadat Nabi and Rossitza Pentcheva — Department of Earth and Environmental Sciences, University of Munich, Theresienstr. 41, 80333 Munich, Germany

The interfaces between complex oxides provide a challenging area to explore new functionality for the development of future devices. To explain the origin of interface magnetism in the $Fe_2O_3$ (canted antiferromanet)- $FeTiO_3$ (room temperature paramagnet) system we have performed density functional theory (DFT) calculation including a Hubbard $U$ parameter. We find that the polar discontinuity at the interface is accommodated through a disproportionation in the Fe contact layer into $Fe^{2+}$, $Fe^{3+}$[1] giving the first theoretical evidence for the lamellar magnetism hypothesis [2].

Furthermore, by using the lateral lattice constant of different substrates (e.g. $Fe_2O_3$, $FeTiO_3$, $Al_2O_3$) we show how the electronic properties and energetic stability of the system can be tuned by strain. In addition, the magnetic exchange interaction parameters are extracted by mapping the DFT total energies of different spin-configurations on a Heisenberg Hamiltonian.

Funding by the German Science Foundation (DFG PE883/4-1), ESF

(EuroMinSci-MICROMAGN) and a grant for computational time at the Leibniz Rechenzentrum are gratefully acknowledged.
[1] R. Pentcheva, H. Sadat Nabi, Phys. Rev. B, **77**, 172405 (2008).
[2] Robinson, P. *et al.* Nature **418**, 517 (2002).

MA 3.9 Mon 13:00 HSZ 401

**Ultrafine nc-NiO: a Néel-type Random Ferrimagnet?** — •Marek Petrik and Bernd Harbrecht — Chemistry Department and Center of Materials Science, Philipps University, Hans-Meerwein-Strasse, 35032 Marburg, Germany

Is ultrafine nanocrystalline nickel oxide nc-NiO an intrinsic random ferrimagnet as hypothesized by Louis Néel in 1962 [1]? Or is the often reported uncompensated magnetic moment of this archetypal antiferromagnet in the finely divided state due to some other cause? The question has never been conclusively settled in spite of efforts by the groups of Richardson [2], Mørup [3], Seehra [4], and others. Unable to locate the uncompensated spins in nc-NiO directly, we have resorted to indirect means of identifying their origin [5]. Since the magnetism is strongly correlated with the crystallite size and shape, we control these two in a novel solid-state synthesis in the full mesoscopic range (2,5-50 nm). An analysis of the Langevin-type superparamagnetism and the Néel-Arrhenius thermal relaxation, as a function of size, for a large number of samples indicates that nc-NiO not only is a random ferrimagnet as considered by Néel, but also that it could either be subject to a size-dependent magneto-crystalline anisotropy or even consist of multiple antiferromagnetic nanodomains. – [1] L. Néel, in Low Temperature Physics, C. De Witt et al., eds., Gordon and Breach, New York, 1962, p. 412. - [2] J. T. Richardson et al, J. Appl. Phys., 70 (1991) 6977. - [3] C. R. H. Bahl et al., J. Phys.: Condens. Matter, 18 (2006) 4161. - [4] H. Shim et al., Solid State Comm., 145 (2008) 192. - [5] M. Petrik, B. Harbrecht, Z. Anorg. Allg. Chem., 634 (2008) 2069.

# MA 4: Surface Magnetism I

Time: Monday 11:00–13:15 Location: HSZ 403

MA 4.1 Mon 11:00 HSZ 403

**Spin-resolved excitations of single atoms with STM** — •Kirsten von Bergmann[1,2], Sebastian Loth[1], Markus Ternes[1], Alexander F. Otte[1,3], Cyrus F. Hirjibehedin[1,4], Christopher P. Lutz[1], and Andreas J. Heinrich[1] — [1]IBM Almaden Research Center — [2]University of Hamburg — [3]NIST Gaithersburg — [4]London Centre for Nanotechnology

STM with its high lateral resolution can be used to obtain information about magnetic properties in two ways: inelastic tunneling spectroscopy has been shown to enable spin flip excitations in single atoms [1], while spin-polarized STM has been used to study ground state properties of nanoscale structures [2].

We have combined these two approaches to gain further insight by using a spin-polarized STM tip to excite the spin of single Co atoms on a thin insulating layer of $Cu_2N$ on Cu(001). While spin-averaged measurements on this system yield the energy of spin-flip transitions [3], the spin-resolved data enables the determination of the character of the observed excitations. The degree of spin polarization is compared to calculations within the Heisenberg model. Since the Co atom shows the Kondo effect in this environment, this measurement provides additional information about the spin polarization of the Kondo resonance, which is split in an external magnetic field.

[1] A.J. Heinrich *et al.*, Science **306**, 466 (2004).
[2] M. Bode, Rep. Prog. Phys. **66**, 523 (2003).
[3] A.F. Otte *et al.*, Nature Phys. **4**, 847 (2008).

MA 4.2 Mon 11:15 HSZ 403

**Right Rotating Néel Type Domain Walls in the Fe Doublelayer on/W(110)** — •Stefan Meckler, Anett Pressler, Mike Gyamfi, Oswald Pietzsch, and Roland Wiesendanger — Institute of Applied Physics and Microstructure Research Center, University of Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

The system of 1.5 atomic layers Fe on W(110) has been studied intensively in the field of spin polarized scanning tunneling microscopy (SP-STM), and its magnetic properties have been investigated in great detail. It was recognized very early that the out-of-plane domains and the walls separating them form spiral-like structures with a unique sense of rotation. However, it could not be shown experimentally if the domain walls are of Bloch or Néel type since there was no complete control of the direction of the magnetization of the SP-STM tips. For the same reason the handedness could not be determined experimentally. Applying SP-STM in the field of a three axes vector magnet enables us for the first time to align the magnetization of our SP-STM tips in any arbitrary spatial direction. Using this technique we show that the walls in the Fe doublelayer on W(110) are right rotating Néel type walls. This observation is in good agreement with recent calculations that ascribe both the observed wall type and the unique right handedness to the important role of the Dzyaloshinkii-Moriya interaction at crystal surfaces.

MA 4.3 Mon 11:30 HSZ 403

**SPEELS Studies of Oxygen Passivated Fe/W(100) Thin Films** — •Yu Zhang[1], Jacek Prokop[1], Ioan Tudosa[1], Wen-Xin Tang[1], Thiago R. F. Peixoto[1,2], Khalil Zakeri[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle — [2]Instituto de Física, Universidade de São Paulo, 05508-900, São Paulo, Brazil

We measured the vibrational spectra of oxygen passivated Fe(100) surface by means of spin-polarized electron energy loss spectroscopy (SPEELS). A 30 ML thick Fe film, epitaxially grown on W(100) was exposed to 5 L $O_2$ at room temperature and annealed at 500 K, under ultrahigh vacuum conditions. The surface exhibits a p(1×1)O-Fe(100) reconstruction in the LEED pattern, with the O atoms occupying fourfold hollow sites. SPEELS measurements were performed at different primary energies and a resolution of about 6 meV. These spectra show many peaks in comparison to the spectra obtained for the clean Fe surface. From the analysis of the energy gain and loss features in the asymmetry, one can distinguish between excitations caused by spin-flip and non-flip scattering processes. The O-Fe(100) vibration peaks, which are dominated by the spin independent dipolar scattering [1], surprisingly reveal asymmetries up to 60%. We show results of specular and off-specular geometries and discuss the nature of the observed excitations.

[1] J.-P. Lu, M. R. Albert and S. L. Bernasek, Surf. Sci. 215, 348 (1989).

MA 4.4 Mon 11:45 HSZ 403

**Magnetic and structural investigations of self-organised iron based nanostructures on GaAs(110)** — •Carsten Godde[1], Sani Noor[1], Athena Rastgoo Lahrood[1], Gregor Nowak[2], Hartmut Zabel[2], and Ulrich Köhler[1] — [1]Institut für Experimentalphysik IV / AG Oberflächen, Ruhr-Universität Bochum, Germany — [2]Institut für Experimentalphysik IV, Ruhr-Universität Bochum, Germany

The structure and the magnetic behaviour of Fe-layers and self-organised iron based nanostructures on GaAs(110) were studied in a UHV system that offers the means for structural analysis by STM and LEED and magnetic characterization by MOKE during deposition. The structure of the Fe-layer when grown at room temperature has a closed granular structure with a magnetic anisotropy depending on the thickness of the Fe-layer. At elevated temperatures a disrupted layer develops. The effect of annealing up to 450°C on the structure and the magnetic behaviour were studied for two different cases - during and after deposition of the iron layer. The increasing temperature leads to a transformation of the Fe-layer to an array of self-organised ferromagnetic nanostructures for both cases. These nanostructures are roof-shaped 3D-islands elongated along the $[1\bar{1}0]$-direction of the GaAs(110) substrate. STM also shows an indication that Ga and As from the substrate diffuse into the Fe-islands. This intermixing by annealing leads to a ternary alloy $Fe_3Ga_{2-x}As_x$ which is proofed by x-ray diffraction. Despite of this alloying magnetic measurements of the nanostructures by MOKE show ferromagnetic characteristics and a correlation between magnetic and structural anisotropy.

MA 4.5 Mon 12:00 HSZ 403

**Visualizing the spin polarizaton of individual molecules** — •Benjamin W. Heinrich[1], Mircea V. Rastei[1], Cristian Iacovita[1],

Thomas Brumme[2], Jens Kortus[2], Laurent Limot[1], and Jean-Pierre Bucher[1] — [1]Institut de Physique et Chimie des Matériaux de Strasbourg, UMR 7504, Université Louis Pasteur, F-67034 Strasbourg, France — [2]Institut für Theoretische Physik, TU Bergakademie Freiberg, D-09599 Freiberg, Germany

Low-temperature spin-polarized scanning tunneling microscopy is employed to study spin transport across single cobalt-phthalocyanine molecules adsorbed on well-characterized magnetic nanoleads. A spin-polarized electronic resonance is identified over the center of the molecule and exploited to spatially resolve stationary spin states [1]. These states reflect two molecular spin orientations and, as established by density functional calculations, originate from a ferromagnetic molecule-lead exchange interaction.

[1] C. Iacovita, M.V. Rastei, B.W. Heinrich, T. Brumme, J. Kortus, L. Limot, J.P. Bucher, Phys. Rev. Lett. **101**, 116602 (2008)

MA 4.6 Mon 12:15 HSZ 403

**The role of magnetic anisotropy in the Kondo effect** — •Markus Ternes[1,2], Alexander F. Otte[1,3], Kirsten v. Bergmann[1,4], Sebastian Loth[1], Harald Brune[1,5], Christopher P. Lutz[1], Cyrus P. Hirijbehedin[1,6], and Andreas J. Heinrich[1] — [1]IBM Almaden Research Center — [2]MPI Stuttgart — [3]NIST Gaithersburg — [4]University of Hamburg — [5]EPF Lausanne — [6]London Centre for Nanotechnology

Using a STM to assemble magnetic structures on a thin insulator, we found that the spin of the atom is influenced by the magnetocrystalline anisotropy of the supporting surface which lifts the spin degeneracy of the ground state and enables the identification of individual atoms by using inelastic electron tunneling spectroscopy [1]. Changes in the observed spectra as a magnetic field was applied along different directions yielded the magnetic anisotropy for individual magnetic atoms [2].

Atoms with half-integer spin remain always degenerated at zero field due to Kramers theorem. We found that if these states differ by an orbital momentum of $\Delta m = \pm 1$ the localized spin is screened by the surrounding conducting electrons of the non-magnetic host and form a Kondo resonance close to the Fermi energy at sufficiently low temperature. Applying a magnetic field splits this Kondo resonance at rates that are strongly direction-dependent, which are well-described by the energies of the underlying unscreened spin states [3].

[1] A. J. Heinrich *et al.*, Science **306**, 466 (2004).
[2] C. F. Hirjibehedin *et al.*, Science **317**, 1199 (2007).
[3] A. F. Otte *et al.*, Nature Physics **4**, 847 (2008).

MA 4.7 Mon 12:30 HSZ 403

**Magnetic anisotropy of single 3*d* atoms on CuN surface** — •Alexander B. Shick[1], Frantisek Maca[1], and Alexander I. Lichtenstein[2] — [1]Institute of Physics ASCR, Prague, Czech Rep. — [2]University of Hamburg, Germany

The magnetic anisotropy energy for Mn, Fe and Co atoms on CuN/Cu(001) surface is investigated making use of the first-principles FP-LAPW calculations and the torque method. For Mn and Fe atoms, the easy magnetization direction is found to be in accord with the experiment [1]. The magnetic anisotropy has a single-ion character and mainly originates from the local magnetic moment of Mn and Fe atoms. The uniaxial magnetic anisotropy constants are calculated in reasonable agreement with the experiment [2].

For Co atom case, the conventional band theory fails to reproduce even qualitatively the experimentally observed magnetic anisotropy [3]. The orbital polarization beyond that given by LSDA has to be included. The effect of the orbital polarization is studied making use of the LDA+U method. The LDA+U induced orbital polarization yields strong enhancement of the orbital component of the magnetic moment for different directions of the Co-atom magnetization and can modify substantially the magnetic anisotropy energy. It is shown that LDA+U induced orbital polarization improves substantially agreement with the experimental magnetic anisotropy energies.

[1] S. Hirjibehedin *et al.*, Science 317, 1199 (2007). [2] A. B. Shick, F. Máca, and A.I. Lichtenstein, arxiv:0810.3389. [3] A. F. Otte *et al.*, Nature Physics 4, 847 (2008).

MA 4.8 Mon 12:45 HSZ 403

**Comparing magnetic properties of Co adatoms measured with X-ray magnetic dichroism and spin excitation spectroscopy** — •M. Etzkorn[1], C. Hirjibehedin[2], A. Lehnert[1], S. Stepanow[3], S. Ouazi[1], C. Tieg[4], P. Thakur[4], S. Rusponi[1], P. Gambardella[3], A. Heinrich[5], and H. Brune[1] — [1]Institut de Physique des Nanostructures, EPF-Lausanne, Switzerland — [2]London Centre for Nanotechnology, UCL, United Kingdom — [3]ICREA and Catalan Institut of Nanotechnology, Barcelona, Spain — [4]ESRF, Grenoble, France — [5]IBM Research Center, San Jose, USA

Spin excitation spectroscopy offers a new approach to determine the magnetic moment and anisotropy of single adatoms and atomic chains with a scanning tunneling microscope [1]. In order to compare these results with established methods we have started a series of X-ray circular magnetic dichroism (XMCD) measurements on one of the systems investigated with STM, namely Co-monomers on $Cu_2N$/Cu(100). The XMCD spectra show that the Co is electronically largely decoupled from the Cu-substrate by the $Cu_2N$-layer in agreement with the STS data. The X-ray adsorption spectra reveal that the electronic state of the Co on this surface has a predominant $d8$-character while the STS studies indicate a $d7$-state. On one hand the XMCD spectra clearly show a large orbital moment of the Co while the STS analysis has been performed in terms of an effective spin moment only. On the other hand the anisotropy determined by STS is in very good agreement with the angular dependance of the magnetic moment measured by XMCD. [1] A. Otte et al., Nature Physics 4 (2008) 847.

MA 4.9 Mon 13:00 HSZ 403

**Magnetic Anisotropy of small metal clusters on Pt(111)** — •Stefan Gerstl[1], Tobias Schuh[1], Timofey Balashov[1], Albert F. Takács[1], Sergey Ostanin[2], Arthur Ernst[2], Jürgen Henk[2], Toshio Miyamachi[1], Shigemasa Suga[3], Ingrid Mertig[2,4], Patrick Bruno[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Universität Karlsruhe (TH), Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]Graduate School of Engineering Science, Osaka University, Japan — [4]Institut für Physik, Martin-Luther-Universität Halle, Germany

The key for higher storage density is the magnetic anisotropy energy (MAE), as it is related to the stability of bits in magnetic storage devices. Giant MAE was found for Co clusters on Pt(111) using X-ray magnetic circular dichroism (XMCD) [1]. We show a new approach to obtain the MAE of individual clusters using inelastic scanning tunneling spectroscopy. Single Fe or Co atoms were deposited on Pt(111) at 4 K and assembled by atomic manipulation to form clusters of up to three atoms. The magnetic excitation energy that we determined corresponds to a spin-flip process and is proportional to the MAE. The excitation energies were recorded on a large number of atoms and clusters and averaged. The obtained values of the MAE are 6.5, 5.2 and 5.5 meV/atom for Fe atoms, dimers and trimers respectively, and 10.2, 5.5 and 5.0 meV/atom for Co atoms and clusters. For Co this corresponds well to the MAE values obtained with XMCD [1]. Relativistic *ab-initio* calculations of fully relaxed structures confirm our results.

[1] P. Gambardella *et al.*, Science 300, 1130 (2003).

## MA 5: Electron Theory of Magnetism

Time: Monday 11:00–13:15 Location: HSZ 103

MA 5.1 Mon 11:00 HSZ 103

*Ab initio* **calculation of the full anti-symmetric conductivity tensor for magnetically ordered systems** — •Stephan Lowitzer, Diemo Ködderitzsch, and Hubert Ebert — Department Chemie und Biochemie, LMU München, Butenandtstraße 11, 81377 München

The *ab initio* calculation of the full anti-symmetric conductivity tensor for magnetically ordered systems is up to now a very difficult task. We present the first results of a recent investigation on the transition metal alloys $Fe_{1-x}Ni_x$ and $Co_{1-x}Pd_x$. For these we employed the fully relativistic Korringa-Kohn-Rostoker (KKR) band structure method in conjunction with the coherent potential approximation (CPA) alloy theory. The calculation of the conductivity tensor is based on the expressions by Středa and its extension by Crépieux and Bruno, that

contain the Kubo-Greenwood expression for the symmetric conductivity tensor as a special case.

MA 5.2 Mon 11:15 HSZ 103

**Spin-polarized relativistic optimized effective potential method for open-shell atoms and magnetic solids** — •Diemo Ködderitzsch[1], Hubert Ebert[1], and Eberhard Engel[2] — [1]Ludwig-Maximilians-Universität, D-81377 München, Germany — [2]J. W. Goethe-Universität, D-60438 Frankfurt, Germany

We introduce the concept of the exact orbital-dependent exchange into relativistic **spin**-density functional theory and give a relativistic formulation of the optimized effective potential method (ROEP). [1,2]

We first present its application to open-shell atoms and discuss the relative importance of exchange splitting and spin-orbit coupling as well as the relative stability of $3d^{n-1}4s^2$ and $3d^n4s^1$ configurations in case of $3d$ transition-metal elements.

In addition, we present an extension of the formalism to solids and its implementation within the KKR formalism.[3] The scheme is an all electron approach treating core and band states formally on the same footing. We use exact exchange (EXX) as approximation to the xc-functional which for the valence states is reformulated in terms of the electronic Green's function. Numerical four-component wave functions for the description of the ingredients of the ROEP integral equation are employed. We present and discuss the application of the formalism to non-magnetic alkali metals and to magnetic $3d$ transition-metals.

[1] D. Ködderitzsch, H. Ebert, E. Engel, PR**B 77**, 045101 (2008)
[2] E. Engel, D. Ködderitzsch, H. Ebert, PR**B 78**, accepted (2008)
[3] D. Ködderitzsch, H. Ebert, H. Akai, E. Engel, J. Phys: Condens. Matter, accepted (2008)

MA 5.3 Mon 11:30 HSZ 103

**Investigating magnetic properties of Heusler compounds with *ab initio* calculations** — •Jan Thoene[1], Gerhard H. Fecher[1], Stanislav Chadov[1], Claudia Felser[1], and Jürgen Kübler[2] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [2]Institut für Festkörperphysik, Technische Universität Darmstadt, D-64289 Darmstadt, Germany

We have studied the magnetic properties of various Heusler compounds with Density Functional Theory calculations. The Kohn-Sham equations were solved using the Korringa-Kohn-Rostoker Green function formalism. Heisenberg exchange energies have been calculated employing the local force theorem to derive total energy changes associated with a rotation of the local magnetisation direction. The exchange constants were used to evaluate finite-temperature magnetic properties as Curie temperatures and spin-stiffness. Further, the influence of local correlation effects on the magnetic properties was investigated in terms of the Dynamical Mean-Field Theory.

The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

MA 5.4 Mon 11:45 HSZ 103

**Local correlation effects in $Co_2Mn_{1-x}Fe_xSi$ Heusler alloys** — •Stanislav Chadov[1], Gerhard H. Fecher[1], Claudia Felser[1], Jan Minár[2], Jürgen Braun[2], and Hubert Ebert[2] — [1]Johannes Gutenberg University Mainz, Germany — [2]Ludwig Maximillians University Munich, Germany

Strongly correlated electron systems possess an important entry among the Heusler materials. Of the special technological interest are $Co_2Mn_{1-x}Fe_xSi$ alloys which being highly spin-polarized systems exhibit the highest known magnetic moments ranging from 5 to 6 $\mu_B$ and the Curie temperatures from 985 to 1100 K. Former theoretical studies evidence the local correlation as an important mechanism responsible for their extreme magnetic properties. We analyze this mechanism by studying the electronic structure with *ab-initio* calculations combining the well-known LSDA approach and the state of the art many-body DMFT scheme. The approach is implemented within the KKR Green's function method. We find both static and dynamic local correlations as an essential ingredient in a description of the electronic structure. Results obtained for the magnetic moments and the photoemission spectra are much improved comparing to the plain LSDA and found to be in a good agreement with experiment. In addition we also discuss the correspondence between the physical properties and the certain types of the many-body interaction.

The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

MA 5.5 Mon 12:00 HSZ 103

**Atom- and bond-resolved analysis of the magnetic anisotropy in multicomponent systems** — •Sergej Subkow[1], Matej Komelj[2], and Manfred Fähnle[1] — [1]Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart, Germany — [2]Jožef Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia

For the understanding of the magnetic anisotropy in multicomponent systems like compounds (e.g., FePt) or multilayer systems it would be helpful to subdivide the total anisotropy energy into contributions arising from various atoms or from various bonds between the atoms. The usefulness and the limitation of such type of analysis is assessed critically for four different approaches.

a) procedures based on the magnetic force theorem [1]

b) the relation of Bruno [2]

c) the covalent bond energy [3]

d) the method of switching off the spin-orbit coupling at various atoms [4].

[1] T. Burkert et al., Phys. Rev. B71, 134411 (2005).
[2] C.-G. Duan et al., Appl. Phys. Letters 92, 122905 (2008).
[3] G. Bester and M. Fähnle, Phys. Rev. B72, 212405 (2005).
[4] M. Komelj, D. Steiauf, and M. Fähnle, Phys. Rev. B73, 134428 (2006).

MA 5.6 Mon 12:15 HSZ 103

**Lifshitz transitions in FePt due to a canted magnetic field** — •Hongbin Zhang and Manuel Richter — IFW Dresden, Helmholtzstraße 20, 01069 Dresden

By density functional calculations, we show that in $L1_0$ FePt, a canted magnetic field can induce changes of the topology of the Fermi surfaces. This is a new driving force for such electronic topological transitions (also called Lifshitz transition) besides pressure, doping, and magnetic field of arbitrary direction. To elucidate its effects, we estimate the variation of thermopower using a simple two-band model. It is shown explicitly, that due to interband scattering, thermopower would have singular behavior at such transitions. However, strong smearing by chemical disorder will make it hard to observe such anomalies experimentally.

MA 5.7 Mon 12:30 HSZ 103

**A new scheme to calculate the exchange coupling tensor** — •Sergey Mankovsky and Hubert Ebert — Dept. Chemie und Biochemie/Phys. Chemie, Universität München, München, Deutschland

A new scheme to calculate the exchange coupling tensor $\underline{\underline{J}}_{ij}$ describing in a phenomenological way the anisotropic exchange coupling of two moments in a magnetically ordered system is presented. The ab-initio approach is based on spin-polarised relativistic multiple-scattering theory within the framework of spin-density functional theory. The scheme is applied to ferromagnetic CrTe as well as the diluted magnetic semiconductor (DMS) system $Ga_{1-x}Mn_xAs$. In the later case the results show that there is a noticeable anisotropy in the exchange coupling present, although not as pronounced as suggested in recent theoretical investigations.

MA 5.8 Mon 12:45 HSZ 103

**Spin-wave excitations from time-dependent density-functional theory** — Manfred Niesert[1], Arno Schindlmayr[2], Christoph Friedrich[1], and •Stefan Blügel[1] — [1]Institut für Festkörperforschung & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich — [2]Department Physik, Universität Paderborn, 33098 Paderborn

Spin waves constitute an important class of low-energy excitations in magnetic solids with a characteristic material-specific dispersion and a direct relation to magnetization dynamics. Until now most theoretical studies were based on the Heisenberg model of localized spins or on the frozen-magnon method, but neither is applicable to investigate the dynamics of spin waves in metallic systems with itinerant electrons. As a possible solution, time-dependent density-functional theory gives access to the full frequency-dependent transverse spin susceptibility, from which not only the spin-wave dispersion but also the corresponding excitation lifetimes and other spectral information can be extracted. We have developed a practical scheme to calculate spin-wave spectra from first principles within this framework and present results for the prototype transition metals Iron, Cobalt and Nickel. Our implementation uses the full-potential linearized augmented plane-wave (FLAPW)

method, and dynamic exchange-correlation effects are in the first instance described by the adiabatic local-density approximation.

MA 5.9 Mon 13:00 HSZ 103

**Electronic structure calculations of uranium compounds** — •Carsten Neise, Manuel Richter, Klaus Koepernik, and Helmut Eschrig — IFW Dresden, P.O.B. 270016, D-01171 Dresden Germany

We performed full-potential density functional theory (DFT) calculations on 5f inter-metallic compounds, which have either tetragonal (FD3M, FM3M, I4/MMM) or hexagonal (P6/MMM) symmetry. We used the local spin density approximation (LSDA) in a full relativistic implementation (http://www.fplo.de) to calculate their magnetic properties. Since it is a known error of LSDA to underestimate the orbital moment, we applied orbital polarisation corrections (OPC) [1,2] to these 5f states.

The magnetocrystalline anisotropy energy (MAE) is connected with orbital moments. Hence OPC affects the MAE. Comparing our results with available experimental data in literature, we find a systematic improvement of orbital moments and MAE with applied OPC. Nevertheless these estimates may be seen as an upper bound.

[1] Eriksson, O. and Brooks, M.S.S. and Johansson, B., Phys. Rev. B. **41** (1990), 7311-7314
[2] Eschrig, H. and Sargolzaei, M. and Koepernik, K. and Richter, M., Europhys. Lett. **72** (2005), 611-617

## MA 6: Invited Talks Hehn / Eimüller

Time: Monday 14:00–15:00 Location: HSZ 04

**Invited Talk** MA 6.1 Mon 14:00 HSZ 04

**Symmetry dependent spin injection from Fe/MgO in single crystal based magnetic tunnel junctions** — •Michel Hehn[1], Fanny Greullet[1], Julien Bernos[1], Coriolan Tiusan[1], Christine Bellouard[1], Francois Montaigne[1], Daniel Lacour[1], Marc Alnot[1], Yuan Lu[1], Gwladys Lengaigne[1], David Halley[2], and Wolfgang Weber[2] — [1]LPM, Vandoeuvre les Nancy (France) — [2]IPCMS, Strasbourg (France)

The transport in crystalline magnetic tunnel junctions (MTJ) attracted the interest of the international community after the theoretical predictions of Butler et al of giant tunnel magnetoresistance (TMR) effects. In these model systems the electrons are classified with respect to the symmetry of their associated electronic Bloch wave function. The large predicted TMR ratio is related to a symmetry dependent attenuation rate within the MgO single crystal barrier combined with a half metallic property of a specific symmetry in the Fe electrode. After a brief introduction to the physics of the transport in Fe/MgO/Fe MTJ, I will show how to exploit the symmetry dependence of the tunnel conductivity to engineer novel MTJs functionalities. We demonstrate that, a suitably chosen Cr(001) epitaxial metallic spacer layer quenches the transmission of particular electronic states, therefore acting as an additional symmetry dependent tunnel barrier for electrons at the Fermi level. Moreover, we show that this ultrathin Cr metallic barrier can promote quantum well states in an adjacent Fe layer. These results confirm the transport mechanism proposed by Butler et al. Extension to other materials will also be discussed.

**Invited Talk** MA 6.2 Mon 14:30 HSZ 04

**Magnetic imaging at the limits of space and time** — •Thomas Eimüller[1,2], Wei He[1], Jie Li[1], Min-Sang Lee[1], Björn Redeker[1], and Stefan Buschhorn[3] — [1]Nachwuchsgruppe Magnetische Mikroskopie, Ruhr-Universität Bochum, 44780 Bochum — [2]Hochschule Kempten, University of Applied Sciences, Bahnhofstr. 61, 87435 Kempten — [3]Institut für Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum

Magnetic technology, driven by "smaller and faster" aims for magnetic imaging methods that obtain simultaneously a high spatial and temporal resolution. For decades this was the domain of optical microscopy. However, recently synchrotron techniques emerged which combine a lateral resolution down to 15 nm with elemental, chemical, spin, and orbital selectivity. Full field (TXM) and scanning (STXM) transmission x-ray microscopy as well as photoemission electron microscopy (X-PEEM) have been used for dynamic magnetic imaging.

Nevertheless, the highest temporal resolution, down to about 200 fs can be obtained by femtosecond laser scanning Kerr microscopy. All-optical two-colour pump-probe experiments reveal variations in the magnetization dynamic of different magnetic dots in arrays. The large temporal resolution enables us to observe higher harmonics of spin waves and nonlinear coupling phenomena in permalloy films. Special coating techniques allow studying the magnetization dynamics of dots with a size below the optical diffraction limit.

Financial support by the DFG via project SFB491-N1 is gratefully acknowledged.

## MA 7: Spin-Dynamics/ Spin-Torque II

Time: Monday 15:15–19:15 Location: HSZ 04

MA 7.1 Mon 15:15 HSZ 04

**Phase-locking of dc current-driven vortex motion to an external signal** — •Ronald Lehndorff[1,2], Daniel E. Bürgler[1], Zbigniew J. Celinski[2], and Claus M. Schneider[1] — [1]Institut für Festkörperforschung und JARA-FIT, Forschungszentrum Jülich GmbH, D-52425 Jülich — [2]Center for Magnetism and Magnetic Nanostructures, University of Colorado at Colorado Springs, CO, USA

The dynamics of magnetic vortices under the influence of magnetic fields and spin-transfer torque has recently been of great interest [1,2]. The gyrotropic motion of vortices, which is their lowest excitation mode, enables the realization of vortex-based spin-torque oscillators [3].

We study the vortex dynamics in nanopillars made of 20nm Fe/6nm Ag/2nm Fe. The 20nm thick Fe layer is structured to a circular disk of 230nm diameter. Due to its size and shape it can hold a magnetic vortex or an onion state. We excite both magnetic structures by dc currents and show that the vortex state is advantageous for the operation of a spin-torque oscillator. Additionally, we study the coupling of the vortex' dynamic mode to externally applied electric hf signals of different frequencies and amplitudes. The observed phase-locking is a prerequisite to achieve sufficient output power for applications since it enables the coupling of a large number of spin-torque oscillators.

[1] B. van Waeyenberge, et al., Nature 444, 461 (2006) [2] R. Hertel, et al., Phys. Rev. Lett. 98, 117201 (2007) [3] V.S. Pribiag, et al., Nature 438, 339 (2005)

MA 7.2 Mon 15:30 HSZ 04

**Current-induced magnetization dynamics in single magnetic-layer nanopillars** — •Sarah Fahrendorf[1,3], Nicolas Müsgens[1,3], Marc Weidenbach[1,3], Matthias Bückins[2,3], Joachim Mayer[2,3], Bernd Beschoten[1,3], and Gernot Güntherodt[1,3] — [1]Physics Institute IIA, RWTH Aachen University, Aachen, Germany — [2]Central Facility for Electron Microscopy, RWTH Aachen University, Aachen, Germany — [3]JARA-Fundamentals of Future Information Technology

The current-induced generation of spin waves in Cu/Co/Cu single magnetic-layer nanopillar devices with asymmetric Cu leads is investigated by means of transport and microwave probes at room temperature. The magnetic field is applied perpendicular to the Co layer. Molecular beam epitaxy is used to deposit the thin film stack in prefabricated nanostencil masks with lateral dimensions below 100 nm. Magneto-transport measurements show peaks and dips in the differential resistance for high negative current densities $j < -2 \cdot 10^8$ A/cm$^2$ and external magnetic fields above $|1.5\,\mathrm{kOe}|$. (Negative current is defined as electron flow from the thin to the thick copper layer.) These nonhysteretic features are due to a continuous change of resistance and can be correlated with measured spin wave excitations. At low fields we measure excitation frequencies which decrease with increasing ab-

solute current, whereas the opposite dependence is found at higher fields.
Work supported by DFG through SPP1133

MA 7.3 Mon 15:45 HSZ 04

**Influence of lead material on spin-transfer torque in MgO based tunnel junctions** — •Christian Heiliger[1], Asma H. Khalil[1], and Mark D. Stiles[2] — [1]I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany — [2]Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, MD 20899-6202, USA

We report calculations of the spin-transfer torque in MgO based tunnel junctions using a non-equilibrium Keldysh formalism implemented in the Korringa-Kohn-Rostoker Green's function method [1]. Our calculations for Fe/MgO/Fe tunnel junctions show excellent quantitative agreement of the voltage dependence with experimental observation [2]. In this talk we discuss the influence of other lead materials on the bias dependence of the spin-transfer torque. We show the importance of the $\Delta_1$ band gap in the ferromagnetic materials. In particular, the bias dependence of the spin-transfer torque is changed drastically if the applied bias voltage is larger than the $\Delta_1$ band gap. This work has been supported in part by the NIST-CNST/UMD-NanoCenter Cooperative Agreement.

[1] C. Heiliger, M. Czerner, B. Yu. Yavorsky, I. Mertig, M. D. Stiles, J. Appl. Phys. **103**, 07A709 (2008)
[2] C. Heiliger and M.D. Stiles, Phys. Rev. Lett. **100**, 186805 (2008)

MA 7.4 Mon 16:00 HSZ 04

**Impact of lateral size of nanopillars on spin wave spectra in magnetic tunnel junctions** — •Annerose Helmer[1], Sven Cornelissen[2,3], Thibaut Devolder[1], Joo-Von Kim[1], Paul Crozat[1], Maaike Op de Beeck[2], Liesbet Lagae[2,4], and Claude Chappert[1] — [1]Institut d´ Electronique Fondamentale, CNRS UMR 8622, Bât. 220, Université Paris-Sud 11, 91405 Orsay, France — [2]IMEC, NextNS, Kapeldreef 75, 3001 Leuven, Belgium — [3]ESAT, KU Leuven, Leuven, Belgium — [4]Natuurkunde en Sterrenkunde, KU Leuven, Leuven, Belgium

As dynamic eigenexcitations of a magnetic system, thermally excited spin waves constitute an excellent probe for the intrinsic magnetic properties of nanopillar devices, such as MRAM. In particular, they provide information on the spatial orientation of the magnetization in the different layers of the pillar. We have studied spin wave spectra (mode frequency versus magnetic field) in rectangular shaped nanopillars of lateral dimensions 50 x 100, 75 x 140, and 100 x 200 nm2, patterned from MgO-based magnetic tunnel junctions, which were deposited at Singulus Technologies AG. The devices were subjected to in-plane magnetic fields either along the long edge (easy axis) or the short edge (hard axis) of the rectangle. For both field directions the spectra become more complex with larger lateral pillar sizes: the number of modes increases, their relative intensity changes, while the spectra become progressively deformed - phenomena, which can be explained by the formation of edge domains. Moreover, there is clear evidence that not even for the smallest pillar size the magnetization is uniform.

MA 7.5 Mon 16:15 HSZ 04

**Spin-torque shot noise** — •Jacek Swiebodzinski[1], Alexander L. Chudnovskiy[1], and Alex Kamenev[2] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, D-20355 Hamburg, Germany — [2]Department of Physics, University of Minnesota, Minneapolis, Minnesota 55455, USA

The role of spin shot noise in magnetization dynamics, though being the dominant contribution to magnetization noise at low temperatures, remains largely unexplored yet. We propose a stochastic version of the Landau-Lifshitz-Gilbert equation taking into account both, thermal and nonequilibrium sources of noise and apply this equation to a system consisting of a free ferromagnetic layer in contact with a fixed ferromagnet. We derive the noise correlator in the magnetic tunnel junction setup using the Keldysh technique. We solve the corresponding Fokker-Planck equations and show that the spin shot noise yields to the experimentally observed nonmonotonic dependence of the precession spectrum linewidth on the current.

MA 7.6 Mon 16:30 HSZ 04

**Influence of microwave irradiation on the spin current induced precession** — •Nathalie Reckers[1], Julien Cucchiara[2], Stéphane Mangin[2], Ralf Meckenstock[1], Horst Zähres[1], Günter Dumpich[1], and Jürgen Lindner[1] — [1]Universität Duisburg-Essen, Standort Duisburg, Institut für Physik und CeNIDE, AG-Farle, Lotharstr. 1, 47048 Duisburg, Germany — [2]Nancy-Université, Laboratoire de Physique des Matériaux, CNRS, Boîte Postal 239, 54506 Vandoeuvre les Nancy, France

Nano-structured magnetic pillars composed of multi-layers containing a free layer and a fixed layer are investigated for their magnetoresistance behaviour. Measurements were conducted using a fixed alternating current in the $\mu$A range and a variable direct current in the mA range. The measurements can be esplained in the framework of spin-torque effects. For high direct currents a precession of the magnetization is observed. By increasing the direct current the range of the precession is shifted to higher magnetic fields. Moreover, the influence of an irradiated microwave in the GHz-range on the precession is investigated. For this purpose a fixed direct current is chosen while the microwave frequency is varied.

MA 7.7 Mon 16:45 HSZ 04

**Spin transfer torque in pillar arrays investigated by ferromagnetic resonance** — •Oliver Posth, Günter Dumpich, and Jürgen Lindner — Fachbereich Physik, Experimentalphysik, AG Farle, Universität Duisburg-Essen, 47048 Duisburg, Germany

It is well known from other studies that a spin polarized current in a ferromagnet exerts a torque on the magnetic moments by spin-momentum transfer. This current can be used to switch the magnetization of one ferromagnetic layer in a ferromagnetic metal / nonmagnetic metal / ferromagnetic metal spin valve device. We investigate the influence of the spin polarized current on the damping in the ferromagnetic layers of the pillar structures directly by means of ferromagnetic resonance (FMR). The pillars are prepared and electrically contacted by high-resolution electron beam lithography (HR-EBL) and electron beam evaporation in a multi-step process. The FMR measurements are carried out on a pillar array, in which all pillars are connected in series, so that we are able to increase the current density to a value being sufficient to observe the effect of the spin transfer torque. The temperature rise due to high current density is avoided by a cooling set-up. An influence of the spin torque effect on the intrinsic damping in the ferromagnet can be observed for in plane orientation as well for out of plane orientation of the magnetic field. The influence of the Oersted-field is estimated in addition. We further investigate the domain structure of the pillars in an applied field by means of micromagnetic calculations. This work is supported by the Deutsche Forschungsgemeinschaft within SFB 491.

MA 7.8 Mon 17:00 HSZ 04

**Light-controlled spin switch in linear metallic chains** — •Tobias Hartenstein, Georgios Lefkidis, and Wolfgang Hübner — Department of Physics and Research Center OPTIMAS, Kaiserslautern University of Technology, PO Box 3049, 67653 Kaiserslautern, Germany

We present an ab initio theory for ultrafast spin dynamics in highly correlated materials [1], which includes the spin-orbit interaction and the interaction with external magnetic fields. In particular we analyze optically induced spin-switch processes in linear metallic chains with a magnetic center at each end; in particular Fe, Co or Ni atoms separated by Na atoms. The electronic structure of the ground and excited states of these clusters is determined using high-level quantum chemistry methods. We show that the spin density for low-lying triplet states is located at one magnetic center only. Through the influence of a laser pulse, transitions between different many-particle states are induced and local spin-switch processes can take place. For the purpose of ultrafast magnetic switching, we consider $\Lambda$-processes with laser pulses optimized by a genetic algorithm [2]. It is shown that local spin switch due to optical electron excitation can occur on a subpicosecond time scale [3].

[1] G. Lefkidis and W. Hübner Phys. Rev. B 76 014418 (2007)
[2] T. Hartenstein, C. Li, G. Lefkidis and W. Hübner J. Phys. D: Appl. Phys. 41 164006 (2008)
[3] T. Hartenstein, G. Lefkidis and W. Hübner J. Phys. D: Appl. Phys. (in press)

**15 min. break**

MA 7.9 Mon 17:30 HSZ 04

**Coherent switching of the vortex core polarization by monopolar magnetic field pulses** — •Markus

Weigand[1], Michael Curcic[1], Bartel Van Waeyenberge[1], Arne Vansteenkiste[3], Vitalij Sackmann[1], Hermann Stoll[1], Tolek Tyliszcak[2], Georg Woltersdof[4], Christian Back[4], and Gisela Schütz[1] — [1]MPI f. Metallforschung, Stuttgart — [2]ALS, Berkeley, USA — [3]Ghent University, Belgium — [4]Uni. Regensburg

Time-resolved imaging of vortex core reversal in 500nm large Permalloy Landau structures has been achieved by 'pump-and-probe' measurements at a scanning-transmission X-ray microscopy (STXM), combining <100 ps and ˜30 nm time and lateral resolution. A fast data aquisition system recorded up to 1000 time frames simultaneously, capturing the entire excitation and relaxation cycle of the vortex core.

The vortex polarization could be switched by in-plane monopolar magnetic pulses as low as 5-15mT, depending on sample geometry. This was achieved by taking advantage of a 'resonance timing' of the rising and falling pulse edges of the excitation field pulse: Provided a correct adjustment of the pulse length, the vortex is accelerated by the rising edge as well as by the falling edge, causing a doubling of the gyration amplitude. When a critical velocity is reached, the vortex core switches.

The excitation and relaxation sequences as shown in our movies and the meassured switching thresholds agree well with micromagnetic simulations. Applications for current (spin torque) induced vortex core reversal will be addressed, too.

MA 7.10 Mon 17:45 HSZ 04

**A Current Controlled Random-Access Memory Based On Magnetic Vortex Handedness** — •Stellan Bohlens[1], Benjamin Krüger[1], André Drews[2], Markus Bolte[2], Guido Meier[2], Ulrich Merkt[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Hamburg, Germany — [2]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Hamburg, Germany

We propose a memory element based on a magnetic vortex which is operated simultaneously by a spin-polarized current and a magnetic field. [1] Starting from our recent analytical description of the vortex motion [2,3] we have developed a scheme that allows to transfer the vortex into an unambiguous binary state. This state is defined as the product of chirality and core polarization named the vortex handedness.

The VRAM is non-volatile and the stability requirements for a memory device are fulfilled: the vortex state is stable against temperature and static magnetic fields as long as they remain in the millitesla regime. Foremost, the VRAM is a fast memory concept which needs no reading and no erasing before writing.

[1] S. Bohlens, et al., Appl. Phys. Lett. 93, 142508 (2008)
[2] M. Bolte, et al., Phys. Rev. Lett. 100, 176601 (2008)
[3] B. Krüger, et al., Phys. Rev. B 76, 224426 (2007)

MA 7.11 Mon 18:00 HSZ 04

**electrical switching of the magnetic vortex core polarities in a magnetic circular disk** — •June-Seo Kim[1], Olivier Boulle[1], Steven Verstoep[1], Mathias Kläui[1], Ulrich Rüdiger[1], and Giancarlo Faini[2] — [1]Fachbereich Physik, Universität Konstanz, Universitätsstr. 10, D-78457 Konstanz, Germany — [2]Phynano team, LPN, Route de Nozay, 91460 Marcoussis, France

The recent discovery that a spin-polarized current can induce magnetization dynamics (DW) without an applied magnetic field has created interest in field-induced oscillations of confined spin structures. Especially, a vortex domain wall in a nanowire pinned at an artificial notch can be driven into large amplitude vortex core oscillations by a high frequency alternative current for very low current density (˜109 A/m2) [1]. Here, we have observed the resonance of a single magnetic vortex core in an asymmetric Py disk, which allows a better control of the energy landscape felt by the magnetic vortex core. We have measured variations of the dc voltage (homodyne detection) for some particular resonance frequencies that indicate the resonance excitation of the vortex. The shape of the DC voltage vs. frequency curve can be determined by the relative polarities (pointing up and down) of the vortex. Moreover, the eigen-frequencies of the magnetic vortex cores are changed as a function of the amplitudes and angles of applied fields from which the 3D potential landscape can be ascertained. This work is supported by the EU-RTNs SPINSWITCH (MRTN-CT-2006-035327). [1] D. Bedau, M. Kläui et al., Phys. Rev. Lett. 99, 146601 (2007); Phys. Rev. Lett. 101 (in press 2008)

MA 7.12 Mon 18:15 HSZ 04

**Polarization selective switching of magnetic vortices with rotating currents** — •Michael Martens[1], Thomas Kamionka[1], Markus Bolte[1], Benjamin Krüger[2], Kang Wei Chou[3], Tolek Tyliszczak[3], Michael Curcic[4], Bartel Van Waeyenberge[4], Hermann Stoll[4], and Guido Meier[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany — [2]I. Institut für Theoretische Physik, Universität Hamburg, Germany — [3]Advanced Light Source, LBNL, Berkeley, CA, USA — [4]Max-Planck-Institut für Metallforschung, Stuttgart, Germany

Magnetic vortices in micron-sized disks and squares are interesting objects of research for understanding fundamental field- and current-induced magnetization dynamics and offer new concepts for data storage devices. The selective switching of the vortex-core polarization, i.e the out-of-plane component of the magnetization, by resonant excitation has been shown both theoretically [1] and experimentally [2]. Here we present our experiments on polarization reversal using rotating currents through a permalloy square. The frequency and power dependent excitation is measured systematically by means of time-resolved scanning transmission X-Ray microscopy (STXM). The phase of the gyration with respect to the exciting current yields information about the Oersted-field and the spin-torque driven contribution to the excitation. In addition we found experimental confirmation of halo-formation near the switching threshold.

[1] S. K. Kim et al., Appl. Phys. Lett. **92**, 022509 (2008).
[2] M. Curcic et al., Phys. Rev. Lett. **101**, 197204 (2008).

MA 7.13 Mon 18:30 HSZ 04

**Spin wave mode spectra of continuous and structured amorphous CoFeB films** — •Henning Ulrichs, Jakob Walowski, Andreas Mann, Benjamin Lenk, Gerrit Eilers, and Markus Münzenberg — I. Physikalisches Institut, Universität Göttingen

Magnetization dynamics within the GHz-range in amorphous CoFeB thin-films are investigated using all optical pump probe experiments. After a fs-laser pulse excites the film, a second time delayed pulse is utilized to record the time dependent magnetization curve M(t) exploiting the time-resolved magneto-optical Kerr effect (TRMOKE). As an experimental variable a bias magnetic field 0mT$\leq \mu_0$H $\leq$ 150mT in an angle to the samples surface between 0° and 30° is applied. From Fourier transformations mode spectra $\omega$(H) are obtained. By comparison with theoretical dispersion curves different spin wave modes are identified. In the thinnest films (5nm to 25nm) only uniform precession is found. From the magnetization curves of the 25nm sample a very low Landau-Lifshitz-Gilbert damping factor of $\alpha \approx$0.006 is extracted. For thicker films (50nm to 225nm) also Damon-Eshbach modes and perpendicular standing spin waves can be seen. In a second step we structured the surface of a 125nm CoFeB film with a focused ion beam. Two-dimensional cubic lattices of holes having a diameter of 5$\mu$m and a lattice constant between 15 and 23$\mu$m were fabricated. The distances were chosen close to the wave length of the propagating DE modes. The mode spectra of the structured regions are significantly altered, indicating Blochstates of DE waves forming due to the periodic potential. Research is supported by DFG Schwerpunkt SPP 1133.

MA 7.14 Mon 18:45 HSZ 04

**Local control of ultra fast dynamics in magnetic nanoparticles** — •Alexander Sukhov[1,2] and Jamal Berakdar[2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle/Saale — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle/Saale

Using the local control theory [1] and the Landau-Lifshitz-Gilbert equation of magnetization motion for a Stoner nanoparticle we deduce analytical expressions for ultra short magnetic pulses that steer the magnetization to a predefined state. Additionally, we obtain conditions for a monotonic positive change of the polar angle providing thus a magnetization switching. Minimal field amplitudes of the pulses needed for switching upon the polar angle for two angle shifts between the magnetization and the field are achieved. Numerical implementation of the Landau-Lifshitz-Gilbert equation extended for finite temperatures allows for more freedom in variation of pulse form, duration and anisotropy types and approves/supplements the analytical results.

[1] R. Kosloff, A. D. Hammerich and D. J. Tannor, Phys. Rev. Lett. **69**, 2172 (1992).

MA 7.15 Mon 19:00 HSZ 04

**Investigating the Spin Dynamics in Nanostructures at Finite Temperature** — •David Bauer, Samir Lounis, Phivos Mavropoulos, and Stefan Bluegel — Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

Magnetic nanoparticles are promising candidates for future information storage. We developed a spin dynamics code and investigated the dynamics of the magnetization in nanoscale systems on the basis of a classical spin model including Heisenberg exchange, magnetic anisotropy, external magnetic fields and dipole-dipole interaction. The spin-system is coupled to a heatbath through a stochastic force within the Langevin approach [1]. This requires the solution of the stochastic Landau-Lifschitz equations. Thermodynamical properties are shown to be in excellent agreement to those obtained by Monte Carlo simulations. The complexity $\mathcal{O}(n^2)$ of the direct evaluation of the dipolar interaction was reduced to $\mathcal{O}(n \log n)$ by the use of multipole methods. Preliminary results are presented on the switching time of different sized nano-islands which are in agreement to the Arrhenius-Néel-law.
This work was supported by the ESF EUROCORES Programme SONS under contract N. ERAS-CT-2003-980409 and the Priority Programme SPP1153 of the DFG grant Bl 444/8-1.
[1] V. P. Antropov, S. V. Tretyakov, and B. N. Harmon, J. Appl. Phys. **81**, 3961 (1997).

## MA 8: Magnetic Coupling Phenomena / Exchange Bias

Time: Monday 15:15–18:30 Location: HSZ 401

MA 8.1 Mon 15:15 HSZ 401

**Exchange bias for a ferromagnetic film coupled to a spin glass** — •Ulrich Nowak[1] and Klaus Usadel[2] — [1]Fachbereich Physik, Universität Konstanz — [2]Fachbereich Physik, Universität Duisburg-Essen

For a model system consisting of a ferromagnetic layer exchange coupled to a spin glass extensive Monte Carlo simulations are performed. For the spin glass the standard short range Gaussian model is used. Exchange bias is observed as a result of a frozen spin glass state. The exchange bias fields are calculated for different temperatures, cooling fields and thicknesses of the spin glass layer and the training effect is investigated. A major result of our simulations is that the bias field decreases with increasing strength of the cooling field in qualitative agreement with recent experiments.

MA 8.2 Mon 15:30 HSZ 401

**Imaging of exchange bias in Co/FeMn bilayers on the nm length scale** — •Florian Kronast, Joachim Schlichting, Florin Radu, Mishra Shrawan, and Hermann A. Dürr — Bessy, Helmholtz Zentrum Berlin, Germany

We investigated the magnetic interface coupling in Co/FeMn bilayers by photoemission electron microscopy (PEEM) in combination with magnetic circular dichroism (XMCD). Using a special sample holder with integrated micro-magnetic yoke we could apply magnetic fields up to 25mT during imaging, without significant reduction of the spatial resolution.

We studied the domain structure in the ferromagnetic Co layer and the arrangement of magnetic moments at the interface of the antiferromagnet as a function of applied magnetic field. Analyzing the local hysteresis loop of each pixel in the recorded images we could map local variations of exchange bias and coercitivity in the ferromagentic Co layer. We can correlate these local variations of exchange bias and coercitivity with the arrangement of magnetic moments at the ferromagnet / antiferromagnet interface.

MA 8.3 Mon 15:45 HSZ 401

**Magnetic domain imaging of perpendicular exchange-coupled FM/AFM systems by soft x-ray holography** — •Carsten Tieg[1], Erika Jiménez[2], Julio Camarero[2,3], Jan Vogel[4], Christophe Arm[5], Gilles Gaudin[5], Eric Gautier[5], Bernard Rodmacq[5], Bernard Dieny[5], and Rodolfo Miranda[2,3] — [1]ESRF, B.P 220, 38043 Grenoble, France — [2]Dpto. de Física de la Materia Condensada-UAM, 28049 Madrid, Spain — [3]IMDEA-Nanociencia, Campus UAM, 28049 Madrid, Spain — [4]Institut Néel-CNRS, 38042 Grenoble, France — [5]SPINTEC (CNRS/CEA) URA 2512, 38054 Grenoble, France

Magnetic domain imaging by soft x-ray holography was employed to investigate the exchange coupling phenomenon in layered systems composed of ferromagnetic (FM) $[Co/Pt]_n$ multilayers with perpendicular anisotropy and antiferromagnetic (AFM) IrMn and FeMn films. We have exploited both element selectivity and the ability to image in applied magnetic fields to follow the magnetization reversal along the hysteresis loop with sub-micrometer resolution. Our setup allows holographic imaging as well as absorption measurements by recording the transmitted intensity or the total electron yield signal. The sensitivity limits of this technique were explored by imaging the uncompensated moments in the AFM layer, which correspond to an equivalent thickness of about one monolayer only. Our domain images show that the uncompensated AFM moments are align parallel to the magnetization of the FM layer.

MA 8.4 Mon 16:00 HSZ 401

**Oscillatory indirect exchange in adatom pairs and triplets** — •Jens Wiebe[1], Lihui Zhou[1], Samir Lounis[2], Elena Y. Vedmedenko[1], Focko Meier[1], Peter H. Dederichs[2], Stefan Blügel[2], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg — [2]Institut für Festkörperfoschung and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich

Impurity spins in nonmagnetic metals induce an oscillatory spin-polarization in the conduction electrons, which mediates an alternately ferro- and anti-ferromagnetic coupling between two impurities. This "indirect magnetic exchange" is well known from layered systems investigated in the course of the discovery of the GMR effect and crucially depends on the atomic discreteness within the ferro- and the non-magnetic spacer layers [1]. Here, we measure the indirect exchange between two Co adatoms on a Pt(111) surface with distances of several lattice spacings and compare to calculations using the full-potential Korringa-Kohn-Rostoker method. We have straight experimental access to the exchange energies by measuring the magnetization of each adatom as a function of an applied magnetic field (single-atom magnetization curves [2]) and compare to Monte-Carlo simulations. Indeed, we observe a damped oscillatory behaviour with coupling strengths on the order of 0.1meV reproduced by the calculations. Additionally, we demonstrate magnetic frustration in adatom triplets with almost equilateral shape. [1] P. Bruno and C. Chappert, Phys. Rev. B 46, 261 (1992). [2] F. Meier et al., Science 320, 82 (2008).

MA 8.5 Mon 16:15 HSZ 401

**Monte-Carlo Study of Hysteretic Properties of Atomic Pairs and Triplets** — •Elena Y. Vedmedenko, Jens Wiebe, and Roland Wiesendanger — University of Hamburg, Jungiusstr. 11, 20355 Hamburg

It has been recently demonstrated that the thermodynamic behavior of single magnetic atoms, atomic pairs and triplets on conducting substrates, which often possess giant magnetic anisotropy, may be successfully described in the framework of the Langevin dynamics [1,2]. As the Langevin distribution can be very well reproduced by means of Monte-Carlo simulations we have studied the hysteretic properties of single atoms and their ensembles in the framework of this technique. For the atomic pairs and triplets coupled by RKKY-type exchange interactions the time-averaged and time-resolved magnetization curves on each individual atom have been investigated. We demonstrate that the hysteretic behavior is very sensitive to the type of interaction (ferromagnetic or antiferromagnetic) as well as to magnetic surrounding, and is determined by the field-dependent paramagnetic switching of individual moments. The occupancy of two energy minima depends on the above mentioned parameters and varies for different atoms. The time-averaged Monte-Carlo data mimic recent experiments performed by spin-polarized scanning tunneling microscopy and reveal very peculiar magnetization curves, unusual for macroscopic magnets.

[1] P. Gambardella et al., Science 300, 1130 (2003) [2] F. Meier, L. Zhou, J. Wiebe, R. Wiesendanger, Science 320, 82 (2008)

MA 8.6 Mon 16:30 HSZ 401

**Thickness Dependence of the Antiferromagnetic Ordering Temperature in Ni/$Fe_xMn_{1-x}$ Bilayers** — •Miriam Stampe, Tobias Homberg, and Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

The ordering temperature of ultrathin single-crystalline antiferromagnetic (AFM) $Fe_xMn_{1-x}$ layers is influenced by magnetic proximity

effects due to a ferromagnetic overlayer. We have determined this ordering temperature $T_{AFM}$ from the polar magneto-optical Kerr effect response of out-of-plane magnetized Ni overlayers (15 ML). Systematic investigations on the influence of the AFM layer thickness (6-10 ML) and composition ($0.4 < x < 0.6$) in these $Ni/Fe_xMn_{1-x}/Cu(001)$ bilayers on $T_{AFM}$ were performed. The ordering temperature is determined from the discontinuity in the temperature dependence of the coercive field. With increasing thickness, the ordering temperature rises, while the influence of the $Fe_xMn_{1-x}$ composition is much smaller than in $Co/Fe_xMn_{1-x}/Cu(001)$ bilayers [1].

[1] F. Offi et al., Phys. Rev. B 66, 064419 (2002)

Financial support by the DFG (KU1115/7-2) is acknowledged.

MA 8.7 Mon 16:45 HSZ 401

**Training Induced Positive Exchange Bias in NiFe/IrMn Bilayers** — •S. K. Mishra, F. Radu, H. A. Dürr, and W. Eberhardt — Albert-Einstein Str. 15, D-12489, Berlin, Germany

Positive exchange bias has been observed in the $Ni_{81}Fe_{19}/Ir_{20}Mn_{80}$ bilayer system via soft x-ray resonant magnetic scattering. After field cooling of the system through the blocking temperature of the antiferromagnet, an initial conventional negative exchange bias is removed after training i. e. successive magnetization reversals, resulting in a positive exchange bias for a temperature range down to 30 K below the blocking temperature (450 K). This new manifestation of magnetic training effect is discussed in terms of metastable magnetic disorder at the magnetically frustrated interface during magnetization reversal.

MA 8.8 Mon 17:00 HSZ 401

**Exchange bias in varied PtMn/CoFe systems** — •Matthias Hawraneck[1,2], Wolfgang Raberg[1], Jürgen Zimmer[1], Klemens Prügl[1], Thomas Bever[1], and Lambert Alff[2] — [1]Infineon Technologies AG, Am Campeon 1-12, 85579 Neubiberg — [2]Institut für Materialwissenschaften, TU Darmstadt, Petersenstr. 23, 64287 Darmstadt

In magnetic spin valves, used e.g. in HDD read heads, the exchange bias (EB) is used to fix the magnetization of one layer, the so called "pinned layer". A very important requirement of spin valves in such applications is their stability with respect to temperature and magnetic field. At elevated temperatures interlayer diffusion degrades the spin valve [1]. In combination with temperature a magnetic field can influence the EB and thus the spin valve performance. We investigated the influence of various parameters in the PtMn deposition regarding the EB strength and stability. We observe that the gas flow at the sputtering process, the annealing temperature during the PtMn formation and the seed layer thickness show big influence on initial performance and stability.

[1] M. Hawraneck et. al., Appl. Phys. Lett. 93 012504 (2008)

MA 8.9 Mon 17:15 HSZ 401

**Successive antiferromagnetic phase transitions in $\alpha$-MnS probed by the exchange bias effect** — •Pavel Borisov[1], Xi Chen[2], Andreas Hochstrat[1], and Wolfgang Kleemann[1] — [1]Angewandte Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Physics, South China University of Technology, Guangzhou, P.R. China

The exchange bias (EB) probe is applied to test the magnetic properties of a material with two successive antiferromagnetic (AF) phase transitions [1]. $\alpha$-MnS has been claimed to reveal a second-order one at $T_{C1} = 152$ K and a discontinuous one at $T_{C2} = 129$ K. A cubic paramagnetic state (phase I) and a slightly rhombohedrally distorted fcc AF spin order (phase II) similar to that in NiO are observed at $T > T_{C1}$ and $T_{C2} < T < T_{C1}$, respectively. However, there was a debate about the spin structure below $T_{C2}$ (phase III).

The EB effect of the heterolayer structure $\alpha$-MnS(111)/Fe(1.5 nm)/Pt(3 nm) arises below $T_{C1}$ and maximizes at $T_{C2}$, below which it vanishes steplike in parallel with a sudden increase of the coercive field of the Fe layer, $H_C$. EB recovers again below the second blocking temperature, $T_{B2} \approx 25$ K. The abrupt vanishing of $H_{EB}$ and the step-like increase of $H_C$ below $T_{C2}$ comply with a first-order AF spin reorientation transition of $\alpha$-MnS to phase III. The strong enhancement of $H_C$ observed in the phase III corroborates the conjectured multi-$k$ spin structure.

[1] X. Chen, A. Hochstrat, P. Borisov, W. Kleemann, submitted to Appl. Phys. Lett. (2008).

MA 8.10 Mon 17:30 HSZ 401

**Influence of Rippled Substrate Morphology on the Interlayer Exchange Coupling in Fe/Cr/Fe Thin Films** — •Michael Körner, Maciej Oskar Liedke, Thomas Strache, Siarhei Dzenisevich, Adrian Keller, Stefan Facsko, and Jürgen Fassbender — Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany

We have investigated the interlayer exchange coupling in Fe (4 nm)/Cr ($x$ nm)/Fe (4 nm) thin film trilayers ($x$=0–5 nm) deposited on rippled armorphous silicon substrates. The substrate surface was periodically modulated (periods of 20 nm, 35 nm, and 50 nm) by $Ar^+$ ion erosion. The influence of the resulting surface and interface structure on the magnetic properties has been investigated by magneto-optical Kerr effect (MOKE). We found an orange peel type coupling, predicted by Néel's theory and, due to the morphology of the magnetic layers, a strong uniaxial magnetic anisotropy in the system.

This work is supported by DFG grant FA 314/6-1.

MA 8.11 Mon 17:45 HSZ 401

**Role of interface alloying on the exchange bias in Fe/Cr bilayers** — •Syed Rizwan Ali, Muhammad Bilal Janjua, Marian Fecioru-Morariu, Coen J. P. Smits, and Gernot Güntherodt — Physikalisches Institut (IIA), RWTH Aachen University, 52056 Aachen, Germany

Exchange bias (EB) in polycrystalline Fe/Cr bilayers has been investigated for either molecular beam epitaxy (MBE) grown or sputtered samples. The EB field ($H_{EB}$) in both series of samples changes its sign as a function of temperature. This zero crossing temperature ($T_0$) was found to increase with the thickness of the Cr layer. The positive part of the $H_{EB}$ shows a maximum and then decreases with temperature up to the blocking temperature of the Cr film. The coercive field $H_C$ was also found to vary in close correlation with $H_{EB}$, exhibiting a maximum near $T_0$. The results are explained by considering a chemically interdiffused Fe/Cr interface, where the interface alloying between Fe and Cr drives Cr into a spin glass (SG) phase. The interfacial exchange interaction between the SG and the ferromagnet is found to be responsible for the observed temperature dependence and sign change of $H_{EB}$ in our samples. $H_{EB}$ of samples containing the intentionally deposited Cr-Fe SG alloy underneath the Fe overlayer show all the features observed in our Fe/Cr bilayer samples, thereby corroborating our arguments.

MA 8.12 Mon 18:00 HSZ 401

**Pinned and rotatable magnetic moments in the MnPd/Fe exchange bias system** — •Sebastian Brück[1], Xiaosong Ji[2], Gisela Schütz[1], Kannan M. Krishnan[2], and Eberhard Goering[1] — [1]Max-Planck-Institut für Metallforschung, Heisenbergstrasse 3, D-70569 Stuttgart, Deutschland — [2]Dept. of Materials Science and Engineering, University of Washington, Seattle, USA

The element-specific magnetic structure of an epitaxially grown $Mn_{52}Pd_{48}$/Fe exchange bias system at the antiferromagnet/ferromagnet interface has been investigated by soft X-ray magnetic circular dichroism and resonant magnetic reflectivity. The magnetic reflectivity measurements were carried out at the UE56/2-PGM1 beamline at BESSY II using our newly developed UHV reflectometer [1]. A complex magnetic interfacial configuration, consisting of a 2-monolayer thick induced ferromagnetic region, and pinned uncompensated Mn moments that reach far deeper, is found in the antiferromagnet [2]. Proof for the direct relationship between the pinned Mn moments and the exchange bias loop shift is found from comparison of measurements parallel and perpendicular to the field cooling direction.

[1] S. Brück et al. *Rev. Sci. Instrum.* **79,** 083109 (2008)
[2] S. Brück et al. *Phys. Rev. Lett.* **101,** 126402 (2008)

MA 8.13 Mon 18:15 HSZ 401

**Tuning exchange spring magnets by ion irradiation and annealing: X-ray investigations** — Jürgen Fassbender[1], Jörg Grenzer[1], •Olga Roshchupkina[1], Y. Choi[2], J. S. Jiang[2], and S. D. Bader[2] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P. O. Box 51 01 19, 01314 Dresden, Germany — [2]Materials Science Division, Argonne National Laboratory, Argonne, Illinois 60439

The coupling effectiveness of the exchange spring effect can be influenced by the interface structure between hard and soft magnetic films. We have investigated the structural and magnetic properties of an $Fe/Sm_2Co_7$ exchange spring bilayer system after annealing and after low-energy ion irradiation. To study the interface properties X-ray

reflectivity (XRR) measurements were carried out. From the XRR measurements it was shown that annealing influences the roughness of the layer surfaces causing an almost symmetrical broadening of the interfacial layers. Irradiation induces changes in the top three layers and the most pronounced effect upon irradiation is a change in electron density of the first two top layers and an interface broadening between Fe and $Sm_2Co_7$. In contrast annealing after irradiation triggers a material flow influencing the whole irradiated layers. The annealing afterwards therefore influences mainly the Fe layer by creating an $Fe/Sm_2Co_7$ intermixed region.

## MA 9: Surface Magnetism II

Time: Monday 15:15–17:00 Location: HSZ 403

MA 9.1 Mon 15:15 HSZ 403

**Correlation between structural, electronic and magnetic properties on nm-small Co islands** — •Hirofumi Oka, Guillemin Rodary, Sebastian Wedekind, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120, Halle, Germany

We used spin-polarized low-temperature scanning tunneling microscopy and spectroscopy in field to study the correlation between local magnetic and electronic properties within single Co nano-islands. Differential conductance (dI/dV) hysteresis loops, which we produce by plotting the dI/dV signal while changing the external magnetic field [1], are analyzed. We measured spatially-resolved hysteresis loops as a function of position on single Co islands. Co islands grown on Cu(111) clearly show spin-polarized $d_{z^2}$ resonant states around the center of the island.[2] Strain-induced structural relaxations in the islands affect the energy position of the states close to the edge of the island.[3] Clear ferromagnetic dI/dV hysteresis loops were observed within the area where the Co island show the resonant states. Just around the edge, the resonant states are strongly diminished in intensity and "rim states" [4] develop. We present dI/dV hysteresis loops measured close to the island edge and discuss the results, also in view of recent work [4].

[1] G. Rodary, S. Wedekind, D. Sander, and J. Kirschner, JJAP (in press). [2] L.Diekhöner *et al.*, PRL 90, 236801 (2003). [3] M. V. Rastei *et al.*, PRL 99, 246102 (2007). [4] O. Pietzsch *et al.*, PRL 96, 237203 (2006).

MA 9.2 Mon 15:30 HSZ 403

**Magnetic properties of Co and Fe on Pt(111), Rh(111) and Pd(111) : From single atoms to ultrathin films** — •Anne Lehnert[1], Stefano Rusponi[1], Markus Etzkorn[1], Géraud Moulas[1], Pietro Gambardella[2], Peter Bencok[3], and Harald Brune[1] — [1]IPN, EPF-Lausanne, Switzerland — [2]CREA and Catalan Institute of Nanotechnology, — [3]ESRF, Grenoble, France

Single atoms of Co on Pt(111) are known to have a giant magnetic anisotropy energy (MAE) of 9.3 meV/atom [1]. This is due to the reduced coordination and the strong spin-orbit coupling of the Pt 5d-states. In order to study the contribution of a highly polarizable substrate to the MAE, we investigated single Co atoms on Pd(111) and Rh(111) using x-ray magnetic circular dichroism (XMCD). We find a decreasing MAE moving from a 5d-substrate (Pt) to 4*d*-substrates (Pd and Rh). Co has a large orbital moment $L$ of about 0.7 independent of the substrate. The easy axis is out-of-plane for Pt(111) and Pd(111) whereas it is in-plane for Co/Rh(111). Fe has on all substrates an out-of-plane easy axis, a very small anisotropy energy, and a $L/S$ ratio of about 0.1. With increasing coverage the coordination number of the adatom increases and generally leads to a reduced MAE and orbital moment compared to the single atom. We measure one monolayer of Co and Fe on Pt(111) and Rh(111) and find MAE values $< 0.5$ meV/atom [2]. For 1 ML Co we find a substantial decrease in the $L/S$ ratio to 0.19. However, the $L/S$ ratio for 1 ML Fe on both substrates does not change much compared with the Fe single atom. [1] Gambardella *et al.*, Science 300, 1130 (2003); [2] Moulas *et al.* PRB in press

MA 9.3 Mon 15:45 HSZ 403

**Magnetic circular dichroism in two-photon photoemission from Co/Cu(001)** — •Cheng-Tien Chiang, Aimo Winkelmann, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle(Saale), Germany

Magnetic circular dichroism in photoemission is an important tool in magnetic imaging and investigation of electronic structure of magnetic materials. Using ultrashort laser pulses for excitation, we observe magnetic circular dichroism in two-photon photoemission from Co/Cu(001) at 3.1 eV incident photon energy. The thickness dependence of the dichroic signal of photoemission from near the Fermi level shows a monotonic increase up to 12 ML and then reaches a saturation value of about 10%. For the 12 ML film, the dichroic signal decreases from 10% for photoelectrons from the Fermi level to 2% at 0.7 eV below the Fermi level. We compare our observation with studies employing one-photon photoemission near threshold and to measurements using VUV synchrotron radiation, where significantly smaller intensity asymmetry of 0.5% [1] and 4% [2] are obtained.

[1] T. Nakagawa and T. Yokoyama, Phys. Rev. Lett. **96**, 237402 (2006) [2] C. M. Schneider *et al.*, Phys. Rev. B **44**, 12066 (1991)

MA 9.4 Mon 16:00 HSZ 403

**fcc Co/Cu(001): Influence of the morphology on spin-dependent surface states and magnetic switching** — •Tobias Allmers and Markus Donath — Physikalisches Institut, Universität Münster, 48149 Münster

The electronic structure and the magnetic properties of fcc Co films on Cu(001) are influenced by the morphology of the film. In our contribution we focus on surface states studied with spin-resolved direct and inverse photoemission and the magnetic reversal behavior studied with magneto-optical Kerr effect. The film morphology was controlled by the substrate temperature during film growth and subsequent annealing at various temperatures. The resulting differences in the film properties were additionally characterized with scanning tunneling microscopy. We found that the intensity of the occupied minority surface state with a binding energy of 0.4 eV [1] depends on the roughness of the surface. The spectral feature is very sharp and pronounced for a flat surface. The exchange-split unoccupied surface state at $\bar{X}$-point is even more sensitive to the roughness of the surface. In addition, we observed that the film morphology influences the shape of the hysteresis curve. While a square-like hysteresis curve was observed for films with a smooth topography, the hysteresis curve for a rough Co surface reflects a more complex switching behavior of the magnetization.

[1] Schmidt *et al.*, J. Phys. D **41** (2008) 164003

MA 9.5 Mon 16:15 HSZ 403

**Origin of the spin polarization of magnetic scanning tunneling microscopy tips** — •Paolo Ferriani, Cesar Lazo, and Stefan Heinze — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

Spin-polarized scanning tunneling microscopy (SP-STM) is a very powerful tool to study magnetism at the nanoscale. The capability to resolve magnetic structures down to single atoms is often achieved by using tips coated with a magnetic 3*d*-metal, e.g. Fe, Cr. Although SP-STM is a well established technique, there has been a long debate about the origin of the spin-polarization in the vicinity of the Fermi level from such tips. We would intuitively expect the *d*-electrons to provide a large spin-polarization at the tip apex atom, with small contribution coming from *s*- and *p*-electrons. On the other hand, the local density of state (LDOS) in the vacuum region above the apex atom, which is the key quantity for the tunneling current, should be dominated by *s*-electrons. In order to clarify this issue, we performed density functional theory calculations using the FLAPW method. We calculated STM tips formed by 3*d* metal adatoms and pyramids on the (001) and (110) surfaces of Fe. By decomposing the LDOS in the vacuum into the contributions of *s*-, *p*-, and *d*- electrons at the apex atom, we analyzed the origin of the spin-polarization. Surprisingly, the spin-polarization in the vacuum region, is positive for Fe and dominated by *s*-electrons, although the LDOS at the apex atom is dominated by minority *d*-electrons. This result is independent of the surface symmetry and can be explained on the basis of *sd*-hybridization at the tip apex.

MA 9.6 Mon 16:30 HSZ 403

**Self-interaction correction in Gd(0001): Surface state and**

**magnetic structure** — •Hossein Mirhosseini, Arthur Ernst, and Jürgen Henk — Max Planck Institute of Microstructure Physics, Halle, Germany

A treatment of on-site electronic correlations beyond the local spin-density approximation is essential for the correct description of the electronic and magnetic properties of $4f$-electron systems. Instead of the LDA+$U$ method, we applied the self-interaction correction (SIC) to paradigmatic Gd(0001). The first-principles calculations were performed within the relativistic Korringa-Kohn-Rostoker framework.

The hybridization of the localized $4f$-majority states—which have to be SI corrected—with the itinerant $d$-electrons has a sizable effect on the dispersion of the spin-orbit split surface state and on the magnetic properties (e. g. structure and critical temperature). The Slater-Janak transition-state approximation improves the overall agreement with experiment significantly, as compared to SIC.

MA 9.7 Mon 16:45 HSZ 403

**Giant orbital moment anisotropy of Cu-Phthalocyanine adlayers at a metal interface** — •Sebastian Stepanow[1], Aitor Mugarza[1], Gustavo Ceballos[1], Paolo Moras[2], Julio Criginski Cezar[3], Carlo Carbone[2], and Pietro Gambardella[1,4] — [1]CIN2-ICN Barcelona — [2]CNR Trieste — [3]ESRF Grenoble — [4]ICREA Barcelona

The magnetic properties of transition metal ions embedded in metal-organic complexes have attracted wide interest due to the interplay between spin and orbital phenomena. Recent studies, however, have shown that the deposition of Metal-Phthalocyanine (MePc) molecules on metal substrates may quench their magnetic moment. Here we investigate the magnetic properties of CuPc adlayers on a Ag(100) surface by x-ray magnetic circular dichroism (XMCD). The Cu centers present a robust spin S=1/2 magnetic moment with extraordinary high orbital moment (L) anisotropy. This effect, amounting to a 400% change of L from the in-plane to out-of-plane direction, is an order of magnitude larger compared to metallic layers and is accompanied by an unprecedented large spin-dipole moment T. By means of ligand-field multiplet theory we are able to simulate both the magnetic moment components and XMCD spectra versus applied field, relating these findings to the electronic structure of the adsorbed molecules.

## MA 10: Magnetic Imaging

Time: Monday 17:15–19:00 Location: HSZ 403

MA 10.1 Mon 17:15 HSZ 403

**HF-MFM on perpendicular write heads** — •R. Pfeifer[1], M.R. Koblischka[1], B.F. Valcu[2], and U. Hartmann[1] — [1]Experimental Physics, Saarland University, P.O.Box 151150, D-66041 Saarbrücken — [2]Seagate Technology, Fremont, CA

The HF-MFM (High Frequency Magnetic Force Microscopy) techique has been employed for the measurement of stray fields emanating from traditional longitudinal write heads [1],[2]. Here we show that it is also possible to apply the HF-MFM technique to perpendicular write heads [3]. The situation is different in so far, that there is no magnetic flux between two poles. In contrast there is only one pole and the flux closure is obtained in combiation with the writing medium. An ac current of 50 mA with a carrier frequency of 2 GHz fed in into the write head, causes an observable contrast in the HF-MFM image. Not only the write pole itself but also the magnetic shieldings around the pole are strongly influenced by the HF-current.

[1]Li S, Stokes S, Liu Y, Foss-Schrader S, Zhu W und Palmer D, J. Appl. Phys. 91 7346 (2002) [2]Koblischka M R, et al., IEEE Trans. Magn. 43 2205 (2007) [3]Valcu B F, Allimi B, Dobnin A, Lynch R, Brockie R, Intermag 2008

MA 10.2 Mon 17:30 HSZ 403

**Soft x-ray holograpic microscopy** — •Daniel Stickler[1], Robert Frömter[1], Holger Stillrich[1], Christian Menk[1], Carsten Tieg[2], Simone Streit-Nierobisch[3], Christian Gutt[3], Lorenz-M. Stadler[3], Olaf Leupold[3], Micheal Sprung[3], Gerhard Grübel[3], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11 A, 20355 Hamburg, Germany — [2]European Synchrotron Radiation Facility (ESRF), 38043 Grenoble, France — [3]Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany

Soft x-ray holography has proven as a powerful technique for imaging of magnetic domain structures [1]. A disadvantage of the technique is the fact that the signal to noise ratio limits the field of view for a given spatial resolution which is basically determined by the size of the reference hole. To overcome this obstacle we have separated the sample from the optical elements. The sample, which is prepared on one membrane, is positioned with nanometer precision with respect to the imaging and reference holes which are fabricated on a second membrane. These are reusable. The concept has been realized at the ID08 beamline of the ESRF. In our talk we will demonstrate that large structures can be imaged by sequential measuring of small segments. The variation of the domain structure along a wedge proves the applicability of the technique for a new class of experiments. It has to be pointed out that this solution can easily applied to imaging of biological specimen as size and positioning are no longer an issue.

[1] Eisebitt et al. - Nature **432**, 885 (2004)

MA 10.3 Mon 17:45 HSZ 403

**Phase sensitive BLS spectroscopy with magneto-optical modulator** — •Frederik Fohr, Alexander A. Serga, Jaroslav Hamrle, and Burkard Hillebrands — FB Physik und Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Space- and time-resolved Brillouin light scattering (BLS) spectroscopy is a well established method to investigate the spin-wave dynamics in thin magnetic films. However, this method is based on a simple counting of inelastically scattered photons and thus no phase information about magnetic excitations is accessible.

The implementation of phase resolution into Brillouin light spectroscopy not only leads to a complete picture of the underlying physical processes by combining space-, time- and phase-resolution into the measurement process, but also enhances the BLS dynamical range.

Here we report on further improvement of phase-resolved BLS by implementation of a new type of magneto-optical modulator, based on Brillouin light scattering in a thin ferrite film.

Support by the DFG (SFB/TRR 49 and Hi 380/21-1) is acknowledged.

MA 10.4 Mon 18:00 HSZ 403

**Nanoscale imaging magnetometry with single spins in diamond** — •Julia Tisler, Gopalakrishnan Balasubramanian, Roman Kolesov, Fedor Jelezko, and Joerg Wrachtrup — 3. Physikalisches Institut, Universitaet Stuttgart

It is shown that single electron spin of a nitrogen vacancy center in diamond can be used as a magnetometer for sensing and imaging weak magnetic fields under ambient conditions. The nitrogen vacancy center is an atomic sensor, has an additional advantage that it can be attached to the tip of a scanning probe and used to measure or image magnetic field at nanometer length scales. The setup to perform this nanoscale magnetometry consists of a combined confocal fluorescent microscope, atomic force microscope and optically detected magnetic resonance setup. We demonstrated this novel magnetometry by imaging the magnetic field created by a magnetic nanostructure. The magnetic field lines as small as 5mT were imaged using this technique. To perform ultra sensitive magnetic field measurements we used a nitrogen vacancy center in an isotopically pure bulk diamond which has a coherence time of 2ms. By synchronizing a hahn echo sequence with the external magnetic field we achieved a resolution of 4nT(Hz)-1/2. This method could have impact in life science, because it has the potential to probe single spins in living cells.

MA 10.5 Mon 18:15 HSZ 403

**Iron filled carbon nanotubes as probes for magnetic force microscopy** — •Franziska Wolny, Uhland Weissker, Kamil Lipert, Thomas Mühl, Albrecht Leonhardt, and Bernd Büchner — Leibniz-Institut für Festkörper- und Werkstoffforschung (IFW) Dresden, Helmholtzstraße 20, 01069 Dresden

Iron-filled carbon nanotubes (Fe-CNTs) were used to prepare probes for magnetic force microscopy (MFM) by attaching them to the tips of conventional atomic force microscopy cantilevers. Fe-CNTs can be

regarded as cylindrically shaped single-domain nanomagnets that are protected from oxidation by a carbon shell. Carbon nanotubes are known to possess both great mechanical stability and elasticity, which lead to a much longer lifetime of these probes compared to conventional magnetically coated probes. It is shown that the prepared probes are suitable for magnetic imaging with a good magnetic resolution.

The long iron nanowire enclosed in the carbon shell can be regarded as an extended magnetic dipole of which only the monopole closest to the sample surface interacts with the sample stray field. Thus, the Fe-CNT probes can be calibrated for quantitative MFM measurements by determining their monopole moment. First calibration experiments to quantify the effective magnetic monopole moment of the probe by measuring test structures with a defined magnetic stray field will be presented.

MA 10.6 Mon 18:30 HSZ 403

**Observation of spin-spiral magnetic order in the 2nd layer of Mn on W(110)** — •Yasuo Yoshida, David Serrate, Andre Kubetzka, Matthias Menzel, Kirsten von Bergmann, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

We have performed spin-polarized scanning tunneling microscopy (SP-STM) measurements on the 2nd layer of Mn on W(110). An in-plane magnetized tip images stripes with 2.5 nm inter-stripe distance. An out-of-plane magnetized tip shows the same stripes but the stripes shift by one-fourth of the period. These results indicate that the striped pattern is due to spin-spiral order of the 2nd layer. This spin-spiral order is close to a ferromagnetic one similar to the one observed in the 1st Mn monolayer on W(001) [1] because the inter-stripe distance is much longer than the lattice parameter of the substrate. The spin spiral runs along the [001] direction which is perpendicular to the antiferromagnetic spin spiral axis in the 1st Mn monlayer on W(110). [2] Additionally, the STM data show stripes with 1.25 nm inter-stripe distance superimposed on the spin-spiral contrast. This striped contrast stays the same by changing the tip magnetization direction, which indicates that spin-orbit coupling (SOC) is its origin. [3] This suggests that combination of SP-STM and SOC-STM is a useful technique to understand complicated magnetic and electronic properties in nanoscale structures. [1] P. Ferriani *et al.*, Phys. Rev. Lett. **101**, 027201 (2008), [2] M. Bode *et al.*, Nature **447**, 190-193 (2007), [3] M. Bode *et al.*, Phys. Rev. Lett. **89**, 237205 (2002).

MA 10.7 Mon 18:45 HSZ 403

**Imaging single atom spins on a magnetic template** — •Andre Kubetzka[1], Paolo Ferriani[1], David Serrate[1], Yasuo Yoshida[1], Saw-Wai Hla[2], Matthias Menzel[1], Oliver Ferdinand[1], Kirsten von Bergmann[1], Stefan Heinze[1], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, Hamburg, Germany — [2]Department of Physics and Astronomy, Ohio University, USA

In the past, magnetic adatoms have been investigated intensively by scanning tunneling spectroscopy on non-magnetic metal surfaces. In these systems the adatom spin is not stable in time, and a Kondo-state may form due to scattering of conduction electrons. It has been shown that the magnetic moments can be stabilized either by external fields [1] or by exchange coupling to a ferromagnetic surface [2], thereby becoming accessible to spin-resolved measurements (SP-STM). In this work we have investigated Co adatoms on a versatile magnetic template at T=10 K. Surprisingly, in addition to an apparent height contrast, the appearance of the atoms in constant current and spectroscopy images depends on their spin orientation. We will discuss details of the contrast mechanism and the electronic states involved.

[1] F. Meier et al., Science 320, 82 (2008).
[2] Y. Yayon et al., Phys. Rev. Lett. 99, 67202 (2007).

## MA 11: Magnetic Materials

Time: Monday 15:15–19:15 Location: HSZ 103

MA 11.1 Mon 15:15 HSZ 103

**Magnetic properties of fcc Ni-based transition metal alloys** — •Josef Kudrnovsky[1], Vaclav Drchal[1], and Patrick Bruno[2] — [1]Institute of Physics AS CR, Prague — [2]ESRF, Grenoble

Electronic properties and finite-temperature magnetism of Ni-based transition metal alloys with the face-centered cubic structureis are studied theoretically by ab initio calculations. While the calculated total and local magnetic moments agree well with the experiment, the evaluation of the Curie temperature from first-principles represents much more delicate problem. The mean-field approximation, the random-phase approximation (RPA), as well as the renormalized RPA by Bruno extended to random alloys were tested, the latter giving the most satisfactory agreement with the experiment for a broad class of Ni-based alloys of the type Ni(1-x)M(x) (M=Cu, Pd, Co, Fe, and Mn) over the whole concentration range.

We will also discuss differences between fcc-phases and artificially prepared bcc-phases of Ni and Permalloy.

MA 11.2 Mon 15:30 HSZ 103

**Electronic and magnetic properties of Gd-based materials: Beyond the LDA** — •Samir Abdelouahed[1], Mebarek Alouani[2], and Jürgen Henk[1] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Institut de Physique et de Chimie des Matériaux de Strasbourg (IPCMS), France

The FLAPW method has been used to study the electronic structure of gadolinium-based materials. The 4f electron-electron interaction was treated by the LDA+U method to improve the description of electronic and magnetic properties. For gadolinium, x-ray absorption spectroscopy (XAS) and x-ray magnetic circular dichroism (XMCD) spectra calculated including U agree better with experiment, as compared to those of the standard LDA (GGA) treatment. Furthermore, the XMCD spin and orbital moments, obtained from the sum rules, compare favorably to the self-consistent results.

The tiny magnetocrystalline anisotropy energies (MAE's) of bulk Gd, GdN, and GdFe2 have been calculated by means of the magnetic-force theorem. The energy position of the 4f-state affects significantly the MAE's. For example, the magnetic anisotropies in GGA and in GGA-core calculations are factors of about 10 and 3 larger than that of the GGA+U approach, indicating the importance of hybridization in these systems.

MA 11.3 Mon 15:45 HSZ 103

**Spin freezing and slow magnetization dynamics in geometrically frustrated magnetic molecules with exchange disorder** — •Christian Schröder[1,2], Yuji Furukawa[2], Marshall Luban[2], Ruslan Prozorov[2], and Ferdinando Borsa[2,3] — [1]Department of Engineering and Mathematics, University of Applied Sciences Bielefeld, D-33602 Bielefeld, Germany — [2]Ames Laboratory & Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA — [3]Dipartimento di Fisica "Alessandro Volta", Università di Pavia, I-27100 Pavia, Italy

We show that intramolecular exchange disorder recently found in the geometrically frustrated magnetic molecules $\{Mo_{72}Fe_{30}\}$ and $\{Mo_{72}Cr_{30}\}$ leads in a classical Heisenberg model description to spin freezing and slow magnetization dynamics reminiscent of spin glass behavior. Our low temperature and low magnetic field NMR measurements on these molecules are explained as a cross-over of the proton line width from paramagnetic behavior to a frozen spin configuration at about 400 mK.

MA 11.4 Mon 16:00 HSZ 103

**Anisotropic magnetoresistance (AMR) of magnetic graphite** — •Jose Barzola-Quiquia, Pablo Esquinazi, Daniel Spemann, and Tilman Butz — Institut für Experimentelle Physik II, Universität Leipzig, D-04103 Leipzig

Complementing the experimental evidence for the existence of magnetic order induced by proton irradiation in graphite obtained by XMCD, SQUID, and LE$\mu$SR, we studied in this work the magneto-transport of irradiated oriented graphite samples. The resistance measured for fields applied parallel to the planes and at different angles respect to the current shows the typical behaviour of the AMR observed in ferromagnets including irreversibility loops. The results confirm the existence of magnetic order in irradiated graphite and rule out magnetic impurities as origin, in agreement with XMCD and LE$\mu$SR

results.

MA 11.5 Mon 16:15 HSZ 103

**Magnetoresistance and magnetoimpedance measurements on iron whiskers** — •Matthäus Langosch, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, 66123 Saarbrücken, Germany

Magnetoimpedance (MI) measurements on iron single crystals (iron whiskers) with growing directions <100> and <111> were carried out at room temperature as a function of applied longitudinal magnetic field, current amplitude and frequency. Simultaneous Kerr microscopy was employed to study the magnetic surface domain structure of the samples. Measurements also provide ordinary magnetoresistance (MR) contributions. The contributions of the MI and MR effects were discussed based on the experimental results. The correlation between domain structure and magnetoimpedance effect was studied on the basis of Kerr microscopy images and resistivity data.

MA 11.6 Mon 16:30 HSZ 103

**Semiconducting and half-metallic ternary rare earth compounds** — •Frederick Casper and Claudia Felser — Institute of Inorganic and Analytical Chemistry,

Rare earth compounds with the LiAlSi and LiGaGe structure types have been investigated by means of band structure calculations. The LiAlSi structure type is more familiarly known as the half-Heusler structure type, whereas LiGaGe is a closely related hexagonal variant. Both structure types can be found within the same REYZ series, depending on the size of the RE element and the Y - Z bond length. A remarkable feature of some REYZ half-Heusler compounds with 18 valence electrons is that despite being composed of only metallic elements, they are semiconductors. Calculated band gaps, in comparison to experimental ones, are frequently too large, which can be attributed to some finite site disorder in the compounds. LiGaGe compounds have an additional degree of freedom, namely the degree of puckering of the layers. These compounds can become semiconducting at a certain value of puckering. Half-metallic behaviour is rarely found in this structure type. This work is supported by by DfG grant FE633/1-1 within SPP1166.

MA 11.7 Mon 16:45 HSZ 103

**Effects of film thickness and Co doping on the magnetism of Pd structures** — •Volker Pankoke and Gemming Sibylle — FZD,Desden,Germany

Palladium in its ground-state has a non magnetic fcc structure. We suggest that it can be forced to get ferro-magnetic by an expansion of the lattice constant, or in case of thin films by a varying number of atomic layers. Another option to induce magnetism is to dope the Pd structures with 3d transition metals. We used first principles methods to calculate the magnetization density of different Co doped and undoped Pd structures. Calculations were carried out with the projector augmented waves (PAW) method in the LDA+U approximation and a plane wave basis set. In addition the linear augmented plane waves (LAPW) method was used and compared with the PAW results. Both methods show, that doping with 3d transition metals leads to magnetic moment at the Pd sites of the crystal. In case undoped Pd films the PAW results are similar to existing LAPW calculations.

MA 11.8 Mon 17:00 HSZ 103

**Interaction Domains in High Performance NdFeB Thick Films** — •Tom Woodcock[1], Kirill Khlopkov[1], Arno Walther[2,3], Nora Dempsey[2], Dominique Givord[2], Ludwig Schultz[1], and Oliver Gutfleisch[1] — [1]IFW Dresden, IMW, P.O. Box 270116, 01171 Dresden, Germany — [2]Insitut Néel, CNRS-UJF, 25 ave. de Martyrs, 38042, Grenoble, France — [3]CEA Léti - MINATEC, 17 rue des Martyrs, 38054 Grenoble, France

Thick sputtered films (5-300 micron) of NdFeB have excellent hard magnetic properties which make them attractive for applications in micro-electro-mechanical systems (MEMS). A two step process consisting of triode sputtering and high temperature annealing produced films with energy densities approaching those of sintered NdFeB magnets.

Magnetic force microscopy (MFM) using hard magnetic tips showed that the films deposited without substrate heating and at 300°C exhibited magnetic domains typical of low anisotropy materials. These films were amorphous in the as-deposited state. The film deposited at 500°C was crystalline and displaid hard magnetic properties. This was reflected in the magnetic microstructure which showed interaction domains typical of highly textured and high magnetic anisotropy materials with a grain size below or equal to the critical single-domain particle limit. With increasing substrate temperature, the domain patterns of the annealed films became coarser, indicating higher degrees of texture.

**15 min. break**

MA 11.9 Mon 17:30 HSZ 103

**Hard X-ray Standing Wave Photoemission from Multilayer Nanostructures.** — •Christian Papp[1], Benjamin Balke[1], Shigenori Ueda[2], Hideki Yoshikawa[2], Shao Long He[2], Keisuke Kobayashi[2], Guiseppina Conti[3], Daniel Buergler[4], Claus Schneider[4], Sven Doering[5], Ulf Berges[5], Carsten Westphal[5], and Charles S. Fadley[1] — [1]Lawrence Berkeley National Laboratory, CA, USA — [2]SPring 8, Japan — [3]Applied Materials, CA, USA — [4]Forschungszentrum Juelich — [5]Lehrstuhl für Physik E1, Uni Dortmund

We have used x-ray standing wave excitation of photoelectrons to study buried layers and interfaces in multilayer nanostructures. In particular, measurements carried out at SPring 8 with 6 keV photon energy will be emphasized. The samples were grown on synthetic multilayer mirrors and the x-ray incidence angle was tuned to the 1st order Bragg reflection. Scanning angle, photon energy, or distance along a wedge profile in the sample permits scanning the resultant standing wave field through nm-scale structures and analyzing the depth distribution of their structural, chemical, electronic, and magnetic properties. Using hard x-ray excitation permits via the higher kinetic energy of the electrons studying those properties at greater depths. The systems discussed will be related to integrated circuit production (titanium nitride on silicon) and to a magnetic tunnel junction (in particular, the electronic properties of the Fe/MgO interface).

MA 11.10 Mon 17:45 HSZ 103

**Coupling between Ho and Cr magnetic sub lattice in rare-earth orthochromite HoCrO3** — •Naveen Kumar Chogondahalli M.[1], Yinguo Xiao[1], Yixi Su[2], Jörg Persson[1], Anatoliy Senyshyn[3], and Thomas Brückel[1,2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Jülich Centre for Neutron Science, IFF, Forschungszentrum Jülich, Outstation at FRM II, 85747 Garching, Germany — [3]Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), 85747 Garching, Germany

HoCrO3 crystallizes in orthorhombic structure with the space group Pbnm in the temperature range 4 to 300 K. Both the magnetization and heat capacity measurements clearly indicate the onset of magnetic ordering at TN =140 K. From Curie-Weiss fit of magnetic susceptibility, the Curie temperature is found to be -28.81 K and the effective moment, Peff = 15.78 bohr magneton. The temperature dependence of magnetic structure is investigated by using the neutron powder diffraction. Below Neel temperature Cr3+ orders antiferromagnetically with the moments aligned along c-axis. The canted ferromagnetic ordering of Ho3+ with moments aligned perpendicular to Cr3+ moments is observed at lower temperatures. The molecular field of Cr cancels at Ho site. It is likely that the ordering of Ho is induced by the fluctuations of Cr subsystem magnetization but not by magnetization itself. This may be order by disorder type of induced ordering [J. Villain et al., 1980]. Such an ordering is only possible if the resulting interactions, Cr-Ho is much stronger than Ho-Ho antiferromagnetic exchange.

MA 11.11 Mon 18:00 HSZ 103

**Hyperfine magnetic field on iron atoms as indication of stoichiometry in $Co_2FeSi$** — •Vadim Ksenofontov[1], Benjamin Balke[1], Claudia Felser[1], Marek Wójcik[2], Sabine Wurmehl[3], Horst Schneider[4], and Gerhard Jakob[4] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg-University, 55099 Mainz, Germany — [2]Institute of Physics, Polish Academy of Sciences, Al. Lotnikow 32/46, 02-668 Warszawa, Poland — [3]Department of Applied Physics, Physics of Nanostructures, Eindhoven University of Technology, PO Box 513, 5600 MB Eindhoven, The Netherlands — [4]Institute of Physics, Johannes Gutenberg - University, 55099 Mainz, Germany

The Heusler compound $Co_2FeSi$ is a promising half-metallic material for thin films spintronic applications. Among the factors reducing spin-polarization, the defects and antisite disordering in such materials play

a crucial role. To clarify effects of the non-stoichiometry, the continuous series of model solid solutions $Co_{3-x}Fe_xSi$ ($0.96 < x < 1.4$) was investigated by $^{57}$Fe Mössbauer spectroscopy and $^{59}$Co nuclear magnetic resonance. It has been shown that hyperfine magnetic fields on Fe can be used to monitor a non-stoichiometry in $Co_2FeSi$-based bulk samples and thin films.

The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

MA 11.12 Mon 18:15 HSZ 103

**Strain induced magnetism in La0.5Ca0.5MnO3 systems** — •Thomas Tietze[1], Daniela Nolle[1], Gisela Schütz[1], Eberhard Goering[1], Gülgün Aydogdu[2], and Hanns-Ulrich Habermeier[2] — [1]Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, 70569 Stuttgart

The La1-xCaxMnO3 exhibits, besides the double exchange relate magneto resistive effects, many interesting properties as a function of the doping level. Depending on the doping level x the system may exhibit ferromagnetism, antiferromagnetism, orbital ordering, and charge ordering. Epitaxial tensile and compressive strains are very important for the fine tuning of the lattice degree of freedom and therefore for the magnetic nearest neighbor coupling. By *adjusting* tensile and compressive strain with corresponding substrates one can switch between FM and AFM coupling between the FM ordered ab-planes. In order to investigate the influence of different substrates and relaxation effects element specific XMCD measurements were performed on La0.5Ca0.5MnO3 systems.

MA 11.13 Mon 18:30 HSZ 103

**Investigations on the MTJ interface $Co_2MnSi$-MgO using electron spectroscopy with x-ray standing wave excitation.** — •Benjamin Balke[1], Christian Papp[1], Catherine A. Jenkins[2], Gerhard H. Fecher[2], Charles S. Fadley[1], and Claudia Felser[2] — [1]Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, USA — [2]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany

We have used x-ray standing wave excitation of photoelectrons to study buried layers and interfaces in multilayer nanostructures. In particular, measurements carried out at the ALS with 1.2 keV photon energy will be emphasized. The samples were grown on synthetic multilayer mirrors and the x-ray incidence angle was tuned to the 1st order Bragg reflection. Scanning angle, photon energy, or distance along a wedge profile in the sample permits scanning the resultant standing wave field through nm-scale structures and analyzing the depth distribution of their structural, chemical, electronic, and magnetic properties. In this study we investigated the interface between the Heusler compound $Co_2MnSi$ and MgO as used in MTJs. Therefore we used a wedge of $Co_2MnSi$ with a MgO top layer and used photoelectron spectroscopy with X-ray standing wave excitations. B.B. and C.P. gratefully acknowledge the Feodor Lynen Fellowship by the Humboldt Foundation. Additionally, the authors gratefully acknowledge financial support by the DfG (Research Unit 559).

MA 11.14 Mon 18:45 HSZ 103

**Polarized neutron scattering on geometrically frustrated magnets with Swedenborgite structure** — •Martin Valldor[1], Yvonne Sanders[2], and Werner Schweika[2] — [1]II. Physikalisches Institut, Universität Köln, 50937 Köln, Germany — [2]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany

Diffuse scattering of polarized neutrons on cobaltate polycrystalline samples with Swedenborgite structure, ABaCo3BO7 (A = Y, Ca, and B = Co, Fe, Al, Zn) was used to study the change in magnetic order depending on chemical composition. The atomic structure contains alternate stacking of kagome and triangular layers of metal ions, all in tetrahedral oxygen coordination. Geometrical frustration of antiferromagnetically coupled spins should suppress long-range order even at low temperatures despite strong spin-spin coupling in the Swedenborgites. The diffuse magnetic scattering in Y0.5Ca0.5BaCo4O7 reveals two dimensional (2D) spin correlations on the kagome sublattices towards the entropically favoured V3*V3 structure and suggests a decoupling of layers on triangular sites. Co-substitution by Al and Zn yields similar diffuse magnetic scattering, however, spin dilution results in even more disordered spin liquid or spin glass states. With B = Fe or Co, differences in the magnetic scattering evolve, indicating the onset of spin correlations perpendicular to the kagome layers.

MA 11.15 Mon 19:00 HSZ 103

**Thermal stability and magnetic properties of Fe-Co-B-Si-Nb glassy alloys** — •Mihai Stoica[1], Ran Li[1], and Jürgen Eckert[1,2] — [1]IFW Dresden, Institute for Complex Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]TU Dresden, Institute of Materials Science, D-01062 Dresden, Germany

The fully glassy rods of $[(Fe_xCo_{1-x})_{0.75}Si_{0.05}B_{0.25}]_{94}Nb_6$ alloys (x = 0.4, 0.5 and 0.6) in diameters up to 2 mm were produced by copper mold casting. The effect of Fe substitution in these glassy alloys on thermal stability and melting behavior were studied by differential scanning calorimetry. Phase evolution of the glassy alloys during heating crystallization process was evaluated using X-rays diffraction. The first crystallization stage results in the precipitation of metastable $(Fe,Co)_{23}B_6$ crystalline phase in the glassy alloys. The behaviour of the glassy alloys in DC applied field was investigated by means of vibrating sample magnetometer. The investigated samples are soft magnetic. Further, the influence of crystallization on the saturation magnetization ($M_s$), coercivity ($H_c$) and Curie temperature ($T_c$) were evaluated, which indicated that $(Fe,Co)_{23}B_6$ phase can improve the $M_s$ and $T_c$, while also increase the $H_c$.

## MA 12: Invited Talk Fähnle

Time: Tuesday 9:30–10:00 Location: HSZ 04

**Invited Talk** MA 12.1 Tue 9:30 HSZ 04

**Electron theory of fast and ultrafast dissipative magnetization dynamics** — •Manfred Fähnle, Daniel Steiauf, and Jonas Seib — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

In recent years the fast (ns-ps) and ultrafast (several hundred fs) dissipative magnetization dynamics in magnetically ordered materials has been studied very extensively, among others because of its great importance for the switching of magnetic devices. Thereby, a comprehensive understanding of the physical mechanisms leading to the transfer of energy and angular momentum from the spin system to the lattice is one of the most challenging and interesting issues in today's condensed matter physics. In the present talk two models are presented to describe damping on the fast near-adiabatic time scale (relevant for the switching of the magnetization by magnetic fields or spin-polarized currents) and on the ultrafast time scale relevant for the demagnetization after excitation with strong laser pulses. For the near-adiabatic time scale the breathing Fermi surface model of Kamberský is combined with the ab-initio electron theory to derive an equation of motion for the magnetization dynamics on the atomic level which exhibits an anisotropic and nonlocal damping term. For the ultrafast time scale the Elliott-Yafet model of spin- flip scattering is discussed. The spin-mixing parameter which is essential for the spin relaxation in this model is calculated by the ab-initio electron theory for several materials. It is shown that this model is in principle able to describe the demagnetization rates after excitation with a strong laser pulse in Ni, for instance.

# MA 13: Poster Ia: Electron Theory (1); Magnetic Imaging (2,3); Thin Films (4-25); MSMA (26-33); Magn. Semiconductors (34-42); Magn. Half Metals and Oxides (43-60)

Time: Tuesday 10:15–13:00 Location: P1A

MA 13.1 Tue 10:15 P1A

**Exact thermodynamics of the extended Hubbard model for a cubic cluster** — •David Zwicker and Rolf Schumann — Institute for Theoretical Physics, TU Dresden, Dresden D-01062, Germany

The Hubbard model extended by nearest-neighbor Coulomb and Heisenberg exchange interaction for an eight-site cubic cluster is studied by means of an exact diagonalization using all known interaction parameter-independent symmetries. The ground state plots in dependence of the model parameters for the complete parameter space show a multitude of ground state crossings for all occupation numbers. We determine the ground state phase diagram in dependence of the chemical potential $\mu$, hence describing the cubic cluster gas. Within the standard Hubbard model, we find 2-4 and 6-8 degeneration points (DPs) for a wide parameter region, i.e. steps in $n(\mu)$ higher than one. These DPs can be destroyed by applying a magnetic field $h$ or a very high correlation energy $U$. The critical field $h_{\mathrm{crit}}$ in dependence on $U$ is calculated. Furthermore, the influence of the additional interactions onto the thermodynamic properties is studied.

MA 13.2 Tue 10:15 P1A

**Setup of a sub-Kelvin scanning tunneling microscope** — •Lei Zhang and Wulf Wulfhekel — Physikalisches Institut, Universität Karlsruhe, Wolfgang-Gaede Strasse 1, 76131 Karlsruhe, Germany

A new ultra-high vacuum sub-Kelvin scanning tunneling microscope with low noise, high stability and high energy resolution <0.1 meV was developed for the measurement of magnetic and vibronic excitations. The construction of the three stage cryostat is finished. The first stage is cooled with liquid $N_2$ with 10 W cooling power, the 2nd stage with liquid $He^4$ with 40 mW. The third stage uses a closed-cycle Joule-Thomson refrigerator (1 mW) with either $He^4$ or $He^3$ to cool down the STM to 0.92 K ($He^4$) and below 500 mK with $He^3$. The cryostat has a very low liquid helium consumption of only 50 ml per hour and standing times of up to 200 hours. The STM has been tested at room temperature in atmosphere, and the vacuum chamber for the STM and sample preparation have been built.

MA 13.3 Tue 10:15 P1A

**A New UHV Operating Scanning X-Ray Microscope at BESSY, Berlin** — •Markus Weigand[1], Kai Fauth[2], Eberhard Goering[1], Christian Wolter[1], Brigitte Baretzky[1], Marcel Mayer[1], Corinne Grévent[1], Rolf Follath[3], and Christian Jung[3] — [1]MPI f. Metallforschung, Stuttgart — [2]Uni Würzburg — [3]Bessy, Berlin

Based on the proven principle of the ALS STX microscope a new scanning soft x-ray microscope has been further developed in cooperation with ACCEL GmbH opening new frontiers in x-ray microscopy.

This microscope is constructed to work in transmission, total electron yield, as well as in reflection mode. In contrast to STXMs available up to now, not only the conventional helium mode, but also UHV operation is possible. In this configuration a UHV transfer and load lock system connects the SXM with a UHV sample preparation chamber.

A main focus of the instrument is static and dynamic XMCD imaging. For this purpose, several dedicated sample holders, one of them motorized rotatable, can be used together with an adjustable magnet system, allowing to apply magnetic fields of +/-0,4T in and out of plane.

The machine will be installed at a new APPLE II-type undulator beamline at BESSY. This SXM will also be available for external users. The development of Fresnel Zone Plates, for improving the lateral resolution, based on the concept of Atomic Layer Deposition, is in progress.

MA 13.4 Tue 10:15 P1A

**Non-Linear Magnetic Vortex Gyration** — •André Drews[1], Benjamin Krüger[2], Stellan Bohlens[2], Markus Bolte[1], and Guido Meier[1] — [1]Institut für Angewandte Physik und Zentrum für Miktrostrukturforschung, Universität Hamburg, Hamburg, Germany — [2]I. Institut für Theoretische Physik, Universität Hamburg, Hamburg, Germany

Magnetic vortices occur in disk- or square-shaped samples of a few hundred nanometers in soft magnetic materials. When applying an external current the vortex core gyrates around its equilibrium position. For small current amplitudes the trajectory of the gyration can be described analytically by a harmonic oscillator [1,2], for larger amplitudes the trajectory becomes nonlinear [3]. In this work the nonlinear motion of vortex cores in square-shaped samples is investigated. The nonlinear analytical equation of motion of the vortex core is solved numerically by a Runge-Kutta method. The analytical results match well with the results from micromagnetic simulations. The amplitude and frequency of the gyration in dependence on the excitation amplitude are investigated, and it is shown that with increasing excitation amplitude the nonlinearities and the blue shift of the resonance frequency increase. For varying lengths and thicknesses of permalloy squares the limits of linear vortex gyration are determined.

[1] B. Krüger et al., Phys. Rev. B. 76, 224426 (2007).
[2] A. Drews et al., Phys. Rev. B. 77, 094413 (2008).
[3] K.-S. Lee and S.-K. Kim, Appl. Phys. Lett. 91, 132511 (2007).

MA 13.5 Tue 10:15 P1A

**Model samples for magneto-impedance measurements** — •Saleh Getlawi, Markus König, Haibin Gao, Michael R. Koblischka, and Uwe Hartmann — Experimental Physics, Saarland University, Campus C 6 3, 66123 Saarbrücken, Germany

The growing interest in the magneto-impedance (MI) effect is mainly caused by the possible use of MI in high-sensitivity magnetic field detectors or magnetic recording heads. Observations of MI have been mainly confined to amorphous wires, magnetic multilayers and ribbon samples. Here, it is difficult to obtain the magnetic domain configuration. In order to find a relation between the magnetic domain structure and the size of the MI effect, we decided to perform measurements on model samples consisting of permalloy ($Ni_{81}Fe_{19}$, Py) nanowires prepared by means of electron beam lithography and lift-off process. Wires and other structures (rectangle, circles) were manufactured with different parameters (width, length, size, thickness, etc.). Py enables the magnetization switching process to be controlled artificially by engineering the sample geometry, Thus, there are manifold possibilities to create different domain patterns. For even smaller structures and to create pinning sites, small notches for domain pinning are manufactured using focused ion beam (FIB) milling, the optimum parameters of which (dose, ion current) were determined in a recent work [2]. Finally, the magnetic structure of our samples and MI effects are confirmed by magnetic force microscopy (MFM) observations and transport measurements.

[1] S. Getlawi et al., Superlattices and Microstructures 44, 699 (2008)

MA 13.6 Tue 10:15 P1A

**Parallel XMCD and XRMS measurements with ALICE** — •Stefan Buschhorn, Frank A. Brüssing, Denise Erb, Melanie Ewerlin, Radu Abrudan, and Hartmut Zabel — Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum

X-ray Magnetic Circular Dichroism (XMCD) is nowadays an established tool in thin film magnetism. The classical way to detect XMCD is by working either in transmission geometry or using Total Electron Yield (TEY) or Fluorescence Yield (FY) as a measure for absorption. These two signals provide surface sensitive and more bulk-like information on the magnetization, but no proper depth profile of the magnetisation. This problem is circumvented by measuring the X-ray Resonant Magnetic Scattering (XMRS) signal in $\Theta - 2\Theta$ geometry. A depth-resolved magnetisation profile for both single- and multilayer samples is then available by tuning the energy to the resonant edges for the respective elements. Additionally, in scattering geometry the magnetic coupling between laterally structured samples is accessible with diffuse scattering.

We present data taken with the ALICE chamber, where all three signals can be measured at once: TEY, FY and XRMS. A comparison is made between the different absorption/reflection spectra, showing the main differences between drain current, fluorescence and reflectivity measurements for a standard sample (Py) and a multilayered spinvalve system (Co/Cr/Fe/Cr).

MA 13.7 Tue 10:15 P1A

**The reflectometer Super ADAM at ILL** — •Max Wolff[1,2,3], Kyrill Zhernenkov[1], Andrew Wildes[2,3], Philipp Gutfreund[1,2], Jörg Meermann[1], Hakan Rundlof[3], Boris Toperverg[3], Adrian Rennie[3], Björgvin Hjörvarsson[3], and Hartmut Zabel[1] — [1]Institute for Solid State Physics/EP IV, Ruhr-University Bochum, Germany. — [2]Insitute Laue-Langevin, Grenoble, France. — [3]Materials Physics, Uppsala University, Sweden.

The angle dispersive neutron reflectometer ADAM at the ILL offers high flux combined with an excellent Q resolution and full polarization analysis with privileged access for the German and Swedisch user comunity. We will give a brief overview on the most recent improvements and most outstanding results obtained during the last years.

Presently a major update of the reflectometer to Super ADAM is in progress. It will combine two possible setups. A high resolution and a high intensity mode on the same monochromatic instrument. To account for this we will use a intercalated graphite monocromator. We expect unique possibilities for the investigation of magnetic thin films due to the high flux, the low background and excellent polarization analysis. A brief report on the status of the project will be given.

MA 13.8 Tue 10:15 P1A

**In situ low temperature ac-susceptibility measurements on ion bombarded AlFe thin films** — •Moritz Trautvetter, Ulf Wiedwald, and Paul Ziemann — Universität Ulm, Institut für Festkörperphysik, 89069 Ulm, Germany

In its chemically ordered state (B2) $Al_xFe_{1-x}$ is paramagnetic at room temperature in the composition range of $30 < x < 50$ at% and can be switched to a ferromagnetic behavior by inducing chemical disorder [1]. For this purpose, ion irradiations are performed at various temperatures. In detail, thin films (ca. 60 nm) of AlFe (composition range as given above) were grown on Sapphire by Pulsed Laser Deposition at 300 K. As prepared $Al_{45}Fe_{55}$films are ferromagnetic with $\mu$= 0,77 $\mu_B$/per formula unit indicating a high degree of disorder. After annealing at 600°C for 2h under hydrogen atmosphere, a reduction of the magnetization to $\mu$= 0,16 $\mu_B$/f.u. is observed in accordance with the formation of an at least partially ordered B2 structure (bcc). The disorder due to the subsequent ion irradiation with 200 keV $Ar^+$ ions leads to an enhancement of the AlFe magnetization. This effect is studied in situ as a function of ion fluence and temperature by means of low temperature ac-susceptometry.

[1] P. Shukla, M.Wortis, Phys Rev B 21, 159 (1980)

MA 13.9 Tue 10:15 P1A

**Growth of epitaxial $CaRuO_3$ films** — •Markus Wissinger[1,2], Dirk Fuchs[1], Rainer Fromknecht[1], Rudolf Schneider[1], and Hilbert v.Löhneysen[1,2] — [1]Institut für Festkörperphysik, Forschungszentrum Karlsruhe, Postfach 3640, 76021 Karlsruhe, Germany — [2]Universität Karlsruhe, 76128 Karlsruhe, Germany

In this work we report on the growth of $CaRuO_3$ films by the pulsed laser deposition (PLD) technique. The films were deposited from stoichiometric targets which were produced by standard solid state reaction. Powder X-ray diffraction (XRD) demonstrated the impurity free orthorhombic Pbnm structure of the targets. The films were grown on (001) oriented $(LaAlO_3)_{0.3}(SrAl_{0.5}Ta_{0.5}O_3)_{0.7}$ and (110) $NdGaO_3$ single crystal substrates. The growth mode and film thickness were studied by in-situ reflection high energy electron diffraction. The composition of the films was checked by electron dispersive x-ray analysis and Rutherford backscattering spectrometry. The substrate temperature, Ts, the oxygen partial pressure, P(O2), and the target-substrate distance, d, were optimized with respect to the crystallinity of the films. The mosaic spread of the films and the of-plane lattice constant were determined from rocking curves and $\theta/2\theta$ scans on 00l reflections, respectively.

MA 13.10 Tue 10:15 P1A

**crystallographic structure and magnetic properties of electrodeposited Co- rich Co-Pt films** — •manvendra khatri[1,2], heike schlörb[1], ludwig schultz[1,2], and sebastian fähler[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 27 00 16, D-01171 Dresden, Germany — [2]Institute for Solid State Physics, Department of Physics, Dresden University of Technology, 01062 Dresden, Germany

Co- rich Co-Pt alloy films have been grown by electrodeposition on Au seed layers. The influence of deposition current density on chemical composition, structure, microstructure and magnetic properties of the films has been investigated. Due to the superposition of the fcc Co-Pt (111) and hcp Co-Pt (002) planes the information supplied by XRD in conventional Bragg Brentano geometry was of limited value. Hence detailed texture measurements have been performed in order to understand the dependence of magnetic properties on phase composition and texture perfection. By comparing the integrated intensity ratio of fcc (200) to hcp (002) and fcc (111) reflections taken from pole figure measurements, it is possible to estimate the formation of hcp phase in the films with respect to current density. The integrated intensity ratio decreases with current density, which indicates the increase in the (002) texture of hcp in the film. The presence of (002) pole of hcp at higher current density indicates the textured growth of the film with c-axis out of plane. The decrease in the integrated intensity ratio is accompanied by an improvement of the out-of plane magnetic properties.

MA 13.11 Tue 10:15 P1A

**Epitaxial $RECo_5$ single layer and bilayer films** — •Marietta Seifert, Felix Fleischhauer, Ajit Patra, Volker Neu, and Ludwig Schultz — IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany

Intermetallic RECo phases are widely used in permanent magnet applications due to their large magnetocrystalline anisotropy. Therefore in previous work we developed epitaxial growth of thin $SmCo_5$ and $PrCo_7$ films on Cr buffered MgO(110) substrates with high coercivity or energy density [1,2]. $RECo_5$ phases with RE = Pr or Nd are also known to exhibit spin reorientation transition from an uniaxial state into easy-cone or easy-plane arrangement and are thus interesting from a fundamental point of view.

In this work we present the temperature and field dependent magnetic behaviour of epitaxial $NdCo_5$, $SmCo_5$ and $PrCo_5$ single layer films and bilayers. Epitaxial $NdCo_5$ films grow with the same single orientation of the *c*-axis established for $SmCo_5$ and exhibit an easy-axis to easy-plane transition. Bilayers of $PrCo_5$ and $SmCo_5$ likewise grow epitaxially with one common orientation of the *c*-axis throughout the layer stack. Despite their largely different coercivity when grown as single layers the bilayer films reverse magnetization in one large irreversible step indicating a strong interlayer exchange coupling.

[1] A. Singh, V. Neu, R. Tamm, K. Rao, S. Fähler, W. Skrotzki, L. Schultz, B. Holzapfel, JAP **99** 08E917 (2006)

[2] A. Patra, V. Neu, S. Fähler, L. Schultz, J. Phys. D: Appl. Phys. **40** (2007) 7261-7266

MA 13.12 Tue 10:15 P1A

**Epitaxial $Fe_3Si$ films: Structure, electrical and magnetic properties** — •Joachim Schumann[1], Hartmut Vinzelberg[1], Christoph Deneke[1], Dieter Elefant[1], Jürgen Thomas[1], Ernest Arushanov[1,2], and Oliver G. Schmidt[1] — [1]IFW Dresden, P.O.Box 270116, D-01171 Dresden, Germany — [2]Institute of Applied Physics, 277028 Chisinau, Moldowa

Epitaxial $Fe_3Si$ films have been prepared by means of UHV electron beam co-evaporation on GaAs (100) substrates for studies on planar [1] and cylindrically shaped [2] samples. High resolution TEM shows that the films are grown with a high crystalline quality and a good interface perfection what makes them comparable with the best $Fe_3Si$ MBE layers. The electrical measurements present a low-temperature $T^3$ term describing the anomalous single-magnon scattering processes in half-metallic materials. So, the hypothesis of half-metallic ferromagnetism in $Fe_3Si$ can be considered as confirmed [1]. The films have an anisotropic magnetoresistance in low magnetic fields. In high magnetic fields a negative longitudinal and transverse magnetoresistance (MR) was found. In the vicinity of 200 K the MR shows a maximum of about 1.5% at fields of about 8 T. The magnetic moment was determined as 0.86 $\mu_B$/atom close to the bulk value of $Fe_3Si$.

[1] H. Vinzelberg et al., J. Appl. Phys. **104**, 093707 (2008).
[2] C. Deneke, et al., phys.stat.sol.(c) **5**, 2704 (2008).

MA 13.13 Tue 10:15 P1A

**Sputtering deposition of epitaxial $Co_2Mn_{1-x}Fe_xSi$ and $Co_2MnAl$ films** — •Enrique Vilanova Vidal, Horst Schneider, and Gerhard Jakob — Institut für Physik, Johannes Gutenberg-Universität Mainz

Recently it has been discussed whether the Heusler compounds $Co_2Mn_{0.5}Fe_{0.5}Si$ and $Co_2MnAl$ are halfmetallic systems. The comparison of band structure calculations with experimental results indicate that electron correlations play an important role in this question. In order to gain further insight into the electronic structure

of these materials, we have prepared thin films of $Co_2Mn_{0.5}Fe_{0.5}Si$ and $Co_2MnAl$. These films were grown by cathode sputtering on $MgO$ (100) with and without $MgO$ buffer layer using an UHV deposition system. The investigated films grow epitaxially and possess the fully ordered $L2_1$ Heusler structure. We discuss the deposition procedure and measurements of composition, crystal structure and magnetic properties of the films with respect to the electronic structure of the alloys.

MA 13.14 Tue 10:15 P1A

**Fe monolayers on InAs(001): An in situ study of surface, interface and volume magnetic anisotropy** — •Florian M. Römer, Christoph Hassel, Khalil Zakeri, Cihan Tomaz, Igor Barsukov, Ralf Meckenstock, Jürgen Lindner, and Michael Farle — Fachbereich Physik and Center for Nanointegration (CeNIDE), Universität Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany.

The magnetic anisotropy of epitaxial Fe films with thicknesses in the range of $2-142$ monolayers (ML) grown on $\{4\times 2\}$ reconstructed InAs(001) was investigated by *in situ* ferromagnetic resonance. The easy magnetization direction was found to be parallel to the $[1\bar{1}0]$-direction for Fe films below 4 monolayers, while it rotates by 45° toward the [100]-direction. It is observed that both surface-interface and volume contribution to the perpendicular anisotropy favor an easy axis perpendicular to the film plane. The cubic surface-interface anisotropy is relatively large with easy axes along $\langle 1\bar{1}0\rangle$-directions in contrast to the volume contribution which favors easy axes along the $\langle 110\rangle$-directions. The volume contribution is found to be larger than the Fe bulk cubic anisotropy. A thickness independent uniaxial anisotropy has been found in films with a thickness of 2 up to 142 monolayers. Changes due to capping with Pt/Ag will be shown.

MA 13.15 Tue 10:15 P1A

**Magnetooptical properties(MOKE) of spin valves based on Co, Cu or Au** — Iryna Cheshko[1], •Dmytro Kutnyakhov[2], Larisa Odnodvorets[1], Sergej Protsenko[1], Sergej Nepijko[2], and Gerd Schoenhense[2] — [1]Sumy State University, 2, R.-Korsakov street, 40007, Sumy, Ukraine — [2]Institute of Physics of University Mainz, 7, Staudingerweg, 55099, Mainz, Germany

Starting from the structural and phase states of the film systems on the basis of Co, Cu and Au, we fabricated a spin valve structure as multilayer film system of Au(3)/Co(3)/Au(Cu)(6)/Co(20)/Au(40)/Cr(3)/s (s-substrate, thickness of layers in nm). The layer Co(3) is more sensible to an external magnetic field and begins the process of remagnetization of the domain structure at lower field amplitudes.

The GMR effect shows up as a variation of the resistivity as function of the magnetic field. It reflects the different fields for the remagnetization of overlayer and underlayer. Thus at the change of the external magnetic field this system is creating a bipolar electric signal with high amplitude. The layers Cr(3) and Au(40) support high adhesion to the sital(glass-ceramic) substrate and provide the electric contacts. X-ray diffraction revealed that at annealing the spin valve structures to 700 K granular solid solutions (Au, Co) or (Cu, Co) occurred. Research of magnetoresistance and magnetooptical Kerr effect (MOKE) confirmed the conclusion about the formation of granular solid solutions.

This work is collaboration between the Institute of Physics of University Mainz (Germany) and Sumy State University (Ukraine).

MA 13.16 Tue 10:15 P1A

**Magnetic and structural properties of epitaxial thin films of the Heusler compounds $Cu_2MnAl$ and $Co_2MnGe$** — •Denise Erb, Jörg Dudek, Frank Brüssing, Gregor Nowak, Kurt Westerholt, and Hartmut Zabel — Ruhr-Universität Bochum Experimentalphysik IV / Festkörperphysik, Bochum, Deutschland

Several Heusler compounds possess half metallic properties in the ordered $L2_1$ structure, which make them promising candidates for spintronic applications. We have grown thin films of the Heusler phases $Co_2MnGe$ and $Cu_2MnAl$ using ion beam sputtering and UHV magnetron sputtering on MgO(100) and sapphire a-plane substrates. The structural properties were studied by x-ray diffraction and x-ray reflectivity. Epitaxial thin films with smooth surfaces can be prepared with the substrates at room temperature. The $Co_2MnGe$ film prepared on $Al_2O_3$ a-plane and a 2nm V seed layer exhibits 12 well defined peaks in the in-plane rocking scan of the (022)-Bragg reflection, indicative of the growth of 3 different crystalline domains rotated by 30° relative to each other. The Heusler phase $Cu_2MnAl$ is actually not half metallic, but exhibits model type behaviour concerning the relations between the structural and magnetic properties. It can be grown on MgO(001) with the in-plane [100]-direction rotated by 45° from the MgO [100]-direction. In the as-grown state the $Cu_2MnAl$ film is non magnetic, ferromagnetic order starts developing when annealing above 280°C. The increasing ferromagnetic magnetization is accompanied by an increasing intensity of the (002) superstructure Bragg reflection.
The authors thank the DFG for financial support within the SFB 491.

MA 13.17 Tue 10:15 P1A

**Fe- Pd thin films: A prototype system for exchange coupling?** — •Thomas Schied[1,2], Jörg Buschbeck[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]Institute for Solid State Physics, Department of Physics, Dresden University of Technology, 01062 Dresden, Germany

High performance hard magnetic films are a key requirement for applications in Micro Electro Mechanical Systems (MEMS) and as perpendicular magnetic recording media. Both applications are expected to benefit from exchange coupled hard/soft magnets. Whereas several L10 ordered systems such as Fe-Pt, Co-Pt and Fe-Pd are known to exhibit a sufficiently high magneto crystalline anisotropy, the Fe-Pd system is the only L10 system thermodynamically demixing into a high Ku hard magnetic and a high Js soft magnetic phase. In this work composition spreads of Fe-Pd are prepared by magnetron sputtering from elemental Fe and Pd targets, covering most of the composition range from the high Js Fe-rich phase to the high Ku L10 phase. Local magnetic properties are analyzed using a scanning magnetometer based on the polar magneto optical Kerr-effect. Together with structural investigations by XRD and surface morphology by AFM the key properties are analyzed locally. These information*s are used to correlate magnetic properties with composition, phase formation and micro structure. In order to obtain an alignment of the easy axis perpendicular to the substrate the influence of two different heated substrates - Si/SiO wafers without buffer and Si/SiO wafers with MgO buffer - is investigated.

MA 13.18 Tue 10:15 P1A

**Electronic and magnetic properties of ferromagnetic $Mn_5Ge_3$(0001) epilayer on Ge(111)** — •Yuriy Dedkov[1], Matthias Holder[2], Gillian Mayer[3], Mikhail Fonin[3], and Alexej Preobrajenski[4] — [1]FHI Berlin — [2]TU Dresden — [3]Uni Konstanz — [4]MAX-lab, Lund

The dramatic situation in the semiconductor spintronic can be improved by the preparation of epitaxial ferromagnetic compounds on the basis of 3*d* metals and silicon or germanium grown on the corresponding semiconducting substrates. The Mn-based materials are most promising candidates because the Curie temperature of corresponding silicides or germanides can reach room temperature. Here we present a study of the electronic structure of high-quality well-characterized epitaxial ferromagnetic $Mn_5Ge_3$(0001) films on Ge(111) by means of x-ray absorption spectroscopy, x-ray photoelectron spectroscopy, and spin-resolved photoelectron spectroscopy. Spin-polarization value of about +15% is measured with 21.2 eV photon energy at the Fermi level at 190 K. The experimental photoemission data is explained on the basis of available band structure calculations of ferromagnetic bulk $Mn_5Ge_3$.

MA 13.19 Tue 10:15 P1A

**Metamagnetic domains in [Co/Pt]/Ru multilayers** — •N. S. Kiselev[1,2], C. Bran[1], U. Wolff[1], L. Schultz[1], A.N. Bogdanov[1], O. Hellwig[3], V. Neu[1], and U. K. Rössler[1] — [1]IFW Dresden — [2]Donetsk Inst. for Physics & Technology — [3]Hitachi GST, San Jose

In antiferromagnetically coupled superlattices with perpendicular anisotropy, a magnetic field induces a cascade of reorientation transitions accompanied by *metamagnetic* multidomain states [1,2]. For a micromagnetic model, we derive equilibrium sizes of stripe and bubble metamagnetic domains as functions of the antiferromagnetic exchange, magnetic field, and geometrical parameters of the multilayers. Magnetic phase diagrams display three different types of metamagnetic domains which separate the ferrimagnetic state from the antiferromagnetic and the saturated ferromagnetic state, and from ferrostripe phases. Experimental investigations have been carried out for an antiferromagnetically coupled $[(Co/Pt)_8Co/Ru]_{18}$ superlattice. Magnetic force microscopy (MFM) imaging in a magnetic fields reveals peculiarities of the nucleation and evolution of metamagnetic domains. Theoretical analysis of MFM data and the magnetization curves gives a consistent description of the magnetization processes in [Co/Pt]/Ru multilayers. Demagnetization processes starting from the multidomain

metamagnetic states lead to specific remanents states, namely metamagnetic band and bubble topological defects[2].

[1] O. Hellwig, A. Berger, J. B. Kortright, E. E. Fullerton, J. Magn. Magn. Mater. **319** 13 (2007). [2] N.S. Kiselev, U. K. Rößler, A. N. Bogdanov, O. Hellwig, Appl. Phys. Lett. **93** 132507 (2008).

MA 13.20 Tue 10:15 P1A

**Micromagnetic analysis of magnetic nanosystems with competing anisotropies** — •Andrei A. Leonov[1,2], Ulrich K. Rössler[1], and Alexei N. Bogdanov[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]Donetsk Institute for Physics and Technology, 83114 Donetsk, Ukraine

The interplay between cubic and uniaxial magnetic anisotropies strongly influences magnetization processes in such novel classes of nanomagnetic systems as ferromagnet-antiferromagnet bilayers, thin epilayers of diluted magnetic semiconductors, Heusler alloys, magnetic nanowires or nanoparticles.We have extended and generalized a micromagnetic model to describe magnetization processes in systems with competing magnetic anisotropies and adopted them to investigate nanomagnetic systems (see [1] and bibliography in [1]). In this contribution we apply the results of [1] for detailed analysis of recent experimental results: (i) remarkable transformation of metastable magnetic states, reorientation effects, and magnetization reversal observed in Fe-Cu-B nanoparticles [2], in (Ga,Mn)As epilayers [3], and in magnetite [4] films. (ii) magnetic-field-driven evolution of magnetic domain walls in nanoconstrictions [5]. (iii) calculation of the parameters for multidomain patterns in (Ga,Mn)As films with perpendicular anisotropy [1].

[1] A.A.Leonov et al. J. Appl. Phys. **104**, 084304 (2008). [2] N. Duxin et al., Langmuir **16**, 11 (2000). [3] K.Pappert et al., Appl. Phys. Lett. **90**, 062109 (2007). [4] A. Brandlmaier et al., Phys. Rev. B **77**, 104445 (2008). [5] M. Yamanouchi et al., Nature (London) **428**, 539 (2004).

MA 13.21 Tue 10:15 P1A

**Coercivity analysis in highly anisotropic $PrCo_7$ films** — •Volker Neu[1], Ajit Kumar Patra[1], Stephen Collocott[2], Sebastian Fähler[1], and Ludwig Schultz[1] — [1]IFW Dresden, Institute for Metallic Materials, PO Box 270116, D-01171 Dresden, Germany — [2]CSIRO Materials Science and Engineering, PO Box 218, Lindfield NSW 2070, Australia

In order to tailor the response of a magnetic material to an external magnetic field a sound understanding of the underlying magnetization process is required. For permanent magnet materials this central question culminates in understanding the origin of coercivity. The known concepts of coercivity analysis, the micromagnetic model and the global or phenomenological model are applied to a permanent magnet film based on epitaxial $PrCo_7$. Such films possess a single orientation of the crystallographic c-axis within the film plane and a square shaped hysteresis with large coercivity. The temperature dependent coercivity is compared on one hand with the expected nucleation or depinning field based on the independently determined anisotropy constants and on the other hand is expressed as a thermally activated domain wall movement within a certain activation volume. For this, the fluctuation field as a function of temperature is extracted from magnetization relaxation and irreversible susceptibility measurements. A consistent description of the data is possible under the assumption of weak pinning. The analysis is however complicated by the spin reorientation from uniaxial anisotropy at high temperature to an easy-cone anisotropy below 110K.

MA 13.22 Tue 10:15 P1A

**Electronic structure of a stabilized bulk-like $\alpha$-Mn thick film on W(110)** — •Elena Voloshina[1], Yuriy Dedkov[2], and Manuel Richter[3] — [1]Institut für Chemie und Biochemie - Physikalische und Theoretische Chemie, Freie Universität Berlin, Germany — [2]Fritz-Haber Institut, Berlin, Germany — [3]IFW Dresden, P. O. Box 270 116, 01171 Dresden, Germany

We report on the successful stabilization of thick bulk-like $\alpha$-Mn films with (110) orientation on W(110) substrate. The observed $(3\times3)$ patterns are consistent with the presented growth model. Angle-resolved photoemission spectra show weak dispersions of the valence band electronic states. These PE data are analyzed on the basis of DFT calculations for non-magnetic bcc $\alpha$-Mn. The observed weak dispersions are caused by the large number of inequivalent Mn atoms of the $\alpha$-Mn structure.

MA 13.23 Tue 10:15 P1A

**Magneto-elastic coupling in $LaCoO_3$ thin films** — •Erhan Arac[1,2], Dirk Fuchs[1], Fadi El-Hallak[3], Rudolf Schneider[1], and Hilbert von Löhneysen[1,2] — [1]Forschungszentrum Karlsruhe, Institut für Festkörperphysik, 76021 Karlsruhe, Germany — [2]Physikalisches Institut, Universität Karlsruhe, 76128 Karlsruhe, Germany — [3]1. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart, German

The magnetization of epitaxial $LaCoO_3$ thin films with respect to magnitude and orientation of the strain is investigated. The magnitude of the epitaxial tensile strain is varied by the growth of thin films on (001) oriented $SrLaAlO_4$, $SrLaGa_4$, $(LaAlO_3)_0.3(Sr_2AlTaO_6)_0.7$ (LSAT) and $SrTiO_3$ single crystal substrates while the orientation is changed by the growth on (001),(110) and (111) oriented LSAT substrates by pulsed laser deposition (PLD). The magneto-elastic constant $B_1$ is determined by "area method". The negative sign implies that in-plane magnetization is favoured which is convenient with obtained in-plane hysteresis loops of (001) samples. Moreover, magnetic anisotropy measurements of (001) and (110) samples revealed 4-fold and 2-fold symmetry. The uniaxial magnetic anisotropy in (110) film can be explained by the dominance of the stress anisotropy over magneto-crystalline anisotropy effects.

MA 13.24 Tue 10:15 P1A

**Geometry and magnetic structure of uranium along the tetragonal epitaxial Bain path** — •Stephan Schönecker, Manuel Richter, Klaus Koepernik, and Helmut Eschrig — IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany

Epitaxially manufactured structures grown pseudomorphically on suitable substrates provide a way to stabilise non-equilibrium structures of materials. This includes grown films which posses a large lattice misfit between substrate and film material under equilibrium conditions, but also if the structure grown differs from the equilibrium structure of the bulk film material. Large misfits do not necessarily mean large lateral stress. Theory can help to predict e.g. geometry, stresses and magnetic properties of pseudomorphically grown metal films. In this work, we considered the epitaxial Bain path (e.g. [1]) of elemental uranium, which provides a reasonable description of tetragonally distorted films on substrates. We employed density functional calculation in the implementation of the full potential local orbital program package FPLO [2]. We found three meta-stable tetragonal phases, in addition a ferromagnetic state close to the fcc phase.

[1] P. M. Marcus, F. Jona, and S. L. Qiu, Phys. Rev. B **66**, 064111 (2002)
[2] K. Koepernik and H. Eschrig, Phys. Rev. B **59**, 1743 (1999); http://www.fplo.de

MA 13.25 Tue 10:15 P1A

**The strained epitaxial Nd-Fe-B films by mechanical elongation** — •Ah-Ram Kwon[1], Volker Neu[1], Vlakimir Matias[2], Jens Hänisch[1,2], Ruben Hühne[1], Bernhard Holzapfel[1], Ludwig Schultz[1], and Sebastian Fähler[1] — [1]IFW Dresden, P.O. Box 270116 D-01171 Dresden — [2]Los Alamos National Laboratory, Mail Stop T004, Los Alamos NM 8545 USA

Though it is well known that a variation of lattice constants strongly influences the functional properties of materials, most of the experiments are limited to hydrostatic pressure or biaxial stress. Here we present an approach, which impresses a large uniaxial strain on epitaxially grown films in order to tune their functional properties. A ductile Hastelloy substrate covered with a (001) oriented ion beam assisted MgO layer is used. Conventional mechanical elongation after deposition breaks the symmetry within the substrate plane compared to the as-deposited state. Consequences are exemplarily examined for an epitaxial hard magnetic Nd2Fe14B film strained by 2%. Though magnetostriction is usually considered to be negligible in this material exhibiting a high magnetocrystalline anisotropy, the uniaxial strain results in an elliptical distortion of the in-plane anisotropy below the spin-reorientation temperature. Our approach is versatile to study the influence of large strain on various materials, as the used MgO (001) layer is a common substrate for epitaxial growth.

MA 13.26 Tue 10:15 P1A

**Thin film growth and shape memory in the Heusler compound Mn2NiGa** — •Catherine Jenkins[1,2], Tobias Eichhorn[2], Ramamoorthy Ramesh[1], and Gerhard Jakob[2] — [1]UC Berkeley, Berkeley, 94720, USA — [2]University Mainz, 55122 Mainz, Germany

The ferromagnetic shape memory effect has been known for more than a decade in cubic to tetragonal Ni2MnGa with a maximum of 10% strain in single crystals. Recent work in fully epitaxial single crystals of Ni2MnGa on MgO and Al2O3 demonstrated our group*s ability to process high quality ferromagnetic shape memory films in novel form [1]. Mn2NiGa has a higher Curie temperature in the stoichiometric compound and an analogous crystal structure to the prototypical Ni2MnGa but due to the higher tetragonal distortion with transformation the theoretical strain is closer to 20%. The first thin films of these compounds are synthesized and the shape memory effect is investigated. Comparison in the magnetic data is made to calculations.

[1] Jenkins et al, APL, December 2008. [2] Liu et al, Phys. Rev. B, 74, 054435 (2006) [3] Barman and Chakrabarti, PRB April 2008.

MA 13.27 Tue 10:15 P1A

**Sputter deposited epitaxial Ni-Mn-Ga films on various substrates** — •Anja Backen[1,2], Stefan Kaufmann[1], Jörg Buschbeck[1,2], Ludwig Schultz[1,2], and Sebastian Fähler[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box: 270116, 01171 Dresden, Germany — [2]Departement of Mechanical Engineering, Institute for Material Science, Dresden University of Technology, 01062 Dresden, Germany

Due to their large strain up to 10 % magnetic shape memory alloys (MSM) are a promising class of active materials that can be integrated in microdevices. The deposition of epitaxial films is most suitable for this application since significant strains have only been observed in bulk single crystals. Tailoring the microstructure of the films is crucial in order to obtain high strains by magnetically induced reorientation (MIR) via twin boundary motion. Extensive research effort has been put into the investigation of the MSM alloy Ni-Mn-Ga which was deposited on various substrates ($Al_2O_3$, $SrTiO_3$, NaCl, MgO) by DC sputtering. In order to release the films from the substrates the concept of a sacrificial buffer layer is used. We focus on epitaxial Ni-Mn-Ga films deposited on MgO substrates with Cr buffers while varying the deposition parameters. First results on both constraint and freestanding films will be presented.

MA 13.28 Tue 10:15 P1A

**Composition and microstructure of sputtered Ni-Mn-Ga magnetic shape memory thin films** — •J. Petersen, Y. Luo, S. G. Mayr, and K. Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Ni-Mn-Ga films close to the composition of $Ni_{50}Mn_{30}Ga_{20}$ were sputter deposited onto different substrates, e.g. thermally oxidized silicon and NaCl(100). Object to the investigation is the influence of deposition parameters on the resulting film composition, phase and microstructure. The Ni content of the original sputtering target ($Ni_{50}Mn_{30}Ga_{20}$) was increased to obtain a higher martensitic transformation temperature $T_M$ above room temperature (here $T_M > 150°C$ measured by temperature dependent x-ray diffraction). First results show a significant depletion of Mn in the films with increasing deposition temperature whereas the ratio of Ni to Ga remains nearly constant. While thermally annealed films deposited at room temperature show the same 7M modulated martensitic phase and depletion of Mn, the advantage is that loss of Mn can be limited by using short annealing times and surface roughness is dramatically reduced. We acknowledge support by the BMBF - project 13N10061 MSM-sens.

MA 13.29 Tue 10:15 P1A

**In-situ studies of the martensitic transformation in epitaxial Ni-Mn-Ga films** — •Robert Niemann[1,2], Jörg Buschbeck[1], Oleg Heczko[1,3], Michael Thomas[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, P.O. Box: 270116, 01171 Dresden, Germany — [2]Institute for Solid State Physics, Department of Physics, Dresden University of Technology, 01062 Dresden, Germany — [3]Institute of Physics, Academy of Science of Czech Republic, Na Slovance 2, 18205 Prague, Czech Republic

The martensitic transformation of epitaxial Ni-Mn-Ga films on rigid substrates is examined with respect to changes of structure, microstructure, magnetic and electronic properties. For this, temperature dependent atomic force microscopy (AFM), X-ray, magnetization and resistivity measurements are used. The combination of these in-situ methods give a comprehensive understanding of the martensitic transformation and allows to identify differences of constrained epitaxial films compared to bulk. Experiments show the formation of a twinned, orthorhombic martensite with high uniaxial magnetocrystalline anisotropy from the austenite around room temperature. While most features are similar to a first order transformation, the transformation proceeds continuously to lower temperatures, an effect which could be explained by the constrain of the rigid substrate. The high-resolution AFM micrographs directly reveal how martensite variants grow and show the converging of variants from different nucleation origins. A crystallographic modell is presented which explains the regular, triangular morphology observed by AFM in the martensite state.

MA 13.30 Tue 10:15 P1A

**Structure and magnetism of Fe-Pd bulk alloys and nanoparticles from first principles** — •Markus Ernst Gruner — Department of Physics and Center for Nanointegration CENIDE, University of Duisburg-Essen, 47048 Duisburg, Germany

In disordered off-stoichiometric $Fe_{70}Pd_{30}$ and in $Fe_3Pt$ as well as in Ni-Mn-Ga full Heusler alloys the magnetic shape memory (MSM) effect is observed, allowing macroscopic strains of several percent to be achieved in realistic magnetic fields which opens up technological applications as nano- or microscale actuators. The underlying mechanism requires a considerable magnetocrystalline anisotropy in connection with an extremely high mobility of martensitic twin boundaries. In addition, Fe-Pt and Fe-Pd exhibit in their stoichiometric $L1_0$ phases a magnetocrystalline anisotropy energy being sufficient to entitle them for recording media applications.

This contribution presents ab initio calculations within the framework of density functional theory of the stoichiometric ordered phases of Fe-Pd as well as for disordered systems with MSM relevant composition which are covered within a supercell approach. The investigation covers bulk systems and nanometer-sized clusters which give an account on the influence of surfaces and the possible importance of multiply twinned morphologies.

This work is supported by the Deutsche Forschungsgemeinschaft through SPP 1239 and SFB 445. Part of the computations were carried out on the supercomputers of the John von Neumann Institute for Computing at Forschungszentrum Jülich.

MA 13.31 Tue 10:15 P1A

**Domain models for ferromagnetic shape-memory alloys: magnetic phase diagrams, transformation and magnetization processes** — •Aristide T. Onisan, Alexei N. Bogdanov, and Ulrich K. Rössler — IFW Dresden, POB 270116, 01171 Dresden

A phenomenological domain theory for magnetic shape memory materials is developed for the case of a ferromagnetic martensite with tetragonal twin variants, as a simplified approach to the archetypical $Ni_2MnGa$ Heusler alloys. A three dimensional model is analysed that is derived from a micromagnetic continuum approach combined with piecewise linear crystal elasticity of the twin variants. The tetragonal variants are assumed to own easy-axis magnetic anisotropy. The phase theory approximation is used to treat the equilibrium domain structure which is composed of six phases describing the two magnetic domains within each of the three possible twin variants created in an austenitic cubic single crystal. Phase diagrams under magnetic fields and stresses have been calculated in the three-dimensional case for a macroscopic sample with ellipsoidal shape. We have also calculated switching fields and the theoretical maximum hysteresis for two-dimensional geometries where only two twin-variants are present and twin-rearrangement is impeded by coercivity. Our results for realistic materials parameters are compared with existing experimental data.

MA 13.32 Tue 10:15 P1A

**Fe-Pd magnetic shape memory foils and films: a comparison of structural, magnetic and electronic properties** — •Iris Kock, Tobias Edler, Lisa Kühnemund, and Stefan Georg Mayr — I. Physikalisches Institut, Georg-August-Universität Göttingen

Miniaturization of shape memory devices is an important challenge for application in microactuation. To ensure adequate functionality, a profound knowledge about size dependent limitations and a detailed understanding of the underlying physics is desirable. For this purpose, Fe-Pd splats (with a thickness of 60$\mu$m) that are martensitic at room temperature, were compared to vapor deposited thin films (thickness $< 1\mu$m) that were optimized by various techniques during and after growth. Especially comparison of structural, magnetic and electronic properties gives insight into substrate and surface induced constraints as well as other impacts of miniaturization. *Funded by the DFG-SPP 1239 (C4)*

MA 13.33 Tue 10:15 P1A

**Influence of Surface Condition and Training on the Twin-**

**ning Stress of Ni-Mn-Ga Magnetic Shape-Memory Alloys** — •Markus Chmielus[1,2], Katharian Rolfs[1], Cassie Witherspoon[2], Walter Reimers[3], Peter Müllner[2], and Rainer Schneider[1] — [1]SF1, Helmholtz Centre Berlin for Materials and Energy, 14109 Berlin, Germany — [2]Department of Materials Science and Engineering, Boise State University, Boise, Idaho 83725, USA — [3]Institut für Werkstoffwissenschaften und -technologien, Technische Universität Berlin, 10587 Berlin, Germany

While the effects of composition of Ni-Mn-Ga magnetic shape memory alloys (MSMAs) on structure, thermal, and magnetic properties have been well studied, effects related to the processing of MSMA single crystals have attracted less attention. Annealing, cutting, and surface preparation are known to impact the magneto-mechanical properties but no quantitative data is available. In this work, the influence of the surface roughness on the twinning stress is evaluated. During spark erosion cutting - commonly used to prepare single crystalline samples - a rough surface layer is produced. Directly after cutting, the single crystals exhibit a high twinning stress. After removal of a surface layer through electro polishing, the twinning stress reduces significantly. It is shown here, however, that a reduction of the twinning stress after each of several electro polishing steps is induced by mechanical training. This softening also occurs for unpolished Ni-Mn-Ga single crystals when subjected to the same training procedure. The results are discussed in terms of twin-surface and twin-twin interactions.

MA 13.34 Tue 10:15 P1A

**Temperature dependent domain wall dynamics in compressively strained GaMnAs** — •Jan Honolka[1], Liza Herrera Diez[1], Reinhard Kremer[1], Ernesto Placidi[2], Fabrizio Arciprete[2], and Klaus Kern[1] — [1]MPI für Festkörperforschung, Stuttgart — [2]Dipartimento di Fisica, Universita di Roma 'Tor Vergata'

The correlation between carrier density and magnetic properties like Tc [1] or the magnetic anisotropy [2] in GaMnAs enables the tuning of magneto-transport properties and opens new ways for magneto-logic devices[3]. A full control over magnetic reversal dynamics mediated via nucleation and propagation of domain walls (DWs) is necessary. While magneto-transport measurements only give spatially averaged information about DW dynamics we use Kerr microscopy to track individual in-plane domains in space and time. Based on the energy landscape given by the interplay of bi- and uniaxial anisotropy contributions in compressively strained GaMnAs we are able to directly observe the nucleation of DWs and their shape and mobility. At low temperatures DW nucleation and propagation depend on the crystalline directions of the film with respect to the applied magnetic field [4]. We now show the temperature dependence of the dynamics which gives valuable information for controlling DW dynamics and for the development of single DW devices.

[1] T.Dietl et al., Science 287, 1019 (2000). [2] T.Dietl, H.Ohno, and F.Matsukura, Phys. Rev. B 63, 195205 (2001). [3] D.Chiba, M.Yamanouchi, F.Matsukura, H.Ohno, Science 301, 943 (2003). [4] L. Herrera Diez et al., Phys. Rev. B 78, 155310 (2008).

MA 13.35 Tue 10:15 P1A

**Effects of thermal treatment on the electronic structure of $Ga_{1-x}Mn_xAs$** — •Benjamin Schmid[1], Dominic Fertig[1], Sebastian Engelbrecht[1], Michael Sing[1], Lars Ebel[2], Charles Gould[2], Karl Brunner[2], Laurens W. Molenkamp[2], and Ralph Claessen[2] — [1]Experimentelle Physik IV, Universität Würzburg, Würzburg, Germany — [2]Experimentelle Physik III, Universität Würzburg, Würzburg, Germany

Despite intense research over the last decade the electronic structure of diluted magnetic semiconductors, especially the prototypical (Ga,Mn)As system, remains subject of controversial discussions. The interplay of substitutional and interstitial Mn and the possible exsistence of a Mn-related impurity band are two major issues. The situation is further complicated by post-growth treatments required for the improvement of the transport and magnetic properties. Photoemission spectroscopy (PES) is an outstanding tool for the investigation of electronic properties of solids, both in regard to the chemical state of ions and the conduction electrons near the Fermi-energy.
We present a detailed study of changes in the electronic structure of $Ga_{1-x}Mn_xAs$ upon various sample treatments. Effects of *ex-situ* and *in-situ* thermal treatment as well as wet-chemical etching and ion-sputtering are discussed on basis of the Mn 2*p*-doublet and the density of states in the vicinity of the Fermi-energy. The results are backed by complementary tools, i.e., low-energy electron diffraction (LEED) and atomic force/scaning tunneling microscopy (AFM/STM).

MA 13.36 Tue 10:15 P1A

**Relativistic electronic structure of Mn-doped GaAs** — •Ilja Turek[1], Vaclav Drchal[2], and Josef Kudrnovsky[2] — [1]Institute of Physics of Materials, ASCR, Brno, Czech Republic — [2]Institute of Physics, ASCR, Prague, Czech Republic

Electronic structure of Mn-doped GaAs diluted magnetic semiconductor is studied by means of the first-principles TB-LMTO method within the local spin-density approximation (LSDA) and the coherent potential approximation (CPA). Particular attention is paid to an interplay of chemical disorder, spin polarization and spin-orbit interaction (SOI). The results prove that the SOI has a negligible effect on integral properties (magnetic moments, densities of states) but it destroys the perfect spin polarization of states at the Fermi energy. Inspection of the Bloch spectral functions, evaluated along high-symmetry lines of the Brillouin zone, reveals that the majority spin states around the Fermi energy exhibit a very strong disorder. The minority spin states at the top of the valence band are only weakly affected by the randomness; their broadening is enhanced due to the SOI and the strong disorder in the majority-spin channel. Magnetic anisotropy of the electronic structure for reciprocal vectors parallel and perpendicular to the magnetization direction is negligible.

MA 13.37 Tue 10:15 P1A

**Spin-flip Probabilities in Concentrated and Diluted Ferromagnetic Semiconductors** — •Gerald Rosenthal and Wolfgang Nolting — Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin

We present an exact Green's function study of the electronic energy spectrum of a ferromagnetic semiconductor at T = 0K within the framework of the single-band as well as multi-band Kondo-lattice model. Main focus is put on quasiparticle densities of states, dispersion relations and spin-flip probabilities. The spectrum decomposes into a scattering part (magnon emission) and a quasiparticle part (magnetic polaron). The spin-flip oscillation period of the magnetic polaron can quantitatively be determined. Furthermore, the influence of disorder (diluted ferromagnetic semiconductors) on the energy spectrum and spin-flip probabilities will be discussed.

MA 13.38 Tue 10:15 P1A

**Investigation of the valence states of $Fe_{1-x}Cu_xCr_2S_4$ by photoelectron spectroscopy** — •Christian Taubitz[1], Michael Raekers[1], Vladimir Tsurkan[2], and Manfred Neumann[1] — [1]Universität Osnabrück, Fachbereich Physik, Barbarastraße 7, D-49069 Osnabrück, Germany — [2]Institute of Applied Physics, Academy of Science of Moldova, Kishinev MD 2028, Republic of Moldova

Spinel compounds of $Fe_{1-x}Cu_xCr_2S_4$ have attracted much attention since the discovery of a very large negative magnetoresistance (MR) effect. The valencies of Fe, Cu and Cr have been a long-standing issue in the attempt to understand the magnetic and electric properties of these compounds. In the region $0 \leq x \leq 0.5$ the Lotgering model predicts Fe to be in a mixed valence state between $Fe^{2+}$ and $Fe^{3+}$. For x=0.5 all Fe-ions are assumed to be trivalent. Mössbauer measurements confirm this model, however investigations with XAS and XPS show Fe to stay in a divalent state for $0 \leq x \leq 0.5$. We show XAS, XPS and XMCD measurements of single crystalline $Fe_{0.5}Cu_{0.5}Cr_2S_4$ and the first XPS measurements of $Fe_{1-x}Cu_xCr_2S_4$ single crystals for $x>0.5$. Our results indicate no ion valency change to be present in $Fe_{1-x}Cu_xCr_2S_4$ over the whole Cu concentration range. When the surface of $Fe_{0.5}Cu_{0.5}Cr_2S_4$ is oxidised we find $Fe^{3+}$ in a paramagnetic state. We discuss our results in view of Mössbauer measurements and theoretic models, and give possible explanations for the contradictory results.

MA 13.39 Tue 10:15 P1A

**Electronic structure of $MnZnFe_2O_4$ spinel ferrite** — •S. Soliman[1], A. Elfalaky[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [2]Department of Physics, Faculty of Science, Zagazig University, Zagazig, Egypt

To fabricate materials with specific characteristics, the electronic structure of these materials should be comprehensively inspected against different conditions and circumstances. Circumstances such as chemical doping, valency of the ions, sites position, etc. might have significant modification to the band structure. Full potential linearized augment plane wave method (FP-LAPW) has been applied to calcu-

late the electronic band structure of $MnZnFe_2O_4$. According to the calculations, the semiconducting parameters were predicted in terms of exchange of Mn and Zn ion substitution.

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MA 13.40 Tue 10:15 P1A

**Electronic structure of $MnFe_2O_4$ spinel ferrite** — •S. Soliman[1], A. Elfalaky[2], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz — [2]Department of Physics, Faculty of Science, Zagazig University, Zagazig, Egypt

Full potential linearized augment plane wave method (FP-LAPW) has been exploited to calculate the electronic band structure of Mn $Fe_2O_4$ spinel ferrite. From the calculations, the crystal structure, position of ionic occupation within the unit cell will be imparted. Some mechanical characterization were revealed. In addition, the semiconducting parameters, density of states magnetic parameters will also be evaluated and compared with the available experimental and theoretical data.

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MA 13.41 Tue 10:15 P1A

**Magneto-optical spectroscopy of europium telluride and europium hydride** — •Bodo Lobbenmeier, Helge Schröter, Peter Clodius, and Joachim Schoenes — Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

Magneto-optical measurements on EuTe and $EuH_2$ have been used to investigate the electronic properties of the highly localized 4-f electrons of europium, i.e. the transition from the 4-f to the 5-d state. Since a magnetic transition from a canted antiferromagnetic to a spin-aligned phase is expected near 7 T in EuTe, the magnetic field dependencies have been measured up to 10 T. The Kerr spectroscopic investigations have been made in the energy range from 1.8 eV to 4.3 eV. The spectra for EuTe have been compared with data obtained for $EuH_2$ which has a similar gap than EuTe. This films of $EuH_2$ have been grown by pulsed laser deposition and show a transition to a ferromagnetic phase at 18 K.

MA 13.42 Tue 10:15 P1A

**Curie point singularity in (Ga,Mn)As** — •Vit Novak, Kamil Olejnik, Miroslav Cukr, Petr Vasek, Zbynek Soban, and Tomas Jungwirth — Institute of Physics AS CR, Cukrovarnicka 10, 162 53 Prague, Czech Republic

A striking cusp-like singularity has been found in the temperature derivative of resistivity at the Curie point of high-quality (Ga,Mn)As ferromagnetic semiconductors [1]. The character of the anomaly is sharply distinct from the critical contribution to transport in conventional dense-moment magnetic semiconductors and is reminiscent of the singularity in transition metal ferromagnets. Applicability of the singularity to accurately determine the Curie temperature is demonstrated and compared to standard magnetometry and Arrott plot technique.

[1] V. Novak et al., Phys. Rev. Letters 101, 077201 (2008).

MA 13.43 Tue 10:15 P1A

**Suppression of resistivity due to thermal treatment of $SnO_2$ thin films** — •Ali Awada[1], Dirk Menzel[1], Joachim Schoenes[1], Frank Ludwig[2], and Meinhard Schilling[2] — [1]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany — [2]Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik, TU Braunschweig, Germany

In the field of diluted magnetic semiconductors, transition metal doped oxides have attracted much interest because of a Curie temperature which is beyond 300 K. Among these materials $SnO_2$ is a promising host material for spintronic applications due to its low electrical resistivity despite a high optical transparency. Conductivity measurements of sputtered $SnO_2$ thin films show a resistivity in a wide range from 0.2 to 80 Ωcm at room temperature depending on the preparation parameters. The stoichiometry of the $SnO_2$ plays a crucial role since the conductivity of the tin dioxide is presumably determined by donor levels originating from oxygen vacancies [1]. In order to exert influence on the amount of defects the films were annealed after deposition. In comparison to the as-grown samples a suppression of the resistivity due to the thermal treatment by a factor of more than 10 is observed. Since it is assumed that the ferromagnetic exchange is mediated via free charge carriers in the sense of a magnetic polaron the tuning of the electrical properties is a key issue towards diluted magnetic semiconductors with large ordered moments and high Curie temperatures.

[1] D. Menzel, A. Awada, H. Dierke, J. Schoenes, F. Ludwig, and M. Schilling, J. Appl. Phys. **103**, 07D106 (2008).

MA 13.44 Tue 10:15 P1A

**Ferromagnetic order above room temperature in cubic Y-stabilized $ZrO_2$ by Fe-implantation** — •Monika Kotzian, Dirk Menzel, and Joachim Schoenes — Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

Diluted magnetic oxides have attracted much interest when room-temperature ferromagnetism was observed e. g. in transition metal doped $TiO_2$ and $SnO_2$. Recently, ferromagnetic order with Curie temperatures far above 300 K was also predicted in $ZrO_2$ when it is doped with magnetic transition elements [1]. For an experimental verification of this prediction single crystalline Y-stabilized $ZrO_2$ was doped with Fe using the ion-implantation technique at high doses leading to Fe concentrations up to 7 at.%. This method was chosen in order to prevent the clustering of the magnetic ions. Due to the implantation the $ZrO_2$ crystals show a brownish color. However, the fundamental band gap of 4.08 eV, which was determined using optical spectroscopy, does not change significantly on doping within the investigated Fe concentration range. The $ZrO_2$ crystals doped with 7 at.% Fe order ferromagnetically with an ordered moment per Fe atom of 0.30 $\mu_B$ at 10 K and 0.25 $\mu_B$ at room temperature. Upon annealing the brownish color vanishes and the ordered moment decreases. This leads to the interpretation of a polaron-mediated magnetic exchange interaction.

[1] S. Ostanin et al., Phys. Rev. Lett. **98**, 016101 (2007).

MA 13.45 Tue 10:15 P1A

**MBE growth of $Fe_3O_4$ films on ZnO** — •Markus Paul[1,2], Nicholas Ingle[2], Andreas Müller[1], Andreas Ruff[1], Michael Sing[1], and Ralph Claessen[1] — [1]Lehrstuhl für Experimentelle Physik 4, Universität Würzburg, Germany — [2]AMPEL, University of British Columbia, Vancouver, Canada

Magnetite ($Fe_3O_4$) is ranked among the promising materials as spin-injector into a semiconducting host. Its ferrimagnetic behaviour with a high Curie temperature of about 850 K, the small conductivity mismatch to semiconductors and its theoretically predicted high spin polarization at $E_F$ are very attractive for this goal. The deposition of magnetite thin fims on ZnO presents a further step towards integration of magnetic materials into semiconductor technology.

We have investigated the MBE growth behaviour and properties of $Fe_3O_4$ thin films on ZnO with various techniques. Growth proceeds as a mixed layer and island growth for typical film thicknesses ranging from 10 to 30 nm. LEED, RHEED and XRD results demonstrate (111) oriented deposition with an epitaxial relationship of $Fe_3O_4\langle 1\bar{1}0\rangle \| \, ZnO\langle 2\bar{1}\bar{1}\rangle$. XPS and HAXPES spectra reveal small changes in Fe and Zn chemical environments with varying probing depth. UPS measurements are in agreement with results obtained on single crystals showing no spectral weight at $E_F$.

MA 13.46 Tue 10:15 P1A

**Searching for Intrinsic Magnetic Order in Pure ZnO Thin Films** — •M. Khalid[1], M. Ziese[1], A. Setzer[1], P. Esquinazi[1], H. Hochmuth[2], M. Lorenz[2], M. Grundmann[2], D. Spemann[3], and T. Butz[3] — [1]Division of Superconductivity and Magnetism — [2]Semiconductor Physics Group — [3]Division of Nuclear Solid State Physics — Faculty of Physics and Geosciences, University of Leipzig, 04103 Leipzig.

Defect-induced room temperature ferromagnetism in oxide semiconductors has attracted wide research interest in recent years. In view of their potential spintronic and optoelectronic properties we studied the magnetic properties of pure ZnO films grown under reducing conditions. The films were grown by pulsed laser deposition onto $Al_2O_3$ $(11\bar{2}0)$ substrates. Substrate temperature was between room temperature and 570°C and $N_2$ partial pressure between 0.007 mbar and 0.3 mbar. The magnetic properties of the bare substrates and the ZnO films were investigated by SQUID magnetometry. The samples were directly clamped in straws for magnetization measurements to minimize spurious magnetic signals from the sample mounting. The $Al_2O_3$ substrates showed a small residual ferromagnetic-like contribution. None of the ZnO films showed reproducible ferromagnetic hysteresis significantly larger than the substrates. The purity of the ZnO films was checked by particle induced X-ray emission and iron con-

tamination between 30 and 200 $\mu$g iron per gram ZnO was detected. In conclusion, ZnO films grown under reducing $N_2$ atmosphere did not show any reproducible ferromagnetic contribution to the SQUID signal.

MA 13.47 Tue 10:15 P1A

**Electronic and magnetic properties of doped ZnO** — •Igor Maznichenko[1], Arthur Ernst[2], Sergey Ostanin[2], Markus Däne[1,3], Ingrid Mertig[1,2], Patrick Bruno[2,4], Wolfram Hergert[1], Jürgen Henk[2], Martin Lüders[3], Zdzislawa Szotek[3], and Walter Temmerman[3] — [1]Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, D-06099 Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [3]Daresbury Laboratory, Daresbury, Warrington WA4 4AD, Cheshire, United Kingdom — [4]European Synchrotron Radiation Facility - BP 220, F-38043 Grenoble Cedex, France

Oxides are interesting materials with a high potential for opto and spin electronics. Semiconductors based on ZnO demonstrate properties wanted for both of these applications. Its combination with the well known spacer material MgO exhibits extraordinary properties as a function of concentration. First of all, the binary alloy $Zn_{1-x}Mg_xO$ undergoes a structural phase transition from the wurtzite structure of ZnO to the rock-salt structure of MgO. Second, the band gap of the alloy changes from 3.4 eV for $x$=0 to 7.2 eV for $x$=1.

ZnO based diluted magnetic semiconductors demonstrate different magnetic properties depending on the type of dopant, its concentration and distribution. Especially important for applications is the existence of room temperature ferromagnetism.

First-principle studies were performed within the framework of the Korringa-Kohn-Rostoker method. The temperature-dependent magnetic properties were calculated by mapping onto a Heisenberg model.

MA 13.48 Tue 10:15 P1A

**Universal scaling relation between Hall and longitudinal conductivity in Zn-substituted magnetite** — Deepak Venkateshvaran, Andrea Nielsen, Matthias Althammer, Sebastian Goennenwein, •Matthias Opel, and Rudolf Gross — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

The anomalous Hall effect (AHE) in the low-conductivity ferromagnetic oxide $Fe_{3-x}Zn_xO_4$ with x = 0, 0.1, and 0.5 is investigated in this work. We used (001), (110), and (111) oriented epitaxial $Fe_{3-x}Zn_xO_4$ films deposited on MgO and sapphire substrates in different oxygen partial pressures to analyze the dependence of the AHE on crystallographic orientation, Zn content, strain state, and oxygen deficiency. Despite substantial differences in their magnetic and transport properties, a universal scaling relation between the anomalous Hall conductivity $\sigma_{xy}^{AHE}$ and the longitudinal conductivity $\sigma_{xx}$ is observed. Specifically, we find that $\sigma_{xy}^{AHE} \propto \sigma_{xx}^{\alpha}$ where $\alpha = 1.69 \pm 0.08$. Our results agree with a recent theoretical prediction for metallic ferromagnets in the dirty limit [2], extending the theory to materials for which hopping conduction prevails. The fact that the scaling relation is independent of crystallographic orientation, Zn content, strain state, and oxygen deficiency suggests that it is universal and does not depend on the detailed nature of the transport mechanism. This work is supported by the DFG within SPP 1157 and 1285 and by the DAAD.

References: [1] D. Venkateshvaran et al., Phys. Rev. B **78**, 092405 (2008). [2] S. Onoda et al., Phys. Rev. Lett. **97**, 126602 (2006).

MA 13.49 Tue 10:15 P1A

**Optical and magnetooptical studies on manganite films** — •Markus Jungbauer, Kai Gehrke, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

The mechanism of the metal-insulator transition and CMR effect in perovskite manganites is still under debates. It was argued that Jahn-Teller polarons and phase separation play an essential role at this point. For further detailed study of these phenomena we built an experimental setup for simultaneous electric transport, optical and magnetooptical measurements on manganite thin films in the range of temperatures 20 K-400 K, magnetic fields up to $H_{max}$=15 kOe and photon energies $h\nu$=1.3 eV to 4 eV. Using this setup we studied three different manganite compounds: $La_{1-x}Sr_xMnO_3$, $La_{1-x}Ca_xMnO_3$ and $(La_{0.6}Pr_{0.4})_{1-x}Ca_xMnO_3$, epitaxially grown on MgO-substrates using MAD technique. The films were also characterized by X-ray diffraction and scanning tunneling microscopy. Then the optical transmission, faraday-rotation, faraday-ellipticity and coercitivity as a function of temperature and magnetic field were measured. The magnetic and electronic phase transition were visualized in optics and magnetooptics and compared with magnetotransport data.

Deutsche Forschungsgemeinschaft via SFB 602, TPA2 is acknowledged.

MA 13.50 Tue 10:15 P1A

**Magnetic anisotropy of (100)- and (110)-oriented $CrO_2$ thin films** — •Franz Czeschka[1], Daniel Rueffer[1], Sebastian T.B. Goennenwein[1], Rudolf Gross[1], Arunava Gupta[2], Christoph Bihler[3], and Martin S. Brandt[3] — [1]Walther-Meißner-Insitut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]MINT Center, Tuscaloosa, Alabama, USA — [3]Walter Schottky Institut, Technische Universität München, Garching, Germany

In the field of spintronics, ferromagnetic materials with a high spin polarization are important. A promising material in this context is the half metal chromium dioxide ($CrO_2$) with a spin polarization of $P \approx 98\,\%$ and a Curie temperature of $T \approx 390\,\mathrm{K}$. However, for the application a quantitative knowledge of its magnetic properties is essential.

We have determined the magnetic anisotropy of thin $CrO_2$ films with thicknesses ranging from 10 nm to 1.2 $\mu$m at room temperature by ferromagnetic resonance spectroscopy (FMR) both in the X-band (9.3 GHz) and in the K-band (24.125 GHz). The films were grown by chemical vapor deposition (CVD) on either (100)- or (110)-oriented $TiO_2$ single crystal substrates. A clear dependence of the magnetic anisotropy on the crystallographic orientation and on the $CrO_2$ thickness was observed. We discuss the influence of epitaxial strain on the magnetic anisotropy and compare our results to literature.

Financial support of the German Excellence Initiative via the "Nanosystems Initiative Munich (NIM)" is gratefully acknowledged.

MA 13.51 Tue 10:15 P1A

**Interface and bulk magnetic properties of Laser-ablated $Co_2$(Mn,Fe)Si films measured by X-ray magnetic circular dichroism (XMCD)** — •Michael Kallmayer, Peter Klaer, Horst Schneider, Gerhard Jakob, and Hans Joachim Elmers — Universität Mainz, Institut für Physik, D-55128 Mainz, Germany

Heusler alloys with a predicted spin-polarization of 100% at the Fermi edge are currently of great interest. One of these half metallic ferromagnets is $Co_2$(Mn,Fe)Si, which makes it a promising candidate for spintronic and TMR devices. For applications interface properties are of utmost importance. Using X-ray absorption spectroscopy, we measured the total electron yield (TEY), which provides a surface sensitive signal with a typical information depth of about 2-3 nm. Simultaneously, we measured the luminescence yield from the substrate. This signal integrates along the surface normal of the film and provides a bulk-like information. We investigated epitaxial films of $Co_2MnSi$, $Co_2FeSi$ and $Co_2Mn_{0.5}Fe_{0.5}Si$ grown on MgO(100) via pulsed laser deposition. We find that the magnetic moments at the surface and in the bulk are similar and in good agreement with theoretical predictions. We discuss details of the spectral features in comparison with theoretical results.

MA 13.52 Tue 10:15 P1A

**X-ray absorption spectroscopy of half-metallic $Co_2TiZ$ (Z = Si, Ge and Sn)** — •Peter Klaer[1], Michael Kallmayer[1], Thorsten Methfessel[1], Hans Joachim Elmers[1], Benjamin Balke[2], Joachim Barth[2], Tanja Graf[2], Gerhard Fecher[2], and Claudia Felser[2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55128 Mainz, Germany — [2]Institut für Anorganische Chemie und Analytische Chemie, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany

X-ray magnetic circular dichroism (XMCD) of core-level absorption spectra has been measured for the Heusler alloys $Co_2TiZ$ (Z = Si, Ge, Sn and Sb) at the $L_{3,2}$-edge. Half-metallic properties have been predicted for Z = Si, Ge and Sn. $Co_2TiZ$ samples were prepared by arc melting of stoichometric quantities of the constituents. Bulk samples were *in situ* cleaved, shortly before data acquisition, to guarantee a clean surface. We have determined the element specific spin and orbital magnetic moments from the XMCD spectrum using a sum rule analysyis. Results are compared with data from SQUID magnetometry and theory. Co and Ti show antiparallel magnetic spin moments, except for the compound containing Sb. This means that $Co_2TiZ$ (Z = Si, Ge, Sn) is a ferrimagnet, in agreement with theory. Assuming, that the x-ray absorption spectra at the $L_3$-edge is proportional to the spin density of states (DOS), we calculated the spin resolved DOS function from the experimental XMCD spectra. These results are in agreement

with the predicted band structure of these materials. We also show atomically resolved STM images of the cleaved surfaces.

MA 13.53 Tue 10:15 P1A

**Thin films of the Heusler compounds Co2FeAl and Co2FeAl0.6Si0.4** — •Elena Arbelo Jorge, Christian Herbort, and Martin Jourdan — Institut of Physics, Johannes-Gutenberg University, Mainz, Germany

Heusler compounds are potential candidates for showing half metallic properties (100% spin polarization) with a large band gap at the Fermi energy and a high Curie temperature above room temperature. Epitaxial thin films of the Heusler compounds Co2FeAl and Co2FeAl0.6Si0.4 were grown by rf sputtering. A study of their crystallographic structure, surface morphology and magnetization has been carried out. For Co2FeAl a B2 structure is found after annealing at 550°C. For Co2FeAl0.6Si0.4 L21 order is found after annealing at the same temperature. The crystallographic order depending on different annealing temperatures is shown. In both compounds a small tetragonal distortion is observed. The surface morphology of each compound is also analysed and compared. Magnetization measurements made in a Quantum Design SQUID magnetometer show a magnetic moment of 4.86$\mu$B/f.u and 4.47$\mu$B/f.u for Co2FeAl and Co2FeAl0.6Si0.4 annealed at 550°C respectively, which is 2.8% and 17,2% less than the value predicted theoretically from the Slater-Pauling rule for half metals, 5.0$\mu$B/f.u and 5.4 $\mu$B/f.u, respectively. The magnetic moment depending on different annealing temperatures is presented. Finally, TMR results obtained up to now are shown.

MA 13.54 Tue 10:15 P1A

**Quadratic Magneto-optical Kerr Effect Magnetometry: Application to $Co_2$-based Heusler Compounds** — •Peter Clausen, Jaroslav Hamrle, Simon Trudel, Oksana Gaier, and Burkard Hillebrands — FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslauten, 67663 Kaiserslautern, Germany

In this poster, we present the results of our investigation of $Co_2$-based Heusler alloys using magneto-optical Kerr effect (MOKE) magnetometry. We find that in addition to the longitudinal MOKE signal, a strong quadratic MOKE signal is present.

As an example, in the first part of this poster we present our study of a series of $Co_2MnSi$ thin films that were subjected to different annealing temperatures, which results in a variation of the degree of atomic ordering within the compound. We show the amplitude of the quadratic MOKE signal also varies as a function of annealing temperature.

In the second part, we present our new MOKE system that is capable of simultaneously measuring the linear and quadratic MOKE signals, as well as the isolated quadratic MOKE signal, in the presence of an arbitrarily aligned in-plane magnetic field.

Financial support by the DFG within the Forschergruppe 559 "Neue Materialien mit hoher Spinpolarisation"is gratefully acknowledged.

MA 13.55 Tue 10:15 P1A

***Ab-initio* calculations of MnO in different crystal structures and magnetic orderings** — •Andreas Schrön, Claudia Rödl, Jürgen Furthmüller, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Antiferromagnetic transition-metal oxides (TMOs) are materials of great interest for applications in new magnetic materials (e.g. dilute magnetic semiconductors) and spintronics. There have been a couple of – theoretical as well es experimental – studies on the ground-state properties of MnO, but only few including also crystal structures different from the experimental rock-salt structure.

We present an *ab-initio* study of structural, electronic, and magnetic properties of MnO using density-functional theory (DFT). The results obtained within the generalized-gradient approximation (GGA) are compared with findings taking into account an additional on-site interaction $U$ (GGA+$U$) and results using the non-local hybrid HSE03 exchange-correlation functional. Besides the rock-salt structure, which is the natural ground-state structure of MnO, we focus especially on the properties of MnO crystallizing in wurtzite structure, which is the ground-state structure of e.g. ZnO, a potential host material for dilute magnetic semiconductors. We present our recent results considering six different magnetic orderings for both crystal structures, respectively, and compare them with experimental and, as far as available, other theoretical data.

MA 13.56 Tue 10:15 P1A

**Ab initio studies of structural, electronic and magnetic properties of pure and doped CoO** — Dmitry I. Bazhanov[1], •Pavel A. Ignatiev[2], Nikolay N. Negulyaev[3], and Valeri S. Stepanyuk[2] — [1]Faculty of Physics, Moscow State University, 119899 Moscow, Russia — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [3]Physics Department, Martin-Luther-University Halle-Wittenberg, 06099 Halle, Germany

Transition metal oxides attract much attention last years due to wide range of possible applications in micro- and magneto-electronics. A particular interest is drawn to the transition-metal oxides doped by another 3d elements. A classical example of such a system is transition-metal doped ZnO, a dilute semiconductor with coexisting magnetic, piezoelectric, optical and semiconducting properties.

We present study of pure and doped CoO with the NaCl crystal structure and type-II-fcc antiferromagnetic order. By means of pseudopotential and full-potential plane wave ab initio codes we calculate the equilibrium crystal structure of CoO, as well as variations of magnetic and electronic properties of CoO introduced by the strain. Dopants are then inserted into the CoO supercell consisting of 108 atoms. Structural relaxations caused by doping of Fe, Ni, Cu and Zn atoms are determined. Fe and Ni are found to align ferromagnetically with Co atoms in the same {111}-sheet. Nonmagnetic Cu inserted into CoO gets significant magnetic moment. Analysis of our results revealed that Ni and Cu dopants most likely do not interact with each other, contrary to the strong magnetic interaction between Fe atoms.

MA 13.57 Tue 10:15 P1A

**Elastic properties of single crystal manganites** — •Markus Michelmann[1], Dennis Bedorf[1], Emanuel Malek[2], Thomas Koeppe[1], Lakshmana Sudheendra[1], Vasily Moshnyaga[1], and Konrad Samwer[1] — [1]I. Physikalisches Institut, Universität Göttingen — [2]Cambridge University

We have studied the metal-insulator-transition in single crystal perovskite manganites by measurements of velocity of ultrasound waves. The single crystals of $La_{1-x}Ca_xMnO_3$ (LCMO), $Nd_{1-x}Ca_xMnO_3$ (NCMO) and $Pr_{1-x}Ca_xMnO_3$ (PCMO) were grown by zone melting technique. For LCMO the dependence of shear modulus on the temperature (40-280K) and magnetic field (0-5T) was measured by means of runtime of shear waves. The results show, that metal-insulator-transition is accompanied by a decrease of the stiffness, which as well can be driven by the temperature and/or the magnetic field. A comparison with the data of NCMO and PCMO crystals will be done.

Deutsche Forschungsgemeinschaft via SFB 602, TPA2 is acknowledged

MA 13.58 Tue 10:15 P1A

**Atomic-scale images of the paramagnetic insulating state in a $Pr_{0.68}Pb_{0.32}MnO_3$ single crystal** — •Sahana Roessler[1], Steffen Wirth[1], Frank Steglich[1], B Padmanabhan[2], Suja Elizabeth[2], and H. L. Bhat[2] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnizer Straße 40, 01187, Dresden, Germany — [2]Department of Physics, Indian Institute of Science, Bangalore 560012, India

Scanning tunneling microscopy and spectroscopy (STM/S) have been performed on a colossal magnetoresistive manganite $Pr_{0.68}Pb_{0.32}MnO_3$ (PPMO) single crystal. In this compound, the metal-insulator transition occurs at temperature $T_{MI}$ = 255 K[1]. STS revealed inhomogeneous maps of the zero-bias conductance with small patches of metallic clusters on a length scale of 2-3 nm only within a narrow temperature range close to but below the metal-insulator transition [2]. Here we present atomic-scale images taken at ambient temperature in the paramagnetic insulating state. The room-temperature image clearly depict the square lattice expected for the (010) suface of PPMO in a simple cubic notation. The corresponding lattice constant $a_0$ =3.75 ±0.6 Å is in agreement with the value determined by powder x-ray diffraction. We will also present STS results on an atomically resolved surface of PPMO.

[1] B. Padmanabhan *et al.* J. Magn. Magn. Mat. **307** 288 (2006). [2] S. Rößler *et al.* Euro. Phys. Lett. **83** 17009 (2008).

MA 13.59 Tue 10:15 P1A

**Ferromagnetic Signals in Nominally Non-magnetic Oxide Single Crystals** — •M. Ziese[1], A. Setzer[1], P. Esquinazi[1], D. Spemann[2], and A. Poeppl[3] — [1]Division of Superconductivity and Magnetism — [2]Division of Nuclear Solid State Physics — [3]Division of Magnetic Resonance of Complex Quantum Solids — Faculty of Physics

and Geosciences, University of Leipzig, 04103 Leipzig.

Defect-induced room temperature ferromagnetism in oxide semiconductors has attracted wide research interest in recent years. It appears that ferromagnetic order can be induced either in the bulk, when a narrow impurity band is present, or at the surface due to the lowering of the symmetry. In this work the magnetic properties of MgO, $MgAl_2O_4$, $SrTiO_3$, $LaAlO_3$, LSAT and ZnO single crystals were investigated. These crystals show three contributions to the magnetization, namely an intrinsic diamagnetic contribution, a paramagnetic contribution due to various transition metal impurities as well as a ferromagnetic contribution. The latter shows remanent magnetization and coercive field values that are strikingly independent of the actual crystal material. The magnetization data are correlated with results from particle induced X-ray emission and electron paramagnetic resonance spectroscopy. The origin of the ferromagnetic contribution is discussed in three different scenarios: (i) as caused by ferromagnetic impurities, (ii) as related to artifacts of the SQUID magnetometer and (iii) as arising from defect-induced ferromagnetism.

MA 13.60 Tue 10:15 P1A

**Structural and DFT studies on $YFeMnO_5$** — •Torsten Weissbach[1], Axel Lubk[1], Tilmann Leisegang[1], Thomas Führlich[1], Falk Wunderlich[1], Dmitri Souptel[2], Günter Behr[2], Igor Chaplygin[4], Gotthard Seifert[4], Dirk C. Meyer[1], and Sibylle Gemming[3] — [1]Institut für Strukturphysik, TU Dresden — [2]Institut für Festkörper-und Werkstoffforschung (IFW) Dresden — [3]Forschungszentrum Dresden-Rossendorf — [4]Institut für Physikalische Chemie und Elektrochemie, TU Dresden

Ferromagnetic and ferroelectric oxides of composition $REMn_2O_5$ have become known for exhibiting a coupling between those properties. On substitution of Fe in $YMn_{2-x}Fe_xO_5$, the crystal structure is conserved, but the magnetic structure changes and the ferroelectricity disappears. X-ray diffraction measurements on a series of powders with different Fe content were employed to inspect the crystal structure whereas extended X-ray absorption fine structure measurements were done to identify the iron substitution site. Density functional theory calculations of the electronic structure for $YMnFeO_5$ were carried out using the experimentally determined crystal structure data and the FPLO-5 program. Different magnetic structures are studied to determine the type of interaction between the magnetic ions.

## MA 14: Poster Ib: Magnetic Materials (1-14); Micro Magnetism/Computational Mag. (15-17); Surface Magnetism (18-22); Spin Structures/Phase Transitions (23-25)

Time: Tuesday 10:15–13:00 Location: P1B

MA 14.1 Tue 10:15 P1B

**$AgCuVO_4$: A quasi one-dimensional S = 1/2 compound** — •Angela Möller[1], Timo Taetz[1], Miriam Schmitt[2], and Helge Rosner[2] — [1]Universität zu Köln, Institut für Anorganische Chemie, Greinstr. 6, 50939 Köln, Germany — [2]Max Planck Institut for Chemical Physics of Solids, Noethnizer Str. 40, 01187 Dresden, Germany

Recently, we have been able to synthesize the new copper-orthovanadate $AgCuVO_4$ [1]. The crystal structure was determined by single crystal x-ray diffraction. $AgCuVO_4$ comprises $Cu^{2+}$ ions coordinated by oxygen in a square-planar fashion, similar to $LiCuVO_4$, which has been identified as a multiferroic material recently [2]. Whereas in $LiCuVO_4$ the square-planar $[CuO_4]$ units are connected via *edges* to form chains along the crystallographic *b* axis, the $[CuO_4]$ units in $AgCuVO_4$ are connected via *corners* resulting in Cu-O-Cu chains along the *b*-axis. The static magnetic susceptibility of $AgCuVO_4$ can be described quite well within a Bonner-Fisher spin-chain scenario.

In order to gain microscopic insight into the the electronic structure and the magnetic exchange interactions of $AgCuVO_4$, we performed LDA band structure calculations. To take the strong Coulomb repulsion at the Cu site into account, we mapped the LDA results onto a tight binding model and subsequently onto a Heisenberg model. In agreement with the experimental data, we find pronounced one-dimensional magnetic exchange along the *b* axis with small inter-chain couplings.

[1] A. Möller, J. Jainski, Z. Anorg. Allg. Chem. 634, 1669 (2008)
[2] M. Enderle *et al.*, Europhys. Lett. 70, 237 (2005)

MA 14.2 Tue 10:15 P1B

**Hard X-ray Photoelectron Spectroscopy of Complex Materials** — •Siham Ouardi, Andrei Gloskovskii, Benjamin Balke, Gerhard H. Fecher, and Claudia Felser — Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz

This work reports on Hard X-ray Photoelectron Spectroscopy of complex materials excited by photons of about 5.9 keV energy. The measurements were performed on Heusler thin films coated by MgO and $SiO_x$ insulating interlayer with different thickness *z* from 1 nm to 20 nm. It is shown that the insulating layer does not affect the high energy spectra of the Heusler compound close to the Fermi energy. The spectra of the buried thin films agree well with previous measurements from bulk samples. The high resolution measurements of the valence band close to the Fermi energy indicate a very large inelastic electron mean free path of the electrons in the insulating layer.

The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

MA 14.3 Tue 10:15 P1B

**EBSD analysis of the microtexture of Ba-hexaferrite samples** — •Anjela Koblischka-Veneva[1], Michael R. Koblischka[2], Jörg Schmauch[3], Yajie Chen[4], and Vincent G. Harris[4] — [1]Institute of Functional Materials, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany — [2]Experimental Physics, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany — [3]Technical Physics, Saarland University, Campus D 2 2, D-66123 Saarbrücken, Germany — [4]Department of Electrical and Computer Engineering, and the Center for Microwave Magnetic Materials and Integrated Circuits, Northeastern University, Boston, Massachusetts 02115, USA

The microtexture of differently prepared Ba-hexaferrite samples is investigated by means of electron backscatter diffraction (EBSD). Kikuchi patterns are obtained with a high image quality, enabling a spatial resolution of the EBSD maps of about 20 nm. The spatially highly resolved EBSD mappings provide additional information (individual grain orientation, misorientation angles, grain size distribution) as compared to the standard analysis techniques, which can contribute to an optimization of the growth process. Furthermore, as the crystallographic orientation of each grain is known, an exact analysis of the grain aspect ratio becomes possible which provides further insight to the microstructural dependence of the magnetic properties of ferrites.

MA 14.4 Tue 10:15 P1B

**UHV Diffractometer for Soft X-Ray Scattering at PETRA III** — •Christian Schüssler-Langeheine — II. Physikalisches Institut, Universität zu Köln

Resonant scattering in the soft x-ray range has recently shown to be a powerful technique to study nano-scale order phenomena like charge, orbital and spin order in strongly correlated electron systems as well as magnetic properties of thin films, multilayers and other nanostructures.

The XUV beamline of the new synchrotron-radiation source PETRA III in Hamburg with its energy range from 200 eV up to 3 keV will cover the most important resonances of 3*d*, 4*d* and 4*f* systems. For this beamline an UHV diffractometer suited for resonant soft x-ray scattering experiments is presently being set up. The experimental possibilities provided by the instrument in particular for the investigation of magnetic systems will be presented.

Funded by the BMBF through project 05KS7PK1.

MA 14.5 Tue 10:15 P1B

**Magnetic properties of the system Fe1-xCoxSi studied by Mössbauer spectroscopy** — •Josefin Engelke[1], Dirk Menzel[1], Jan Kreitlow[1], Mathias Thede[1], Gregor Bransky[1], Joachim Schoenes[1], Jochen Litterst[1], Dalber Sanchez[2], Yutao Xing[2], and Elisa Baggio Saitovitch[2] — [1]IPKM, TU Braunschweig, Germany — [2]CBPF, Rio de Janeiro, Brazil

The system Fe1-xCoxSi has been studied since many years also using Mössbauer spectroscopy amongst others methods. From magnetiza-

tion one can follow the development of magnetic ordered moments depending on Co concentration, from pure FeSi which is paramagnetic down to lowest temperatures, to very small ferromagnetic moments at intermediate concentrations with maximum ordering temperatures around 50 K, and finally diamagnetism in CoSi. This development is related to changes in the electronic band structure with rather narrow gaps. For low Co concentrations a helical structure of Co moments is derived which however is modified already in weak magnetic fields to a conical structure.

A long standing question concerns the moment at iron. In order to receive more reliable information on the magnetic state of iron in zero magnetic field we have performed Mössbauer spectroscopy on a series of Fe1-xCoxSi in the temperature range between 4 - 300K and also selected samples in applied external fields. Our data clearly show that there are indeed small ordered moments at iron in the concentration range between about x = 0.1 to 0.6 which are on the order of 0.2 uB.

MA 14.6 Tue 10:15 P1B

**Magnetic excitations in $R_2PdSi_3$ studied by inelastic neutron scattering** — Fei Tang[1], •Matthias Frontzek[1], Peter Link[2], Astrid Schneidewind[1,2], I. Mazilu[3], and Michael Loewenhaupt[1] — [1]IFP, TU Dresden, D-01062 Dresden, Germany — [2]FRM II, TU Munich, Lichtenbergstr. 1, 85747 Garching, Germany — [3]IFW Dresden, D-01069 Dresden, Germany

$R_2PdSi_3$ compounds have been found to exhibit rich magnetic phenomena arising from the interplay between RKKY interaction, crystal electric field effects and geometric frustration due to the derived hexagonal $AlB_2$ structure. The observed crystallographic superstructure further complicates the CEF level scheme.

Inelastic neutron scattering measurements on single crystals of $Tm_2PdSi_3$ and $Er_2PdSi_3$ have been performed at the cold triple axis spectrometer PANDA in FRM-II. Both compounds order antiferromagnetically at $T_N$ = 7 K and 2.1 K respectively; $Er_2PdSi_3$ undergoes a second phase transition at $T_2$ = 2 K. Several low lying CEF excitations (below 10 meV) were observed. The intensity of the lowest excitation show strong directional dependence (in HK0 plane for $Er_2PdSi_3$ and in HHL plane for $Tm_2PdSi_3$), from which the details of the transitional matrix could be deduced. Measurements in magnetic fields up to 13 T show Zeeman splitting of the CEF excitations.

In this contribution we will present and discuss the results of the inelastic neutron scattering experiments and try to entangle the CEF level scheme.

MA 14.7 Tue 10:15 P1B

**Magnetism of $La_{0.875}Sr_{0.125}MnO_3$ studied by means of magnetometry and XMCD** — •K. Kuepper[1], M. Raekers[2], C. Taubitz[2], M. Prinz[2], M. Uhlarz[3], V.R. Galakhov[4], Ya. M. Mukovskii[5], and M. Neumann[2] — [1]University of Ulm, Department of Solid State Physics, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [2]Department of Physics, University of Osnabrück, D-49069 Osnabrück, Germany — [3]FZ Dresden-Rossendorf, Bautzner Landstr. 128, 01328 Dresden, Germany — [4]Institute of Metal Physics, Russian Academy of Sciences, Ural Division, 620219 Yekaterinburg GSP-170, Russia — [5]Moscow State Steel and Alloy Institute, 117936 Moscow, Russia

The manganites $La_{1-x}Sr_xMnO_3$ exhibit a remarkable rich phase diagram as function of temperature, doping concentration and magnetic field, accompanied by attractive properties like colossal magneto resistance (CMR). Furthermore, $La_{0.875}Sr_{0.125}MnO_3$ shows an unusual ferromagnetic insulating (FMI) ground state which can not be explained by the conventional double exchange model. We studied the magnetic properties of a $La_{0.875}Sr_{0.125}MnO_3$ single crystal by means of temperature dependent magnetometry and applied x-ray circular magnetic dichroism (XMCD) at the Mn $L_{2,3}$ edges. In contrast to previous results reported [1] we do not find a significant Mn orbital moment, neither in the FMI phase (T < 180K) nor in the high temperature paramagnetic insulating phases (T > 180K).

[1] M. Platé et al., Phys. Rev. B **72**, 085102 (2005).

MA 14.8 Tue 10:15 P1B

**Measurements of nanocrystalline ferromagnetic materials and their potential for use as core materials at low temperatures** — •René Geithner[1], Alexander Steppke[2], Ralf Neubert[1], Wolfgang Vodel[1], and Paul Seidel[1] — [1]Institute of Solid State Physics, Friedrich Schiller University of Jena, Germany — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

A low temperature SQUID-based measuring instrument, which employs the Cryogenic Current Comparator (CCC) principle, is used for high-precision, non-contact current measurements of particle beams. The CCC consists of a high-performance LTS DC SQUID system, a toroidal pick-up coil and a meander-shaped superconducting niobium shield. Theoretical investigations show that as external noise decreases, improvements in performance depend on the properties of the ferromagnetic core material, especially the relative permeability, embedded in the pick-up coil. Here we present the temperature and frequency dependence of several candidate ferromagnetic and nanocrystalline materials (Vitroperm by VAC Hanau and Nanoperm by Magnetec). Measurements of the magnetic losses and associated noise figures are presented in respect to the permeability.

MA 14.9 Tue 10:15 P1B

**$Rh_2MnGe$: a Heusler compound with 4*d* valence electrons.** — •Lubna Basit, Jan Thoene, Stanislav Chadov, Gerhard H. Fecher, and Claudia Felser — Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz

We report on the structural and magnetic properties of $Rh_2MnGe$ Heusler alloy. Polycrystalline samples of $Rh_2MnGe$ have been prepared and the bulk properties were charaterized by bulk techniques (X-ray diffraction and magnetization). $Rh_2MnGe$ is $L2_1$ ordered. The magnetic properties of $Rh_2MnGe$ were measured by means of SQUID magnetometry. $Rh_2MnGe$ is a candidate for ferromagnetic alloys with a saturation moment of 3.6 $\mu_B$ in the primitive cell at 5 K. The magnetic moments are considerably more localized for $Rh_2MnGe$ in comparison to the isoelectronic compound $Co_2MnGe$. In spite of the localization of the Mn moment, the Heisenberg model fails to describe the temperature dependence correctly, which might be due to the remaining itinerant character of the Rh moment. In addition, we have studied the electronic properties of $Rh_2MnGe$ by *ab-initio* calculations using the fully-relativistic spin-polarized Korringa-Kohn-Rostoker (SPR-KKR) Green's function method. Computational results agree with experiment by predicting this compound as metallic with the low degree of the spin-polarization. However the calculated magnetic moment (4 $\mu_B$) obeys the Slater-Pauling rule closely. The authors gratefully acknowledge financial support by the DfG (Research Unit 559).

MA 14.10 Tue 10:15 P1B

**Hard X-ray photoelectron spectroscopy of Heusler materials** — •Andrei Gloskovskii, Siham Ouardi, Xeniya Kozina, Gregory Stryganyuk, Gerhard H. Fecher, and Claudia Felser — Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz

Hard X-Ray photoemission spectroscopy (HAXPES) is an unique technique that makes feasible studies of the electronic properties of deeply buried layers. If needed, the surface sensitivity of the conventional XPS can be reached in HAXPES by changing the experiment geometry. This work reports on the HAXPES of Heusler thin films and bulk materials. The experiments were performed at the beamlines BL15XU and BL47XU of SPring-8. The maximal thickness of the insulating layer that is still transparent for the photoemission signal from underlying layer was estimated experimentally for different insulating materials.

This work is supported by the DFG (project P7 in research unit FOR 559) by BMBF 05KS7UM1 and by JST-DfG (Project FE 633/6-1).

MA 14.11 Tue 10:15 P1B

**Adiabatic temperature change in giant magnetocaloric effect compounds** — Julia Lyubina, •Philipp Rosendahl, Jian Liu, Ludwig Schultz, and Oliver Gutfleisch — IFW Dresden, Institute for Metallic Materials, Helmholtzstr. 20, 01069 Dresden, Germany

The magnetic refrigeration based on the magnetocaloric effect (MCE) is becoming a promising technology to replace the conventional gas-compression/expansion technique. The two parameters, the adiabatic temperature change, $\Delta T_{ad}$, and the magnetic entropy change, $\Delta S_M$, are used for the evaluation of the MCE [1,2]. Most of the MCE studies are performed by indirect methods, among which the $\Delta S_M$ calculation using the Maxwell relation is the most widespread. Here, we report on direct adiabatic temperature change $\Delta T_{ad}$ measurements in giant MCE materials, La(Fe,Si)$_{13}$- and Ni-Mn-In Heusler-type alloys. $\Delta T_{ad}$ was measured using a direct contact with a thermocouple in magnetic fields up to 1.93 T produced by a permanent magnet assembly (Halbach cylinder). In $Ni_{50}Mn_{34}In_{16}$, the maximum $\Delta T_{ad}$ of 2 K is observed around the Curie temperature of the austenite (317 K), whereas $\Delta T_{ad}{}^{max}$ is -1.3 K near the martensite-austenite transition (181 K).

On cooling, i.e. during the austenite-martensite transition, $\Delta T_{ad}{}^{max}$ reduces to about -0.5 K. In $LaFe_{12}Si_1$, the maximum $\Delta T_{ad}$ reaches -5.4 K at 184 K. The contribution of the latent heat to the adiabatic temperature change during first-order phase transitions is discussed. [1] J. Lyubina et al., J. Magn. Magn. Mater. 320 (2008) 2252; [2] J. Lyubina et al., Phys. Rev. Lett. 101 (2008) 177203.

MA 14.12 Tue 10:15 P1B

**Electrodeposition of thin soft-magnetic layers in magnetic gradient fields** — •Kristina Tschulik, Jakub Koza, Margitta Uhlemann, Annett Gebert, and Ludwig Schultz — Leibniz Institute for Solid State and Materials Research Dresden, P.O. Box 270016, D-01171 Dresden, Germany

Thin soft magnetic layers are of interest as sensor layers or as write head component in magnetic data storage devices. Due to the fact, that in these fields of applications high saturation magnetization in combination with low coercivity is desired, deposits based on iron and cobalt are favorable. As it has already been shown, externally applied homogeneous magnetic fields can significantly influence the deposition process as well as morphology, texture and magnetic properties of deposits. Hence, influencing these deposit properties should be possible by tailoring the magnetic field distribution applied during the deposition process, which in turn can be generated via different arrangements of magnets. Therefore electrochemical measurements in various magnetic gradient fields have been performed and the resulting deposits have been characterized via optical microscopy, SEM, AFM, MFM, XRD and MOKE.

MA 14.13 Tue 10:15 P1B

**Magnetic field effect on the anodic behaviour of a ferromagnetic electrode in acidic solutions** — •Ralph Sueptitz, Jakub Koza, Margitta Uhlemann, Annett Gebert, and Ludwig Schultz — IFW Dresden, Helmholtzstraße 20, 01069 Dresden

The magnetization of a ferromagnetic electrode in an external homogeneous magnetic field leads to a stray field in front of the electrode. This stray and its gradients can alter the anodic behaviour of the electrode significantly. Potentiodynamic polarisation measurements of an iron wire in two acidic electrolytes without and with applied magnetic fields up to 0.6 T in different orientations to the electrode surface were performed. In sulfuric acid solution an increase of the diffusion-limited dissolution current density and a shift of the active-passive transition potential to more noble potentials was observed when the magnetic field was applied parallel to the electrode surface. In contrast, in perpendicular field configuration the diffusion-limited current density is lowered and the active-passive transition potential is shifted to less noble values. In phthalate buffer a shift of the active-passive transition to less noble potentials occurred irrespective of the magnetic field configuration. The observed effects of a superimposed magnetic field on the anodic behaviour of iron are discussed with respect to an increase of the mass transport due to the magnetohydrodynamic (MHD) effect, the magnetic field gradient force and its interaction with the paramagnetic iron ions. The results show that the effect of the field gradient force can become very important due to the high magnetic field gradient at ferromagnetic electrodes.

MA 14.14 Tue 10:15 P1B

**Local resolved ferromagnetic resonance measurments** — •Sven Stienen, Ralf Meckenstock, Jürgen Lindner, and Michael Farle — Universität Duisburg-Essen, Duisburg, Deutschland

A scanning thermal microscope (SThM) was designed to measure local resolved ferromagnetic resonance (FMR). To realize the required stability for slow thermal scans in combination with high magnetic fields an AFM (XE-70) is used. This guarantees a lateral stability of 10 nm during a 200 mT variation of the field. For this a specially shaped magnet was developed, which emits only a small stray field towards the microscope. A non magnetic tip holder was also developed. Due to the use of the magnet, the conventional XE-70 had to be modified. Using a modulated constant-current source in combination with a lock-in technique, the sensitivity of the thermal measurements could be improved by a factor of 10 compared to an old SThM setup. With the new setup, a lateral resolution of less then 100 nm is achieved. The new setup of the scanning thermal microscope has proven to characterize thermal and magnetic properties of nanostructured systems. The thermal resolution limit of the setup was demonstrated as low as 0,2 mK by a thermal characterizations of single-crystalline silver wire. For the first time a local thermal FMR spectrum was received with a resolution of less then 100 nm on a single Py wire. This spectrum was compared to a conventionally detected FMR signal of whole Py wire array. In addition, a thermal image of a single Py wire was taken during resonance.

MA 14.15 Tue 10:15 P1B

**TetraMag - A general-purpose finite-element micromagnetic simulation package** — •Riccardo Hertel and Attila Kakay — Institut für Festkörperforschung, Elektronische Eigenschaften, Forschungszentrum Jülich GmbH

In the past years, the investigation of micromagnetic structures and dynamic magnetization processes on the nanoscale has greatly benefited from the availability of various free and commercial micromagnetic simulation packages. These programs have allowed a very large number of scientific groups to perform studies on countless systems, thereby obtaining a broad knowledge on this topic. Almost all of these publicly available codes have similar structures and are based on finite-difference formulations. Finite-element algorithms, on the contrary, are rather rare. Despite a number of advantageous features, micromagnetic studies with finite element codes are quite seldom, partly because such codes are often considered to be too complicated to develop and to use. The main plus of finite element algorithms is their geometric flexibility, which allows the modeling of three-dimensional objects of arbitrary shape with smooth boundaries. Our finite-element code TetraMag has several attractive features, such as easy implementation and usage, full parallelization, and the possibility of considering electric currents, surface anisotropies and the magnetostatic interaction of spatially separated nanomagnets. In this poster the structure of the program, the basics of the numerical formulation and the main features of the simulation package will presented. The release of the first public-domain version of TetraMag is planned for the first quarter of 2009

MA 14.16 Tue 10:15 P1B

**High resolution large-scale micromagnetic simulations with hierarchical matrices** — •Attila Kákay and Riccardo Hertel — Institute for Solid State Research, Research Center Jülich GmbH, 52428 Jülich, Germany

The hybrid finite element/boundary element method (FEM/BEM) [1] is a powerful, high precision method in micromagnetic simulations. The BEM is used to map the open boundary conditions of the magnetostatic potential at infinity on equivalent boundary conditions at the surface of the magnetic region. However, the calculation of the magnetostatic potential involves a densely populated matrix which for large problems can become of considerable size (up to several TBytes), since it is proportional to the square of the number of boundary nodes. The hierarchical matrices or H-matrix technique [2] can be used to drastically reduce the size of the dense matrix, without significant loss in accuracy. We present applications of this technique to micromagnetic problems of such size and complexity what could not be addressed before. The examples include the cross-tie domain wall structure and its field-pulse induced dynamics in a long Permalloy stripe (1 um) and a study on the fine details of the magnetic structure in a large (5 um) Permalloy disk. These magnetic structures involve three different length scales: domain size, domain wall width and vortex core width. The calculated domain configuration for both examples is in very good agreement with experiments.[1] D.R. Fredkin and T.R. Koehler, J. Appl. Phys. 63, 3385 (1988) [2] S. Boerm and L. Grasedyck, HLib - A library for H - and H2 - atrices,1999,http://www.hlib.org/

MA 14.17 Tue 10:15 P1B

**Investigation of the Dynamic Behaviour of Thin Magnetic Layers under the Influence of Magnetic Particles** — •Alexander Weddemann, Camelia Albon, and Andreas Hütten — Bielefeld University, Universitätsstraße 25, D-33615 Bielefeld, Germany

Magnetic particles on the micro- or nanoscale have a growing number of different applications in many different physical, chemical or medical fields, e.g. as contrast agents or drug carriers. Because of their magnetic stray field such particles interact with thin magnetic layers, making it possible to detect them with the help of GMR- or TMR-sensor arrays. However, the obtained signals strongly depend on the particle size, the distance from the sensor as well as the number of particles above the sensor. Also material properties, especially, if superparamagnetic or ferromagnetic particles are to be detected, have a strong influence on the results. The different dependencies are investigated systematically. Furthermore, dynamic measurements of particles moving close to the sensors are discussed.

Micromagnetic simulations solving Landau-Lifschitz-Gilbert and Brown equation for thin films are compared to experimental results.

MA 14.18 Tue 10:15 P1B

**An interface between two non-magnetic metals turns magnetic: The case of $YCo_2$(111)/Cu(111)** — •Josef Redinger and Peter Mohn — Dept. General Physics/CMS, Vienna University of Technology, Austria

Thin films of a material with a magnetic surface and a non-magnetic bulk are natural magnetic multi-layers with a perfect matching of the electronic potentials at the magnetic/nonmagnetic interface. Using full-potential DFT calculations the existence of a stable magnetic (111) surface of the nonmagnetic bulk inter-metallic compound $YCo_2$ was predicted, with large magnetic moments in the topmost Co layer for both Y- and Co-terminated (111) surfaces [1] und subsequently verified experimentally [2]. In the present contribution we focus on the interface between $YCo_2$(111) and Cu(111). An almost perfect lateral match facilitates the growth of magnetically dead Cu cap or spacer layers. Our DFT studies predict that, despite a stable Y termination of the $YCo_2$(111) surface, a Co/Cu interface with sizeable Co moments (averaged 0.8-0.9 $\mu_B$) at the interface is formed, while Y floats on top. For $YCo_2$/Cu(111) multilayers a similar magnetic behavior is predicted.

[1] S. Khmelevskyi, P. Mohn, J. Redinger, and M. Weinert, Phys. Rev. Lett. 94,146403 (2005)
[2] Yu. S. Dedkov, C. Laubschat, S. Khmelevskyi, J. Redinger, P. Mohn, and M. Weinert, Phys. Rev. Lett. 99,047204 (2007)

MA 14.19 Tue 10:15 P1B

**Delayed phase transition from fcc(111) to bcc(110) for Fe on vicinal Au(111)** — •Tobias Allmers and Markus Donath — Physikalisches Institut, Universität Münster, 48149 Münster

Vicinal surfaces offer the opportunity for the fabrication of a regular array of nanostructures and for studying the influence of a reduced symmetry. The morphology and the magnetism of Fe films on flat Au(111) were already thoroughly investigated by various groups [1,2]. At a certain film thickness a phase transition from Fe fcc(111) to bcc(110) was identified, accompanied by a spin reorientation transition from out-of-plane to in-plane. We used Fe on vicinal Au(111), in our case Au(23 25 25), to study the influence of the modified substrate topography on the growth mode and the resulting magnetic properties. For thicknesses beyond the phase transition, the pseudomorphic growth of Fe is disrupted and rectangular structures appear. The orientation and development of these structures is different on the flat and the vicinal surface. Our results obtained with scanning tunneling microscopy (STM), low energy electron diffraction (LEED) and magneto-optical Kerr effect provide a consistent picture. Different from Fe on flat Au(111), the phase transition from fcc(111) to bcc(110) occurs at a higher Fe coverage on vicinal Au(111). We present a structural model for the phase transition of Fe on Au(23 25 25), which explains the observed differences in the development and orientation of the rectangular structures as observed in STM and LEED.

[1] Strosio *et al.*, J. Vac. Sci. and Technol. A **10**, 1981 (1992)
[2] Lugert *et al.*, J. Magn. Magn. Mater. **121**, 498 (1993)

MA 14.20 Tue 10:15 P1B

**Influence of chiral interactions on vortex states in magnetic nanodisks** — •A.B. Butenko[1,2], A.A. Leonov[1,2], U.K. Rössler[1], and A.N. Bogdanov[1] — [1]IFW Dresden — [2]DIPT Donetsk

Magnetic circular nanostructures exhibit curling vortices which have a sense of rotation and an up/down polarity of the core magnetization. Broken mirror symmetry at surface/interfaces of nanosystems induces chiral Dzyaloshinskii-Moriya interactions, which should strongly affect their magnetic properties [1,2]. In particular, these chiral couplings energetically favour one sense of rotation in a vortex state and suppresses vortices with the opposite chirality [3]. Using a micromagnetic approach, we investigate the influence of these Dzyaloshinskii-Moriya interactions on vortex states in magnetic nanodisks. From numerical solutions for (metastable) equilibrium states with cylindrical symmetry, we calculate shapes and sizes of the vortices as functions of a bias magnetic field and the material and geometrical parameters. These solutions correspond to core structure of vortices in thin film elements with Dzyaloshinskii-Moriya interactions. Calculated magnetic phase diagrams display existence regions for vortices with different chirality and magnetic polarization. As a result, under the influence of the chiral magnetic interactions vortices of opposite chirality should have different sizes. We provide detailed numerical analysis of this effect, which can be applied to measure the strength of the induced Dzyaloshinskii-Moriya coupling. — [1] A. Bogdanov, U.K. Rößler, Phys. Rev. Lett. **87**, 037203 (2001). [2] M.Bode et. al., Nature **447**, 190 (2007). [3] A. Bogdanov, A. Hubert, J. Magn. Magn. Mater. **195**, 185 (1999).

MA 14.21 Tue 10:15 P1B

**Influence of Atomic Protrusions on a Nanolead Spin Structure** — •Benjamin W. Heinrich[1], Mircea V. Rastei[1], Cristian Iacovita[1], Pavel A. Ignatiev[2], Valeri S. Stepanyuk[2], Patrick Bruno[2], Laurent Limot[1], and Jean-Pierre Bucher[1] — [1]Institut de Physique et Chimie des Matériaux de Strasbourg UMR 7504, Université Louis Pasteur, F-67034 Strasbourg, France — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle/Saale, Germany

Single Ni, Co and Cu atoms deposited in the center of cobalt nanoislands grown on Cu(111) are investigated by low-temperature scanning tunneling spectroscopy. Atomic protrusions profoundly modify the surface states of this model magnetic nanolead, *ab initio* calculations predicting the existence of atomic-like and surface-induced states. Contrary to the first, the second contribution is predicted by calculations to favor a change in sign of the spin polarization with respect to the pristine lead [1].

[1] B.W. Heinrich, C. Iacovita, M.V. Rastei, L. Limot, J.P. Bucher, P.A. Ignatiev, V.S. Stepanyuk, P. Bruno, submitted

MA 14.22 Tue 10:15 P1B

**Bcc Co/Fe(110) measured by spin-polarized scanning tunneling spectroscopy** — •Torsten Methfessel and Hans-Joachim Elmers — Johannes Gutenberg-Universität Mainz, Institut für Physik, Staudingerweg 7, D-55099 Mainz

Highly spin polarized metals are of great interest e.g. for the application in spin-valves. Recently observed large tunneling magnetoresistance (TMR) effect values of 410 % at room temperature for Co/Fe(100) electrodes indicate a high spin-polarization at the Fermi energy of bcc Co [1]. Using STM and STS we have recently shown that two monolayer of undistorted bcc Co grow on Fe(110) [2]. By covering the STM tip with 5 ML Fe we perfom spin-polarized scanning tunneling microscopy on the Co(110) surface. The magnetization of the Co layers follow the magnetization of the Fe buffer layer with an easy axis along the the $[1\bar{1}0]$ axis. Spin-polarized spectroscopy reveals an asymmetry of the differential conductivity for the first Co layer with a maximum value of 5 % at 0.1 eV below $E_F$ in close agreement with the data measured for the Fe(110) surface. The second layer shows a maximum of ca. 4 % of the opposite sign at 0.1 eV above $E_F$. The experimental results are compared with theoretical calculations.

[1] S. Yuasa et. al., Appl.Phys.Lett. 89 (2006) 042505.
[2] T. Methfessel, and H.J. Elmers, Surf.Sci. (accepted).

MA 14.23 Tue 10:15 P1B

**Domain Effects, Giant Magnetoresistance and Quantum Phase Transitions in NbFe2** — •William Duncan[1], Philipp Niklowitz[1], Carsten Albrecht[1], Dennis Moroni[1], Manuel Brando[2], and Malte Grosche[3] — [1]Department of Physics, Royal Holloway, Egham, TW20 0EX, UK — [2]Max-Planck-Institute CPfS, 01187 Dresden, Germany — [3]Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, UK

The C14 Laves phase NbFe2 offers an intriguing perspective on ferromagnetic quantum criticality in clean transition metal compounds. Slightly (1%) iron-rich samples of NbFe2 are low-temperature band ferromagnets. On approaching stoichiometry, an unidentified modulated magnetic state with a high uniform susceptibility (Stoner enhancement factor ˜ 150) replaces ferromagnetism. This modulated, possibly long-wavelength spiral order eventually disappears in slightly niobium-rich samples, giving rise to a quantum critical point (QCP).

Numerous polycrystals of varying stoichiometries have been prepared and their respective magnetic and transport properties have been investigated. There are several intriguing phenomena present, these include quantum critical behaviour near the QCP (see other poster, [1]), GMR approaching 40% coupled with strong domain effects near the region of the ferromagnetic to modulated state change and robust non-Fermi liquid behaviour. Hydrostatic pressure has been used to reproduce the effects of changing composition, suggesting that disorder and impurity effects play a minor role in doped samples.

[1] M. Brando et al, Phys. Rev. Lett. 101, 026401 (2008)

MA 14.24 Tue 10:15 P1B

**Magnetic excitations and ordering in azurite** — •Clare Gibson[1], Kirrily Rule[1], Stefan Süllow[2], Alan Tennant[1], Jens-Uwe Hoffmann[1], and Mark Telling[3] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, D-14109 Berlin, Germany — [2]Institut für Physik der Kondensierten Materie, TU Braunschweig, D-38106 Braunschweig, Germany — [3]ISIS, Chilton, Oxfordshire, UK

Azurite, Cu3(CO3)2(OH)2 realises a distorted diamond chain with a 1/3-magnetisation phase. A combination of time-of-flight spectroscopy and polarized neutron scattering has been used to elucidate the excitation spectrum in the sub-plateau phase. Not only does the excitation spectrum prove the dynamics of the system to be one-dimensional but also reveals a highly unusual interplay of excitations. A lower mode comprises unconventional continua and an upper mode consists of dimer excitations combined with spinons. In addition to the study of the dynamics, we propose a magnetic structure for the ordered phase below T=1.86K.

MA 14.25 Tue 10:15 P1B

**Magnetic correlations in half-doped manganates** — •Holger Ulbrich[1], Olaf Schumann[1], Daniel Senff[1], Yvan Sidis[2], Klaudia Hradil[3], Wolfgang Schmidt[4], and Markus Braden[1] — [1]Universität zu Köln, Zülpicher Str. 77, 50937 Köln — [2]Laboratoire Léon Brillouin, CE-Saclay — [3]FRMII TU-München — [4]Institut Laue-Langevin, 38042 Grenoble

The coupled ordering of charge orbital and spin degrees of freedom in the manganates constitutes a key element to understand the mechanism of colossal magneto resistivity, which consists in switching from the antiferromagnetically ordered insulating state into the ferromagnetic metallic phase. Starting with the half doped layered material La0.5Sr1.5MnO4 [1,2] we have analysed the magnon dispersion as well as the temperature dependence of the magnetic correlations in several compounds with a Mn4+:Mn3+ ratio close to half doping. In slightly over-doped La0.4Sr1.6MnO4 we find a coupling of incommensurate ordering of orbitals, charges and Mn3+ spins combined with commensurate ordering of Mn4+ spins. We further discus the magnetic correlations in Pr0.5Ca1.5MnO4 and in Nd0.5Sr0.5MnO3.

[1] D. Senff, F. Krüger, S. Scheidl, M. Benomar, Y. Sidis, F. Demmel, and M. Braden, Phys. Rev. Lett. 96, 257201 (2006) [2] D. Senff, O. Schumann, M. Benomar, M. Kriener, T. Lorenz, Y. Sidis, K. Habicht, P. Link, and M. Braden, Phys. Rev. B 77, 184413 (2008).

## MA 15: ThyssenKrupp Dissertationspreis der AG Magnetismus

Time: Tuesday 14:00–16:15 Location: HSZ 04

**4 Talks/see web site MA**

## MA 16: Invited Talk Lottermoser

Time: Wednesday 9:30–10:00 Location: HSZ 04

**Invited Talk** MA 16.1 Wed 9:30 HSZ 04

**Nonlinear optics on spin-spiral multiferroics** — •Thomas Lottermoser — HISKP, Universität Bonn, Bonn, Deutschland

Induced multiferroics (MF) in which a spin spiral induces a spontaneous ferroelectric (FE) polarization have reached high experimental and theoretical interest. This is mainly due to the complex and pronounced interaction between the magnetic and electric structure. In spite of the vast research activity a lot of questions about the precise nature of spin-spiral MFs remain unanswered. In particular the nature of the induced FE polarization is not understood in detail.

Optical second harmonic generation (SHG) will be presented as tool to get a deeper understanding of spin-spiral MFs. SHG is sensitive to symmetry and therefore an ideal tool for investigating coexistence and interaction of different types of ferroic order with a single technique. Together with high spatial resolution this allows, for example, the investigation of properties and coupling of ferroic domains.

As examples results on $MnWO_4$, $DyMnO_3$ and $TbMn_2O_5$ will be presented. All materials exhibit SHG signals up to six orders of magnitude larger than conventional FEs. This points to an electronic rather than an ionic nature of the induced polarization because SHG couples more efficiently to the electronic system than to ionic distortions. In addition results on the ferroic domain properties and the control of magnetic domains by electric fields and electric domains by magnetic fields will be presented.

## MA 17: Magnetic Thin Films I

Time: Wednesday 10:15–12:45 Location: HSZ 04

MA 17.1 Wed 10:15 HSZ 04

**Magnetocrystalline anisotropy of strained FeCo alloys** — •Stephan Schönecker, Carsten Neise, Manuel Richter, Klaus Koepernik, and Helmut Eschrig — IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany

Tetragonally distorted $Fe_{1-x}Co_x$ alloys recently attracted interest due to their potential application as new media for high density recording, combining both a large uniaxial magnetocrystalline anisotropy (MAE) and a large saturation magnetisation for certain chemical composition $x$ and tetragonal distortion. Volume relaxation was neglected in earlier calculations [1], which is however present at epitaxially grown layers and may alter the concluded magnetic properties of these alloys.

By considering the epitaxial Bain path, which provides a reasonable description of tetragonally distorted films on substrates (e.g. [2]), we investigated the influence of volume relaxation on the MAE and on the magnetic moment of $Fe_{1-x}Co_x$ alloys and on the ordered $L1_0$ phase ($Fe_{0.5}Co_{0.5}$). We employed density functional calculations in the implementation of the full potential local orbital program package FPLO [3]; disorder was described within the virtual crystal approximation.

[1] T. Burkert, L. Nordström, O. Eriksson, and O. Heinonen, Phys. Rev. Lett. **93**, 027203 (2004)
[2] P. M. Marcus, F. Jona, and S. L. Qiu, Phys. Rev. B **66**, 064111 (2002)
[3] K. Koepernik and H. Eschrig, Phys. Rev. B **59**, 1743 (1999); http://www.fplo.de

MA 17.2 Wed 10:30 HSZ 04

**On origin of perpendicular anisotropy in $Fe_{1-x}Co_x$ alloy films grown on Pd(001), Ir(001) and Rh(001) substrates** — •Fikret Yildiz, Marek Przybylski, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

We have shown that the $Fe_{1-x}Co_x$ alloy films of the composition around x = 0.5 show a maximum perpendicular anisotropy when their cubic lattice is tetragonally distorted by growing the films on mismatching substrates like Pd(001), Ir(001) and Rh(001) [1,2]. The easy magnetization axis reorients at different temperatures showing that the perpendicular anisotropy depends on distortion of cubic symmetry, i.e. on the c/a ratio. For the same composition the uniaxial anisotropy reaches maximum for the $Fe_{0.5}Co_{0.5}$ films grown on Rh(001) (c/a = 1.24). To verify this hypothesis we have grown a buffer layer of Pd a few ML thick on Rh(001). Low energy electron diffraction (LEED) pattern shows that the spots are exactly at the same positions as for the clean Rh(001) substrate which proves that the lattice constant of the Pd-buffer is the same as the one of the Rh(001) substrate. The hysteresis loops of the $Fe_{0.5}Co_{0.5}$ films grown on top of it are just the same as the loops measured for the films grown directly on the Rh(001) substrate.

This confirms that the strong perpendicular anisotropy originates from an appropriate tetragonal distortion.

[1] A. Winkelmann, M. Przybylski, F. Luo, Y. Shi, J. Kirschner, Phys. Rev. Lett. 96, 257205 (2006) [2] F. Yildiz, F. Luo, C. Tieg, R. Abrudan, X. L. Fu, A. Winkelmann, M. Przybylski, J. Kirschner, Phys. Rev. Lett. 100, 037205 (2008)

MA 17.3 Wed 10:45 HSZ 04

**Tailoring the FePt orientation on amorphous substrates by magnetron sputtering - Structural and magnetic investigations** — •Valentina Cantelli, Johannes von Borany, Jörg Grenzer, and Jürgen Fassbender — Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, Dresden, Germany

High magnetocrystalline (001) oriented $L1_0$ FePt layers are widely studied for perpendicular recording magnetic media. We will report about the tuning of FePt (001) orientation using Ar and Xe gases, onto a-$SiO_2$/Si substrates by magnetron sputtering deposition at 0.3 Pa. Layer-by-layer and co-deposition were investigated comparatively. Thin (∼12 nm) $Fe_{55}Pt_{45}$ layers were deposited at RT, subsequently annealed at 750°C to induce the A1-$L1_0$ ordering transformation. Sputtering in Ar delivers energetic particles (∼ 12 eV sputtered Fe or Pt atoms and ∼ 100 eV Ar reflected neutrals from Pt target). This energy budget enhances surface adatom mobility, creates vacancies [1], and supports vertical intermixing into the layer, during deposition. At RT, a randomly oriented crystalline FePt A1 structure is produced. After annealing, the $L1_0$ phase is obtained with coercive field $H_C$ = 20 kOe and weak (001) orientation, irrespective of deposition methods. Sputtering in Xe significantly reduces energetic impacts from backscattered neutrals. Using a layer-by-layer deposition, $L1_0$ films have $H_C$ = 5.6 kOe with the lowest (∼ 2.5°) angular dispersion around the (001) direction. [1] V. Cantelli, J. von Borany, A. Mucklich, Shengqiang Zhou, J. Grenzer, Nucl. Instr. and Meth. B 257, (2007) 406

MA 17.4 Wed 11:00 HSZ 04

**Investigation of the magnetic properties in thin Fe50Pt50-xRhx films by neutron diffraction** — •J. Fenske[1], D. Lott[1], G.J. Mankey[2], W. Schmidt[3], K. Schmalzl[3], E. Tartakowskaya[4], and A. Schreyer[1] — [1]GKSS Research Centre — [2]The University of Alabama, MINT Center — [3]Jülich Research Centre — [4]Institute for Magnetism, National Accademy of Science

FePt-based alloys are typically the material of choice for magnetic information storage media. The high magnetic moment of Fe gives a large magnetization and the large atomic number of Pt results in a high magnetic anisotropy. This combination enables the written bits to be smaller than ever before, since magnetic grains with a high magnetic anisotropy are more thermally stable. One way to control the magnetic properties in these materials is through the introduction of a third element into the crystal matrix, e.g. Rh. When Rh is added to replace Pt in the equiatomic alloy, new magnetic phases emerge. Bulk samples of Fe50Pt40Rh10 for example, studied by magnetization measurements refer to an antiferromagnetic (AF)/ferromagnetic (FM) phase transition at about 150K when heated[1]. Additional magnetostriction measurements indicate that the phase transition could also be induced by applying a magnetic field[2]. Here we present results on several Fe50Pt50-xRhx films. These films were examined by neutron diffraction in dependence of temperature and magnetic field. The observed magnetic behaviours differ significant from the behaviour of the bulk system. [1] S. Yuasa, H. Miyajima and Y. Otani, J. Phys. Soc. Jpn. 63 (8), 1994 [2] P.A. Algarabel, et. al, J.Appl. Phys. 79 (8), 1996

MA 17.5 Wed 11:15 HSZ 04

**Trends in exchange interactions for bcc Fe/TaW(001)** — •Martin Ondráček[1], Josef Kudrnovský[1], Olivier Bengone[2], Ilja Turek[3,4], and František Máca[1] — [1]Institute of Physics ASCR, Prague — [2]University of Strasbourg, IPCM, Strasbourg — [3]Institute of Physics of Materials ASCR, Brno — [4]Department of Condensed Matter Physics, Charles University, Prague

A recent study of Ferriani et al. [1] investigated the possibility of tuning the magnetic order of the Fe monolayer on the disordered bcc-Ta(x)W(1-x)[001] surface. We will further extend this study by constructing the effective two-dimensional Heisenberg Hamiltonian, which describes exchange interactions in the iron monolayer in detail. We will investigate the behavior of exchange integrals as a function of the composition of the alloy substrate, but also as a function of distance (damping due to disorder) and the dependence on the crystallographic directions in the overlayer. The calculated exchange integrals allow us to estimate the spin stiffness and the corresponding critical temperatures. We also wish to investigate the crossover between the ferromagnetic and antiferromagnetic state from the point of view of the stability of the Heisenberg Hamiltonian with respect to magnon excitations. The present study will help us to deeper understand the character of magnetic phase transition of the Fe overlayer due to disorder in the alloy substrate.

[1] P. Ferriani, I. Turek, S. Heinze, G. Bihlmayer, and S. Blügel, Phys. Rev. Lett. 99 (2007) 187203.

MA 17.6 Wed 11:30 HSZ 04

**Properties of the Fe/GaAs(110) interface investigated by ab inito calculations** — •Anna Grünebohm, Heike C. Herper, and Peter Entel — Fachbereich Physik, Universität Duisburg-Essen, Duisburg

Fe/GaAs is a widely used system for spintronic devices. For example the small lattice mismatch (<2%) and the cheap preparation of layered systems are promising. Because of this many studies on Fe/GaAs have been performed in the last decades mostly on the (001) direction. Recently the (110) direction has attracted plenty of attention as the free GaAs(110) surface doesn't reconstruct and allows to grow flat interfaces. Unfortunately, diffusion and alloy formation occur at both interfaces which may lead to reduced spin injection and magnetic inactive regions.

To get an insight into the interface properties we do calculations within the PAW method using VASP [1] adopting the GGA/PBE form for the exchange-correlation potential. To simulate the free surface the slap method is used thereby one side of the slab is passivated through pseudo-hydrogen to guarantee a bulk-like behavior in a moderate sized slap. The adsorption of single Fe-atoms as well as the first monolayers of iron are investigated with respect to the energy landscape for different structures and the magnetic moments. While diffusion of atoms through the interface was shown to be low in energy no magnetic inactive phase could be observed. Hence our results don't show any fundamental limitations for spintronic applications.

[1] G.Kresse and J.Furthmüller, Phys. Rev. B 54, 11169 (1996)

MA 17.7 Wed 11:45 HSZ 04

**Stress, structure and magnetism of epitaxial Fe monolayers on Ir(100)-(1x1)** — •Zhen Tian, Dirk Sander, Fikret Yildiz, Marek Przybylski, and Jürgen Kirschner — Max-Plank Institute of Microstructure Physics, 06120, Halle, Germany

We have performed combined LEED, stress and magneto optic Kerr effect (MOKE) measurements on Fe monolayers on Ir(100). Our experimental results indicate pseudomorphic growth of Fe layers from 0 to 10 ML. The large mismatch of −5.3% between Fe and the Ir(100) substrate leads to a bct Fe lattice under compressive stress of −10 GPa[1]. Ferromagnetic hysteresis loops are observed for Fe thickness above 4 ML at room temperature, with an easy magnetization axis in plane. The Curie temperature of 4 ML Fe is around 200 K. MOKE measurements are performed with both longitudinal and polar geometry from 300 K down to 5 K. Up to 3 ML, the film does not show a ferromagnetic responses in magnetic fields of up to 0.5 T. These results are discussed in view of results on the related system of Fe on Rh(001)[2], and also in view of a possible 2 ML fcc Fe precursor on Ir(100)[1].

[1]V. Martin et al. Phys. Rev. B, 76 (2007) 205418 [2]K. Hayashi et al. Phys. Rev. B, 64 (2001) 054417

MA 17.8 Wed 12:00 HSZ 04

**Magnetoelectric phase transition in Fe/Cu(111)** — •Lukas Gerhard[1], Toyo K. Yamada[1], Timofey Balashov[1], Albert F. Takács[1], Arthur Ernst[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Universität Karlsruhe (TH), Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

Both the crystallographic and the magnetic structure of Fe exhibit a rich phase diagram. Two different crystallographic phases, fcc and bcc, have been reported to coexist in Fe islands on Cu(111) [1]. Comparing our scanning tunnelling spectroscopy to ab-initio calculations, we identified the magnetic ordering of these two phases as layer-wise antiferromagnetic and ferromagnetic. Surprisingly, we observed transitions between these two phases during our STM measurements at 4 K. A systematic study of the tunnelling parameters revealed the electric field of the STM tip as the origin. Applying different electric fields, we could switch between the two different phases on nm scale. The observed coupling of the crystallographic and magnetic structure with an external electric field is explained by a difference in the work func-

tion of the two phases and thus evidences Fe/Cu(111) as a multiferroic system.

[1] A. Biedermann, W. Rupp, M. Schmid and P. Varga, Phys. Rev. B 73, 165418 (2006)

MA 17.9 Wed 12:15 HSZ 04

**Topological defects and remanent states in antiferromagnetically coupled multilayers with perpendicular anisotropy** — •Nikolai S. Kiselev[1,2], U.K. Rössler[1], A.N. Bogdanov[1], and O. Hellwig[3] — [1]IFW Dresden — [2]Donetsk Institute for Physics and Technology — [3]Hitachi GST, San Jose

In antiferromagnetically coupled multilayers with strong perpendicular magnetic anisotropy the antiferromagnetic state may include complex networks of "antiferromagnetic domain walls". In contrast to bulk antiferromagnets these defects are determined by a close competition between antiferromagnetic interlayer exchange and dipolar coupling [1,2]. Within a phenomenological theory [1,2] we have classified the topological magnetic defects in the antiferromagnetic ground state. Depending on the material parameters and the magnetic history the antiferromagnetic remanent monodomain state may include sharp domain walls, "trapped" strips of ferro and antiferro defect domains within the wall, and various metastable isolated defects formed from remanent domains with internally ferrimagnetic state. The metastable domain wall of the antiferromagnetic monodomain state can acquire a certain width as ferro strips, which exist either in single domain state or split into a system of domains creating "tiger-tail"patterns. We have calculated equilibrium parameters of ferro strips with tiger-tail textures and determined the conditions of their transition into the single domain state.

[1] N.S. Kiselev, U. K. Rößler, A. N. Bogdanov, O. Hellwig Appl. Phys. Lett. **93** 132507 (2008). [2] N.S. Kiselev, et al. arXiv: cond-mat/0811.2378.

MA 17.10 Wed 12:30 HSZ 04

**Microscopic theory of spin waves in ferromagnetic films** — •Andreas Kreisel, Francesca Sauli, and Peter Kopietz — Institut für Theoretische Physik, Universität Frankfurt, Max-von-Laue Straße 1, 60438 Frankfurt/Main

Motivated by experiments on finite ferromagnetic films consisting of Yttrium iron garnet (YIG), we have used a microscopic method of calculating the spin-wave spectrum in those systems. Both the long range magnetic dipole-dipole interactions and the Heisenberg exchange interactions are taken into account in our approach. We calculate the spin wave energy as well as the magnon states and compare our results with predictions based on the phenomenological Landau-Lifshitz equation and with experiments on YIG films.

## MA 18: Spin Structures and Magnetic Phase Transitions

Time: Wednesday 10:15–13:00 Location: HSZ 401

MA 18.1 Wed 10:15 HSZ 401

**New ways of magnetoelastic measurements up to very high magnetic fields** — •Mathias Doerr[1], Ariane Haase[2], Erik Kampert[3], Martin Rotter[4], Manuel Zschintzsch[5], Yasuo Narumi[6], and Michael Loewenhaupt[1] — [1]TU Dresden, Institut für Festkörperphysik — [2]FZ Dresden-Rossendorf, Hochfeld-Magnetlabor — [3]St. Radboud Universiteit Nijmegen, High Field Magnet Laboratory — [4]University of Oxford, Clarendon Lab. — [5]TU Dresden, Institut für Strukturphysik — [6]University of Tokyo, ISSP

Scattering methods (x-rays or neutrons) as well as capacitive dilatometry can be used to investigate the magnetostriction (i.e. the change of length or shape) of solids with high accuracy and sensitivity (resolution limit for relative length changes about $10^{-9}$). The experimental range of scattering methods, especially, was extended to high magnetic fields of about 30 T in the last years. Therefore, these methods accompany the traditional dilatometry which was developed to work well up to the highest available fields (45 T in constant field magnets and 60 T in pulsed field systems). As examples, thermal expansion (investigated by x-ray diffraction and dilatometry), magnetostriction and magnetization measurements on the rare-earth based compounds $Gd_5Ge_3$, $Tb_5Ge_3$ and GdSi are discussed. The magnetoelastic behaviour of both Gd-containing substances shows an unexpected magnetic anisotropy which is caused by exchange striction effects. The complete set of (complementary) experimental methods resulted in a clear knowledge of the phase transitions from which, at least, the magnetic phase diagrams were constructed.

MA 18.2 Wed 10:30 HSZ 401

**Spin-phonon coupling in $CuCrS_2$ probed by inelastic neutron scattering** — •Julia C.E. Rasch[1,2], Martin Böhm[1], Jürg Schefer[2], Hannu Mutka[1], Galina M. Abramova[3], and Inga G. Vasilyeva[4] — [1]Institut Laue-Langevin, 6 rue Jules Horowitz, BP 156, 38042 Grenoble, Cedex 9, France — [2]Laboratory for Neutron Scattering, ETH Zurich & Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [3]L.V. Kirensky Institute of Physics SB RAS, Krasnoyarsk 660036, Russia — [4]Nikolaev Institute of Inorganic Chemistry SB RAS, Novosibirsk 630090, Russia

The triangular lattice Heisenberg antiferromagnet $CuCrS_2$ ($S = 3/2$) with a quasi two-dimensional layered structure shows a complex three-dimensional magnetic long range order at $T_N = 37$ K. The onset of the magnetic ordering is directly coupled to a lattice distortion from $R3m$ to monoclinic $Cm$ as seen from high resolution neutron powder diffraction data on D1A (ILL). Inelastic neutron powder time-of-flight experiments on IN4 (ILL) revealed below $T_N$ a strong non-dispersive mode localized in $Q$ at about $\hbar\omega = 12$ meV which is characteristic for magnetic clusters. An enhanced scattering intensity at the spin wave-phonon crossing point at $\hbar\omega = 8$ meV is additionally observed. We assume that the monoclinic lattice distortion in $CuCrS_2$ plays a key role in relieving geometrical frustration and is analog to a Spin-Peierls transition in one dimension. Below $T_N$ the nearest neighbor Cr distances change irregular which makes the formation of a valence bond solid [1] favorable and accounts well for the non-dispersive mode at 12 meV. [1] C. Jia and J. H. Han, Phys. Rev. B 73, 172411 (2006)

MA 18.3 Wed 10:45 HSZ 401

**Diffuse neutron scattering of interesting phases in Dy2Ti2O7** — •Jonathan Morris[1], Alan Tennant[1,2], Santiago Grigera[3,4], Kirrily Rule[1], and Bastian Klemke[1] — [1]Helmholtz-Zentrum Berlin for Materials and Energy, Glienicker Str. 100, 14109 Berlin, Germany. — [2]Institut fur Festkorperphysik, Technische Universitat Berlin, Hardenbergstr. 36, Berlin 10623, Germany. — [3]St. Andrew's University, St. Andrews, Scotland — [4]Instituto de Física de Líquidos y Sistemas Biológicos, La Plata, Argentina

The prospect of observing emergent magnetic monopoles in spin-ice has recently increased the interest in these systems [1]. Dy2Ti2O7 is a effective spin-1/2 pyrochlore which is a clean model frustrated system where interesting physics may be observed and compared with theory.

Here we present new neutron measurements from E2 at the Helmholtz-Zentrum Berlin which show an agreement with spin-ice correlation functions at 0.7K and 0T, and a complex Q-dependent diffuse scattering at fields below the saturation field along [100]. These are being understood in the context of spin-strings, or spin-random-walks, which are the prerequisite for monopoles. The scattering allows us to follow the development of these strings with field and provides new insight into the Kastelyn physics within this pyrochlore.

[1] "Magnetic monopoles in spin ice" C. Castelnovo, R. Moessner & S. L. Sondhi. Nature 451, 42-45 (3 January 2008)

MA 18.4 Wed 11:00 HSZ 401

**Electronic structure and nesting-driven enhancement of the RKKY interaction at the magnetic ordering propagation vector in $Gd_2PdSi_3$ and $Tb_2PdSi_3$** — •Dmytro Inosov[1], Daniil Evtushinsky[2], Andreas Koitzsch[2], Volodymyr Zabolotnyy[2], Sergey Borisenko[2], Alexander Kordyuk[2], Matthias Frontzek[3], Michael Loewenhaupt[3], Wolfgang Löser[2], Irina Mazilu[2], Holger Bitterlich[2], Günter Behr[2], Jens-Uwe Hoffmann[4], Rolf Follath[5], and Bernd Büchner[2] — [1]MPI-FKF, Stuttgart, Germany — [2]IFW-Dresden, Germany — [3]TU-Dresden, Germany — [4]HMI, Berlin, Germany — [5]BESSY GmbH, Berlin, Germany.

We present first-time measurements of the Fermi surface and low-energy electronic structure of intermetallic compounds $Gd_2PdSi_3$ and $Tb_2PdSi_3$ by means of angle-resolved photoelectron spectroscopy

(ARPES). We show that the Fermi surface in both compounds consists of an electron barrel at the Γ point surrounded by spindle-shaped electron pockets originating from the same band, with the band bottom of both features lying at 0.5 eV below the Fermi level. From the experimentally measured band structure, we estimate the momentum-dependent RKKY coupling strength and demonstrate that it is peaked at the $\frac{1}{2}\Gamma K$ wave vector. Comparison with neutron diffraction data from the same crystals shows perfect agreement of this vector with the propagation vector of the low-temperature in-plane magnetic order, thereby demonstrating the decisive role of the Fermi surface geometry in explaining the complex magnetically ordered ground state of ternary rare earth silicides.

MA 18.5 Wed 11:15 HSZ 401

**Magnetic properties of $LaO_{1-x}F_xFeAs$** — •Sangeeta Sharma[1,2], John Kay Dewhurst[1,2], Sam Shallcross[3], Christophe Bersier[1,2], Francesco Cricchio[4], Antonio Sanna[2,5], Sandro Massidda[5], E. K. U Gross[2], and Lars Nordstroem[4] — [1]Fritz Haber Institute of the Max Planck Society, Faradayweg 4-6, D-14195 Berlin, Germany — [2]Institut für Theoretische Physik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany — [3]Lehrstuhl für Theoretische Festkörperphysik, Staudstr. 7-B2, 91058 Erlangen, Germany. — [4]Department of Physics, Uppsala University, Box 530, SE-75121 Uppsala, Sweden. — [5]Dipartimento di Fisica, Universita' di Cagliari, Cittadella Universitaria, I-09042 Monserrato(CA), Italy

Using state-of-the-art first-principles calculations we have elucidated the complex magnetic and structural dependence of LaOFeAs upon doping. Our key findings are that (i) doping results in an orthorhombic ground state and (ii) there is a commensurate to incommensurate transition in the magnetic structure between $x = 0.025$ and $x = 0.04$. Our calculations further imply that in this system magnetic order persists up to the onset of superconductivity at the critical doping of $x = 0.05$. Finally, our investigations of the undoped parent compound reveal a small itinerant moment and orthorhombic structure with both moment and distortion angle in excellent agreement with experiments.

MA 18.6 Wed 11:30 HSZ 401

**Stripes to bubble transition in Fe/Cu(001) observed using SEMPA in applied magnetic field** — •Niculin Saratz, Andreas Lichtenberger, Urs Ramsperger, Thomas Bähler, and Danilo Pescia — Laboratory for Solid State Physics, ETH Zurich, Zurich, Switzerland

Ultrathin Fe films on the Cu(001)-surface have a strong perpendicular magnetic anisotropy. The competition between the dipolar and the exchange interaction results in the formation of magnetic domains. The ground state in zero field consists of parallel stripes of alternating magnetization, whereas in an applied magnetic field the minority domains form bubbles in a homogeneous background of opposite magnetization.

We present the reversible transition from stripe- to bubble domains observed using SEMPA in applied magnetic DC field as a function of both, applied magnetic field and temperature. The associated phase diagram is mapped in T-H-space and an inverse behaviour of the transition line is observed.

MA 18.7 Wed 11:45 HSZ 401

**Chirality in Dy/Y Multilayer** — •Dieter Lott[1], Sergey V. Grigoriev[2], Yury O. Chetverikov[2], and Andreas Schreyer[1] — [1]GKSS Forchungszentrum, 21502 Geesthacht — [2]Petersburg Nuclear Physics Institute, Gatchina, St. Petersburg 188300, Russia

Chirality plays a crucial role in a wide variety of disciplines from biology to chemistry and physics. However, in the field of magnetism it did not attract a lot of attention until recently, when it was demonstrated for the first time that a single layer of manganese on tungsten orders of a specific chirality. It was interpreted being caused by the Dzyaloshinskii-Moriya (DM) interaction which arises from spin-orbit interactions of electrons due to the breaking of the inversion symmetry at the interface. Here, we present studies using polarized neutron scattering on Dy/Y multilayer structures demonstrating that the magnetic system possess a coherent spin helix with a preferable chirality induced by the magnetic field [1]. The average chirality, being proportional to the difference in the left- and right-handed helix population numbers, is measured as a polarization-dependent asymmetric part of the magnetic neutron scattering. The magnetic field applied in the plane of the sample upon cooling below $T_N$ is able to repopulate the otherwise equal population numbers for the left- and right-handed helixes. The experimental results strongly indicate that chirality observed here for the first time in a multilayer system is a more general phenomenon and may play an important role in future spintronic devices. [1] S.V. Grigoriev, Yu. O. Chetverikov, D. Lott, and A. Schreyer, Phys. Rev. Lett. 100, 197203 (2008).

MA 18.8 Wed 12:00 HSZ 401

**Skyrmion textures in uniaxially distorted cubic helimagnets** — •U.K. Rössler[1], A.B. Butenko[1,2], A.A. Leonov[1,2], and A.N. Bogdanov[1] — [1]IFW Dresden — [2]Donetsk Inst. for Physics & Technology

In magnetic systems with intrinsic or induced chirality localized and modulated multidimensional structures "Skyrmions" have been predicted to exist as metastable or thermodynamically stable states [1,2]. We show that in cubic helimagnets, as the intermetallic compounds MnSi, FeGe with B20-structure, uniaxial distortions stabilize Skyrmion lattices in a broad range of magnetic fields. Using a phenomenological theory for modulated and localized states in noncentrosymmetric magnetic crystals, the equilibrium parameters of the vortices, helices, and cycloids are determined in dependence on magnetic field and the uniaxial anisotropy induced, e.g., by uniaxial strains. Magnetic phase diagrams hold existence regions for different modulated and homogeneous phases. In particular, multiply modulated Skyrmionic textures are stabilized by an external field similar to the states described earlier for uniaxial crystals [3]. We argue that Skyrmion states could be stabilized in thin layers of cubic helimagnets or ordinary ferromagnets by applying uniaxial stresses. The formation of Skyrmion lattices is determined by the balance of energy gains through double-twist structures in the core and the tails of vortex states. — [1] A.N. Bogdanov, U.K.Rößler, Phys. Rev. Lett. **87**, 037203 (2001). [2] U.K.Rößler, A.N.Bogdanov, C.Pfleiderer, Nature (London) **442**, 797 (2007). [3] A.N. Bogdanov, D.A. Yablonskii, Sov. Phys. JETP **68** 101 (1989).

MA 18.9 Wed 12:15 HSZ 401

**Torque anomalies at magnetization plateaux in quantum magnets with Dzyaloshinskii-Moriya interactions** — •Salvatore R. Manmana and Frédéric Mila — Institute of Theoretical Physics (CTMC), EPF Lausanne, CH-1015 Lausanne, Schweiz

We investigate the effect of Dzyaloshinskii-Moriya (DM) interactions on torque measurements of quantum magnets with magnetization plateaux in the context of a frustrated spin-1/2 ladder. Using extensive DMRG simulations, we show that the DM contribution to the torque is peaked at the critical fields, and that the total torque is non-monotonous if the DM interaction is large enough compared to the g-tensor anisotropy. More remarkably, if the DM vectors point in a principal direction of the g-tensor, torque measurements close to this direction will show well defined peaks even for small DM interaction, leading to a very sensitive way to detect the critical fields. We propose to test this effect in the two-dimensional plateau system $SrCu_2(BO_3)_2$.

MA 18.10 Wed 12:30 HSZ 401

**A generic phase diagram for $R_2PdSi_3$ ($R$ = heavy rare earth)?** — •Matthias Frontzek[1], Fei Tang[1], Peter Link[2], Jens-Uwe Hoffmann[3], Jean-Michel Mignot[4], and Michael Loewenhaupt[1] — [1]TU Dresden, Institut für Festkörperphysik, D-01062 Dresden — [2]Forschungsneutronenquelle Heinz-Maier-Leibnitz, Lichtenbergerstr. 1, D-85747 Garching — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Glienickerstr. 100, D-14109 Berlin — [4]Laboratoire Léon Brillouin, CE-Saclay, F-91191 Gif-sur-Yvette

The series $R_2PdSi_3$ ($R$ = heavy rare earth) crystallize in a special variant of the hexagonal $AlB_2$ structure where the Pd and Si ions order on the B-sites resulting in a crystallographic superstructure. The rare earth ions occupy the Al-sites on a triangular and therefore geometrically frustrated lattice. In zero field the $R_2PdSi_3$ order in a rich variety of antiferromagnetic structures. The diversity reflects the influence of the magneto-crystalline anisotropy based on crystal-electric field effect.

The geometric frustration can be lifted by the application of a magnetic field. Apparently this leads to a more generalized behavior as suggested by ac-susceptibility measurements.

In our contribution we will present and combine results from field dependent ac-susceptibility measurements and magnetic neutron diffraction on single crystalline $R_2PdSi_3$ for selected samples. The existence of a general high-field magnetic structure and a generic behavior for all $R_2PdSi_3$ will be discussed. Its connection to a special variant of the $AlB_2$ crystallographic structure will be emphasized.

MA 18.11 Wed 12:45 HSZ 401

**Single-copy entanglement and entanglement spectrum in spin chains** — •Masudul Haque and Andreas Lauchli — Max Planck Institute for Physics of Complex Systems, Dresden, Germany

Features of many-particle physics are often manifested in the entanglement between two parts of a condensed-matter system. The entanglement can be characterized by, e.g., the reduced entropy, the single-copy entanglement, or the complete entanglement spectrum.

I will present results on these quantities in several prominent 1D models of quantum magnetism, namely, the XXZ model, the Majumdar-Ghosh chain, and the spin-1 bilinear-biquadratic chain.

## MA 19: Micro Magnetism / Computational Magnetism

Time: Wednesday 10:15–12:45 Location: HSZ 403

MA 19.1 Wed 10:15 HSZ 403

**Quantized spin waves in ferromagnetic and antiferromagnetic systems with domain wall.** — •Robert Wieser, Elena Y. Vedmedenko, and Roland Wiesendanger — Institute of Applied Physics and Microstructure Research Center Hamburg, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg

The understanding of the magnetization dynamics of nanosized magnets has been the aim of many recent experimental and theoretical studies. Micromagnetic simulations have become a powerful tool to study the static and dynamic processes. One interesting topic in this field are standing spin waves. We investigate standing spin waves in ferromagnetic and antiferromagnetic systems in the presence of a transverse 180° domain wall. To investigate the spin waves, we have performed simulations by solving the Landau-Lifshitz-Gilbert equation and calculated the time dependent power absorption. We compare the numerical results with analytical calculations to proof the applicability. Further we demonstrate the fundamental differences between ferromagnetic and antiferromagnetic spin wave solutions [1] and show new analytical formulas to describe spin waves in frustrated antiferromagnetic spin rings.

[1] R. Wieser, E. Y. Vedmedenko, R. Wiesendanger, Phys. Rev. Lett. **101**, 177202 (2008)

MA 19.2 Wed 10:30 HSZ 403

**Proposal for a Standard Problem for Micromagnetic Simulations Including Spin-Transfer Torque** — Massoud Najafi[1], •Benjamin Krüger[1], Stellan Bohlens[1], Matteo Franchin[2], Hans Fangohr[2], Markus Bolte[1], Antoine Vanhaverbeke[3], Rolf Allenspach[3], Ulrich Merkt[1], Daniela Pfannkuche[1], Dietmar Möller[1], and Guido Meier[1] — [1]Universität Hamburg, Hamburg, Germany — [2]University of Southampton, Southampton, United Kingdom — [3]IBM Zurich Research Laboratory, Rüschlikon, Switzerland

The spin-transfer torque between itinerant electrons and the magnetization in a ferromagnet is of fundamental interest for the applied physics community. To investigate the spin-transfer torque powerful simulation tools are mandatory. For a comparison of different simulation tools it is important to develop standard problems that can be simulated by different tools and allow us to easily verify the implementation. Previous standard problems do not include spin-transfer torque. We propose a micromagnetic standard problem, including the spin-transfer torque, that can be used for the validation and falsification of micromagnetic simulation tools. The work is based on the micromagnetic model extended with the spin-transfer torque terms proposed by Zhang and Li [1]. The suitability of the proposed problem as a standard problem is proven by numerical results from four different finite-difference-method and finite-element-method based simulation tools.

[1] S. Zhang and Z. Li, Phys. Rev. Lett. 93, 127204 (2004).

MA 19.3 Wed 10:45 HSZ 403

**Nanostructured FePt/Fe composite particles for ultrahigh density magnetic recording** — •Dagmar Goll, Gisela Schütz, and Helmut Kronmüller — MPI für Metallforschung, Stuttgart, Germany

Composite particles based on bilayers consisting of a magnetically hard and a magnetically soft layer are promising candidates for realizing the main conditions for ultrahigh density magnetic recording: Thermal stability of $> 10$ a, coercive fields of 1 - 1.5 T and switching times in the subns region. FePt/Fe composite particles are predestinated to fulfill these conditions if the microstructure is designed suitably. In particular the coercive field may be tailored either by varying the thickness of the soft layer or by manipulating the width of the phase boundary between the soft and the hard magnetic layer. Both methods have been investigated experimentally and by analytical and computational micromagnetism. It is shown that the thickness dependence of the coercive field follows a $1/d_{\mathrm{soft}}^{3/2}$ law ($d_{\mathrm{soft}}$: thickness of the soft layer) for particles with lateral dimensions larger than the thickness of the particle and a $1/d_{\mathrm{soft}}$ law for particles where lateral dimensions and the particle thickness are comparable with each other.

MA 19.4 Wed 11:00 HSZ 403

**IrMn: the role of the anisotropy for exchange bias** — •Jerome Jackson[1], Ulrich Nowak[1], Laszlo Szunyogh[2], Bence Lazarovits[2,3], and Laszlo Udvardi[2] — [1]Fachbereich Physik, Universität Konstanz, Germany — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Hungary — [3]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Hungary

We present ab-initio work concerning the anisotropy in the industrially significant antiferromagnet $IrMn_3$, and results of an atomistic spin model parametrised using ab-initio data[1]. In particular, we obtain the surprising result that the cubic crystal symmetry is locally broken, leading to a strong second order anisotropy, $K \approx 3 \times 10^8$ erg/cc. The easy axis is oriented along the three different (100) axes for each of the three sublattices in the $L1_2$ structure. This anisotropy structure is confirmed by ab-initio calculations and reproduces the experimentally observed ground state spin structure[2].

Using the spin model, the response of individual antiferromagnetic grains to the exchange field of a reversing ferromagnet have been investigated. For the case of the fully compensated (111) interface, we discuss the distortion of the "T1" ground state and the possibility of exchange bias at such interfaces; the stability and reversal mechanisms of $IrMn_3$ grains are also examined.

[1]L. Szunyogh, L. Udvardi *et.al. Phys. Rev. B, submitted* (2008)
[2]I. Tomeno, H.N. Fuke *et.al. J. Appl. Phys* 86 (1999) 3853

MA 19.5 Wed 11:15 HSZ 403

**Micromagnetic structure in permalloy rectangles** — Holger Stillrich, Sebastian Hankemeier, Nikolai Mikuszeit, Daniel Stickler, Sabine Pütter, Elena Vedmedenko, Robert Frömter, and •Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

Soft magnetic materials like permalloy ($Ni_{80}Fe_{20}$) are widely used for magnetic nano- and micrometer size elements. The magnetic properties are controlled by the shape of the elements [1]. For rectangular elements with an aspect-ratio of 1:2 two configurations avoiding magnetic poles are found: the Landau and the diamond pattern.

We have studied the micromagnetic structure of $1\,\mu\mathrm{m} \times 2\,\mu\mathrm{m} \times 23\,\mathrm{nm}$ elements utilizing a SEM with spin-polarization analysis (SEMPA). An array of well separated elements contains Landau and diamond patterns with equal frequency, as expected from micromagnetic calculations [2]. The histogram of measured magnetization orientations reveals a splitting of the long axis magnetization for Landau structures, while the diamond shows four predominant directions. Analyzing the Landau structure obtained by micromagnetic simulations (OOMMF) reveals similar splitting. In chains of particles with the long edges separated by a gap smaller than particle size magnetostatic coupling occurs and solely Landau patterns are found. The splitting angle increases. A cross-tie wall like domain structure is created across the particles.

[1] A. Hubert and R. Schäfer, Magnetic Domains, (Springer, 1998).
[2] W. Rave and A. Hubert, IEEE Trans. Magn. **36**, 3886 (2000). R. Hertel, Zeitschrift für Metallkunde. **93**, 957 (2002).

MA 19.6 Wed 11:30 HSZ 403

**Magnetic friction and "turbulence" at ferromagnetic surfaces** — •Martin Magiera[1], Lothar Brendel[1], Dietrich E. Wolf[1], and Ulrich Nowak[2] — [1]Department of Physics, University of Duisburg-

Essen, D-47058 Duisburg, Germany — [2]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

We theoretically study the magnetic contribution to friction force by simulating a ferromagnetic Heisenberg system scanned by a magnetic tip represented by a dipole field. The spin dynamics is given by the Landau-Lifshitz-Gilbert equation including a stochastic term describing thermal fluctuations. Friction force is calculated from energy dissipation terms, where thermal and magnetic energy flow contributions have to be distinguished.

For small velocities the friction force depends linearly on the scanning velocity, as well as on the phenomenological damping constant. This so-called laminar regime is in perfect agreement with our findings from a macrospin-model. Above a certain velocity vortices may occur, which propagate in the system – which is now called turbulent. Here the friction force measured is no more viscous, and its correlation with the occurence and propatation of vortices is studied.

ACKNOWLEDGEMENT: This work was supported by the German Research Foundation (DFG) via SFB 616. Computation time was granted by the John-von-Neumann-Institute of Computing (NIC) in Jülich.

MA 19.7 Wed 11:45 HSZ 403

**Propagation of spin waves through domain walls in Permalloy thin-film wires: scattering and interference** — •Ming Yan, Sebastian Gliga, Riccardo Hertel, and Claus Schneider — Research Centre Jülich, Institute of Solid State Research, 52425 Jülich

The influence of domain walls on propagating spin waves is of great interest to both fundamental physics and potential applications in novel logic devices [1]. Using a finite-element micromagnetic code, we simulate the propagation of monochromatic spin waves through transverse and vortex walls formed in Permalloy thin-film wires. At lower frequencies, the planar waves propagate through the domain walls without being noticeably scattered. A phase shift, however, is induced by the domain walls as reported in Ref. [1]. At higher frequencies, periodic interference patterns are generated after the planar waves have been scattered by the domain walls. These patterns can be understood in terms of self-interference of the scattered waves or, alternatively, as the superposition of the original planar wave and the allowed transmission modes for the magnetic strip acting as a waveguide. These modes are quantized along the width direction of the wire and can be either symmetric or anti-symmetric with respect to the central wire axis. Similar interference effects of spin waves have also been observed recently in transversely magnetized wires without domain walls [2].

References [1] R. Hertel, W. Wulfhekel, and J. Kirschner, Phys. Rev. Lett. 93, 257202 (2004) [2] V. E. Demidov, S. O. Demokritov, K. Rott, P. Krzysteczko, and G. Reiss, Phys. Rev. B 77, 064406 (2008)

MA 19.8 Wed 12:00 HSZ 403

**Stimulated vortex-antivortex pair creation in ferromagnetic thin film elements** — •Sebastian Gliga, Riccardo Hertel, and Claus M. Schneider — Institut für Festkörperforschung (IFF-9), Forschungszentrum Jülich, Jülich, Germany

Charged pair production from the vacuum is a ubiquitous phenomenon in quantum mechanics, and can be triggered by high-intensity focused laser pulses. Using micromagnetic simulations, we demonstrate that the production of vortex-antivortex pairs can equally be stimulated by applying a strong local field in the direction opposite to the magnetization, even in samples too small to permanently sustain a vortex-antivortex structure. The dynamics of such pairs has recently attracted increased attention: they play a crucial role in the vortex core reversal process [1] and it has also been found that they could annihilate in zero field [2], interact with each other altering their dynamic behavior [3] or rotate under the influence of a DC spin-polarized current [4]. As an example of pair creation, we show that a short 1.2 Tesla field pulse over a small region (20 $nm^3$) in a sub-micron sized Permalloy disk of 20 nm thickness leads to the temporary creation of a vortex-antivortex pair. This pair production is consistent with the local increase of the energy density due to the applied field. These energy densities are compared to the ones found during the vortex core switch process.

[1] R. Hertel et al., Phys. Rev. Lett. 98, 117201 (2007); [2] R. Hertel and C. M. Schneider, Phys. Rev. Lett. 97, 177202 (2006); [3] K. Kuepper et al., Phys. Rev. Lett. 99, 167202 (2007); [4] G. Finocchio et al., Phys. Rev. B 78, 174408 (2008)

MA 19.9 Wed 12:15 HSZ 403

**Annihilation of 360°-domain-walls by high-frequency magnetic field pulses.** — •Felix Kurth, Rudolf Schäfer, Jeffrey McCord, and Ludwig Schultz — Leibniz Institute for Solid State and Materials Research IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany

360°-domain-walls are metastable blocked domain walls in thin magnetic films. Such walls are only removable in external fields much higher than needed for regular 180° Neel-wall movement. In order to eliminate the walls magnetic fields up to 10 times the regular coercivity field of the system and well above the apparent saturation fields are necessary. The process of wall annihilation was studied by Kerr microscopy in the longitudinal mode in patterned Permalloy/Ta/CoFe (50 nm/4 nm/5 nm) thin magnetic double-layers. We were able to remove the 360° -walls by high-frequency magnetic field pulses significantly lower in amplitude than the quasi-static fields necessary for wall annihilation. The demonstrated route of 360°-wall annihilation by hf-pulses introduces a new path to homogenize the magnetization in patterned magnetic thin films for sensor applications. Possible annihilation mechanisms will be discussed.

MA 19.10 Wed 12:30 HSZ 403

**Chiral symmetry breaking in magnetic vortices due to sample roughness.** — •Arne Vansteenkiste[1], Bartel Van Waeyenberge[2], Markus Weigand[2], Michael Curcic[2], Hermann Stoll[2], and Gisela Schutz[2] — [1]Ghent University, Gent, Belgium — [2]Max Planck Institute for Metals Research, Stuttgart, Germany

An asymmetry between magnetic vortices with core polarizations up and down has been experimentally observed for square and disk-shaped nanostructures. E.g., different vortex core switching threshold excitations were measured, which was unexpected since the two core polarizations in these structures should behave perfectly symmetric. It was suggested that, e.g., surface roughness might cause the symmetry breaking, but it remained unclear if a small roughness could cause such a large asymmetry.

We have investigated the symmetry breaking with a new 3D finite-element micromagnetic package, which is specifically designed to handle non-perfect thin-film structures. The package uses a modified fast multipole method to calculate magnetostatic fields efficiently, without breaking the intrinsic symmetry of the sample, and employs a dynamically adaptive mesh to speed-up the calculations.

Our simulations confirm that a small roughness can indeed cause a large symmetry breaking between the two vortex core polarizations. The asymmetry can be explained by the lack of mirror-symmetry of the rough thin-film structures. The local character of the roughness causes a strong coupling with the vortex core and consequently a large asymmetry.

## MA 20: Micro- and Nanostructured Magnetic Materials I

Time: Wednesday 12:45–13:15 Location: HSZ 403

MA 20.1 Wed 12:45 HSZ 403

**Magnetization reversal of single submicron NiFe rectangles** — •Hendrik Spahr, André Kobs, Daniel Stickler, Sebastian Hankemeier, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

The magnetization reversal of single submicron NiFe rectangles with aspect ratio of two has been investigated by means of magnetotransport measurements using anisotropic magnetoresistance (AMR). The structures have been carved into a Cr(10nm)/NiFe(20nm) double layer utilizing a highly focused ion beam (FIB). The material surrounding the rectangles has been rendered paramagnetic by applying an ion dose of 6000 $\mu C/cm^2$, which destroys ferromagnetism without decreasing the electric conductivity much. To perform *in situ* two-point MR measurements the structures have been contacted via a tungsten tip attached to a micromanipulator [1]. To investigate the hard- and easy-axis hysteresis loops, measurements have been performed with

varying orientation of magnetic field with respect to current and main axis of the rectangles. The magnetization behaviour of the rectangles is mainly determined by the uniaxial shape anisotropy. The shape anisotropy constant can be estimated from the hard axis loops. The state in remanence of the rectangles has been investigated via scanning electron microscopy with polarization analysis (SEMPA).

[1] Daniel Stickler et al., Rev. Sci. Instr. **79**, 103901 (2008)

MA 20.2 Wed 13:00 HSZ 403

**Magnetic properties of exchange-coupled $L1_0$-FePt/Fe nanostructures** — •Achim Breitling, Thomas Bublat, and Dagmar Goll — MPI für Metallforschung, Stuttgart, Germany

Nanopatterned $L1_0$-FePt/Fe composite media with perpendicular magnetization are considered to be one of the most straightforward concepts to achieve ultrahigh storage densities in magnetic recording. The hard magnetic component $L1_0$-FePt guarantees thermal stability for smallest dot sizes whereas the soft magnetic component Fe reduces the coercivity and thus enables conventional write heads to store information in such patterns.

To optimize the $L1_0$-FePt/Fe nanopatterns the influence of the microstructure and of the composition on the magnetic properties of the $L1_0$-FePt part has been studied systematically within the ferromagnetic temperature range. Furthermore a technique has been developed to manipulate the character of the $L1_0$-FePt/Fe interface resulting in a gradual change of the material parameters. The nanostructures have been fabricated by advanced lithography methods and by annealing at elevated temperatures.

## MA 21: Magnetic Shape Memory Alloys I

Time: Wednesday 10:15–13:00 Location: HSZ 103

MA 21.1 Wed 10:15 HSZ 103

**Straining of Fe70Pd30 Films by Coherent Epitaxial Growth** — •Jörg Buschbeck[1], Ingo Opahle[1,2], Gerhard Jakob[3], Ludwig Schultz[1], and Sebastian Fähler[1] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]Institute for Theoretical Physics, Johann Wolfgang Goethe University, Frankfurt am Main, Germany — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55128 Mainz, Germany

Martensitic transformations in the Fe70Pd30 magnetic shape memory alloy follow the Bain path, describing the conversion from fcc to bcc structure by a tetragonal distortion. According to density functional calculations, a flat energy landscape is expected along the Bain path. Since changes in tetragonal distortion only cost little energy, this allows for the stabilization of intermartensitic phases in strained Fe70Pd30 films. Straining is realized by pseudomorphic epitaxial growth of Fe70Pd30 films using magnetron-sputtering at room temperature on different epitaxial buffer layer prepared on MgO(100) substrates. Pseudomorphic film growth of 50 nm thick disordered Fe70Pd30 films is observed. In agreement, XRD measurements show a tetragonal distortion in the films which is determined by the lattice parameter of the buffer layer. The tetragonal distortion reaches exceptionally high values of up to 27.5%, covering most of the Bain path from fcc to bcc phase, reflecting the structural instability of Fe70Pd30 as predicted by theory. The stabilization by an epitaxial interface allows for the thorough investigation of the physical properties of intermediate phases inaccessible in bulk materials.

MA 21.2 Wed 10:30 HSZ 103

**Stress relaxation and structure of vapor deposited FePd MSM films** — •Tobias Edler, Lisa Kühnemund, and Stefan Georg Mayr — I. Physikalisches Institut, Georg-August-Universität Göttingen

The magnetoelastic properties of magnetic shape memory alloy thin films are fundamentally affected by the microstructure. For optimum performance epitaxial films are desirable, which requires a detailed understanding of processing parameters and their impact on film morphology. In the present contribution, we focus on $Fe_{70}Pd_{30}$ epitaxial films, which have been grown by vapor deposition on MgO single crystal substrates, both with and without the presence of an additional ion beam during film growth. A key parameter for epitaxial growth proves to be the stresses inside the film, as measured in situ with a laser-beam deflection method during film growth. Together with high-resolution TEM studies, these experimental results are compared to molecular dynamics simulations of the stress relaxation to track down the underlying atomic mechanisms. *Funded by the DFG-SPP 1239 (C4)*

MA 21.3 Wed 10:45 HSZ 103

**Characterization of the transformation behavior of Fe-Pd ferromagnetic shape memory splats** — •Iris Kock[1], Sven Hamann[2], Stefan Mayr[1], and Alfred Ludwig[2] — [1]Georg-August-Universität Göttingen, I. Physikalisches Institut, 37077 Göttingen, Germany — [2]Institute of Materials, Faculty of Mechanical Engineering, Ruhr-University Bochum, 44780 Bochum, Germany

The $Fe_{70}Pd_{30}$ system is part of the promising new class of ferromagnetic shape memory alloys (FSMA). $Fe_{70}Pd_{30}$ shows a reversible martensitic transformation and a magnetic field induced strain (up to 3%) by detwinning of martensite variants (MFIS effect). In comparison to conventional SMAs the speed of actuation is not limited by heat conduction. If the material could be arranged as a freestanding thin film and showed this MFIS effect, it would be best suited for micro-actuator applications. Therefore freestanding $Fe_{70}Pd_{30}$ films were fabricated using the splat-quenching technique. Temperature-dependent changes in crystal structure (x-ray diffraction), resistance and magnetization of the splats were investigated. It was found that all three methods allow the determination of transformation temperatures. The results were used to investigate the influence of different post-annealing treatments on the martensitic transformation behavior of $Fe_{70}Pd_{30}$ splats. A significant increase of transformation temperatures with increasing post-annealing temperature was observed. The authors gratefully acknowledge funding by the DFG SPP 1239.

MA 21.4 Wed 11:00 HSZ 103

**Epitaxial growth of $Ni_2MnGa$ films on perovskite manganite oxides** — •Yuansu Luo, Jan Petersen, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund Platz 1, 37077 Göttingen

Magnetic sharp memory (MSM) films $Ni_2MnGa$ were sputtered onto perovskite manganite oxide layers, such as $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) to show a potential affect coupled with Jahn-Teller distortion and MSM effect. The manganite layer (80 nm) was deposited at deposition temperature $T_s$= 700°C on MgO(100) substrate and subsequently the MSM layer (150nm) at varied $T_s$ in the range 500-600°C. Structural investigation was carried out by x-ray diffraction and scanning electron microscopy. The initial result indicates a well epitaxial growth of $Ni_2MnGa$ on the LCMO layer, showing a martensitic phase at room temperature with twin structure strips along two vertical orientations. The microstructure of the samples strongly depends on $T_s$ used. Compared to polycrystalline samples prepared on $SiO_2$, the epitaxial growth used here is advantageous to form the martensitic phase. (Supported by BMBF-project 13N10061 MSM-Sens)

MA 21.5 Wed 11:15 HSZ 103

**Adaptive martensite phase in constrained epitaxial Ni-Mn-Ga films** — •Stefan Kaufmann[1,2], Ulrich Rössler[1], Robert Niemann[1,2], Oleg Heczko[1], Jörg Buschbeck[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, PO Box 270116, 01171 Dresden, Germany — [2]Institute for Solid State Physics, Department of Physics, Dresden University of Technology, 01062 Dresden, Germany

Following the concept of Khachaturyan et al. [1] of adaptive martensite we show that the tetragonal, non-modulated (NM) and the orthorhombic 7M modulated phase in Ni-Mn-Ga magnetic shape memory films fulfil all requirements for an adaptive phase formation. By means of epitaxial film growth we could confirm this concept and probe the transformation path in detail. The constraint by the substrate leads to films with austenite, 7M and NM phase coexisting over a very broad temperature range, contrary to the first order phase transformation common for bulk. Since the pole figures for the NM martensite violate the 4-folded symmetry of the cubic austenite, this shows that NM was not formed directly from the austenite but through the adaptive 7M

phase. The rigid substrate is used as a reference frame and allows confirmation of the transformation matrix from austenite to 7M martensite by the Wechsler-Lieberman-Read theory. The results prove the orthorhombic 7M phase not to be an intermediate, thermodynamically stable phase but an adaptive phase stabilized due to the constraint by the substrate-film-interface. The resulting complex microstructure is analyzed from a few *nm* to the $\mu m$ range. [1] Khachaturyan A.G. et al., Phys. Rev. B 43, 10832 (1991)

MA 21.6 Wed 11:30 HSZ 103

**Magnetic control of twinning structure in thin $Ni_2MnGa$ films** — •Tobias Eichhorn[1], Catherine Anne Jenkins[2], Michael Kallmayer[1], Hans-Joachim Elmers[1], Gerhard Jakob[1], and Michael Huth[3] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Department of Materials Science and Engineering, University of California, Berkeley, 94720, USA — [3]Physikalisches Institut, Goethe-Universität Frankfurt, 60438 Frankfurt/Main, Germany

We report on the preparation and investigation of thin epitaxial films of the ferromagnetic shape memory alloy $Ni_2MnGa$. Sample preparation is done by dc-magnetron sputtering from different NiMnGa targets onto heated substrates. The orientation of the film can be tailored by selecting different substrates. The complex crystal structure is studied by temperature-dependent x-ray diffraction in 4-circle geometry. Magnetometry measurements reveal the martenistic transformation that is crucial for the appearance of magnetically induced shape changes. To get insight on microscopic magnetism and electronic structure x-ray absorption spectroscopy and magnetic circular dichroism measurements have been performed at the German synchrotron light source BESSY II (Berlin). Free-standing films that will be needed for technical applications have been prepared using water-soluble NaCl substrates. Another approach is the fabrication of free-standing cantilevers that allow the observation of magnetically induced changes in the microstructure. This work is part of the priority program SPP 1239 and founded by the DFG.

MA 21.7 Wed 11:45 HSZ 103

**Twin variant distribution and twin boundary motion in single and polycrystalline Ni2MnGa imaged by electron back-scatter diffraction** — •Nils Scheerbaum, Jian Liu, Ludwig Schultz, and Oliver Gutfleisch — IFW Dresden, Institut für Metallische Werkstoffe, P.O. Box 270116, D-01171 Dresden, Germany

Magnetic shape memory (MSM) alloys show large magnetic field induced strain of several percent caused by a magnetic field-induced twin boundary motion within the martensite phase. Ni2MnGa single crystals show a maximum strain of 6% or 11% depending on the present martensite phase (5M or 7M, respectively). The existence of mobile twin boundaries is crucial in MSM alloys. Therefore, the twin distribution was analysed by electron back-scatter diffraction (EBSD) in a Ni49Mn27Ga24 single crystal (at.%) as well as in polycrystalline Ni50.9Mn27.1Ga22.0 fibres (produced by crucible melt extraction, 60-100um diameter, several mm length). EBSD was done at room temperature, at which in both samples the ferromagnetic 5M martensite phase is present (determined by XRD and magnetometry). In the single crystal, the twin variants are separated from each other by straight twin boundaries. Due to constraints from grain boundaries in the polycrystal, the twin boundaries are not always straight and their density increases near grain boundaries, especially in corners, where several grains touch. Both samples show magnetic field induced twin boundary motion giving rise to 1% and 6% strain for polycrystalline fibres and single crystal, respectively. This was investigated by magnetic measurements and imaged by EBSD for polycrystalline fibres.

MA 21.8 Wed 12:00 HSZ 103

**Ni-Mn-Ga: annealing for microstructure development** — •Franziska Thoss[1], Martin Pötschke[1], Gaitzsch Uwe[1], Jens Freudenberger[1], Wolfgang Anwand[2], Stefan Roth[1], Bernd Rellinghaus[1], and Ludwig Schultz[1] — [1]IFW Dresden — [2]FZ Dresden-Rossendorf

Recently the Magnetic Shape Memory Effect was observed in polycrystalline alloys near the stoichiometric composition $Ni_2MnGa$. The microstructure plays a crucial role for the achievable magnetic field induced strain, because grain boundaries inhibit twin boundary motion.

The microstructure development with regard to grain growth behavior was investigated for polycrystalline Ni-Mn-Ga samples of various compositions. Therefore, the influence of the annealing temperature and annealing time was studied. Grain growth was only observed for compositions with a Ni-content of less than 50 at.-%. The suspected existence of constitutional vacancies as a possible reason for the different grain growth behavior of such compositions was excluded by Positron Annihilation Spectroscopy. In order to activate grain boundary motion and henceforth grain growth in the MSM-active alloy $Ni_{50}Mn_{29}Ga_{21}$ the samples were compressed during the first minute at the annealing temperature at various degrees of deformation. At a deformation between 8 % and 10 % compression we observed a sharp threshold towards grain growth.

MA 21.9 Wed 12:15 HSZ 103

**Twinning behaviour of textured polycrystalline NiMnGa** — •Robert Chulist[1], Martin Pötschke[2], Andrea Böhm[3], Heinz-Günter Brokmeier[4], Thomas Lippmann[5], Carl-Georg Oertel[1], and Werner Skrotzki[1] — [1]Institut für Strukturphysik, Technische Universität Dresden, 01062 Dresden — [2]Institut für Metallische Werstoffe, Leibniz-Institut für Festkörper und Werstoffforschung, 01069 Dresden — [3]Fraunhofer-Institut für Werzeugmaschinen und Umformtechnik, 01187 Dresden — [4]GKSS Forschungszentrum, 21494 Geesthacht — [5]GKSS Forschungszentrum, 21502 Geesthacht

Magnetically actuated shape memory alloys such as NiMnGa have recently attracted special attention due to large strains achieved by the reorientation of martensitic twin variants in which twin boundaries are highly mobile. Until now, a magnetic field induced strain (MFIS) has been mainly reported for NiMnGa single crystals. Since for large-scale production growth of single crystals is economically unfavourable, it is necessary to investigate polycrystalline samples on their suitability for MFIS. Therefore, the texture of NiMnGa alloys obtained by the different fabrication processes has been measured by diffraction of high energy synchrotron radiation and neutrons. The twinning behaviour will be discussed with respect to type of texture, grain size, phase transformations including variant selection, and MFIS.

MA 21.10 Wed 12:30 HSZ 103

**Preparation of textured Ni-Mn-Ga alloys** — •Martin Pötschke, Uwe Gaitzsch, Claudia Hürrich, Franziska Thoss, Stefan Roth, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden, Helmholzstr. 20, 01069 Dresden

NiMnGa alloys have gained large research interest because of their possible application as magnetic shape memory materials. This effect is caused by the motion of twin boundaries in a magnetic field. Up to now most of the research was concentrated on single crystals. However, the preparation of single crystals is a time consuming and cost intensive process and compositional changes along the growth axis as well as segregations may occur. This is why for technical applications there is a great interest in polycrystals. To extend this effect to polycrystals, directional solidification was applied in order to prepare coarse grained, textured samples. Stationary casting in a pre-heated ceramic mold mounted on a copper plate was employed to generate a heat flow towards the bottom of the sample and thereby a directional solidification in the opposite direction. The martensitic transformation temperature which strongly depends on the composition was monitored by DSC, and it is shown that the chemical homogeneity along the sample axis is improved in likewise treated samples. The preferred solidification-induced growth direction was determined by EBSD. Investigations on the influence of MnS - precipitates in the samples, originating from the used rare Manganese, are discussed. The results are compared to samples, which were prepared by a Bridgeman method with draw rates in the range of several 100 mm/h to obtain a texture.

MA 21.11 Wed 12:45 HSZ 103

**Observation of pulsed field induced twin boundary motion in bulk NiMnGa** — •Ryan Yiu Wai Lai, Jeffrey McCord, Rudolf Schaefer, and Ludwig Schultz — Leibniz-Institute for Solid State and Materials Research, P.O.Box 270116, Dresden D-01171, Germany

A study of the twin boundary motion in bulk NiMnGa magnetic shape memory single crystals under pulsed magnetic fields with various rise-times is presented. A dynamic actuation experimental setup with the ability to apply mechanical stress and pulsed magnetic field perpendicularly is developed in cooperation with time-resolved microscopy. Reversible twin boundary motion activated by repetitive pulsed fields with rise-time down to 1 ms is directly observed. The maximum field induced strain increases with reducing rise-time. The mechanism of the enhancement of the twin boundary mobility will be discussed. Funding through the DFG priority program SPP1239 is gratefully acknowledged.

## MA 22: Invited Talk Schoeller

Time: Wednesday 14:00–14:30 Location: HSZ 04

**Invited Talk** MA 22.1 Wed 14:00 HSZ 04

**Quantum Transport through Single Molecular Magnets** — •Herbert Schoeller — Institut für Theoretische Physik A, RWTH Aachen University, Germany — JARA-Fundamentals of Future Information Technology

Quantum transport through single molecular magnets (SMM) is starting to become a new exciting field in molecular spintronics. Experiments have shown that magnetic excitations can be identified in transport measurements. Several theoretical suggestions are presented how to identify magnetic anisotropy, the spin excitations, and quantum tunneling of magnetization (QTM) in transport through SMM. NDC effects, complete current suppression, and unexpected resonance lines are discussed for weak coupling to the leads. For strong coupling, it is shown that a pseudo spin-1/2 Kondo effect is induced by QTM, either from ground-state degeneracy in half-integer spin molecules or by Berry-phase induced degeneracies due to transverse magnetic fields. Estimations of the Kondo temperature are provided and selection rules depending on spin and symmetry of the SMM are derived for the Kondo effect to occur. The effect of longitudinal and transverse magnetic fields is shown together with the effect of spin-polarized leads. It is shown that SMMs give rise to new spin-valve effects which depend on the relative as well as the absolute orientations of the electrode polarizations due to the presence of the SMM magnetic easy axis. This additional degree of external control allows complex non-equilibrium spin states to be realized and identified in single-molecule transistors.

## MA 23: Magnetic Thin Films II

Time: Wednesday 14:45–18:15 Location: HSZ 04

MA 23.1 Wed 14:45 HSZ 04

**Effect of a Cr overlayer on the switching field of epitaxial FeCo contacts on GaAs(001)** — •Bernhard Endres, Julien Vigroux, and Günther Bayreuther — University Regensburg Germany

Many experiments on spin-dependent transport require separate switching fields, $H_S$, for two ferromagnetic contacts for alternating between a parallel and an antiparallel magnetic configuration. For the case of two identical contact materials, magnetic pinning of one of the contacts by a suitable overlayer seems an appropriate solution. In this study Cr was used as a magnetic pinning material for MBE-grown $Fe_{34}Co_{66}$ contacts. The influence of a Cr overlayer grown by sputter-deposition was investigated for different $Fe_{34}Co_{66}$ thicknesses and at various temperatures. It is shown that a Cr overlayer leads to a more than five-fold increase of the easy axis switching field of $Fe_{34}Co_{66}$ films for all temperatures from 10 K to room temperature.

By the use of two shadow masks, two $Fe_{34}Co_{66}$ contacts on GaAs(001) could be realized, one pinned by a Cr layer on top and one without Cr with a 10 $\mu$m wide gap in between. Since a spin decay length up to 30 $\mu$m for an injected spin polarized current into GaAs was found in a previous experiment [1], the present layer structure should allow for all-electric detection of spin injection in GaAs. Finally, the influence of a Cr overlayer on domain nucleation and wall propagation is discussed in comparison to numerical simulations of the spin configuration at the FeCo-Cr interface.

[1] P. Kotissek et al., Nature Physics 3, 872, (2007)

MA 23.2 Wed 15:00 HSZ 04

**Néel state of a Cr monolayer on Pd(111):spin-polarized STM and first-principles calculations** — •Marta Waśniowska[1,2], Silke Schröder[3], Paolo Ferriani[3], and Stefan Heinze[3] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle — [2]Max Planck Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart — [3]Institute of Applied Physics, University of Hamburg, Jungiusstr. 11, D-20355 Hamburg

Spin averaged and spin polarized scanning tunneling microscopy at 5 K was performed on a Cr monolayer on Pd(111). The results reveal that the initial film grows in 3D irregular islands and the first layer grows pseudomorphically. Conventional STM measurements with non-magnetic tips show the hexagonal chemical unit cell containing three different contrast levels corresponding to the Cr atom and the fcc and hcp site. Using spin polarized STM operated in the constant current mode, we observe a $(\sqrt{3} \times \sqrt{3})$ superstructure indicative of a non-collinear magnetic ground state with moments forming 120° angles between nearest neighbor Cr atoms. The magnetic ground state and the STM images are explained based on *ab initio* calculations.

MA 23.3 Wed 15:15 HSZ 04

***Ab initio* prediction of a novel magnetic phase of Fe on Rh(111)** — •Ali al-zubi, gustav bihlmayer, and stefan blügel — Institut für Festkörperforschung & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich

We study a Fe monolayer (ML) on the hexagonal Rh(111) and Tc(0001) surfaces using density functional theory with the full-potential linearized augmented plane wave method as implemented in the FLEUR code. Surprisingly, antiferromagnetic (AFM) exchange interaction between the Fe atoms is dominating. Due to topological frustration on the triangular lattice, the AFM coupling leads to a 120° Néel structure on Tc, while a novel double-row-wise AFM structure (an AFM sequence of ferromagnetic bi-atomic rows of atoms) is found on Rh(111). A better understanding of these phases of Fe on the *4d* transition-metals substrates [1] is obtained by analyzing the role of exchange interactions in terms of the classical Heisenberg model and additional higher order interactions. From this it can be seen that higher order terms, in the form of 4-spin and bi-quadratic interactions, as well as the induced magnetic moments in the substrate play an important role in the formation of the double-row-wise structure. Possibilities to observe these structures with the spin-polarized scanning tunneling microscope are discussed.

[1] B. Hardrat, A. Al-Zubi, P. Ferriani, S. Blügel, G. Bihlmayer and S. Heinze, submitted to Phys. Rev. B

MA 23.4 Wed 15:30 HSZ 04

**Magnetic nanocomposite preparation, characterization and applications** — •amit kulkarni[1], vladimir zaporojtchenko[1], ulrich schürmann[2], lorenz kienle[3], eckhard quandt[2], and franz faupel[1] — [1]Chair for Multicomponent Materials, Faculty of Engineering, CAU Kiel, Germany — [2]Chair for Inorganic Functional Materials, Faculty of Engineering, CAU Kiel , Germany — [3]Synthesis and Real Structures, Faculty of Engineering, CAU Kiel, Germany

Hybrid materials consisting of metal nanoparticles dispersed in a dielectric matrix are the subject of extensive research due to their novel functional properties. The present talk is concerned with the preparation of oxide-based nanocomposites by vapor phase co- and tandem deposition and the resulting functional properties. The technique allows the preparation of nano-composites which contain alloy clusters of well defined composition with either a particulate or a multilayer nanostructure.

Thin multilayer films of tandem - sputtered TiO2 / SiO2 as dielectric and Fe54Ni27Co19 as ferromagnetic components with different layer thicknesses were prepared. Multilayer system shows a cut-off frequencies up to 3 GHz and HF-permeability above 100. A comparative study with polymer based composites will also be presented.

On other hand co-sputtering will lead to granular films. Structural and chemical analysis, by HRTEM, of TiO2 - FeCo shows that the surface of as-deposited film is completely amorphous, chemically and optically homogeneous. Composite films are superparamagnetic in nature with 5% TMR near to the percolation threshold.

MA 23.5 Wed 15:45 HSZ 04

**Analysis of intergrain interactions in epitaxial $SmCo_5$ thin films** — •Aarti Singh, Volker Neu, Sebastian Fähler, Ludwig Schultz, and Bernhard Holzapfel — IFW Dresden, Institute for

Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany

Epitaxial $SmCo_5$ films on MgO single crystal substrates show pinning dominated magnetization reversal. The films are known to consist of sub-100 nm sized grains with either parallel or perpendicular orientation and interactions between the grains are expected to exist. However this partially contradicts the angular dependent coercivity analysis where an independent switching of magnetizing along the individual easy axes is observed suggesting that the easy axes are decoupled. A detailed analysis was undertaken by extracting irreversible susceptibilities in the magnetizing and demagnetizing branches from recoil loop measurements. The irreversible susceptibility in the demagnetizing branch is very sharp as compared to that in the magnetizing branch which is relatively broad. We discuss this asymmetry by considering the system to be in a multi-domain state formed through interaction between neighboring grains and a largely different domain configuration in the thermally demagnetized state and saturated state. Few nucleation sites select only the strongest pinning centers to be active during the reversal mechanism which leads to the observed strong switching in the demagnetizing branch.

MA 23.6 Wed 16:00 HSZ 04

**Tuning Coercivity in CoCrPt-$SiO_2$ Hard Disk Material** — •Thomas Strache[1], Stefan Tibus[2,3], Felix Springer[2], Hartmut Rohrmann[4], Manfred Albrecht[3], Kilian Lenz[1], and Jürgen Fassbender[1] — [1]Forschungszentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, P.O. Box 51 01 19, 01314 Dresden, Germany — [2]University of Konstanz, Department of Physics, 78457 Konstanz, Germany — [3]Chemnitz University of Technology, Institute of Physics, 09107 Chemnitz, Germany — [4]OC Oerlikon Balzers, AG Data Storage, P.O. Box 1000, 9496 Balzers, Liechtenstein

In order to increase the storage density of modern computer disk drives and to push the superparamagnetic limit to the smallest achievable bit sizes further, smaller grains with even larger magnetic anisotropies are required, which are accompanied by large coercive fields obstructing the writing process. One route to overcome this problem is to independently reduce the coercive field without altering anisotropy and remanence by tailoring the intergranular exchange in granular CoCrPt-$SiO_2$ films.

Here we demonstrate that by means of ion implantation of Co and Ne a continuous reduction of the coercive field can be achieved without significant modification of the remaining magnetic parameters. In addition to the magnetization reversal behavior of the entire film investigated by magneto-optic Kerr effect and SQUID magnetometry, also the magnetic domain configuration in the demagnetized state is imaged by magnetic force microscopy.

MA 23.7 Wed 16:15 HSZ 04

**Ion Irradiation Induced Modification of Magnetic Properties in Py-Ta-Multilayers** — •Daniel Markó[1], Thomas Strache[1], Kilian Lenz[1], Jürgen Fassbender[1], and Rainer Kaltofen[2] — [1]Forschungszentrum Dresden-Rossendorf e.V., Institut für Ionenstrahlphysik und Materialforschung, Abteilung Nanofunktionsschichten Bautzner Landstr. 128, D-01328 Dresden, Germany — [2]IFW Dresden, Institut für Integrative Nanowissenschaften, Helmholtzstr. 20, D-01069 Dresden, Germany

We have investigated Py-Ta thin film systems with varying numbers of interfaces, but a constant overall thickness of 20 nm Py and 35 nm Ta. The samples have been irradiated with $Ne^+$ ions at various fluences in order to modify their magnetic properties, that have been probed using ferromagnetic resonance (FMR), magneto-optical Kerr effect (MOKE), and SQUID magnetometry. The saturation magnetization $M_s$ decreases both with increasing number of Py-Ta inferfaces and with increasing ion fluences. The uniaxial anisotropy of the samples is only of small magnitude and remains almost unaffected. There is a critical fluence depending on the number of interfaces for which ferromagnetism vanishes.

MA 23.8 Wed 16:30 HSZ 04

**Synthesis and characterization of Permalloy thin films prepared by DC-magnetron sputtering** — •Saleh Getlawi[1], Frank Müller[1], Michael Wick[1], Michael R. Koblischka[1], Stefan Hüfner[1], Jörg Schmauch[2], Vassil Skumryev[3], and Uwe Hartmann[1] — [1]Experimental Physics, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany — [2]Technical Physics, Saarland University, Campus D2 2, D-66123 Saarbrücken, Germany — [3]Departament de Física, Universitat Autònoma de Barcelona, 08193 Bellaterra, Barcelona, Spain

Recently, the interest in permalloy ($Ni_{81}Fe_{19}$; Py) thin films has again increased. This is mainly due to their utilization in integrated thin layers, magnetic heads and in small-size magnetic sensor and memory applications. Several fabrication methods such as vacuum evaporation, electroplating, and most recently, sputtering have been employed for the preparation of Py thin films. Here, we report on the preparation of Py thin films by means of DC sputtering, and perform a thorough analysis of the resulting thin film samples. XPS depth profiling experiments were performed in detail, resulting in a Ni:Fe ratio close to the nominal value. The Py films exhibit nearly no oxygen inclusion, and C impurities are in the range of about 5% throughout the film.The grain size of the films was examined by TEM. The magnetic characterization of the Py films was performed by means of SQUID and magnetoresistive measurements including Hall effect analysis. The magnetic domain structures on lithography patterned samples were investigated in detail by magnetic force microscopy.

MA 23.9 Wed 16:45 HSZ 04

**Magneto-optical properties of organic/ferromagnetic bilayers** — •Wen Li, Michael Fronk, and Georgeta Salvan — Physics Department, Chemnitz University of Technology, D-09107 Chemnitz

The magneto-optical Kerr effect (MOKE) of organic/ferromagnetic bilayers consisting of rubrene on top of nickel layers or vice versa was measured spectroscopically resolved in the energy range from 1.5 eV to 5.5 eV. In the MOKE hysteresis recorded at room temperature at fixed wavelength the heterostructures exhibit a superparamagnetic superimposed on a ferromagnetic behaviour. The MOKE spectra of the heterostructures were simulated using a multi-layer model that takes into account the dielectric functions of the organic layer and Ni as well as the Voigt constant of Ni. To improve the match to the experimental spectra, the film thicknesses were adjusted and a gradient in their optical properties was implemented in the simulation. From the comparison between the simulated and the experimental spectra conclusions are drawn regarding the structure of the bilayers. When the rubrene is deposited onto Ni the rubrene film oxidizes upon exposure to atmosphere with the formation of rubrene peroxide. The growth of Ni on top of the rubrene layer has a capping effect preserving the oxidation of the rubrene underlayer.

MA 23.10 Wed 17:00 HSZ 04

**Non-contact Temperature Sensor Based on Inverse Magnetostriction** — •Claas Thede, Steffen Chemnitz, and Eckhard Quandt — Christian-Albrechts-Universität zu Kiel

Sensors based on magnetic effects can be used for non-contact measurement. We present such a sensor capable of determining the thickness and also the temperature of magnetostrictive thin films.

These films can be prepared as multilayers of magnetostrictive and non-magnetostrictive material or by embedding a magnetostrictive phase into a bulk material. In both options the amount of magnetic material is related directly to the overall film thickness. Temperature measurement is achieved due to the magnetostrictive properties of the films and the difference in strain modulus between the films and their supporting material. Thus temperature induces mechanical stress, which is linked to the permeability.

The magnetic thin films act as a magnetic core for a measurement coil, which is part of an LC-oscillator driven at its resonance frequency. The presence of magnetic material affects the coils inductance and therefore shifts the resonance frequency. This generates a phase discrepancy between the oscillator and its driving circuit, as the temperature-induced change of the materials permeability does, too. By applying an additional external magnetic field the signal can be separated from the background while the monitoring of the spectral response to the saturation allows to distinguish the two effects.

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

MA 23.11 Wed 17:15 HSZ 04

**Interlayer coupling of orthogonally magnetized $(Rh/Fe_{1-x}Co_x)_N/Rh(001)$ thin films** — •Fikret Yildiz, Marek Przybylski, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

We report on fully epitaxial $(Rh/Fe_{1-x}Co_x)_N/Rh(001)$ exchange-coupled multilayer system in which every other magnetic layer ($Fe_{1-x}Co_x$, $0.4 < x < 0.6$) has an easy-magnetization axis perpendicular to the multilayer plane, and the intermediate Fe or Co (i.e. for x = 0 and x = 1, respectively) layers are magnetized in plane.

A strong perpendicular magnetic anisotropy in the $Fe_{1-x}Co_x$ films grown on Rh(001) originates from an appropriate tetragonal distortion and varies with the film composition with a maximum around x = 0.5. The most attractive advantage of the system is that the magnetic anisotropy can be continuously tuned by varying the alloy film composition. The magnetic layers are separated by Rh non-magnetic spacers which mediate a ferro- or antiferromagnetic exchange coupling depending on the thickness The Rh spacer layers support the distortion and thus the perpendicular easy magnetization axis up to tens of MLs. In reality the magnetization does not alternate between out-of-plane for the $Fe_{1-x}Co_x$ and in-plane for the Fe (or Co) layers since the interlayer exchange interaction tends to orient the magnetization of both layers in parallel.

MA 23.12 Wed 17:30 HSZ 04

**Epitaxial and layer-by-layer growth of EuO thin films on YSZ (001) using MBE distillation** — •Ronny Sutarto[1], Simone G. Altendorf[1], Beatrice Coloru[1], Marco Moretti Sala[1], Tim Haupricht[1], Chun Fu Chang[1], Zhiwei Hu[1], Christian Schüssler-Langeheine[1], Nils Hollman[1], Harald Kierspel[1], Hui-Huang Hsieh[2], Hong-Ji Lin[3], Chien-Te Chen[3], and Liu Hao Tjeng[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany — [2]Chung Cheng Institute of Technology, National Defense University, Taoyuan 335, Taiwan — [3]National Synchrotron Radiation Research Center, 101 Hsin-Ann Road, Hsinchu 30077, Taiwan

We have succeeded in growing epitaxial and highly stoichiometric films of EuO on yttria-stabilized cubic zirconia YSZ (001). The use of the Eu-distillation process during the molecular-beam-epitaxy (MBE) assisted growth enables the consistent achievement of stoichiometry. We have also succeeded in growing the films in a layer-by-layer fashion by fine tuning the Eu vs. oxygen deposition rates. The initial stages of growth involves the limited supply of oxygen from the YSZ substrate, but the EuO stoichiometry can still be well maintained. The films grown were sufficiently smooth so that the capping with a thin layer of aluminium was leak tight and enabled *ex-situ* experiments free from trivalent Eu species. The findings were used to obtain recipes for better epitaxial growth for EuO on MgO (001).

MA 23.13 Wed 17:45 HSZ 04

**Growth and magnetic properties of epitaxial Gd-doped EuO thin films on YSZ (001)** — •Simone G. Altendorf[1], Ronny Sutarto[1], Beatrice Coloru[1], Marco Moretti Sala[1], Tim Haupricht[1], Chun Fu Chang[1], Zhiwei Hu[1], Christian Schüssler-Langeheine[1], Nils Hollman[1], Harald Kierspel[1], Hui-Huang Hsieh[2], Hong-Ji Lin[3], Chien-Te Chen[3], and Liu Hao Tjeng[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany — [2]Chung Cheng Institute of Technology, National Defense University, Taoyuan 335, Taiwan — [3]National Synchrotron Radiation Research Center, 101 Hsin-Ann Road, Hsinchu 30077, Taiwan

We have been able to prepare high quality single-crystalline Gd-doped EuO thin films with well defined Gd concentrations. Using Eu-distillation assisted molecular beam epitaxy (MBE) and a systematic variation of the Gd and oxygen deposition rates, we have observed layer-by-layer epitaxial growth on yttria stabilized cubic zirconia (YSZ) (001). The RHEED and LEED patterns are extremely crisp. Soft x-ray absorption spectroscopy (XAS) at the Eu $M_{4,5}$ edges confirm that the films are completely free from $Eu^{3+}$ contaminants. The true Gd concentration has been determined using XAS at the Gd $M_{4,5}$ edges. This concentration could significantly deviate from the nominal Gd/Eu evaporation ratio, consistent with the distillation process during growth. We also found that the Curie temperature $T_C$ increases continuously up to 135 K with the Gd concentration, in agreement with most recent theoretical predictions.

MA 23.14 Wed 18:00 HSZ 04

**Dispersion relation separation revealed by inelastic neutron scattering on Dy/Y and Gd/Y superlattices** — •Alexander Grünwald[1], Elena Tartakovskaya[2], Andrew Wildes[3], Wolfgang Schmidt[4], Gregor Nowak[5], Katharina Theis-Bröhl[6], Roger Ward[7], Peter Link[8], Astrid Schneidewind[9], and Andreas Schreyer[1] — [1]GKSS-Research Centre, Geesthacht, Germany — [2]Institute for Magnetism, Kiev, Ukraine — [3]Institut Laue-Langevin, Grenoble, France — [4]Jülich Centre for Neutron Science, Germany — [5]Ruhr-Universität Bochum, Germany — [6]University of Applied Sciences, Bremerhaven, Germany — [7]University of Oxford, United Kingdom — [8]Forschungsneutronenquelle Heinz Maier Leibnitz, Garching, Germany — [9]Technische Universität Dresden, Germany

Special features of the magnetic dispersion relations in long-range exchange-coupled rare earth superlattices have been revealed with inelastic neutron scattering and can be explained by our theory. In details we have investigated magnetic low energy excitations propagating normal to the interfaces in Dy/Y and Gd/Y superlattices. The data, obtained by cold three-axis-spectroscopy, strongly suggest a separation of the 'continuous' bulk dispersions into discrete energy levels and Brillouin zone folding effects, due to the periodic sample structures and the finite number of magnetic atomic planes in each bilayer. The observed inelastic intensities are broad in energy though, but match with similar results on a (thick) Dy film. A considerably opening of the spin wave gap at the Brillouin zone center has been found as a function of an increasing applied magnetic field on the Gd/Y superlattices.

## MA 24: Magnetic Semiconductors

Time: Wednesday 14:45–19:15 Location: HSZ 401

MA 24.1 Wed 14:45 HSZ 401

**Element specific structural and magnetic properties of Co-doped ZnO - from a paramagnet to a superparamagnetic ensemble** — •Katharina Ollefs[1], Shuangli Ye[1], Verena Ney[1], Tom Kammermeier[1], Fabrice Wilhelm[2], Andrei Rogalev[2], and Andreas Ney[1] — [1]Fachbereich Physik, Universität Duisburg-Essen, Duisburg, Germany — [2]ESRF, Grenoble, France

The structural and magnetic properties of the dilute magnetic semiconductor (DMS) Co:ZnO prepared by reactive magnetron sputtering were studied using hard x-ray synchrotron radiation. By means of x-ray linear dichroism (XLD) measurements and respective simulations using the FDMNES code [1] the local crystallographic structure was investigated. For Co:ZnO with optimized growth conditions the local environment for both Co and Zn is the wurtzite structure of the ZnO bulk material. Virtually all Co dopant atoms are incorporated on cation lattice sites like previously shown for pulsed laser deposited samples [2]. X-ray magnetic circular dichroism (XMCD) and the corresponding element specific hysteresis at the Co K-edge reveal pure paramagnetic behavior as corroborated by SQUID measurements. Altered preparation conditions lead to the onset of phase-separation as revealed by a clear reduction of the XLD signal. With the onset of clustering a superparamagnetic blocking behavior arises which is typical for a particle ensemble. Changes in magnetic and electronic properties of such an ensemble due to annealing effects will be discussed.

[1] Y. Joly, Phys. Rev. B **63**, 125120 (2001)
[2] A. Ney *et al.*, Phys. Rev. Lett. **100**, 157201 (2008)

MA 24.2 Wed 15:00 HSZ 401

**Structural and Magnetic Properties of Gd doped ZnO** — •Verena Ney[1], Fabrice Wilhelm[2], Tom Kammermeier[1], Shuangli Ye[1], Katharina Ollefs[1], Andrei Rogalev[2], and Andreas Ney[1] — [1]Experimentalphysik Universität Duisburg-Essen and CeNIDE, Lotharstr.1, D-47057 Duisburg, Germany — [2]European Synchrotron Radiation Facility (ESRF), 38043 Grenoble, France

The hope of discovering a dilute magnetic semiconductor (DMS) with ferromagnetic order up to room temperature still motivates research on suitable material combinations. Approaches with Co doped ZnO have shown that films with high quality show a purely paramagnetic behaviour [1], which turns to be superparamagnetic as soon as clusterformation starts. The comparison of ion-implanted Co:ZnO with Gd:ZnO showed that Gd might be a better candidate [2]. Therefore Gd doped ZnO was prepared by reactive magnetron sputtering with high concentrations ranging from 1.4% to up to 16% of Gd in ZnO. X-ray diffraction and element specific x-ray linear dichroism (XLD) were used for the structural characterization. The corresponding magnetic properties were measured with SQUID magnetometry and - again ele-

ment specific - with x-ray magnetic circular dichroism (XMCD). Due to the large Gd-atom, the structural quality of the films is reduced with increasing Gd-content. Nevertheless, in the entire doping range we find no sign of intrinsic ferromagnetic interaction for the homogeneous Gd doped ZnO system as well as no long range magnetic order.

[1] A. Ney et al, Phys. Rev. Lett. **100**, 157201 (2008)
[2] V. Ney et al, J. Appl. Phys. **104**, 083904 (2008)

MA 24.3 Wed 15:15 HSZ 401

**Room temperature ferromagnetism in carbon-implanted ZnO** — •Shengqiang Zhou[1], Qingyu Xu[2], Kay Potzger[1], Juergen Fassbender[1], Manfred Helm[1], Holger Hochmuth[3], Michael Lorenz[3], Marius Grundmann[3], and Heidemarie Schmidt[1] — [1]Forschungszentrum Dresden-Rossendorf, Bautzner Landstraße 128, 01328 Dresden — [2]Southeastern University, Nanjing 211189, China — [3]Universität Leipzig, Linnéstraße 5, 04103 Leipzig

Transition metal (TM) doped ZnO has been extensively investigated due to its potential application as a diluted magnetic semiconductor with Curie temperature above room temperature. After one decade effort, however, the reported results are still very controversial concerning the reproducibility and the origin of the observed ferromagnetism. H. Pan et al. reported strong room temperature ferromagnetism in C-doped ZnO films grown by pulsed laser deposition [1]. Together with the first-principles calculations, evidence is given that carbon ions substitute for oxygen and their p-orbitals contribute the local magnetic moments. In this contribution [2], we introduced carbon into ZnO films by ion implantation. Room temperature ferromagnetism has been observed. Comparing with two reference samples, C implanted Ge and Ne implanted ZnO, which show only diamagnetism, our analysis demonstrates (1) the achievement of C-doped ferromagnetic ZnO by an alternative method, i.e. by ion implantation, and (2) the chemical involvement of carbon in the local magnetic moments is indirectly proven. [1] H. Pan et al., Phys. Rev. Lett. 99, 127201 (2007). [2] S. Zhou et al., Appl. Phys. Lett., arXiv:0811.3487 (2008).

MA 24.4 Wed 15:30 HSZ 401

**Room temperature ferromagnetism without element specific ferromagnetism? A detailed XMCD study on doped ZnO** — T. Tietze[1], M. Gacic[2], G. Schuetz[1], G. Jakob[2], S. Brück[1], A. Myatiev[3], B. Straumal[1,3], P. Straumal[3], and •E. Goering[1] — [1]MPI-MF, Stuttgart, Germany — [2]Institute of Physics, Johannes Gutenberg-University, Mainz, Germany — [3]Moscow Institute of Steel and Alloys, Moscow, Russia

On the quest for the intrinsic origin of ferromagnetism (FM) in ZnO doped with a few percent of nonmagnetic (d0) and magnetic transition metals, we present detailed XMCD measurements, performed in various detection modes to be sensitive to the surface, bulk, and interface related magnetism. The PLD prepared samples show strong FM at room temperature (RT) (SQUID: about 2muB/Co). On the other hand, XMCD at the Co L2,3 edges revealed only very small paramagnetic moments, while the Zn L2,3 and the O K edge measurements do not show any sign for magnetism at all. The Co L2,3 edge spectra reveal a multiplet like shape, which is clear evidence for Co located at the Zn site in a 3d7 configuration, also excluding metallic precipitates [1,2]. Therefore, we can exclude without doubt Co as a possible origin for FM in this system [2]. In addition, we have performed systematic investigations on the role of grain boundaries. These results strongly suggest grain boundary based vacancies, most likely at the oxygen site, as the source for the intrinsic RT-FM in doped ZnO. [1] M. Gacic et al., Phys. Rev. B 75 (2007) 205206 and APL 93 (2008) 152509 [2] T. Tietze et al., New Journal of Physics 10 (2008) 055009.

MA 24.5 Wed 15:45 HSZ 401

**'Invisible' ferromagnetic secondary phases in Co doped ZnO** — •Kay Potzger, Shengqiang Zhou, Arndt Mücklich, Qingyu Xu, Heidemarie Schmidt, Manfred Helm, and Jürgen Fassbender — Forschungszentrum Dresden-Rossendorf, Bautzner Landstraße 128, 01328 Dresden

The search for ferromagnetic transition-metal doped ZnO, i.e., diluted magnetic semiconductors (DMS), has turned into the search for unwanted secondary phases by high-resolution structural analysis [1]. Such phases even can lead to anomalous Hall effect arising from charge carrier spin polarization. In this talk we show that the general analysis technique for the identification, i.e. x-ray diffraction spectroscopy, fails to identify a recently observed kind of ferromagnetic inclusions with heavy crystalline disorder. We discuss the properties of those clusters using the popular Co:ZnO system.

[1] K. Potzger, S. Q. Zhou, H. Reuther, A. Mucklich, F. Eichhorn, N. Schell, W. Skorupa, M. Helm, J. Fassbender, T. Herrmannsdorfer, T. P. Papageorgiou, Appl. Phys. Lett. 88, 052508 (2006).

MA 24.6 Wed 16:00 HSZ 401

**Magnetic phase of cobalt doped zinc oxide from first-principles and Monte Carlo methods** — •Sanjeev kumar Nayak, Alfred Hucht, and Peter Entel — Physics Department, University of Duisburg-Essen, 47048 Duisburg, Germany

Understanding the magnetic properties of transition metal doped II-VI semiconductors, such as zinc oxide, is one of the active problems in materials science. Theoretically various mechanisms are sought to explain any underlying magnetic phenomena. Experimentally the situation is not yet conclusive. Hence, the need for thorough studies of this material is a priority. We studied the cobalt doped zinc oxide from a combination of different theoretical methods. The exchange interactions of cobalt spins in zinc oxide were calculated at various distances and for different compositions by the *ab-initio* technique. Treating the exchange interactions in a classical Heisenberg model, Monte Carlo simulations were done to study the phase diagram. Our results show no magnetization for doping concentrations below 20% cobalt. Intermediate concentrations of cobalt doping sustain stable ferromagnetic phase, however, for large concentrations of cobalt, the system acquires a complicated phase with antiferromagnetically coupled ferromagnetic bi-layers. The Neél temperature of cobalt oxide from our calculations match very well with that of the experimental value for fcc lattice.

MA 24.7 Wed 16:15 HSZ 401

**DMS GaMnN/AlGaN heterostructures** — •Till Benter, Dong-Du Mai, Arne Urban, Joerg Malindretos, Michael Seibt, and Angela Rizzi — IV. Physikalisches Institut, Georg-August Universität Göttingen, 37077 Göttingen, Germany

GaMnN is a prototype GaN-based dilute magnetic semiconductor. Our earlier work showed only weak ferromagnetic coupling of single layer systems at room temperature with a saturation magnetisation of $M_S$ = 0.025 $\mu_B$/Mn and a small coercive field of 250 Oe, which leads to the assumption that only a small fraction of the incorporated Mn-ions participate in the ferromagnetic coupling. As an alternative system AlGaN/GaMnN/AlGaN heterostructures have been grown. The magnetization as well as the coercive field are strongly increased in these samples and the results are well reproducible. A TEM analysis exhibits regions of high Mn concentration at the upper heterojunction, which could be responsible for the coercivity. Mechnanical strain, polarization charges and diffusion barriers at the heterojunctions seem to influence the Mn incorporation into the GaN matrix. Diverse heterostructure configurations have been characterized concerning the magnetic and structural properties and the results are discussed with reference to the assumed double-exchange mechanism for the magnetic coupling.

MA 24.8 Wed 16:30 HSZ 401

**Magnetization Control in Multifunctional Heterostructures** — •M. Althammer[1], C. Bihler[2], W. Schoch[3], W. Limmer[3], R. Gross[1], M. S. Brandt[2], and S. T. B. Goennenwein[1] — [1]Walther-Meißner-Institut, Garching, Germany — [2]Walter Schottky Institut, Garching, Germany — [3]Institut für Halbleiterphysik, Ulm, Germany

The functionality of magnetoelectronic devices depends on the efficiency and scalabilty of magnetization control schemes. We here discuss the voltage control of magnetization orientation via the magnetoelastic channel in ferromagnetic semiconductor/piezoelectric actuator hybrid structures. The hybrids consist of a thin $Ga_{0.955}Mn_{0.045}As$ film cemented onto a piezoelectric actuator [1]. Using anisotropic magnetoresistance techniques, we have quantitatively determined the magnetic anisotropy within the plane of the $Ga_{0.955}Mn_{0.045}As$ films. Exploiting the substantial changes of the magnetic anisotropy in $Ga_{0.955}Mn_{0.045}As$ as a function of temperature $T$, different ratios between the magnetoelastic and the magnetocrystalline anisotropies can be realized in one and the same sample. At $T = 5$ K the magnetoelastic anisotropy term is only a small contribution to the total anisotropy, so that only the coercive fields are slightly modified as a function of the control voltage. For $T = 50$ K the magnetoelastic contribution dominates the magnetic anisotropy which allows to achieve a voltage control of the magnetization orientation by about 70°.

Financial Support by the DFG (SPP 1157, Li 988/4 and GO 944/3) is gratefully acknowledged.

[1] Bihler, *et al.*, PRB **78**, 045203 (2008)

MA 24.9 Wed 16:45 HSZ 401

**On the formation of secondary phases in Fe implanted GaN** — •Georg Talut[1], Helfried Reuther[1], Joerg Grenzer[1], Carsten Baehtz[1], Dmitri Novikov[2], and Bente Walz[2] — [1]Institute of Ion Beam Physics and Material Research, Forschungszentrum Dresden-Rossendorf e.V., P.O. Box 510119, 01314 Dresden — [2]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg

The request for room-temperature diluted magnetic semiconductors resulted in a large interest in GaN doped with transition metals. Recent investigations have shown that beside of the real dilute state spinodal decomposition as well as the formation of secondary phases may play an important role in the discussion of the origin of the ferromagnetism in GaN [1,2]. In this study, the formation of secondary phases was investigated in GaN epilayers deposited on sapphire and implanted with $^{57}$Fe ions (3, 8 and $16\times10^{16}$ cm$^{-2}$) at room temperature. Samples were annealed at 750° - 1200° C in $N_2$ and Ar flow for durations between some ms and some minutes. The formation of secondary phases in Fe implanted GaN upon annealing a $N_2$-flow was detected ex-situ by means of x-ray diffraction and Mössbauer spectroscopy and supported by SQUID magnetometry. During annealing in reduced $N_2$ atmosphere the reverse phase change from $Fe_3N$ at room temperature to $Fe_{2.4}N$ at 1023 K was observed by means of in-situ x-ray diffraction. Samples, annealed by a flash lamp illumination in an Ar flow showed the formation of different secondary phases depending on annealing time and temperature. [1] Bonanni et al., PRL 101, (2008) 135502; [2] Li et al., Journal of Crystal Growth 310,(2008) 3294

MA 24.10 Wed 17:00 HSZ 401

**Structural and magnetic properties of pulsed laser annealed GaMnAs** — •Danilo Bürger[1], Mukesh Pandey[2], Shengqiang Zhou[1], Jörg Grenzer[1], Helfried Reuther[1], Wolfgang Anwand[1], Manfred Helm[1], and Heidemarie Schmidt[1] — [1]Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden (Germany) — [2]High Pressure Physics Division, Bhabha Atomic Research Centre, 400085 Mumbai (India)

Magnetic semiconductors with high Curie temperatures $T_C$ and large coercivity are very promising materials for spintronic applications. An approach to fabricate GaMnAs is the Mn-implantation of GaAs followed by pulsed laser annealing (PLA). We investigated the influence of Mn concentration and PLA conditions, e.g. number of pulses, pulse length, and pulse energy, on the structural and magnetic properties of GaMnAs. Using SQUID magnetometry, we revealed a strong decrease of the saturation magnetization with increasing number of pulses. HR-XRD-measurements revealed a lattice expansion normal to the surface after implantation. PLA leads either to a strain decrease (1 pulse) or even to a strain over compensation (10 pulses). We conclude that Mn implantation into GaAs followed by PLA is not sufficient for increasing the $T_C$ in GaMnAs. In addition, the drawback of the Mn implantation is the loss of As from the GaAs surface as detected by means of Auger electron spectroscopy. Heat transfer calculations and coimplantation with suitable elements are possible approaches to enhance the properties of GaMnAs.

**15 min. break**

MA 24.11 Wed 17:30 HSZ 401

**Ferromagnetism in $MgO_{1-x}N_x$: density-functional calculations** — •Phivos Mavropoulos, Marjana Ležaić, and Stefan Blügel — Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

We examine the possibility of a magnetic state in Nitrogen-doped MgO. To this end, we discuss results of density-functional calculations within the Korringa-Kohn-Rostoker Green-function method in the coherent potential approximation for the description of disorder in $MgO_{1-x}N_x$ and within the pseudopotential method for structural relaxations. We find that, when Nitrogen is substituted in MgO, a spin-polarized impurity band emerges close to the MgO valence band, with a ferromagnetic state stabilized by the double-exchange mechanism. The Curie temperature, estimated within the random phase approximation with exchange constants calculated by the Liechtenstein formula, is found to increase linearly above a percolation threshold of $x \approx 2\%$, reaching 35 K at 10% and 90 K at 20% concentration. While for isolated substitutional impurities structural relaxation is insignificant, for dimers or trimers we find that it can lead to an insulating but still magnetic state. In the case of interstitial impurities we see that the O atom is pushed out of the ideal lattice position, forming a dumbell configuration around it together with the N atom. A pair of close-by N interstitials also push the two associated O atoms out of their lattice positions, resulting in a non-magnetic configuration.

MA 24.12 Wed 17:45 HSZ 401

**Evidence for a magnetic proximity effect up to room temperature at Fe/(Ga,Mn)As interfaces** — Francesco Maccherozzi[1], Matthias Sperl[2], Giancarlo Panaccione[2], Giorgio Rossi[1,3], Jan Minar[4], Svitlana Polesya[4], Hubert Ebert[4], Ursula Wurstbauer[2], Georg Woltersdorf[2], Werner Wegscheider[2], and •Christian Back[2] — [1]Laboratorio Nazionale TASC, INFM-CNR — [2]Fakultät für Physik, Universität Regensburg — [3]Dipartimento di Fisica, Universita di Modena e Reggio Emilia — [4]Department of Chemistry, Ludwig-Maximilians University Munich

The combination of Diluted Ferromagnetic Semiconductors (DMS) and conventional semiconductors promises electronic devices with new functionalities such as non-volatility and the additional spin degree of freedom. Here we demonstrate that the low Curie temperature of DMS can be increased by using ferromagnetic proximity polarization. We show that a thin layer of (Ga,Mn)As can be spin polarized at room temperature by the proximity to an iron overlayer. X-ray magnetic circular dichroism and superconducting quantum interference device magnetometry are used to study magnetic order in the iron film and in (Ga,Mn)As films. We conclude that the induced magnetic order in the (Ga,Mn)As layer extends over more than 2 nm, even at room temperature. Furthermore, we show by experiment as well as by theory that the magnetic moments of the Mn ions are coupled antiparallel to the magnetization direction of the Fe layer. Our findings indicate that the ferromagnetic proximity polarization effect can be used to control the spin state of a thin DMS at room temperature.

MA 24.13 Wed 18:00 HSZ 401

**Local mapping of anisotropy in individual (Ga,Mn)As micro and nanostructures** — •Frank Hoffmann, Georg Woltersdorf, and Christian H. Back — University Regensburg, Germany

(Ga,Mn)As films show a superposition of various magnetic anisotropies which have different physical origins. Recently it was shown that the effective anisotropy can be altered significantly when the film is patterned into nanoscale elements [1]. For spin-injection and magnetotransport experiments with (Ga,Mn)As microstructures the knowledge of the magnetic ground state, the magnetic anisotropies and the switching behavior is crucial. By combining time-resolved Kerr microscopy and ferromagnetic resonance (FMR) we are able to perform local resonance and hysteresis measurements on individual nanostructures. The influence of strain on the magnetic anisotropies was investigated for two sample geometries. We observe a strong strain-relaxation induced uniaxial anisotropy with an easy axis parallel to the long edge for rectangular-shaped structures. Anisotropic relaxation of compressive strain in the (Ga,Mn)As stripes on a GaAs(001) substrate is the underlying mechanism for this behavior. In contrast our experiments on disk-shaped elements with laterally isotropic strain relaxation only show a lowering of the out-of-plane strain-induced anisotropy. These local changes of the magnetic anisotropy which take place at the boundary of the elements can be even imaged with our spatially resolved measurements.

[1] Wenisch et al., PRL 99, 077201 (2007)

MA 24.14 Wed 18:15 HSZ 401

**Multifarious-magnetism in copper oxide nanostructures from first-principles** — •Xiang-Yuan Cui[1], Aloysius Soon[1], Bernard Delley[2], Su-Huai Wei[3], and Catherine Stampfl[1] — [1]University of Sydney, Australia — [2]Paul Scherrer Institut, Switzerland — [3]National Renewable Energy Laboratory, USA

Driven by the ever-increasing demand for novel spin-dependent advanced materials, investigation of nanoscale magnetic materials is currently actively pursued. With the latest developments focusing more on magnetic semiconducting oxides, materials based on cuprous oxide, $Cu_2O$, are of high interest as potential $p$-type semiconducting candidates. Thus developing an understanding of how intrinsic defects influence both its electronic and magnetic properties is important.

We perform density-functional theory calculations[1] and analyze both the electronic and magnetic properties of native defects in both bulk $Cu_2O$ and its surfaces, as well as their respective formation/surface energies under different growth conditions. We find that under oxygen-lean conditions, the experimentally observed ferromagnetic behaviour[2] could originate from copper vacancies on $Cu_2O(111)$ while under oxygen-rich conditions, low energy bulk oxygen intersti-

tials might explain the ferromagnetic moment found in the same material. This suggests that the origin of observed magnetism in substoichiometric copper oxide nanoparticles could be multifarious, highlighting the complimentary role of bulk and surface native magnetic defects. 1. A. Soon *et al.* submitted, 2. A. Ye. Yermakov *et al.* J. Magn. Magn. Mater. **310**, 2102 (2007)

MA 24.15 Wed 18:30 HSZ 401

**Strong electron correlation in transition-metal (TM) doped silicon crystals** — •Frank Küwen[1], Roman Leitsmann[2] und Friedhelm Bechstedt[2] — [1]LaserAnwendungsCentrum, Technische Universität Clausthal, Am Stollen 19, 38640 Goslar — [2]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität, Max-Wien-Platz 1, 07743 Jena

A first priniciple investigation in density functional theory (DFT) has been made for TM doped silicon bulk crystals as well as for Si nanoparticles. Using the Vienna ab inito simulation package (VASP) we have calculated for relaxed geometries, single-particle energies, and magnetic moments in the spin-polarized generalized gradient approximation (GGA). The strong electron correlation has been taken into account through an effective Coulomb interaction via GGA+U and a non-local exchange-correlation potential within the Heyd-Scuseria-Ernzerhof (HSE) approach. The comparison of the resulting density of states (DOS) reveal significant influence of the strong electron correlation on the DOS, especially on the fundamental gap region, and hence on the total magnetic moments of the nanocrystals with TM atoms at different doping sites.

MA 24.16 Wed 18:45 HSZ 401

**Impurity formation energies and effective interactions in DMS** — Vaclav Drchal and •Josef Kudrnovsky — Institute of Physics, AS CR, Praha, Czech Republic

We use a recently developed method (Phil. Mag. 88 (2008), 2777) based on the TB-LMTO scheme to calculate the electronic structure of atomic clusters embedded in an ideal crystal or in an effective medium that represents a random alloy. We determine from the first principles impurity formation energies and effective interatomic interactions (i.e. the parameters of the alloy Ising Hamiltonian that governs structural stability of materials) and exchange interactions (i.e. parameters of the Heisenberg Hamiltonian that determines the magnetic structure). We will present the results for impurities in (Ga,Mn)As alloys and for vacancies and alkali metal impurities in zirconia that can induce the the so-called d0-magnetism.

MA 24.17 Wed 19:00 HSZ 401

**Structural, chemical and magnetic characterization of epitaxial Fe on (Ga, Mn)As (001)** — •Marcello Soda, Martin Utz, Werner Wegscheider, Josef Zweck, and Christian Horst Back — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätstr. 31, 93053 Regensburg, Germany

An epitaxial Fe-film grown on the dilute magnetic semiconductor GaMnAs (001) induces antiferromagnetic coupling between the two materials at room temperature.

It is known that a 2 nm thick GaMnAs layer at the interface shows induced magnetic order at room temperature [1].

TEM analysis of the Fe/(Ga, Mn)As interface, in situ XPS measurements and MOKE measurements characterize the epitaxial quality and the magnetic properties of this material. TEM micrographs shows an epitaxial growth of Fe with a roughness of 2-3 monolayer confirming the good quality of the surface treatment. XPS measurements demonstrate the absence of intermixing between the two materials.

Finally MOKE curves of Fe/(Ga, Mn)As, compared to that of the as grown GaMnAs, demonstrate the superposition of the magnetic properties of Fe and GaMnAs.

[1] F. Maccherozzi et al. accepted for publishing on PRL

## MA 25: Micro- and Nanostructured Magnetic Materials II

Time: Wednesday 14:45–19:15 Location: HSZ 403

MA 25.1 Wed 14:45 HSZ 403

**Anisotropy of the Curie temperature in ultrathin epitaxial Fe(001) wire arrays** — Roland Meier and •Günther Bayreuther — Universität Regensburg, 93040 Regensburg, Germany

According to Mermin and Wagner [1] long-range ferromagnetic order in isotropic 2D systems with short-range magnetic interactions is destroyed by spin fluctuations at any temperature $T > 0$. Curie temperatures, $T_C$, above 200 K in single atomic layers can be understood by considering magnetic anisotropies and long-range dipolar interactions. The relevance of dipolar interaction was verfied in ultrathin Fe(001) dot arrays epitaxially grown on GaAs(001) by variation of dot diameter and dot separation. By assuming that magnetization fluctuations in space and time close to $T_C$ are partially suppressed by combined exchange and dipolar interactions in the same way as purely spatial magnetization fluctuations in polycrystalline films ("magnetization ripple"), the result of a Green's function approach [2] predicts that $T_C$ should be higher in a long wire magnetized perpendicular to the wire axis compared to a parallel magnetization and to a circular dot. This was confirmed by exploiting the strong uniaxial interface magnetic anisotropy in Fe/GaAs(001). Compared to the extended film a reduction of $T_C$ by 3% was observed for perpendicular magnetization versus 8% for the parallel case; for a dot with the same dimension the reduction was indeed the sum of both, i.e.11%. This means that in epitaxial ultrathin ferromagnetic wires the Curie temperature is indeed anisotropic. [1] N. D. Mermin and H. Wagner, Phys. Rev. Lett 17 (1966) 1133 [2] W. Maass, PhD thesis, University of Regensburg, 1984

MA 25.2 Wed 15:00 HSZ 403

**Magnetization Reversal of Electrochemically Synthesized Nanowires** — •Judith Moser, Tim Böhnert, Kristina Pitzschel, Robert Zierold, Lars Bocklage, Michael Martens, Shadyar Farhangfar, Ulrich Merkt, Kornelius Nielsch, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

We suggest novel nanostructures for spin momentum transfer studies. The electrodeposition of ferromagnetic materials in self-organized pores of an $Al_2O_3$-membrane provides the unique ability to process ultrathin wires of complex shape and with reproducible properties [1]. For both fundamental research and technological applications it is of interest to understand the pinning and the dynamics of domain walls as well as the interaction between domain walls and spin-polarized currents in such nanostructures [2]. We synthesize Ni nanowires with diameters between 30 nm and 300 nm and aspect ratios up to 500. The magnetization reversal of single wires is studied by magnetic-force microscopy (MFM), X-ray microscopy, and anisotropic magnetoresistance measurements in straight wires, in bent wires, and in wires with diameter modulations serving as tailored pinning sites. The angle dependence of the switching field is proportional to $1/cos(\theta)$ and the MFM images support the idea of magnetization reversal via domain-wall motion.

[1] K. Nielsch et al., Handbook of Magnetism and Adv. Magnet. Mat., Vol. 4, John Wiley and Sons (2007). [2] G. Meier et al., Phys. Rev. Lett. 98, 187202 (2007).

MA 25.3 Wed 15:15 HSZ 403

**Iron filled carbon nanotubes studied with the Magnetic Force Microscope under applied magnetic fields** — •Matthias Lutz, Uhland Weissker, Christian Müller, Franziska Wolny, Martin Bauch, Thomas Mühl, Albrecht Leonhardt, Rüdiger Klingeler, and Bernd Büchner — Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany

We present MFM (Magnetic Force Microscopy) studies of ferromagnetic nanowires formed inside carbon nanotubes (CNT) during the CVD (Chemical Vapour Deposition) growth process. The single domain configuration of the nanowires as well as their predominantly single crystal nature render them promising candidates for novel magnetic applications. The remanent magnetization states of the CNT encapsulated $\alpha$-iron and iron carbide nanowires are contrasted as well es their switching behavior studied with the aid of applied magnetic fields. Measuring vertical arrays of $\alpha$-Fe nanowires reveals a tip triggered switching, indicating a nucleation based magnetization reversal

mechanism. Despite the extreme aspect ratio in $Fe_3C$ nanowires the magnetization is aligned perpendicular to the long axis which is discussed in terms of the magnetocrystalline anisotropy in combination with a preferred crystal orientation.

MA 25.4 Wed 15:30 HSZ 403

**Magnetic properties and applications of ferromagnetic nanowires inside carbon nanotubes** — •Thomas Mühl[1], Franziska Wolny[1], Uhland Weissker[1], Markus Löffler[1], Matthias Lutz[1], Rüdiger Klingeler[1], Palash Banerjee[2], Denis Pelekhov[2], Chris Hammel[2], Albrecht Leonhardt[1], and Bernd Büchner[1] — [1]IFW Dresden, Dresden, Germany — [2]Ohio State University, Columbus, USA

A short overview comparing the magnetic properties of iron-filled and cementite-filled carbon nanotubes is presented. Thereafter, their potential as novel probes for magnetic force microscopy and for magnetic resonance force microscopy will be shown. In addition, the nearly 100 years old Einstein-de-Haas experiment will be discussed in terms of spectacular scaling effects when applied to self supported magnetic nanowires.

MA 25.5 Wed 15:45 HSZ 403

**Magnetization switching in $\alpha$-Fe filled Carbon nanotubes using micro-Hall gradiometry** — •Pintu Das[1], Jens Müller[1], Steffen Wirth[1], Kamil Lipert[2], Franziska Wolny[2], Thomas Mühl[2], Rüdiger Klingeler[2], and Bernd Büchner[2] — [1]Max Planck Institute of Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany — [2]Leibniz Institute for Solid State and Materials Research (IFW), Helmholtz Str. 20, 01069 Dresden, Germany

Using the Hall response of a two-dimensional electron gas (2DEG) in GaAs/AlGaAs heterostructures, we employed a micro-Hall gradiometry technique to quantitatively study the magnetization behavior of $\alpha$-Fe cylinders of diameter $\sim 20\,\mathrm{nm}$, which are filled into Carbon nanotubes ($\sim 10\,\mu\mathrm{m}$ long). A Hall cross size of $800 \times 800\,\mathrm{nm}^2$ has been used for the measurements. From the measurements of a single $\alpha$-Fe-filled nanotube placed in the active area of the Hall cross (see talk of K. Lipert *et al.*), clear magnetization switching has been observed. The dependence of the switching field on the angle between the nanotube and the applied magnetic field has been studied in order to identify the switching mode. At certain magnetic fields, we also have observed switching which is not symmetric with respect to the direction of the field. A detailed calculation of the perpendicular stray field due to the $\alpha$-Fe-filled nanotube at the location of the 2DEG has been carried out to analyze the experimental data. We discuss the results and the analysis to understand the possible mode of the magnetization switching.

MA 25.6 Wed 16:00 HSZ 403

**Magnetization behaviour of perpendicular magnetized particles and nanostructures** — •Matthias Jacobi[1], Daniel Stickler[1], André Kobs[1], Simon Hesse[1], Holger Stillrich[1], Andreas Frömsdorf[2], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany — [2]Institut für Physikalische Chemie, Universität Hamburg, Grindelallee 117, 20146 Hamburg, Germany

We have investigated the magnetization reversal of submicron Co/Pt structures using anomalous Hall effect (AHE). Two different methods have been used to create the structures from films. The first method is based on highly focused ion beam (FIB), which has been used to pattern the film magnetically. A dose of $5{\cdot}10^{14}\mathrm{Ga}^+/\mathrm{cm}^2$ has been applied which destroys ferromagnetism due to intermixing of Co and Pt [1]. Ordered arrays of submicron, ferromagnetic squares are generated. The magnetisation curves obtained by AHE show stepwise reversal, while the homogeneous films exhibit single jump behaviour. The second method is based on the self assembly of diblock-copolymer micelles with silica cores. The cores act as shadow masks during $Ar^+$ sputtering. Hence, arrays of nanometre-sized dots with diameters of about 12 nm and 18 nm are created [2]. In the AHE measurements we can identify the magnetisation curves of the dots although the area filling factor is about 15%. The 12 nm particles show superparamagnetism at room temperature.

[1] P. Warin et al., J. Appl. Phys. **90**, 3850 (2001)
[2] H. Stillrich et al., Adv. Funct. Mat. **18**, 76 (2008)

MA 25.7 Wed 16:15 HSZ 403

**Critical behaviour of nanocrystalline gadolinium** — •Adrian Ferdinand[1], Frank Döbrich[1], Anne Catherine Probst[1], Andreas Michels[1], Sharika Nandan Kaul[2], and Rainer Birringer[1] — [1]Technische Physik, Universität des Saarlandes, Saarbrücken, Germany — [2]School of Physics, University of Hyderabad, Hyderabad, India

For single crystalline gadolinium (Gd), Srinath, Kaul, and Kronmüller [1] have demonstrated that Gd belongs to the uniaxial dipolar universality class with a Curie temperature $T_c = 292.77$ K. For polycrystalline Gd, the critical behaviour seems to be strongly affected by the microstructure when the crystallite size D is reduced to the nanometer regime. The most striking feature in this context is the continuous reduction of $T_c$ with decreasing D which yields $T_c$-shifts of 10 K and more for grain sizes below 30 nm [2]. Here, we report on the critical behaviour of inert-gas condensed nanocrystalline Gd (with 8 nm $<$ D $<$ 21 nm) which has been studied by means of ac-susceptibility and small-angle neutron scattering.

[1] S. Srinath, S.N. Kaul, H. Kronmüller, Phys. Rev. B 59, 1145 (1999) [2] D. Michels, C.E. Krill III, R. Birringer, J. Magn. Magn. Mater. 250, 203 (2002)

MA 25.8 Wed 16:30 HSZ 403

**The effect of the tapered shape on the magnetostatic anisotropy of magnetic elements** — •Sabine Pütter, Nikolai Mikuszeit, Holger Stillrich, Elena Vedmedenko, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

Magnetic nano– and microstructures are commonly fabricated by mask techniques. At first glance, the size of the structure depends only on the holes in the mask. However, due to the finite size of the evaporation source and the finite distance of mask and substrate the structure has a certain edge profile. In general, a tapered shape is produced.

In this paper the influence of the tapered shape on the magnetostatic anisotropy is studied for elements with rectangular base. Based on the approach of Rhodes and Rowlands [1] and on straight forward integration of the Poisson equation the demagnetizing energy of uniformly magnetized elements is calculated. We find that the shape anisotropy is drastically reduced due to the modified shape.

When two rectangular elements are aligned parallel to their long axes there is a critical distance at which the easy axis of magnetization switches from the single element's easy axis to the direction of the connecting line due to the magnetostatic interaction. This distance is increased significantly in case of elements with tapered shape.

The theoretical predictions are compared with the results for micron sized permalloy elements studied by the magneto-optical Kerr effect.

[1] P. Rhodes and G. Rowlands, Proc. Leeds Phil. Liter. Soc. 6 (1954), 191.

MA 25.9 Wed 16:45 HSZ 403

**Hall micromagnetometry of domain walls in permalloy nanostructures** — •Peter Lendecke[1], Lena Breitenstein[1], Stellan Bohlens[2], Guido Meier[1], and Ulrich Merkt[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg — [2]I. Institut für Theoretische Physik, Universität Hamburg

We investigate domain-wall depinning in permalloy nanowires and the hysteresis of micron-sized square platelets by ballistic Hall micromagnetometry. The technique allows to measure the stray field of individual nanostructures between liquid helium temperature and 50 K. The pinning and depinning of single domain walls at constrictions is detected non-invasively by sensing the stray field of the walls [1]. Results on the temperature dependence of depinning fields at constrictions of different sizes as well as experiments on current-assisted depinning are presented. By measuring the stray field of square thin-film platelets we are able to investigate their hysteresis loop at low temperatures. Nucleation of a Landau pattern, displacement of the vortex in its centre by an in-plane external field, and vortex annihilation are clearly identified by analyzing minor loops and return branches [2]. These results are corroborated by magnetic-force microscopy images and micromagnetic simulations.

[1] P. Lendecke, R. Eiselt, U. Merkt, and G. Meier, J. Appl. Phys. **103**, 073909 (2008).
[2] L. Breitenstein, P. Lendecke, S. Bohlens, G. Meier, and U. Merkt, J. Appl. Phys. **104**, 083909 (2008).

MA 25.10 Wed 17:00 HSZ 403

**Freezing dynamics of magnetite ferrofluids studied by time-resolved Small Angle Neutron Scattering** — •Sylvain Prévost[1], Albrecht Wiedenmann[2], Uwe Keiderling[3], Dirk Wallacher[3], Michael Meissner[3], and Joachim Kohlbrecher[4] — [1]Stranski Lab., TU Berlin, Berlin, Germany — [2]Institut Laue

Langevin, Grenoble, France — [3]Helmholtz-Zentrum Berlin, Berlin-Wannsee, Germany — [4]Laboratory for Neutron Scattering, ETH Zurich & PSI, Villigen, Switzerland

The dynamics of particle ordering in ferrofluids has been studied by time-resolved stroboscopic SANS. Two samples are compared, with nearly monodisperse Co and Fe3O4 nanoparticles of similar magnetic moments, dispersed in oil and stabilized by surfactant. The SANS scattering response was measured stroboscopically in an oscillating applied magnetic field, with an optional static field superimposed, the temperature ranging from 100 to 300K.

As long as the magnetic moments follow the applied field, the 2D scattering patterns alternate between fully isotropic and strongly anisotropic. Oscillating behavior with decreasing amplitudes is clearly observed down temperatures lower than the melting point of the pure solvent. Scattered intensities can be successfully fitted in terms of the Langevin statistics. The dynamics of field-induced ordering in the ferrofluid systems is governed by the fast Brownian rotation of individual nanoparticles and small aggregates while the magnetic relaxation of longer dipolar chains and local hexagonal domains is much slower.

**15 min. break**

MA 25.11 Wed 17:30 HSZ 403

**(001) textured FePt thin films on spherical $SiO_2$ nanoparticle template** — Christoph Brombacher[1], •Christian Schubert[1], Andreas Teichgräber[1], Sara Romer-Urban[2], Mireille Maret[3], Denys Makarov[4], Michael Hietschold[1], and Manfred Albrecht[1] — [1]Institute of Physics, TU Chemnitz, Chemnitz, Germany — [2]Nanoscale Materials Science, Empa, Dübendorf, Switzerland — [3]Laboratoire de Thermodynamique et Physico-Chimie Métallurgiques, ENSEEG, Saint Martin d'Heres, France — [4]Department of Physics, University of Konstanz, Konstanz, Germany

Due to its high magnetocrystalline anisotropy and excellent corrosion resistance, FePt is considered one of the most promising candidates for future magnetic data storage devices. In this study, densely-packed arrays of $SiO_2$ nanoparticles have been used as a template to create regular FePt nanostructures suitable for application as patterned media. The sputter deposited FePt film displays a chemically disordered fcc phase. Postannealing in a commercial RTA setup yields both a high ordering parameter and the desired (001) texture as shown by XRD and TEM. The heating rate, heating time and heating temperature have been optimized on planar $SiO_2$ substrates, obtaining perpendicular magnetic anisotropy and coercivities of up to 2 T. Furthermore, the FePt films exhibit a strong dewetting behavior on both planar substrates and spherical nanoparticles. By tuning the thickness of the FePt layer, the characteristic length scales of the dewetting process can be controlled. This was used to create isolated FePt nanostructures on $SiO_2$ particle arrays with periodicities down to 50 nm.

MA 25.12 Wed 17:45 HSZ 403

**Magnetic single-phase behaviour of die-upset magnets made from $\mu$m-sized $Nd_2Fe_{14}B$ and Fe-particles** — •Juliane Thielsch, Dietrich Hinz, Konrad Gueth, Oliver Gutfleisch, and Ludwig Schultz — IFW Dresden, Institute for Metallic Materials, P.O. Box 27 01 16, D-01171 Dresden, Germany

Textured composite magnets containing hard magnetic NdFeB and soft magnetic $\alpha$-Fe were produced by hot pressing and subsequent die upsetting. As starting material NdFeB melt spun ribbons (MQU-F) and $\mu$m-sized Fe-particles were blended in varying compositions from a NdFeB:Fe-weight ratio of 100:0 to 70:30. The addition of Fe leads to a drastic decrease in coercivity from 13.20 kOe for pure NdFeB ribbons to 1.54 kOe for a sample with 30 wt-% Fe but has surprisingly almost no influence on the remanence. In contrast values for saturation magnetisation increase with larger amounts of Fe. The diameter of the Fe-particles exceeds by far the maximum length of effective exchange interactions. Therefore magnetostatic coupling between the two phases is proposed to explain the magnetic single-phase hysteresis behaviour when measured along the nominal easy direction of magnetisation. Measurements along the hard direction of magnetisation show two-step curves. SEM and Kerr investigations were carried out to investigate phase distribution and coupling.

MA 25.13 Wed 18:00 HSZ 403

**Microresonator fabrication for lower sensitivity limit for ferromagnetic resonance measurements** — •Anja Banholzer[1], Ryszard Narkowicz[2], Sven Stienen[1], Jürgen Lindner[1], Dieter Suter[2], and Michael Farle[1] — [1]Universität Duisburg-Essen, Standort Duisburg, Institut für Physik und CeNIDE, AG Farle, Lotharstr. 1, 47048 Duisburg — [2]Universität Dortmund, Institut für Physik, Otto-Hahn-Str. 4, 44227 Dortmund

By measuring Ferromagnetic Resonance (FMR) there is a minimum number of spins which can be detected, depending on the measurement device used. We are currently developing a microresonator from which higher sensitivity can be expected. Therefore, it would be possible to measure FMR even for a small amount of sample material. We process the microresonator using Electron Beam Lithography on Silicon. For the measurement we use an external magnetic field, while the microwave field is generated inside the microresonator. The frequency of the microwave depends on the layout of the microresonator. By varying the layout, it is possible to optimise the quality factor and the signal to noise ratio. Our test measurements are performed on Permalloy nanostructures.

MA 25.14 Wed 18:15 HSZ 403

**Local setting of magnetic anisotropy in FeCoSiB thin films by means of indirect ion implantation** — •Norbert Martin[1], Jeffrey McCord[1], Andreas Gerber[2], Thomas Strache[3], Thomas Gemming[1], Ingolf Mönch[1], Rudolf Schäfer[1], Jürgen Fassbender[3], Eckhard Quandt[2], and Ludwig Schultz[1] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]Chair for Inorganic Functional Materials, CAU Kiel, Kaiserstrasse 2, 24143 Kiel, Germany — [3]Forschungszentrum Dresden Rossendorf e.V., P.O. Box 510119, 01314 Dresden, Germany

The magnetic anisotropy direction and strength of amorphous FeCoSiB thin films was modified locally by masked ion implantation without alteration of the magnetic material's structure and the intrinsic magnetic properties of the ferromagnetic film. The changes were introduced by local ion implantation in a SiO2 covering and protection layer, inducing additional stress-induced magnetic anisotropy to the magnetostrictive ferromagnetic layer. Hybrid hysteresis curves combining switching and rotational processes were measured and the underlying local variation of magnetic anisotropy was confirmed by magnetic domain observations. A good agreement between the calculated stress distribution and the experimentally obtained magnetic data was found. The described indirect method, relying purely on magneto-elastics, introduces a new path to the creation or alteration of magnetic properties subsequent to magnetic film preparation in structured magnetic samples without introducing any structural changes to the ferromagnetic layers.

MA 25.15 Wed 18:30 HSZ 403

**Structure and magnetic properties of HDDR $Nd_2Fe_{14}B$ powders** — •Konrad Güth, Juliane Thielsch, Oliver Gutfleisch, and Ludwig Schultz — IFW Dresden, Institute for Metallic Materials, Postfach 270116, D-01171 Dresden, Germany

The HDDR process (Hydrogenation Disproportionation, Desorption, Recombination) is a unique method to produce highly coercive powders for bonded permanent magnets. The starting material is a Nd-rich $Nd_2Fe_{14}B$ alloy. The first step starts with the absorption of hydrogen atoms at room temperature which fill the vacancies and cause expansion of the lattice. This large stress causes decrepitation of the alloy resulting in a powder with a particle size of several micrometers. An additional heating of the alloy at 840°C under 0.3 bar hydrogen pressure leads to the disproportionation of the $Nd_2Fe_{14}B$ phase into a very fine mixture of neodymium hydride, $\alpha$-iron and Fe-boride. Desorption of hydrogen and recombination can be induced at high temperatures, leading to the recovering of the original $Nd_2Fe_{14}B$ phase but with a dramatically refined grain size (200-300 nm). Phase analysis and grain size determination of the powders are characterized by XRD using Rietveld analysis. High resolution scanning electron microscopy (HR SEM LEO 1530 GEMINI) was used to study the microstructure. Magnetic properties were investigated by vibration sample magnetometry (VSM) with a maximum magnetic field of 9 T at room temperature. Prior to the VSM measurement the $Nd_2Fe_{14}B$ powders were aligned applying a magnetic field of 2 T during cold compaction.

MA 25.16 Wed 18:45 HSZ 403

**High resolution *in-situ* MOKE and STM setup with all optical components in UHV** — •Anne Lehnert, Philipp Buluschek, Nicolas Weiss, Johannes Giesecke, Matthias Treier, Stefano Rusponi, and Harald Brune — Institute of the Physics of Nanostructures, EPF-Lausanne, Switzerland

A surface magneto-optic Kerr effect (MOKE) setup fully integrated in an ultra high vacuum chamber is presented [1]. The system has been designed to combine high resolution *in-situ* MOKE and variable temperature scanning tunnelling microscopy. The coverage detection limit is 0.5 ML for transverse MOKE and 0.1 ML for polar MOKE. For island superlattices, the latter limit corresponds to islands composed of about 50 atoms. Magnetic fields up to 0.3 T can be applied at any angle in the transverse plane allowing the study of the in-plane and out-of-plane magnetization. The setup performance is demonstrated for a continuous film of 0.9 ML Co/Rh(111) with in-plane easy axis and for a superlattice of nanometric double layer Co islands on Au(11,12,12) with out-of-plane easy axis. For Co/Au(11,12,12) we demonstrate that the magnetic anisotropy energies (MAE) deduced from thermally induced magnetization reversal by measuring the zero field susceptibility and from applying a torque onto the magnetization by turning the field are the same. Assuming the MAE to be proportional to the perimeter length 0.95±0.01 meV/perimeter atom and 0.87±0.01 meV/perimeter atom have been inferred.

[1] A. Lehnert *et al.*, submitted to Rev. Sci. Instrum.

MA 25.17 Wed 19:00 HSZ 403

**Quasi-Antiferromagnetic 120° Néel-State in 2D Clusters of Dipole-Quadrupole-Interacting Particles Arranged on a Hexagonal Lattice** — •Nikolai Mikuszeit[1], Larysa Baraban[2], Elena Y. Vedmedenko[1], Artur Erbe[2], Paul Leiderer[2], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg Jungiusstr. 11, 20355 Hamburg, Germany — [2]Department of Physics, University of Konstanz, Universitätsstr. 10, Konstanz, 78457, Germany

Recent experiments on colloidal particles, capped with Co/Pt multilayers, have shown a 120° Néel-state [1], which was unexpected for particles interacting via stray field. The state, where all particles are reversed, is not observed. In the framework of multipole expansion [2] this asymmetry requires not only odd but also even parity moments (e.g. a quadrupole (**q**)). The even parity moments significantly alter the dipolar ordering of the presumably dominant dipole (**d**).

We performed Monte Carlo simulations of particle clusters taking into account a **d**- and a **q**-moment. Although the symmetries of the pure dipolar (vortex) or pure quadrupolar (pinwheel) ground states strongly differ from the observed Néel-state, the latter one can be established by competing **d** and **q** interactions. The relative strength of **d**-**d**- and **q**-**q**-interaction as well as the cluster size was varied. A small region was found, where the 120° Néel-state is formed.

[1] L. Baraban, et al. Phys. Rev. E **77**, 031407 (2008)
[2] E. Y. Vedmedenko and N. Mikuszeit, ChemPhysChem, **9**, 1222 (2008)

## MA 26: Magnetic Shape Memory Alloys II

Time: Wednesday 14:45–16:30 Location: HSZ 103

MA 26.1 Wed 14:45 HSZ 103

**First principles determination of phase transitions in magnetic shape memory alloys** — •Tilmann Hickel, Matthe A Uijttewaal, and Jörg Neugebauer — Max-Planck-Institut für Eisenforschung GmbH, Max-Planck-Str.1, 40237 Düsseldorf, Germany

Magnetic shape memory alloys have recently attracted a lot of excitement, since they allow shape changes of more then 10% with a frequency in the kHz regime. The fundamental origin of this property is related to a martensitic phase transition. The material system $Ni_2MnGa$ is the most promising candidate for applications, but its operation temperatures and ductility still need to be improved. Hence, an extension of the currently limited knowledge on the phase diagram is decisive. In order to identify the stable structures and their transitions we performed ab initio calculations of free energies for the austenite, the (modulated) pre-martensite and the unmodulated martensite. Quasiharmonic phonons and fixed-spin magnons are considered, employing density functional theory. Using this approach we were able to successfully describe the phase transition in detail, to reveal the involved delicate interplay of vibrational and magnetic excitations and to accurately determine the transition temperature. The methods are used to interpret the experimental findings and to make predictions for modified material compositions.

MA 26.2 Wed 15:00 HSZ 103

**Binding energies of tetragonally distorted magnetic Heusler alloys** — •Mario Siewert, Markus Ernst Gruner, and Peter Entel — Fachbereich Physik, Universität Duisburg-Essen

Binding surfaces of the magnetic Heusler Alloys $Ni_2MnX$ (X=Al, Ga, In, Zn, Ge, Si, Sn, Sb, As) and $Cu_2MnY$ (Y=As, Ga, Ge, Sb) have been calculated by using density functional theory. The binding surfaces tend to show a global minimum of the total energy at c/a-ratios larger than 1.0 with increasing valence electron density e/a. The c/a-ratios refer to a tetragonal distortion that can be linked to the low-temperature martensitic state. In some systems with large values of e/a the minimization of the energy is linked to a decrease of the volume which can be as large as 3.9%.

Fixed-spin moment calculations (FSM) reveal that the energy barrier between two minimums can be lowered or shifted in some systems by applying a magnetic field.

MA 26.3 Wed 15:15 HSZ 103

**A general phase-field model for polycrystals with elastic and micromagnetic contributions** — •Christian Mennerich, Andreas Melcher, and Britta Nestler — Institute of Computational Engineering, Karlsruhe University of Apllied Sciences, Germany

A phase-field model coupled with elastic and micromagnetic contributions is introduced to describe the time spatial evolution of a polycrystal under the influence of strains and in the presence of a magnetic field. We introduce the model in terms of a general Ginzburg-Landau free energy functional and derive a coupled system of partial differential equations for the vector valued phase-field variables, for the displacement-field and for the spontaneous magnetisation. Applications of the model to cubic and tetragonal crystal symmetries of the polycrystal are discussed. Finally we give a short insight into the numerical implementation.

MA 26.4 Wed 15:30 HSZ 103

**Modelling the phase diagram of Ni-Mn-X (X = In, Sn, Sb) alloys:*A q-state Potts model monte Carlo study** — •P. Entel[1], V. D. Buchelnikov[2], S. V. Taakaev[2], V. V. Sokolovskiy[2], A. Hucht[1], M. Ogura[3], H. Akai[3], M. E. Gruner[1], and S. K. Nayak[1] — [1]Physics Department, University of Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Condensed Matter Physics, Chelyabinsk State University, 454021 Chelyabinsk, Russia — [3]Department of Physics, Osaka University, Osaka 560-0043, Japan

On the basis of Monte Carlo simulations using Heisenberg and Potts model Hamiltonians, we investigate the complex temperature dependence of the phase diagram of Ni-Mn-X (X = In, Sn, Sb) Heusler alloys. For Mn excess concentration, we find Mn atoms on the X sites, whose magnetic moments interact antiferromagnetically with the Mn spin moments on the Mn sublattice. Using ab initio data for the magnetic exchange interactions, it is shown that this antiferromagnetic exchange is responsible for metamagnetic behavior and a series of magnetic phase transitions, which compete or act in favor of the martensitic transformation being present in the Heusler alloys. This scenario is finally responsible for the occurrence of magneto-structural phase transitions in this class of ferromagnetic Heusler alloys.

MA 26.5 Wed 15:45 HSZ 103

**Reversibility of magnetostructural transition in Ni-Mn-In-Co magnetic shape memory alloys** — •Jian Liu, Julia Lyubina, Nils Scheerbaum, and Oliver Gutfleisch — IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany

For Ni-Mn-based Heusler alloys showing a magnetic-field induced martensitic transition, the reversibility of the magnetostructural transition is of crucial importance for magnetic-shape-memory actuator materials. It is desirable that the austenite induced by the magnetic field is able to transform back to the initial martensite when the magnetic field is removed. A complete recovery of the initial martensite state may bring about magneto-elasticity (two-way shape memory effect), while the irreversible magnetostructural transition would result in magneto-plasticity (one-way shape memory effect). Here, by ana-

lyzing isothermal magnetization curves under magnetic field cycling, the reversibility of the magnetostructural transition was investigated in Ni45Mn37In13Co5 in form of bulk sample and melt-spun ribbons. Hysteresis in the thermally and magnetically induced martensitic transformation plays an important role in the reversibility of the magnetostructural transition. In ribbons with a large hysteresis of 18 K, a residual field-induced austenite is present after removing the magnetic field, while, in the bulk sample, the magnetostructural transition is reversible at moderate temperatures due to a relatively smaller hysteresis of 8 K. Additionally, the magnetocaloric effect strongly depends on the sample history due to the occurrence of the irreversible magnetostructural transition, especially for the ribbons.

MA 26.6 Wed 16:00 HSZ 103

**Orientation characterisation of NiMnGa MSM** — •Claudia Hürrich, Martin Pötschke, Stefan Roth, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden, PF 27 01 16, 01171 Dresden

Magnetic shape memory alloys (MSMA) have gained a large research interest due to their capability of showing magnetic field-induced strain (MFIS). In contrast to conventional shape memory alloys, plastic deformation in the martensitic phase, which is due to twin boundary motion, may be caused not only by mechanical stress but also by an external magnetic field. $Ni_{50}Mn_{29}Ga_{21}$ shows magnetic field induced strain (MFIS) in single crystals. Polycrystalline $Ni_{50}Mn_{29}Ga_{21}$ was prepared by directional solidification and was cut erosively from a cast ingots into cubes with a 5 mm edge length. These samples have a martensite - austenite transformation at approximately 60°C. The change in surface topography during this transformation is followed by an optical microscope. The configuration of the twin boundaries was analysed before and after compressing the samples.

Financial support by the DFG within SPP 1239 is gratefully acknowledged.

MA 26.7 Wed 16:15 HSZ 103

**Influence of alloying Ni-Mn-Ga with cobalt on structural, mechanical, and magnetic properties** — •Katharina Rolfs[1,2], Markus Chmielus[1,3], Peter Müllner[3], Robert C. Wimpory[1], Winfried Petry[2], and Rainer Schneider[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Glienicker Str.100, D-14109 Berlin, Germany — [2]Technische Universität München, Lichtenbergstr. 1, D-85747 Garching, Germany — [3]Department of Materials Science and Engineering, Boise State University, 1910 University Dr., Boise, Idaho 83725, USA

Magnetic Shape-Memory Alloys (MSMAs) can potentially substitute giant magnetostrictive materials as well as piezoelectrical ceramics in actuating devices due to their large magnetically induced strain. By alloying the most commonly studied MSMA Ni-Mn-Ga with 5 at-% Co, the martensite- and Curie-temperature was increased to values above 160°C. Two structures have been observed in Ni-Co-Mn-Ga single crystalline samples. Besides the non-modulated tetragonal structure, one of the common structures of Ni-Mn-Ga, a non-modulated orthorhombic structure, has been observed, which shows a cyclic permutation of all three crystallographic axes by applying a mechanical stress. The stress-strain analysis and the crystallographic characterization will be discussed here in detail. The giant magnetocaloric effect at the first order phase transition in Ni-Mn-Ga is well known. This effect is strongly influenced by alloying Ni-Mn-Ga with Co. Depending on the Mn-Ga-ratio the entropy change at the phase transition is still huge, however with an opposite sign. The results will be discussed here as well.

## MA 27: Spin Electronics / Spininjection in Heterostructures

Time: Wednesday 16:45–17:45 Location: HSZ 103

MA 27.1 Wed 16:45 HSZ 103

**The interface of tunnelling junctions with the Heusler electrode $Co_2Cr_{0.6}Fe_{0.4}Al$** — •Martin Jourdan, Christian Herbort, Elena Arbelo Jorge, Michael Kallmayer, and Hans Joachim Elmers — Institut für Physik, Johannes Gutenberg Universität, Staudingerweg 7, 55128 Mainz, Germany

The compound $Co_2Cr_{0.6}Fe_{0.4}Al$ was the first Heusler material for which half metallic properties and a magnetic ordering temperature well above room temperature were predicted. However, no Jullière spin polarisation larger than $\simeq 60\%$ could be observed up to now. The affinity of Cr for oxidation is considered to be the origin for this reduced value. We improved the vacuum condition of our preparation system to below $10^{-9}$mbar. This resulted in a pronounced change of the morphology of the rf sputter deposited Al layer which is deposited on top of the Heusler electrode in order to become the tunnelling barrier after oxidation. In situ STM investigation show the growth of Al islands on the $Co_2Cr_{0.6}Fe_{0.4}Al$ surface. This growth mode results in an increased roughness of the barrier, which limits the achievable tunnelling magnetoresistance (TMR). Alternative methods of barrier deposition are employed and investigated by in situ STM and RHEED. Additionally, the effect of the Al deposition method and oxidation process on the surface magnetisation of the Heusler electrode is investigated by XMCD-TEY experiments.

MA 27.2 Wed 17:00 HSZ 103

**Optimized spin-injection and detection in lateral all-metal spin-valve devices with integrated tunnel barriers** — •Andreas Vogel, Jeannette Wulfhorst, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

Injection, manipulation, and detection of spin-polarized currents are fundamental issues in spintronics. We study the spin-dependent transport in lateral all-metal spin-valve devices with different tunnel barriers at the interface between the ferromagnetic electrodes ($Ni_{80}Fe_{20}$) and the interconnecting metal strip (Al or Cu). A tunnel barrier can enlarge the spin polarization of the injected current [1-3]. Different total conductivities per cross-sectional area $\Sigma_C$ of the aluminum oxide tunnel barriers are achieved by varying the oxygen pressure, the oxidation time, and the thickness of the naturally oxidized Al film. The spin-dependent transport in nonlocal geometry is described theoretically [3]. Transport measurements at temperatures of liquid helium are performed and compared to the theoretical description. A nonlinear increase of the spin polarization in the normal metal is observed for a decreasing tunnel conductance $\Sigma_C$. We experimentally verify a saturating behavior for lower $\Sigma_C$.

[1] F. J. Jedema et al., Nature **416**, 713 (2002)
[2] S. O. Valenzuela et al., Appl. Phys. Lett. **85**, 5914 (2004)
[3] A. van Staa, J. Wulfhorst, A. Vogel, U. Merkt, and G. Meier, Phys. Rev. B **77**, 214416 (2008)

MA 27.3 Wed 17:15 HSZ 103

**Determination of spin injection and transport in a ferromagnet/organic semiconductor heterojunction by two-photon photoemission** — •Mirko Cinchetti[1], Kathrin Heimer[1], Jan-Peter Wüstenberg[1], Oleksiy Andreyev[2], Michael Bauer[2], Stefan Lach[1], Christiane Ziegler[1], Yongli Gao[3], and Martin Aeschlimann[1] — [1]University of Kaiserslautern, Germany — [2]Universität Kiel, Germany — [3]University of Rochester, USA

A fundamental prerequisite for the implementation of organic semiconductors (OSC) in spintronics devices is the still missing basic knowledge about spin injection and transport in OSC. Here, we consider a model system consisting of a high-quality interface between the ferromagnet cobalt and the OSC copper phthalocyanine (CuPc) [1]. We focus on interfacial effects on spin-injection and on the spin transport properties of CuPc. Using spin-resolved two-photon photoemission we have measured directly and in-situ the efficiency of spin injection at the cobalt/CuPc interface. We report a spin injection efficiency of 85%-90% for injection into unoccupied molecular orbitals of CuPc. Moreover, we estimate an electron inelastic mean free path in CuPc in the range of 1nm and a much higher quasi-elastic spin-flip length. We demonstrate that quasi-elastic spin-flip processes with energy loss smaller than 200 meV are the dominant microscopic mechanism limiting the spin diffusion length in CuPc.

[1] M. Cinchetti et al., Nature Materials, DOI:10.1038/NMAT2334

MA 27.4 Wed 17:30 HSZ 103

**Study of the Spin Properties of the Organic Semiconductor CuPc doped by Alkali Metals** — •Sabine Neuschwander, Jan-Peter Wüstenberg, Alexander Fischer, Mirko Cinchetti, and

Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany

It has been recently shown [1], that the spin-resolved two-photon photoemission (SR-2PPE) is a method allowing to collect direct experimental information about the spin properties of interfaces with OSC, such as the spin injection efficiency and the spin transport properties of OSC. Such knowledge is a fundamental prerequisite for the implementation of OSC-based spintronics devices [2]. Following the approach presented in [1], we considered the model system of a namely the heterojunction between a cobalt thin film and the OSC copper phthalocyanine (CuPc). According to [3] the electronic structure of CuPc can be modified by alkali metal doping. In particular, it is known that Cs and Na doping results in the lowering of the the energy of the unoccupied molecular orbital (LUMO) and highest occupied molecular orbital (HOMO) of CuPc. This reduction can be specifically tuned in order, to study the spin injection in the LUMO+1 state with SR-2PPE. Our results show that, resonant excitation from an occupied 3d-bulk band into the LUMO+1 gives rise to an almost 100% spin injection efficiency and to an extremely high quasi elastic spin flip length in CuPc.

[1] M. Cinchetti et al., DOI:10.1038/NMAT2334 (2008) [2] Sanvito, S., NMAT 6, 803-804 (2007) [3] H. Ding et al., APL 92,053309 (2008)

## MA 28: Focused Session: Spin Transport and Coherence in Emerging Materials

Time: Wednesday 14:45–17:45 Location: HSZ 101

**Topical Talk** MA 28.1 Wed 14:45 HSZ 101

**Gate-tunable magnetic exchange and giant g-factor fluctuations in InAs nanowire quantum dots** — Szabolcs Csonka[1], Lukas Hofstetter[1], Frank Freitag[1], •Christian Schönenberger[1], Thomas S. Jespersen[2], Martin Aagesen[2], and Jesper Nygard[2] — [1]Department of Physics, Univ. of Basel, CH-4056 Basel, Switzerland — [2]Nano-Science Center, Niels-Bohr Institute, Univ. of Copenhagen, DK-2100 Copenhagen, Denmark

We use the spin-1/2 Kondo effect to measure the field-induced splitting of the spin-doublet, and hence the g-factor. We do this in hybrid quantum dots using both normal (N), ferromagnetic (F) and superconducting (S) contacts. Unlike to previous studies, the g-factors of neighboring states can scatter between 2 and 18 and can therefore be even larger than in the bulk (g=15). We demonstrate further the electric gate tunability of the g-factor in a single charge state. When using F contacts, a zero-field splitting is induced. This prox-imity induced exchange field has recently been measured for the first time by Hauptmann et al. (Nature Physics Vol 4, (2008)) in carbon nanotubes. Here, we show the same effect in a semiconducting nanowire, demonstrating that this effect is universal. Employing a pair of S and F contacts, the proximity-induced exchange shows up as a minigap in superconducting spectroscopy.

This work has been supported by the Swiss NSF, the NCCR on Nanoscale Science, and the Danish Natural Science Research Council. S. Csonka is a grantee of the Marie Curie Fellowship.

**Topical Talk** MA 28.2 Wed 15:15 HSZ 101

**Spin transport theory in carbon-based materials** — •Reinhold Egger — Universität Düsseldorf

This talk discusses aspects of spin transport in carbon-based materials, in particular carbon nanotubes and graphene. The influence of spin-orbit couplings and the case of ferromagnetic contacts with non-collinear magnetizations will be studied. We also discuss the spin effects in graphene when magnetic barriers are present.

**Topical Talk** MA 28.3 Wed 15:45 HSZ 101

**Visualizing heat transport in quantum magnets** — Marian Otter[1], Dmitry Fishman[1], Viktor V. Krashnikov[1], Maxim S. Pshenichnikov[1], Romualt Saint-Martin[2], Alexander Revcolevschi[2], and •Paul H.M. van Loosdrecht[1] — [1]Zernike Institute for Advanced Materials, Nijenborgh 4, 9747 AG Groningen, The Netherlands — [2]Laboratoire de Chimie des Solides, Universite& Paris-Sud, 91405 Orsay Cedex, France

Low dimensional quantum magnets show an unusually high thermal conductivity originating from the magnetic excitations in these compounds. The conductivity is highly anisotropic and dwarfs the usual phonon contribution, making low dimensional quantum magnets highly relevant for heat management in electronic devices. The present work focuses on optical methods to study and control the heat conduction in magnetically low dimensional cuprate systems as for instance found in the magnetic chain compounds SrCuO2 and Sr2CuO3, and the so-called telephone number ladder compounds (La,Sr,Ca)14Cu24O41. Magnon heat conduction can be visualized using time resolved luminescence microscopy techniques, yielding direct information on both the magnitude and the anisotropy of the heat diffusion in these materials, even when in thin film form. In addition a more bulk sensitive optical 'time of flight' technique will be discussed.

This work is supported by the NOVMAG EU-FP6 project (proj. nr. 032980, www.novmag.eu)

**15 Min. break**

MA 28.4 Wed 16:30 HSZ 101

**Optically induced spin coherence by linear polarized light in InGaAs** — •Klaus Schmalbuch[1,3], Stefan Göbbels[1,3], Marten Patt[1,3], Paul Schlammes[1,3], Christian Rodenbücher[1,3], Markus Hagedorn[1,3], Gernot Güntherodt[1,3], Thomas Schäpers[2,3], Mihael Lepsa[2,3], and Bernd Beschoten[1,3] — [1]II. Physikalisches Institut, RWTH Aachen, Templergraben 55, 52056 Aachen — [2]Institut für Bio- und Nanosysteme IBN-1, Forschungszentrum Jülich, 52425 Jülich — [3]JARA - Fundamentals of Future Information Technology

Optical orientation is a well established technique to optically excite electron spins in semiconductors. In conventional all-optical pump-probe experiments a circularly polarized pump beam is used to generate spin-polarized electrons by transferring angular momentum from the photons to the electrons.

We present a new method for the generation of a coherent spin ensemble by linearly polarized laser pulses. The dependency of this spin polarization on the direction of the linear pump polarization is measured by time-resolved Faraday rotation. We show that the spin polarization originates from internal magnetic fields due to bulk inversion asymmetry in zinc-blende semiconductors and quantitatively monitors the internal Dresselhaus fields.

*Work supported by DFG through FOR 912*

MA 28.5 Wed 16:45 HSZ 101

**Spin resonance of electrons confined in low dimensional SiGe heterostructures** — •Ferdinand Lipps, Fabio Pezzoli, Mathieu Stoffel, Armando Rastelli, Vladislav Kataev, Oliver G. Schmidt, and Bernd Büchner — IFW Dresden, D-01171 Dresden,

Different kind of SiGe quantum dots (Pyramids, Domes, Barns) were grown with MBE. Due to strain induced in the silicon a confinement of electrons is caused. We performed ESR measurements at 9.56GHz on those low dimensional SiGe heterostructures in order to study the coherence times and relaxational processes of the confined spins. Shape of the dots as well as variations in spacing between stacked layers of dots critically influence the induced strain in the Si. This directly reflects in the confinement of spins and therefore their coherence times determined with ESR. Illumination with light above and below the Si bandgap generates additional electron-hole pairs. We discuss the relationship between shape of dots and resulting spin coherence and relaxation times of the confined spins as measured by ESR.

MA 28.6 Wed 17:00 HSZ 101

**The Spin Polaron in the one-dimensional Kondo lattice model at partial fillings of the conduction band using the density matrix renormalization group** — •Sebastian Smerat[1,3], Ian P. McCulloch[4], Herbert Schoeller[2,3], and Ulrich Schollwöck[1,3] — [1]Insitut für theoretische Physik C, RWTH Aachen University — [2]Insitut für theoretische Physik A, RWTH Aachen University — [3]JARA-Fundamentals of Future Information Technology — [4]School of physical Sciences, University of Queensland, Australia

We study the spectral properties of the one-dimensional Kondo lattice model as function of the exchange coupling, the band filling, and the quasimomentum in the ferromagnetic and paramagnetic phase. Using the density-matrix renormalization group method, we compute

the dispersion relation of the quasiparticles, their lifetimes, and the Z-factor. As a main result, we provide evidence for the existence of the spinpolaron at partial band fillings. We find that the quasiparticle lifetime differs by orders of magnitude between the ferromagnetic and paramagnetic phase and depends strongly on the quasimomentum.

MA 28.7 Wed 17:15 HSZ 101

**Magnet heat transport of impurity doped spin chains** — •N. Hlubek, C. Hess, U. Schaufuss, V. Kataev, C. Sekar, G. Krabbes, and B. Büchner — Leibniz-Institute for Solid State and Materials Research, IFW Dresden, 01171 Dresden, Germany

We investigate the magnetic thermal conductivity $\kappa_{\mathrm{mag}}$ of the spin chain material $CaCu_2O_3$ doped with non-magnetic Zn impurities. $\kappa_{\mathrm{mag}}$ of the pure compound is linear up to room temperature which is indicative of a $T$-independent scattering rate of the magnetic excitations [1]. Both, magnitude and $T$-dependence of $\kappa_{\mathrm{mag}}$ exhibit a very unusual doping dependence. At moderate Zn-doping the linear temperature dependence of $\kappa_{\mathrm{mag}}$ is preserved and the absolute value of $\kappa_{\mathrm{mag}}$ *increases*. A slight suppression of $\kappa_{\mathrm{mag}}$ occurs only at high Zn doping, where, surprisingly, the $T$-dependence of $\kappa_{\mathrm{mag}}$ changes from linearity to one with a higher power of $T$. In order to clarify this surprising behavior, we have performed a detailed study of the $g$-tensor of the impurities in the material by means of ESR experiments which reveals change of impurity type with increasing Zn-content.

[1] C. Hess et al., Phys. Rev. Lett. **98**, 027201 (2007).

MA 28.8 Wed 17:30 HSZ 101

**Spin relaxation in graphene quantum dots** — •Philipp Struck and Guido Burkard — University of Konstanz

The spin relaxation time $T_1$ in graphene quantum dots due to spin-orbit interaction is investigated. The calculations are performed in the framework of the Dirac theory, and both Rashba and Dresselhaus type spin-orbit coupling are taken intro account. We compare the results to previous calculations performed for GaAs. We also discuss how applied magnetic and electric fields can be used to influence the relaxation time for potential use in spin qubits.

## MA 29: Invited Talk Ardavan

Time: Thursday 9:30–10:00 Location: HSZ 04

**Invited Talk** MA 29.1 Thu 9:30 HSZ 04

**Quantum information processing with electron spin resonance** — •Arzhang Ardavan — The Clarendon Laboratory, Department of Physics, University of Oxford

Electron spin systems were among the earliest proposed physical embodiments of quantum information processors. We have addressed a range of basic questions surrounding the practicalities of exploiting electron spins as qubits. We have shown that electron spin resonance can be used to perform quantum gates with a very high fidelity. We have studied the prospects for application of various candidate spin systems including N@C60 (a nitrogen atom encapsulated in a fullerene cage), molecular nanomagnets and phosphorus donors in silicon (P:Si). While in molecular nanomagnets magnetic nuclei in the vicinity of the electron qubit provides the dominant decoherence path, we have found that in N@C60 and P:Si nuclear moments can provide a valuable subsidiary resource in a quantum information processor.

## MA 30: Spin-Dynamics / Spin-Torque III

Time: Thursday 10:15–13:00 Location: HSZ 04

MA 30.1 Thu 10:15 HSZ 04

**Current and Field Induced Domain-Wall Motion in Permalloy Nanowires** — •Gesche Nahrwold[1], Lars Bocklage[1], Toru Matsuyama[1], Jan M. Scholtyssek[1], Benjamin Krüger[2], Ulrich Merkt[1], and Guido Meier[1] — [1]Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Universität Hamburg, Jungiusstr. 9, 20355 Hamburg

Magnetic domain walls (DWs) in nanowires have attracted a lot of interest because of their possible application in logic and memory devices [1]. We present results obtained in curved permalloy wires where DWs are pushed by ns current pulses. By an externally applied magnetic field the DW is generated in the curved region of the wire. Measurements of the anisotropic magnetoresistance verify the presence of the wall. The resistance values before and after a current pulse indicate whether the DW has been depinned and moved out of the wire or not. Motivated by the pioneering work of L. Thomas et al. [2] we are able to measure the oscillatory dependence of the depinning behaviour of DWs on the pulse length with a characteristic frequency of 267 MHz if the current induced force on the DW is aligned opposite to the applied background field. The quality of the utilized permalloy for these experiments is crucial for their success. By sputtering permalloy on heated substrates we are able to considerably decrease the specific resistance, that is assumed to directly correspond to unwanted pinning centres for the DW. [1] S. S. P. Parkin et al., Science 320, 190 (2008), [2] L. Thomas et al., Nature 443, 197 (2006).

MA 30.2 Thu 10:30 HSZ 04

**Non-adiabatic spin transfer torque in high anisotropy magnetic nanowires with narrow domain walls** — •Jan Heinen, Olivier Boulle, Johannes Kimling, Mathias Kläui, and Ulrich Rüdiger — Fachbereich Physik, Universität Konstanz, Universitätsstrasse 10, 78457 Konstanz, Germany

The recent discovery that a spin polarized current can move a domain wall (DW) through a transfer of spin angular momentum opens a new path to manipulating magnetization without any external magnetic field. So far, current induced DW motion (CIDM) has been experimentally investigated in details for in-plane magnetized wires with a large DW widths ($\geq$ 100 nm) where spin transfer is expected to occur in the "adiabatic limit". Here, we report on current driven depinning experiments of a narrow ($\approx$ 6 nm) Bloch domain wall (DW) in perpendicularly magnetized $(Pt/Co)_3$ multilayer studied by magnetotransport. Such materials are ideal to tackle the key question of the non-adiabaticity of the spin transfer as a larger effect is expected due to the high DW magnetization gradient. We find that for conventional measurements, Joule heating effects conceal the real spin torque efficiency and so we use a measurement scheme at a constant sample temperature to unambiguously extract the spin torque contributions. From the variation of the depinning magnetic field with the current pulse amplitude, we directly deduce the large non-adiabaticity factor in this material and we find that its amplitude is consistent with momentum transfer [1].

[1] Boulle et al., Phys. Rev. Lett. 101, 216601 (2008).

MA 30.3 Thu 10:45 HSZ 04

**Current-Induced Domain Wall Coupling and Domain Wall Motion in Magnetic Nanowires** — •Nicholas Sedlmayr[1], Jamal Berakdar[1], and Vitalii Dugaev[2,3] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Str. 4, 06120, Halle, Deutschland — [2]Department of Physics, Rzeszów University of Technology, al. Powstańców Warszawy 6, 35-959 Rzeszów, Poland — [3]Department of Physics and CFIF, Instituto Superior Técnico, TU Lisbon, av. Rovisco Pais, 1049-001, Lisbon, Portugal

We consider the problem of two domain walls (DWs) inside a quasi-one dimensional magnetic nanowire. It is assumed that the distance between DWs is rather small so that the transmission of current results in the current-induced DW coupling. The primary cause of the current-induced interaction between the DWs is the spin torque transferred by the spin current to the second DW after the electrons are transmitted through the first one. The interaction between the two walls

is investigated by studying the increased energy caused by scattering events from both walls. Calculating the interaction between the DWs, we found that the current-induced effective potential is oscillating in space, which leads to the oscillating motion of the DW. We go on to see what effect the scattering of current electrons from one wall has on the spin density and spin torque acting on the second domain wall. Assuming, for definiteness, that the first wall is pinned we investigate the motion of the second domain wall.

MA 30.4 Thu 11:00 HSZ 04

**Time-Resolved Imaging and Modeling of Oscillations of a Single Magnetic Domain Wall** — •Lars Bocklage[1], Benjamin Krüger[2], René Eiselt[1], Markus Bolte[1], Peter Fischer[3], and Guido Meier[1] — [1]Institut für Angewandte Physik, Universität Hamburg — [2]I. Institut für Theoretische Physik, Universität Hamburg — [3]Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, California

Current-induced magnetization dynamics are an intersting field of research. Domain walls and vortices can be moved by spin-polarized currents. We image oscillations of a single domain wall in a confining potential in time steps of 200 ps by time resolved x-ray microscopy with a spacial resolution of 25 nm and a temporal resoution of 70 ps [1]. The oscillation of the domain wall is triggered by nanosecond current pulses. The spin-polarized current and the accompanied Oersted field can contribute to the motion of the wall. An analytical model of a rigid particle precisely describes the domain-wall motion. From the observed oscillations we extract the confining potential, the driving force, the domain-wall mass, and the damping parameter of permalloy. Higher than harmonic terms determine the motion of the wall. By looking at various phase spaces the influence of these nonharmonic contributions are studied.

This work was supported by DOE BES, SFB 668 and GrK 1286.

[1] L. Bocklage, B. Krüger, R. Eiselt, M. Bolte, P. Fischer, and G. Meier, PRB 78, 180405(R) (2008)

MA 30.5 Thu 11:15 HSZ 04

**Simulations of current-induced domain wall motion including temperature effects using the Landau-Lifshitz-Bloch equation** — •Christine Schieback, Denise Hinzke, Mathias Kläui, Ulrich Rüdiger, Ulrich Nowak, and Peter Nielaba — Department of Physics, University of Konstanz, Germany

By numerically solving the stochastic Landau-Lifshitz-Gilbert (LLG) equation, computer simulations can be performed on a classical atomistic spin model. Spin torque effects can be taken into account by further inclusion of an adiabatic and a non-adiabatic torque term [1]. Due to the computational expense of atomistic simulations, system sizes are restricted to a nanometer range, so that micromagnetic approaches are desirable. However, conventional micromagnetic calculations for larger system sizes lack the correct description of temperature effects because of the assumption of a constant magnetisation length.

An alternative novel approach to investigate realistic systems sizes including temperature effects is to employ the so-called Landau-Lifshitz-Bloch (LLB) equation [2]. This equation forms a new basis for micromagnetic calculations at elevated temperatures using a macro spin model [3], where longitudinal relaxation processes are taken into account. We extend the LLB equation of motion by adding spin torque terms and study domain wall motion under the influence of current and temperature in permalloy films. Domain wall velocities show a strong temperature dependence.

[1] C. Schieback et al. EPJ B 59, 429 (2007). [2] D. A. Garanin PRB 55, 3050 (1997). [3] N. Kazantseva et al. PRB 77, 184428 (2008).

MA 30.6 Thu 11:30 HSZ 04

**Correlation between the pinning behavior of domain walls (dw) and the edge roughness of etched GMR nanostrips** — •Sascha Glathe, Marco Diegel, and Roland Mattheis — IPHT Jena, Albert-Einstein-Str. 9, 07745 Jena

During dw motion in nanostrips a dw samples the energy landscape, caused for example by edge roughness. As a result the dw can be pinned at local energy minima. The pinning and depinning process of dw in long GMR nanostrips (width = 160 nm, length = 200 000 nm) was examined using time resolved resistance measurements. We found many small fluctuation of the potential giving rise to weak dw pinning with thermally activated depinning. However there are some large pinning sites acting as deep potential wells for the dw. To get further inside in the pinning mechanism at these potential wells we examined the influence of a transversal field on the depinning fields and pinning probability and found significant dependencies.

MA 30.7 Thu 11:45 HSZ 04

**Damping of the domain wall dynamics by phonon and magnon dragging** — •Daniel Hähnel, Daniel Steiauf, and Manfred Fähnle — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

The understanding of the damped domain-wall motion, especially in nanoparticles and nanowires, is of central interest for many technological applications. Commonly, the damping of the domain wall is discussed in terms of spin-lattice interactions via spin-orbit coupling. At finite temperatures, however, the movement of the domain walls is also hampered by phonon or magnon dragging, i.e., by transfer of momentum between thermally excited phonons or magnons and the moving domain wall. We present a theory which describes the phonon dragging due to the scattering of phonons at the magnetoelastic strain field of the moving domain wall. The numerical results for this phonon dragging are compared with those obtained for the magnon dragging of domain walls [1].

[1] H. Glock, PhD thesis, University of Stuttgart, 1974.

MA 30.8 Thu 12:00 HSZ 04

**Tailoring the Gilbert damping coefficient in Permalloy thin films by Ho doping** — •Jakob Walowski[1], Benjamin Lenk[1], Andreas Mann[1], Henning Ulrichs[1], Stephen Krzyk[2], Mathias Kläui[2], and Markus Münzenberg[1] — [1]Physikalisches Institut, Universität Göttingen, Germany — [2]Fachbereich Physik, Universität Konstanz, Gemany

The implementation of spintronics requires well-funded knowledge of the speed limits regarding magnetic switching. We use all-optical pump-probe experiments to explore the dynamics of 20 nm permalloy thin films triggered by strong Ti:Sa laser pulses ($30\,\mathrm{mJ/cm^2}$, 60 fs) on two timescales after demagnetization. The fast demagnetization after excitation within the first $100 - 250$ fs and the subsequent spin relaxation on a timescale up to 1 ns. It is generally described by the Landau-Lifshitz-Gilbert equation, from which the Gilbert damping parameter $\alpha$ can be extracted. Doping ferromagnetic materials with impurities in low concentrations can influence the intrinsic damping parameter ($\alpha(\mathrm{Py}) = 0.008$), as has been shown using transition metal (Pd) and rare earth impurities (Dy) in concentrations up to 2% in our group. Here we extend of our study, using the rare earth Ho as an impurity dopant. It shows a stronger increase of $\alpha$, for the same percentage of dopant than Dy. According to the model by Koopmans, the demagnetization time should be inversely proportional to $\alpha$ which doen not necessarily have to agree for the Ho doped samples, because of different dissipation channels in the rare earth impurities. Support by the DFG within the priority program SPP 1133 is gratefully acknowledged.

MA 30.9 Thu 12:15 HSZ 04

**Spin-wave excitation in Permalloy by oscillating pinned domain walls** — •Sebastian Hermsdörfer, Helmut Schultheiss, Christopher Rausch, Sebastian Schäfer, Philipp Pirro, Britta Leven, and Burkard Hillebrands — Fachbereich Physik und Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

In this presentation a new mechanism for the spin-wave excitation will be presented. The excitation of spin waves by oscillating pinned domain walls is an alternative approach to the well-known excitation via an antenna or, as another example, via vortex-anti-vortex-annihilation. The investigations have been carried out using micromagnetic simulations. The basic idea of the mechanism is to deflect a pinned domain wall out of its equilibrium position within the limits of the domain wall pinning. The following relaxation caused by the pinning potential which is driving the wall back towards the equilibrium position occurs as a damped oscillation with characteristic eigenfrequency. In case that the domain wall is excited by an external field with this eigenfrequency, a "steady-state"oscillation forms out with the eigenfrequency and an amplitude determined by the energy balance between the dissipation processes due to damping and the external triggering by the applied field. The energy pumped into the system by the external field leads not only to the compensation of the damping but also to the radiation of spin waves.

Financial support by the DFG within the SPP1133 is gratefully acknowledged.

MA 30.10 Thu 12:30 HSZ 04

**Lifetime of quantized spin waves in nano-scaled magnetic**

**ring structures** — •Helmut Schultheiss, Björn Obry, Christian Sandweg, Sebastian Hermsdörfer, Sebastian Schäfer, Thomas Sebastian, Britta Leven, and Burkard Hillebrands — Fachbereich Physik and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

The magnetization dynamics of rings, magnetized in the onion state, shows a rich eigenmode spectrum. Quantization of spin waves takes place not only due to the spatial confinement in radial and azimuthal directions, but also in spin-wave wells in the so-called pole regions created by the inhomogeneity of the internal magnetic field. To understand the dissipation mechanisms and coupling between different spin-wave modes, we have investigated the relaxation processes using time- and space-resolved Brillouin light scattering microscopy. The decay of the magnetization after excitation with a short microwave pulse was studied as a function of frequency and position. We have determined the decay constants of the spin-wave modes that can be excited with in-plane microwave pulses. The comparison of the dissipation times of the ring eigenmodes confined in the pole and equatorial regions, respectively, of the onion state indicates that different dissipation mechanisms are responsible for the relaxation of the magnetization, depending on the position and the quantization conditions of the spin-wave eigenmodes. Financial support by the DFG (SPP1133) is acknowledged.

MA 30.11 Thu 12:45 HSZ 04

**Coupling of spin-wave eigenmodes in small magnetic ring structures** — •Björn Obry[1], Helmut Schultheiss[1], Christian Sandweg[1], Sebastian J. Hermsdörfer[1], Sebastian Schäfer[1], Vasyl Tiberkevich[2], Britta Leven[1], Andrei N. Slavin[2], and Burkard Hillebrands[1] — [1]FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics, Oakland University, Rochester, MI, USA

Understanding the coupling of spin-wave eigenmodes in small magnetic structures is of great importance for future applications of those structures in technical devices. Measurements with time- and space-resolved Brillouin light scattering microscopy were performed on permalloy rings placed on top of a coplanar waveguide in order to excite spin waves by the Oersted field of a microwave current. The rings under investigation have outer diameters between 1 and 3 $\mu$m, ring widths of 100 to 400 nm and a thickness of 15 nm. Being magnetized in the onion state the rings reveal a direct coupling of spin-wave modes excited near the poles of the ring with modes confined to the equatorial region via three-magnon scattering processes. Excitation of spin waves confined only to the pole regions will result in the appearance of a spin-wave signal at the equators, if the frequency ratio between modes in the equatorial and pole regions is 2:1, fulfilling energy conservation for three-magnon scattering. The coupling turns out to be tunable by the external magnetic field and can be shown for rings of various diameters and widths. Financial support by the DFG (SPP1133) is acknowledged.

## MA 31: Magnetic Particles and Clusters I

Time: Thursday 10:15–13:00 Location: HSZ 401

MA 31.1 Thu 10:15 HSZ 401

**Direct characterization of the superparamagnetic-ferromagnetic transition of single nano-islands** — •Guillemin Rodary, Sebastian Wedekind, Hirofumi Oka, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120, Halle, Germany

The transition from a superparamagnetic to a ferromagnetic state is studied on single Co nano-islands by spin-polarized scanning tunneling spectroscopy. Magnetic hysteresis loops of the local differential conductance on individual island are measured [1] as a function of the size of the nanostructure and of the temperature. A clear transition of magnetic response from a hysteresis free to a hysteretic behavior due to magnetization direction switching [1] is observed when increasing the island size. This is ascribed to the superparamagnetic to ferromagnetic transition. The same transition is demonstrated to be also accessible by decreasing the temperature and crossing the blocking temperature. We find a blocking temperature of 10 K for an island of 1010 atoms. We discuss these experimental results in the perspective of a simple model of thermally activated magnetization switching that allows quantitative finding of local magnetic anisotropy.

[1] G. Rodary, S. Wedekind, D. Sander, and J. Kirschner, JJAP (in press)

MA 31.2 Thu 10:30 HSZ 401

**Size-selected supported ferromagnetic clusters: correlation of structural and magnetic properties** — •Wolfgang Rosellen[1], Furkan Bulut[1,2], Christian Kleinhans[1], R. Kerstin Gebhardt[1], Joachim Bansmann[2], Armin Kleibert[3,4], Karl-Heinz Meiwes-Broer[3], and Mathias Getzlaff[1] — [1]Institute of Applied Physics, University Düsseldorf — [2]Dep. of Surface Chemistry, University Ulm — [3]Institut of Physics, University Rostock — [4]now Paul Scherrer Institute, Switzerland

The bulk and thin film behaviour of softmagnetic materials have extensively been studied in the past. Concerning the increase of density in magnetic data storge systems magnetic clusters become interesting because of their particular size dependence of electronic and magnetic properties. We report on the magnetic properties of size-selected clusters, deposited on bare W(110) and on a thin Ni(111)/W(110) film system, by the element specific XMCD spectroscopy allowing the determination of spin and orbital moments. The crystalline nanoparticles consist of pure Fe and Co as well as an FeCo alloy and exhibit tunable diameters between 5-15 nm. The clusters are produced using an UHV compatible gas aggregation source avoiding any oxidation. Mass separation is carried out by a subsequent electrostatic quadrupole. The shape after deposition was investigated in situ by STM and compared with the lateral size being determined by HRTEM. This enables a direct correlation of structural and magnetic properties in combination with the XMCD measurements.

MA 31.3 Thu 10:45 HSZ 401

**Influence of stress on the magnetic properties of nanoparticles** — •Srinivasa Rao Saranu, Ulf Wiedwald, Sören Selve, Ute Kaiser, Paul Ziemann, and Ulrich Herr — Ulm University,89081 Ulm,Germany

Magnetic nanoparticles are interesting candidates for high density data storage. However, thermal stability of the stored information requires sufficiently large magnetic anisotropy. Here we present a new approach to optimization of the magnetic anisotropy of nanoparticles by applying large persistent stress. Fe and Ni nanoparticles were produced using plasma gas condensation technique and analyzed using XRD, SEM and TEM. Particles were deposited on Ta substrates and in-situ covered with Cu films. The Ta substrate was subsequently loaded with hydrogen. The volume expansion of the substrate induces a biaxial tensile stress in the Cu film. For 40nm Ni particles embedded in Cu films, we find that the effective anisotropy increases linearly with the applied stress. Fe particles with an average diameter of 14nm show super-paramagnetic behavior at room temperature. Upon applying in-plane biaxial stress, the blocking temperature as determined from FC/ZFC cooled magnetization measurements increases significantly.

MA 31.4 Thu 11:00 HSZ 401

**Surprising insensitivity of the orbital magnetism in $L1_0$ ordered FePt nanoparticles to surface modifications by Al** — •Carolin Antoniak[1], Marina Spasova[1], Anastasia Trunova[1], Florian Römer[1], Bernhard Krumme[1], Markus E. Gruner[1], Tobias Umbach[2], Adham Amyan[2], Kai Fauth[2], and Heiko Wende[1] — [1]Fachbereich Physik, Universität Duisburg-Essen, D-47048 Duisburg — [2]Physikalisches Institut, Universität Würzburg, D-97074 Würzburg

FePt nanoparticles in the chemically ordered $L1_0$ state are the subject of intense research activities driven both by fundamental interest and technological perspective. In this work, the influence of an Al cap layer on the magnetism of pure metallic $L1_0$ FePt nanoparticles of different sizes between 6nm and 2nm in diameter is studied by means of x-ray absorption spectroscopy and its associated magnetic circular dichroism (XMCD) at the Fe $L_{3,2}$ absorption edges. It was found that the net magnetisation at the Fe sites is reduced significantly with respect to the non-capped particles. The ratio of orbital-to-spin magnetic moment remains largely unchanged indicating that the enhanced orbital

magnetism reported earlier [1,2] is not affected by an Al cap layer. The experimental results will be compared to recent ab-initio calculations for chemically ordered FePt clusters covered by an additional Al layer. Financially supported by the DFG (SFB445 and SPP1239), the BMBF (05 ES3XBA/5), and the ESRF.

[1] C. Antoniak et al., Phys. Rev. Lett. 97, 11201 (2006)
[2] O. Dmitrieva et al., Phys. Rev. B 76, 064414 (2007)

MA 31.5 Thu 11:15 HSZ 401

**Near-surface strain in FePt nanoparticles** — •Ulrich Wiesenhütter, Darius Pohl, Elias Mohn, Ludwig Schultz, and Bernd Rellinghaus — IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

The structure of single crystalline, decahedral, and icosahedral FePt nanoparticles is systematically investigated by aberration-corrected HRTEM. Particular attention is paid to near-surface lattice strains which are indicative of a possible Pt segregation towards the surface. Statistical HRTEM investigations reveal that in icosahedral FePt nanoparticles, an average expansion of the crystal lattice of 9.5% is observed within the outermost atomic layers. In order to check if this reproducibly observed near-surface strain is merely a property of the bare particle surface or if it is rather due to a segregation of Pt towards the surface, the effect of electron beam-induced sintering of adjacent particles on the lattice expansion is studied. It is found that the near-surface strain survives the inter-particle coalescence and remains located at the former surface position which in deed corroborates the picture of a local enrichment of Pt at the particle surface. Similar lattice expansions are observed in decahedral and truncated octahedral FePt nanoparticles. In single crystalline particles however, the magnitude of the lattice dilation is found to be smaller as compared to the icosahedra. This indicates that in the latter, the observed near-surface lattice dilation may be enhanced due to strains inherent to the particle structure. The effect of the particle size on the magnitude of the strain will be discussed.

MA 31.6 Thu 11:30 HSZ 401

**Detailed study on oxidation behavior of FePt thin film and nanoparticles** — •Luyang Han[1], Kuerbanjiang Balati[1,2], Ulf Wiedwald[1], and Paul Ziemann[1] — [1]Institut für Festkörperphysik, Universität Ulm, A.-Einstein-Allee 11, 89081 Ulm, Germany — [2]Institut für Mikro- und Nanomaterial, Universität Ulm

FePt nanoparticles and thin films attract great attention due to their potential application as magnetic data storage media [1]. In this study the oxidation of FePt nanoparticles and an epitaxial FePt reference film are investigated in detail. The nanoparticles are prepared by means of reverse micelles [2]. Oxidation is tracked in detail using X-ray photoelectron spectroscopy and a core-shell model is established to extract the oxide layer thickness. During the oxidation process a layer of $Fe_2O_3$ is formed at the surface, while Pt atoms remain metallic. After oxygen exposure of $10^8$ L chemically disordered FePt particles start to oxidize, while the partially ordered particles after in-situ annealing at 950 K show only slight oxidation after $10^{10}$ L oxygen exposure. Similar behavior is observed for FePt thin films, indicating that the formation of the chemically ordered $L1_0$ structure reduces the oxidation speed significantly.

[1]S. Sun, *Adv. Mater.*, **18**, 393, (2006)
[2]A. Ethirajan et al., *Adv. Mater.*, **19**, 406, (2007)

MA 31.7 Thu 11:45 HSZ 401

**Spectroscopic investigation of magnetic CoPt nanoparticles** — •Leif Glaser[1], Michael Martins[1], Christine Boeglin[3], Vesna Alesandrovic[2], Host Weller[2], and Wilfried Wurth[1] — [1]Department Physik, Universität Hamburg, 22761 Hamburg , Germany — [2]Department Chemie, Universität Hamburg, 20146 Hamburg, Germany — [3]Institut de Physique et Chimie des Materiaux de Strasbourg,23, 67034 Strasbourg, France

The size dependent magnetic properties of wetchemically synthesized $Co_xPt_{100-x}$ nanoparticles (3.7nm to 8.4nm) in their organic ligand shell were investigated at the Cobalt L-edges with X-ray magnetic circular dichroism (XMCD). A 7 Tesla high field magnet setup was used at the Bessy II storage ring. Oxidization effects due to the synthesis process and post synthesis aging were adressed by choosing particles of equal size, but different age and storage condition. The particles were deposited on silicon wafers as a single layered thin film using dip and spin coating techniques. The quality of the films was checked with Scanning Electron Microscopy (SEM).

Strongly enhanced magnetic moments of the investigated particles compared with bulk and thin film systems could be determined, The orbital magnetic moments of fresh particles displayed a favour of in plane magnetization increasing with cluster size.

Size dependent oxidization and size dependent aging effects could be detected and explained by model calculations.

Funding for this project by BMBF under contract 05 KS4 GUB/6 is gratefully acknowledged.

MA 31.8 Thu 12:00 HSZ 401

**Structure and magnetism of free and decorated Fe-Pt nanoclusters** — •Markus Ernst Gruner and Peter Entel — Department of Physics and Center for Nanointegration CENIDE, University of Duisburg-Essen, 47048 Duisburg, Germany

Arrays of $L1_0$ ordered nanoparticles of near-stoichiometric Fe-Pt and Co-Pt with diameters are considered as promising material for future ultra-high density recording media due to the large magnetocrystalline anisotropy energy (MAE) in their bulk alloys. In small particles, the required magnetic properties are not realized in experiments. Possible reasons are the occurrence of multiply twinned morphologies which are frequently encountered in experiment and energetically preferred for small diameters as demonstrated in recent large scale ab initio calculations of Fe-Pt clusters [1,2] of up to 923 atoms. On the other hand, preparation of particles in a carbon matrix has been recently reported to support $L1_0$ order.

Within this contribution we present first principles structure optimizations on the basis of density functional theory of small Fe-Pt particles decorated with monolayers of typical covering elements as gold, aluminum or carbon. Based on these results, we discuss the influence of a surrounding matrix on structural and magnetic properties of small Fe-Pt nanoparticles, taking into account spin-orbit coupling and non-collinear spin-structures.

[1] M. E. Gruner, G. Rollmann, P. Entel and M. Farle, Phys. Rev. Lett. **100**, 087203 (2008).
[2] M. E. Gruner and P. Entel, Psi-k Newsletter **89**, 36 (2008).

MA 31.9 Thu 12:15 HSZ 401

**Splitting of the Curie temperature for two-dimensional anisotropic nanoparticles** — •Elena Y. Vedmedenko, Thim Stapelfeldt, and Roland Wiesendanger — University of Hamburg, Jungiusstr. 11, 20355 Hamburg

The Curie temperature Tc is defined as the critical temperature above which magnetization vanishes. For superparamagnets the magnetization vanishes at the so-called blocking temperature Tb < Tc. Therefore, the determination of the Curie point via measurements of the mean magnetization is often impossible. In another common procedure the Curie point is determined via the peak in the susceptibility and/or the peak in the specific heat, which should appear at the same characteristic temperature. We demonstrate by means of Monte-Carlo simulations that for two-dimensional superparamagnets with uniaxial anisotropy these two peaks appear at different, size-dependent characteristic temperatures Tc > Ts. At temperatures Tb < T < Tc such a particle is in the regime of thermally induced switching. The Néel-Brown switching mechanism is only possible below Ts. The attempt frequency of the switching via a domain wall is size- and form-dependent.

MA 31.10 Thu 12:30 HSZ 401

**Fe nanoparticles embedded in MgO crystals** — •Artem Shalimov[1], Kay Potzger[1], Dorin Geiger[2], Hannes Lichte[2], Georg Talut[1], Andrzej Misiuk[3], Helfried Reuther[1], Frank Stromberg[4], Shengqiang Zhou[1], Carsten Baehtz[1], and Jürgen Fassbender[1] — [1]Forschungszentrum Dresden-Rossendorf, Bautzner Landstraße 128, 01328 Dresden — [2]Technical University, Dresden, Germany — [3]Institute of Electron Technology, Warsaw, Poland — [4]Universität Duisburg-Essen, Germany

Iron nanoparticles embedded in MgO crystals were synthesized by Fe+ ion implantation at an energy of 100 keV and varying fluences from 3*10E16 to 3*10E17 cm-2. Investigations of structural and magnetic properties of Fe nanoparticles have been performed using magnetometry, x-ray diffraction, transmission electron microscopy and Mössbauer spectroscopy, as well as by theoretical Preisach modeling of bistable magnetic systems. It has been found that alpha- and gamma-Fe nanoparticles are formed for all fluences. The content of the alpha-Fe phase increases at higher fluences and after annealing. The influence of post implantation annealing at 800 C in vacuum and under enhanced up to 10 kbar hydrostatic pressure in argon atmosphere on

the formation of nanoparticles has been analyzed. Investigations have been performed within DFG project PO1275/2-1 "SEMAN".

MA 31.11 Thu 12:45 HSZ 401

**Growth and magnetism of ordered alloy nanostructures** — •YASMINE NAHAS[1,2], VINCENT REPAIN[1], and SYLVIE ROUSSET[1] — [1]Laboratory Material and Quantum Phenomena, University Paris 7, UMR 7162, 10 rue Alice Domon et Léonie Duquet, 75205 Paris, France — [2]Physikalisches Institut, Universität Karlsruhe (TH), Wolfgang-Gaede-Str., D-76131, Karlsruhe, Germany

Nanomagnetism is a growing field of interest both from technological and fundamental motivations. Ordered growth allows to obtain structures with a controlled size and density [1], so enables the use of averaging technique to study magnetic properties of nanostructures. I will present two original systems of ordered magnetic nanostructures on gold surfaces. The first one deals with ordered alloy nanostructures of Fe-Pt, the second deals with core-shell nanostructures of Co-Au. Fe-Pt alloy nanodots well caracterized, regular in size, and ordered, were obtained. Systems with various concentrations of magnetic atoms can be elaborated. Moreover, magnetic measurements on Co-Au system were done with a good knowledge of the structure at the atomic scale. An increase of the magnetic anisotropy energy is observed for a given gold coverage. To interpret magnetic measurements on these systems of nanostructures of alloy, importants effects have to be taken into account, beyond the morphology : the atomic structure first, and an other effect very important even for simple structures : the relaxations.

[1] V. Repain et al., J. Phys.: Condens. Matter. 18 (2006) S17-S28

## MA 32: Magnetic Thin Films III

Time: Thursday 10:15–12:30 Location: HSZ 403

MA 32.1 Thu 10:15 HSZ 403

**Epitaxial growth of Heusler alloy cobalt iron silicide films on Si(111) and Si(001) substrates** — •MARLENE ZANDER, KAZUHIDE KUMAKURA, ACHIM TRAMPERT, and JENS HERFORT — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

The Heusler alloy $Co_2FeSi$ is a promising candidate for a spin injection source into semiconductors, because of its high Curie temperature and predicted half-metallic behavior. Si has an enhanced spin lifetime and a large transport length of the electrons. In addition to its importance in electronics, Si has therefore been predicted to be a highly attractive semiconductor for spintronic devices. However, $Co_2FeSi$ has a large lattice mismatch of 4% relative to the Si(001) substrate. Here, we present our results on the fabrication as well as the structural and magnetic properties of $Co_2FeSi$/Si(111) and -/Si(001) heterostructures grown by molecular beam epitaxy at various growth temperatures $T_G$. We found that $Co_2FeSi$ layers were epitaxially grown on Si(111), while poly-crystalline $Co_2FeSi$ layers were formed on Si(001). As evidenced by X-ray diffraction at least B2 ordered $Co_2FeSi$ films were grown on Si(111) in a relatively narrow range between $T_G$ = 150 and 200 °C. Above this $T_G$ interfacial reactions set in. Reflection high energy electron diffraction and transmission electron microscopy measurements revealed the existence of different orientations of the $Co_2FeSi$ crystal on the Si(111) substrate. The layers are ferromagnetic at room temperature with the easy axis within the film plane. The magnetic anisotropy is correlated to the structural properties of the layers.

MA 32.2 Thu 10:30 HSZ 403

**On amorphous CuMnAl- and NiTiAl-alloys, precursors of Half-Heusler and Heusler systems** — JAN RAUCHHAUPT and •PETER HÄUSSLER — Chemnitz University of Technology, Institute of Physics, 09107 Chemnitz

Liquid and amorphous phases are the precursors of any crystalline phase and hence of Half-Heusler- and Heusler-alloys too. They may be of high interest to understand the stability and the physical properties of these phases. Generally, we describe structural stabilization as a self-organized resonance effect between global subsystems as all the valence electrons as one and the forming static structure as another one, enhanced occasionally by e.g. hybridization or charge transfer.

We are able to prepare (in situ, at $T$=4 K, in high vacuum) thin films of amorphous ternary alloys of different concentrations of Al with an early, and a late transition metal. As a function of temperature and composition we measure the static structure, by means of electron diffraction, the resistivity, the Hall coefficients, the thermopower, as well as relative White Line-intensities. We report on amorphous CuMnAl- and NiTiAl-alloys and indeed observe resonance effects, causing electronic transport anomalies. We find these effects near concentrations where so-called Half-Heusler- and Heusler-alloys exist and are able to grow their crystalline form by annealing the amorphous thin films.

MA 32.3 Thu 10:45 HSZ 403

**Thickness and temperature dependent magnetization measurements on $Fe_3Si$ films on GaAs(001)** — •BERNHARD KRUMME, CLAUDIA WEIS, ANNE WARLAND, CAROLIN ANTONIAK, DIETGER BOVENSCHEN, ULRICH VON HÖRSTEN, WERNER KEUNE, and HEIKO WENDE — Universität Duisburg-Essen, Lotharstraße 1, D-47048 Duisburg, Germany

$Fe_3Si$ is a Heusler-like system for which spin injection into GaAs at room temperature is reported. Due to its high spin polarization and the small lattice mismatch to GaAs, $Fe_3Si$ is a very interesting material for spintronics and magnetoelectronics.

In order to investigate the effects of the interface between GaAs and $Fe_3Si$ on the magnetic properties of $Fe_3Si$ we performed thickness and temperature-dependent x-ray magnetic circular dichroism (XMCD) as well as Mössbauer-spectroscopic measurements. The temperature is varied between 40 K and 350 K and the thickness ranges from bulklike films (80 Å) down to the ultrathin limit (7 Å). Mössbauer spectra were recorded to characterize the chemical ordering in the $Fe_3Si$ films. The XMCD effect was used to measure the magnetization of the $Fe_3Si$ films and the magnetic moments of the Fe atoms were determined spin- and orbital-resolved by the sum rules. The 80 Å thick $Fe_3Si$ film yields a magnetic moment of 1.4 $\mu_B$ per Fe atom which is close to the expected value of 1.6 $\mu_B$. However, even for the bulklike $Fe_3Si$ film on GaAs(001) the Mössbauer spectrum revealed a second Fe phase which is probably caused by an interdiffusion at the interface.

– Supported by DFG (SFB 491) and BMBF (05 ES3XBA/5).

MA 32.4 Thu 11:00 HSZ 403

**Magnetism and interface roughness in Fe/GaAs and $Fe_3Si$/GaAs systems: An ab initio study** — •HEIKE C. HERPER and PETER ENTEL — Theoretische Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany

The combination of Fe or the quasi Heusler $Fe_3Si$ with GaAs has attracted quite some interest due to the high spin-polarization of the ferromagnets and the tiny lattice mismatch. However, the actual size of the magnetic moments in hybrid structures depends on the growth conditions, direction, and surface termination. We studied the magnetic properties of Fe and Fe-Si films grown on GaAs with respect to interdiffusion and surface orientation. In case of GaAs(001) surface reconstruction is also included. From our calculations it turns out that nearly no diffusion occurs if $Fe_3Si$ is grown on GaAs(110), which seems to be related to the absence of surface reconstruction. The Vienna Ab-initio Simulation Package (VASP) using the Projector Augmented Wave (PAW) method has been employed to study the structural and magnetic properties of the systems [1]. In order to investigate interdiffusion effects additional calculations are performed by using a Korringa-Kohn-Rostoker (KKR) method within the coherent potential approximation (CPA) [2].

[1] G. Kresse and J. Furthmüller, Phys. Rev. B 54, 11169 (1996); G. Kresse and J. Hafner, Comput. Mater. Sci. 6,15 (1994)

[2] H. Ebert, in Electronic Structure and Physical Properties of Solids, ed. H. Dreyssé, Lecture notes in physics, Vol. 535, 191, Springer; SPR-KKR, version 3.6

MA 32.5 Thu 11:15 HSZ 403

**Epitaxial growth of magnetite thin films for spintronics** — •MEHRDAD BAGHAIE-YAZDI[1], JOSE KURIAN[1], EMANUEL IONESCU[2], ERWIN HILDEBRANDT[1], and LAMBERT ALFF[1] — [1]Dünne Schichten, Materialwissenschaft TU-Darmstadt, Darmstadt, Deutschland — [2]Disperse Feststoffe, Materialwissenschaft TU-Darmstadt, Darmstadt, Deutsch-

land

Magnetite is a promising material for spintronics application due to its high Curie temperature and half-metallic behavior. We have deposited magnetite thin films using both RF-Magnetron Sputtering and reactive Molecular Beam Epitaxy (MBE). Single crystal *c*-cut sapphire and MgO were used as substrates. Layer-by-layer growth was monitored by Reflection High-Energy Electron Diffraction (RHEED). The thin film samples were characterized by X-Ray diffraction and reflectometry, Superconducting Quantum Interference magnetometry, Raman spectroscopy and temperature vs. resistivity measurements. Optimized deposition conditions in MBE growth lead to $Fe_3O_4$ epitaxial thin films with a magnetization very close to the ideal value of $4\,\mu_B$/f.u. at 300 K and an extremely sharp Verwey transition around 119 K.

MA 32.6 Thu 11:30 HSZ 403

**Large photoconductivity and light-induced recovery of the insulator-metal transition in $La_{0.7}Ce_{0.3}MnO_{3-\delta}$ thin films** — •Andreas Thiessen[1], Elke Beyreuther[1], Stefan Grafström[1], Kathrin Dörr[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, D-01062 Dresden, Germany — [2]Institut für Metallische Werkstoffe, IFW Dresden, D-01171Dresden, Germany

Tetravalent-ion-doped lanthanum manganite films typically suffer from overoxygenation in the as-prepared state, which in turn leads to an effective hole doping instead of the nominal and desired electron doping. This problem can be overcome by post-deposition annealing in a reducing atmosphere, which, however, removes the typical phase transition from a paramagnetic insulating to a ferromagnetic metallic phase and makes the films insulating in the whole temperature range.

Such electron-doped $La_{0.7}Ce_{0.3}MnO_{3-\delta}$ thin films were investigated with respect to their transport characteristics under photoexcitation. While the films are insulating in the dark, even exposure to diffuse daylight dramatically decreases the low-temperature resistance and recovers the insulator-metal transition (IMT). Exposure to continuous visible laser light further decreases the resistance by up to seven orders of magnitude and shifts the IMT towards higher temperatures. Investigations of the spectral, transient, and intensity-dependent behaviour of the photoconductivity suggest that (i) both photogeneration of carriers in the film as well as charge injection from the substrate contribute to the effect, and that (ii) the excess carriers are electrons.

MA 32.7 Thu 11:45 HSZ 403

**Analysis of electronic defect states in lanthanum manganite / strontium titanate heterointerfaces by photovoltage and photoconductivity spectroscopy** — •Elke Beyreuther[1], Andreas Thiessen[1], Stefan Grafström[1], Kathrin Dörr[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, D-01062 Dresden, Germany — [2]Institut für Metallische Werkstoffe, IFW Dresden, D-01171Dresden, Germany

Similar to conventional microelectronic device structures, the performance of all-oxide electronic devices crucially depends on the electronic defect state distribution at the surfaces and interfaces of a given heterostructure. As soon as wide-bandgap oxides are involved, the analysis of the electronic properties becomes a challenge due to low carrier concentrations, which make classical electrical characterization methods fail.

Thus, in the present approach we choose *optical* techniques such as surface photovoltage and photoconductivity spectroscopy to map the distribution of defect states in heterostructures, consisting of lanthanum manganite ($La_{0.7}Ca_{0.3}MnO_3$, $La_{0.7}Ce_{0.3}MnO_3$) thin films on $SrTiO_3$ substrates.

Within the framework of a comparative evaluation of our spectra we also discuss the information content and the perspective of the methods applied.

MA 32.8 Thu 12:00 HSZ 403

**Frequency-dependent Ferromagnetic Resonance (FMR) on thin ironfilms on semiconducting substrates** — •Christian Schöppner, Florian M. Römer, Christoph Hassel, Ralf Meckenstock, Jürgen Lindner, and Michael Farle — Fachbereich Physik, AG Farle, CeNIDE, Universität Duisburg-Essen

Epitaxial iron films prepared within UHV environment (base pressure of $10^{-10}$ mbar) and capped with Ag/Pt were investigated by frequency dependent Ferromagnetic Resonance (FMR) in the range 6-26GHz. As substrates InAs(100) as well as GaAs(110) were used. In addition to the frequency dependent investigation full in-plane and out-of-plane angular dependent FMR measurements were conducted at a fixed frequency in order to determine the magnetic anisotropy fields. Provided that these fields are known, the frequency dependent results yield the possibility to quantify the g-factor of the system (being a measure of the orbital magnetism) with high accuracy. The results are discussed in terms of anisotropic orbital magnetic moments.

MA 32.9 Thu 12:15 HSZ 403

**Damping by slow relaxing rare earth impurities in $Ni_{80}Fe_{20}$** — •Matthias Kiessling[1], Georg Woltersdorf[1], Gereon Meyer[2], Jan-Ulrich Thiele[2], and Christian H. Back[1] — [1]University of Regensburg, 93040 Regensburg, Germany — [2]San Jose Research Center, Hitachi Global Storage Technologies 650 Harry Road, San Jose, CA 95120, U.S.A

The relaxation of the magnetization in soft ferromagnetic $Ni_{80}Fe_{20}$ films can be efficiently controlled by rare earth (RE) dopants. We investigate the frequency and temperature dependence of the ferromagnetic resonance (FMR) linewidth of $Ni_{80}Fe_{20}$ films doped with various RE elements of different concentrations. The central lanthanides Terbium, Dysprosium and Holmium give rise to a large increase of the damping even at very low doping levels. A Terbium concentration of only 2% leads for example to a broadening of the FMR linewidth by a factor of 50 compared to a pure NiFe film.

By means of ferromagnetic resonance measurements performed over a wide frequency (0.1-35 GHz) and temperature (20-350K) range the origin of the RE induced damping was identified. It can be concluded that the slow relaxing impurity mechanism is responsible for the relaxation observed in the RE intermetallic alloy films.

## MA 33: Bio- Molecular Magnetism

Time: Thursday 10:15–12:45 Location: HSZ 103

MA 33.1 Thu 10:15 HSZ 103

**$Mn_{12}$ Single-Molecule Magnets on Surfaces: Achievements and Perspectives** — •Sönke Voss[1], Michael Burgert[2], Mikhail Fonin[1], Ulrich Groth[2], and Ulrich Rüdiger[1] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]Fachbereich Chemie, Universität Konstanz, 78457 Konstanz

During the past years, a variety of studies on the structural, electronic as well as magnetic properties of $Mn_{12}$ single-molecule magnets (SMMs) deposited on surfaces have been performed. Recent investigations on molecular monolayers indicated the absence of all the fascinating magnetic properties known from SMM single crystals, like hysteresis of purely molecular origin or the ability to directly observe quantum tunnelling of magnetization. Nevertheless, results obtained by means of advanced characterization techniques indicated that fundamental structural as well as electronic properties of individual $Mn_{12}$ molecules are preserved after the deposition on a surface.

We will present the most recent achievements in the characterization of $Mn_{12}$ monolayers by means of scanning probe techniques, synchrotron radiation, and magnetization measurements. Potential reasons for the lack of a magnetic hysteresis in the monolayers will be discussed. Furthermore, advanced approaches towards an ultimate clarification of the suitability of $Mn_{12}$ SMMs for studies on molecule-based spintronic devices will be described.

MA 33.2 Thu 10:30 HSZ 103

**Magnetic properties of planar TM-Ni binuclear single molecular magnets** — •Ulf Wiedwald[1], Florian Mögele[2], Bernhard Rieger[3], and Paul Ziemann[1] — [1]Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]Institut für Materialien und Katalyse, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [3]WACKER-Lehrstuhl für Makromolekulare Chemie, Technische Universität München, Lichtenbergstraße 4, 85747 Garching bei München

Single molecular magnets are fascinating because of various pos-

sible coupling schemes between magnetic sites and resulting differences of the total magnetic moment, magnetic anisotropy and ordering temperature. Planar TM-Ni metallo-organic molecules (TM=V,Mn,Fe,Co,Ni,Cu) are synthesized each consisting of two magnetic sites and two identical alkyl chains forming a V-shape molecule. Dried powders are investigated by SQUID magnetometry. We find a resulting magnetization ranging from 0.2 $\mu_B$/molecule for V-Ni molecules to 1.7 $\mu_B$/molecule for Co-Ni molecules at B= 5.5T and T = 2K. Temperature-dependent susceptibility measurements suggest antiferromagnetic coupling of the two magnetic sites at T = 2K while at higher temperature a transition to ferromagnetic coupling is likely. The ordering temperatures are found between 9 and 34 K for Ni-Ni and Mn-Ni molecules, respectively.

MA 33.3 Thu 10:45 HSZ 103

**magnetic excitations and spin correlations in the spherical keplerate molecular magnet {Mo72Fe30}** — •ZhenDong Fu[1], Paul Kögerler[1,2], Ulrich Rücker[1], and Thomas Brückel[1] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Institut für Anorganische Chemie, RWTH Aachen, D-52074 Aachen, Germany

As one of the biggest molecular magnets that have been synthesized, the polyoxomolybdate {Mo72Fe30} allows us to investigate a highly symmetric and frustrated spin structure and provides us an ideal testbed for the theory on frustrated quantum spin systems. In our work, the low-field magnetic susceptibility measurement yields a Curie temperature about -20 K, indicating weak antiferromagnetic exchange interactions between the nearest neighbors. The low lying magnetic excitations of {Mo72Fe30} are characterized in terms of field-dependent heat capacity and inelastic neutron scattering measurements. The energy gaps resolved from the experimental data are located at about 0.1 and 0.7 meV, consistent with the quantum rotational band model for {Mo72Fe30} system [1]. The diffuse neutron scattering study with polarization analysis on {Mo72Fe30} polycrystals reveals characteristic spin correlations close to a coplanar three-sublattice ground state. Our observations agree with the previous theoretical model for this system, but also suggest that refinements should be done to the existing theoretical models. [1] J. Schnack, M. Luban and R. Modler, Europhys. Lett., 56 (6), pp. 863*869 (2001)

MA 33.4 Thu 11:00 HSZ 103

**Symmetry assisted approximate diagonalization of antiferromagnetic molecules** — •Roman Schnalle[1] and Jürgen Schnack[2] — [1]Universität Osnabrück, Fachbereich Physik, D-49069 Osnabrück — [2]Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

The spectrum of many interesting molecular antiferromagnets is theoretically often inaccessible due to the prohibitive size of the underlying Hilbert space. Experimentally the system of interest might very well be accessible for instance by neutron scattering, EPR, specific heat or magnetization measurements. The interpretation of the experimental data thus suffers from numerical restrictions.
In order to get insight into the low-temperature behaviour of large spin systems describing magnetic molecules - either bipartite or frustrated - we develop an approximate diagonalization. This theory rests on the observation that the low-lying spectrum of many finite size antiferromagnets can be rather successfully approximated by so-called rotational bands [1], which are the eigenstates of the rotational band Hamiltonian. We use an increasing number of these basis states (bands) for an approximate diagonalization of the full Heisenberg Hamiltonian [2]. Additionally point-group symmetries are used for a further reduction of the dimensionalities of the occuring matrices and a specific labelling of the eigenstates.

[1] J. Schnack, M. Luban, Phys. Rev. B **63**, 014418 (2000).
[2] O. Waldmann, Phys. Rev. B **75**, 012415 (2007).

MA 33.5 Thu 11:15 HSZ 103

**Complete diagonalization studies of anisotropic magnetic molecules** — •Juergen Schnack — Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

Thanks to recent progress both on the level of computer resources as well as on the level of theoretical modeling it is nowadays possible to discuss the behavior of anisotropic magnetic molecules in the context of a full spin Hamiltonian. This goes far beyond the giant spin Hamiltonian approach and offers the opportunity to investigate for instance effects of more than the ground state multiplet. We will comment on these recent developments and discuss two specific molecules in detail which possess the magnetic cores $Mn_6Fe$ and $Mn_3Cr$.

[1] T. Glaser, J. Schnack *et al.*, Inorg. Chem. (2008) in press

MA 33.6 Thu 11:30 HSZ 103

**Can the Hubbard model explain the steps observed in the magnetization curve of {$Ni_4Mo_{12}$}?** — •Martin Höck and Jürgen Schnack — Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

The low-temperature magnetization curve of the magnetic molecule {$Ni_4Mo_{12}$} features four nonequidistant steps which cannot be explained using a Heisenberg model [1]. In his article [2], V. Kostyuchenko presents a spin-1 model with biquadratic and three-spin interactions and claims that it is the strong coupling limit of a certain Hubbard model. This spin-1 model correctly predicts the position of the steps in the magnetization curve.

We investigate whether the Hubbard model proposed in [2] is really capable of describing {$Ni_4Mo_{12}$}. To this end, we calculate its eigenvalues using numerical exact diagonalization and try to fit its parameters to the experimental magnetization data. We are unable to find suitable fit parameters although the parameter space of the model is only two-dimensional.

Therefore, we analyze the strong coupling limit of the Hubbard model and rederive its effective spin model up to order $\mathcal{O}(U^{-3})$. The spin Hamiltonian which we obtain differs from the one presented by Kostyuchenko. We arrive at the final conclusion that the Hubbard model as proposed in [2] is not suited to describe the molecule {$Ni_4Mo_{12}$}.

[1] J. Schnack *et al.*, Phys. Rev. B **73**, 094401 (2006);
[2] V. V. Kostyuchenko, Phys. Rev. B **76**, 212404 (2007)

MA 33.7 Thu 11:45 HSZ 103

**SMM-like magnetic properties of Cobalt(II) Cubane $[Co_4(HL)_4(Cl)_4]$** — •Klaus Gieb[1], Konstantin Petukhov[1], Andreas Scheurer[2], Ayuk M. Ako[2], Rolf W. Saalfrank[2], and Paul Müller[1] — [1]Department für Physik, Universität Erlangen-Nürnberg, Germany — [2]Department für Chemie und Pharmazie, Universität Erlangen-Nürnberg, Germany

We report on magnetic properties of the novel tetranuclear cobalt compound $[Co_4(HL)_4(Cl)_4]$. We have found that this Co(II) cubane system shows evident single-molecule magnet (SMM)-like behavior. In particular, we have found that the nominal ground spin state of this complex is S = 6. The uniaxial anisotropy parameter D has a negative value of around -1.6 Kelvin. Relaxation studies have evidenced a single relaxation process following an Arrhenius law. The anisotropy barrier is $\Delta \approx 55.8$ K and the relaxation time is $\tau_0 \approx 10^{-8}$s. The measurements were performed by means of SQUID magnetometry, AC susceptibility measurements, and micro-Hall-probe hysteretic characterization.

MA 33.8 Thu 12:00 HSZ 103

**Anisotropy and frustration of the high-spin $[Cr^{III}Mn^{II}_3(PyA)_6Cl_3]$ molecule** — •Manuel Prinz[1], Michael Raekers[1], Karsten Kuepper[2], Marc Uhlarz[2], Sumit Khanra[3], Biplab Biswas[3], Thomas Weyhermüller[3], Jürgen Schnack[4], and Manfred Neumann[1] — [1]University of Osnabrück, Fachbereich Physik, D-49069 Osnabrück — [2]Forschungszentrum Dresden-Rossendorf, POB 51 01 19, D-01314 Dresden — [3]MPI für Bioanorganische Chemie, D-45470 Mülheim an der Ruhr — [4]Universität Bielefeld, Fakultät für Physik, D-33501 Bielefeld

Molecular magnets incorporate transition metal ions with organic groups providing a bridge to mediate magnetic exchange interactions between the ions. There are star-shaped molecules in which antiferromagnetic couplings between the central and peripheric atoms is predominantly present. Those configurations lead to an appreciable spin moment in the non-frustrated ground state. In spite of its topologically simple magnetic system, the $[Cr^{III}Mn^{II}_3(PyA)_6Cl_3]$ (**$CrMn_3$**) molecule exhibits non-trivial magnetic properties, like anisotropy and frustration. In the present work we elucidate the underlying magnetic properties of the hetero nuclear, spin-frustrated **$CrMn_3$** molecule applying high magnetic field measurements, X-ray magnetic circular dichroism (XMCD), anisotropic Heisenberg simulations and classical spin dynamic methods. Modeling the high field data by anisotropic Heisenberg simulations and dicussion of the various spin Hamiltonian parameters leads to a validation of our element selective transition metal XMCD spin moments at a magnetic field of 5 T and a temperature of 5 K.

MA 33.9 Thu 12:15 HSZ 103

**Effects of the Ligand Shell on the Single-Molecule Magnet Behavior in $Co_5$ Clusters** — •J. Nehrkorn[1], O. Waldmann[1], F. Klöwer[2], Y. H. Lan[2], and A. K. Powell[2] — [1]Physikalisches Institut, Universität Freiburg, D-79104 Freiburg, Germany — [2]Institut für Anorganische Chemie, Universität Karlsruhe, D-76128 Karlsruhe, Germany

Enhancing single-molecule magnet (SMM) behavior in molecular nanomagnets to higher temperatures is one of the great aims in this field. Incorporating $Co^{II}$ ions, because of their high magnetic anisotropy, has recently attracted much interest. In this work we study three $Co_5$ clusters which exhibit similar cores, but differ in their coordination spheres due to the use of different ligands. Our dc and ac magnetic data revealed that one compound is clearly a SMM, one is a weak SMM, and the third one is no SMM. We interpret the data on the basis of an effective-spin Hamiltonian, which reproduces the magnetic data well and allows us to understand the trend of SMM behavior. A subtle effect of highly anisotropic systems was observed: anisotropic ferromagnetic couplings together with highly anisotropic **g** matrices can yield susceptibility curves with a temperature dependence usually associated to antiferromagnetic interactions.

MA 33.10 Thu 12:30 HSZ 103

**Controlling the magnetic coupling of Fe-porphyrin molecules to ferromagnetic films: a temperature-dependent XMCD investigation** — •Matthias Bernien[1], Jorge Miguel[1], Claudia Weis[2], Marten Piantek[1], Xiaoying Xu[1], Philipp Eckhold[1], Julia Kurde[1], Klaus Baberschke[1], Wolfgang Kuch[1], and Heiko Wende[2] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin — [2]Fachbereich Physik, Experimentalphysik - AG Wende and Center for Nanointegration (CeNIDE), Universität Duisburg-Essen, Lotharstrasse 1, D-47048 Duisburg

Metal complexes on surfaces are the topic of intensive scientific investigations, since the properties of their central ion, determined by the adjacent ligands, can be widely tuned by the chemical design of the molecule. When paramagnetic porphyrin molecules are deposited onto ferromagnetic substrates, the spin of the metal center aligns parallel to the magnetization of the substrate. Tuning the molecule-substrate interaction would be an important step towards the realization of a surface-mounted molecular spintronic device. Here we have realized different magnetization directions and coupling strengths by choice of the substrate. We have determined the coupling strength between submonolayers of Fe octaethylporphyrins and ferromagnetic substrates by detailed temperature-dependent X-ray magnetic circular dichroism measurements. The vision of tailoring the magnetic coupling between the porphyrin molecules and the ferromagnetic substrates will be discussed.

Supported by BMBF (05 KS4 KEB/5) and DFG (SFB 658).

## MA 34: Invited Talks Winklhofer / Zabow

Time: Thursday 14:00–15:00 Location: HSZ 04

**Invited Talk** MA 34.1 Thu 14:00 HSZ 04

**The biophysics of geomagnetic-field reception in animals** — •Michael Winklhofer — LMU Munich, Germany

I will give an overview of the recent progress towards understanding the physical basis of the magnetic sense of animals. Research into magnetic field reception is currently driven by two hypotheses. One proposal relies on the presence of molecules that undergo magnetically anisotropic chemical reactions due to transient formation of a spin-correlated radical pair. Lately, the proposed chemical compass mechanism has been corroborated in principle by in-vitro experiments on artificial radical-pair systems. Specifically designed behavioral experiments suggest the involvement of radical-pair molecules in the compass sense of birds, but the biological structures hosting such molecules remain elusive. The second hypothesis builds on specialized sensory structures that contain ferrimagnetic particles and assumes that the magnetic input energy is converted into mechanical output energy to be transduced into a nerve signal by means of strain-sensitive ion channels. Magnetite has indeed been identified in sensory nerve structures, with stable magnetic single-domain particles in fish and micrometer-scale clusters of superparamagnetic nanocrystals in birds. While it is straightforward to explain the basic compass sense with the magnetite-based transduction mechanism, it is still a challenge to explain its sensitivity, which in some animals has been reported to be lower than 100 nT. Funding by the German Science Foundation (DFG Wi1828/4-1) and HFSP (RGP 45/2008) is gratefully acknowledged.

**Invited Talk** MA 34.2 Thu 14:30 HSZ 04

**Micromagnets for multispectral magnetic resonance imaging** — •Gary Zabow[1,2], Stephen Dodd[1], John Moreland[2], and Alan Koretsky[1] — [1]National Institutes of Health, Bethesda, MD, USA — [2]National Institute of Standards and Technology, Boulder, CO, USA

New optical bio-imaging techniques are behind much of the recent growth in molecular and cellular biology research. Many of these imaging advances are due to the introduction of new coloured fluorophores such as fluorescent proteins and quantum dots. Used as biological tags / labels, their distinct colours enable simultaneous tracking of multiple biological indicators. Unfortunately, equivalent multiplexing capabilities are largely absent in magnetic resonance imaging (MRI). Corresponding MRI labels have generally been limited to chemically synthesized paramagnetic molecules and superparamagnetic nano- and microparticles that are substantially indistinguishable from one another.

This talk introduces a top-down microfabrication approach to MRI contrast agent engineering that enables encoding of distinct spectral signatures into the geometry of magnetic microstructures. Although based on different principles to those of optically-probed nanoparticles, these new magnetic microstructures permit a multiplexing functionality in the magnetic resonance radio-frequency (RF) spectrum that is in many ways analogous to that permitted by quantum dots in the optical spectrum. Additionally, in situ modification of particle geometries may facilitate RF probing of various local physiological variables.

The talk will be aimed at an introductory level and will not assume any prior biology or MRI knowledge.

## MA 35: Spin-Dynamics / Spin-Torque IV

Time: Thursday 15:15–19:30 Location: HSZ 04

MA 35.1 Thu 15:15 HSZ 04

**Ultrafast Demagnetization of Lanthanide-Doped Permalloy Thin Films Studied with Time-Resolved Magneto-Optics** — •Ilie Radu[1,2], Matthias Kiessling[1], Georg Woltersdorf[1], Alexey Melnikov[3], Uwe Bovensiepen[3], Jan-Ulrich Thiele[4], and Christian Back[1] — [1]Regensburg University, Regensburg, Germany — [2]BESSY GmbH, Berlin, Germany — [3]Free University Berlin, Berlin, Germany — [4]Hitachi Global Storage, San Jose, CA, USA

The fs laser-induced magnetization dynamics of Permalloy thin films doped with Ho and Gd impurities is investigated by time-resolved magneto-optical Kerr effect. Varying the Ho concentration from 0% to 8% we observe a gradual change of the demagnetization time constant from approximately 60 fs to about 150 fs. In contrast, concentrations of Gd up to 15% do not affect the time scale of the demagnetization process. These results are at variance with recent theoretical work [1], that proposes a laser-induced demagnetization mechanism based on impurity- or phonon-assisted spin-flip scattering. We propose a demagnetization mechanism which relies on the strong magnetic inertia of the rare-earth dopant within the framework of the so-called slow relaxing impurity model [2,3].

[1] B. Koopmans et al., PRL 95, 267207 (2005); [2] J.H. van Vleck and R. Orbach, PRL 11, 65 (1963); [3] G. Woltersdorf et al.,

arXiv:0802.3206v2

MA 35.2 Thu 15:30 HSZ 04

**Femtosecond Dynamics of Spin and Orbital Angular Momentum in Nickel** — •Christian Stamm, Niko Pontius, Karsten Holldack, Torsten Quast, Torsten Kachel, Marko Wietstruk, Rolf Mitzner, and Hermann A. Dürr — Elektronenspeicherring BESSY II, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin

At the BESSY femtoslicing source we measure x-ray magnetic circular dichroism (XMCD) with 100 fs time resolution [1,2]. By virtue of the XMCD sum rules, we find that the spin and orbital momenta in a thin nickel film are quenched with a time constant of 150 fs upon excitation with a fs laser pulse. This represents the first unambiguous proof that the total electronic angular momentum is transferred to the lattice on the same ultrafast time scale. The quenching of orbital angular momentum also is a serious constraint for models of angular momentum dissipation.

[1] S. Khan et al., Phys. Rev. Lett. 97, 074801 (2006).
[2] C. Stamm et al., Nature Mater. 6, 740 (2007).

MA 35.3 Thu 15:45 HSZ 04

**Demagnetization processes on ultrashort timescales revisited** — •Jakob Walowski[1], Andreas Mann[1], Henning Ulrichs[1], Benjamin Lenk[1], Markus Münzenberg[1], Unai Atxitia[2], and Oksana Fesenko[2] — [1]I. Physikalisches Institut, Universität Göttingen, Germany — [2]Instituto de Ciencia de Materiales de Madrid (CSIC), Spain

All-optical pump-probe experiments give an insight into magnetization dynamics on ultrashort timescales. Femtosecond pulses generated by a Ti:Sa laser are used to trigger magnetization dynamics. Having an optical penetration depth of up to 15 nm the deposited energy is highest for of the topmost layers. A two-temperature type model including the electron heating after excitation and the equilibration with the phonon system, describes the dynamics. Within this process two timescales are of interest, first the demagnetization within the first $150-200$ fs and second the magnetization recovery which takes place on the timescale of $1-20$ ps after excitation. On the first timescale the characteristic slowing down of the demagnetization was revisited, since it is a fingerprint of the correlation effect from incoherent spin-waves occuring at high pump fluencies. The connection between the electron temperatures in the magnetic system is established by a Langevin field term in the modeling of this process. For the modeling an atomistic level description using Landau-Lifshitz-Bloch equations is applied. We find a scaling behavior of the total demagnetization as a function of the pump fluency ($10-50\,\mathrm{mJ/cm^2}$) and the thickness of the magnetic layer ($d_{\mathrm{Ni}} = 10-40$ nm). Support by the DFG within the priority program SPP 1133 is gratefully acknowledged.

MA 35.4 Thu 16:00 HSZ 04

**Absolute measurements of the excitation amplitude at ferromagnetic resonance** — •P. Majchrak[1], G. Woltersdorf[1], T. Martin[1], T. Kachel[2], C. Stamm[2], H. Dürr[2], and C. H. Back[1] — [1]Institut für Exp. und Angewandte Physik, Uni Regensburg, 93040 Regensburg — [2]BESSY, Albert-Einstein-Straße 15, 12489 Berlin

Using X-ray magnetic circular dichroism (XMCD) we directly measure the transversal components of the precessing magnetization in a thin film under cw microwave excitation (phase locked to the X-ray flashes). The real and imaginary parts of the rf-magnetic susceptibility are obtained by adjusting the phase between exciting microwave signal and the X-ray flashes to 0° and 90°, respectively. Measurements at different angles between the sample plane and the X-ray beam allow to determine the in and out-of-plane rf magnetization components and thereby the ellipticity of the precession. Since the signal is calibrated by XMCD hysteresis loops the excursion angle can be evaluated. At large microwave fields the susceptibility becomes nonlinear due to the decrease of the effective magnetization and the excitation of parametric spin waves (Suhl instability). We measure the precession angle and the ellipticity as function of rf power up to the nonlinear regime. XMCD also allows for an element specific and therefore layer sensitive investigation of the magnetization dynamics. Optic and acoustic modes are observed in an interlayer exchange coupled sample $Co_{90}Fe_{10}/Ru/Ni_{80}Fe_{20}$. From the phase difference between the precessing magnetizations of both layers the coupling energy is determined.

MA 35.5 Thu 16:15 HSZ 04

**Experimental check of the Elliott-Yafet model in laser-induced ultrafast demagnetization** — •Tobias Roth[1], Daniel Steil[1], Sabine Alebrand[1], Bert Koopmans[2], Grégory Malinowski[2], Francesco Dalla Longa[2], Daniel Steiauf[3], Manfred Fähnle[3], Mirko Cinchetti[1], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany — [2]Department of Applied Physics, center for NanoMaterials (cNM), Eindhoven University of Technology, The Netherlands — [3]Max-Planck-Institut für Metallforschung Stuttgart, Germany

The deep interest in the area of femtosecond magnetism results both from the very fundamental physical question about the involved interactions between light, spin, and matter and from the fact that magnetization dynamics on an ultrafast time scale may serve as a potential candidate for the future of data processing. In 2005 B. Koopmans et al. proposed an Elliott-Yafet (EY) type spin-flip process to be the responsible mechanism for the observed loss in magnetic order [1,2]. The model is based on electron-phonon or electron-impurity interaction whereby each scattering event carries a spin-flip probability to end up in a changed spin state. In this contribution we present time resolved magnetooptical Kerr measurements in the high perturbation regime that check the validity of the EY type spin-flip process by changing external key parameters. The results will be discussed behind the background of the model's predictions. [1] B. Koopmans et al., PRL 95 267207 (2005) [2] M. Cinchetti et al., PRL 97 177201 (2006)

MA 35.6 Thu 16:30 HSZ 04

**Ab-initio calculations on the Elliott-Yafet mechanism for the discussion of femtosecond magnetization dynamics** — •Daniel Steiauf and Manfred Fähnle — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

Ultrashort laser pulses are able to reduce the magnetization of ferromagnetic metals such as Ni. Thereby, angular momentum is transferred from the spin system faster than a picosecond, however, not into the electronic orbital moments, as shown by recent experiments. Thus the lattice has to be involved. The Elliott-Yafet [1,2] mechanism, a spin-orbit mediated spin-flip scattering of an electron at a phonon, is one possible, however questioned, candidate to explain the ultrafast demagnetization after fs laser excitation. The doubts have arisen as the value of the Elliott-Yafet spin-mixing parameter of Ni has not been known and has been assumed to be similar to the one of Cu which is very small. We present ab-initio calculations of the spin-mixing within the density functional electron theory for various alkali, transition and rare earth metals. The spin mixing of the electronic system is induced by spin-orbit coupling as well, and is a measure for the strength of the spin-flip scattering.

[1] R. J. Elliott, Phys. Rev. 96, 266 (1954).
[2] Y. Yafet, in "Solid State Physics", F. Seitz and D. Turnbull (eds.) (Academic, New York, 1963), Vol. 14

MA 35.7 Thu 16:45 HSZ 04

**Calculation of ultrafast demagnetization following laser excitation** — •Sabine Alebrand, Michael Krauss, Tobias Roth, Daniel Steil, Mirko Cinchetti, Hans Christian Schneider, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schrödinger-Straße 46, 67663 Kaiserslautern, Germany

In this presentation, we investigate a model for optically induced ultrafast magnetization dynamics in ferromagnets. In our approach we include electron-electron (and electron-phonon) scattering processes and a simplified spin-split electronic band structure. In this model, Elliott-Yafet type spin-flip scattering between electrons, and electrons and phonons leads to the demagnetization after optically excitation. The total spin-polarization dynamics can be compared with experiments, such as time resolved magneto optical Kerr measurements. For magnetic metals, such as Co and Ni, we find that calculated fluence dependence of the demagnetization dynamics reproduces experimental trends.

MA 35.8 Thu 17:00 HSZ 04

**Laser-induced quenching of the spin polarization in 3d-ferromagnets studied by time and spin resolved photoemission** — •Alexander Weber — Universität Regensburg

In the field of ultrafast magnetization dynamics most progress was achieved by all optical measurements. With optical measurements no direct access to the spin polarization is possible. In order to gain direct insight into the time evolution of the spin polarization after ex-

citation with a fs laser pulse a time and spin-resolved pump probe experiment is applied to measure the quenching of spin polarization in 3d-ferromagnets on a fs timescale. In our experiment the spin polarization of the photoexcited electrons of 8ML Fe/W(110) and 8ML Co/W(110) is measured directly with a Mott-detector. Three different timescales could be distinguished, a fast quenching of spin polarization, a fast remagnetization, and a slow remagnetization. The measured data fit well to a heat-diffusion expanded three temperature model. The fit yields demagnetization times of 0.8 ps and 0.3 ps for Co and Fe, respectively. The qualitative and quantitative accordance to Kerr measurements is discussed.

**15 min. break**

MA 35.9 Thu 17:30 HSZ 04

**Anisotropic and nonlocal damping in near-adiabatic magnetization dynamics** — •Jonas Seib, Daniel Steiauf, and Manfred Fähnle — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

Recently, a Gilbert type equation of motion was derived by the combination of the phenomenological breathing Fermi surface model and the ab-initio density functional electron theory [1]. This equation is valid on the near-adiabatic time scale. The Gilbert damping scalar is replaced by an anisotropic damping matrix for the case of collinear magnetization. In the case of noncollinear systems, nonlocal damping matrices lead to a nonlocal equation of motion on the atomic length scale.

We show, from the viewpoint of theory, to what extent a FMR (ferromagnetic resonance) experiment can give insight to anisotropic damping parameters in collinear systems. Additionally, we present results for damping parameters in noncollinear systems, which lead to a much stronger damping than in the collinear case.

[1] D. Steiauf, J. Seib, and M. Fähnle, Phys. Rev. B **78**, 020410(R) (2008).

MA 35.10 Thu 17:45 HSZ 04

**Magnetization Dynamics of Co-based Heusler Alloys** — •Daniel Steil, Tobias Roth, Sabine Alebrand, Mirko Cinchetti, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany

For more than a decade now the microscopic mechanisms responsible for ultrafast magnetization dynamics after strong optical excitation have been investigated. Today the most likely candidates for this process seem to be Elliott-Yafet-type spin-flip processes [1,2]. To give a strong experimental proof for the above assumption, it would be necessary to compare the dynamics of different magnetic materials, while ideally changing only a single parameter of the system. In this context, Heusler alloys serve as a nearly ideal test system for probing the microscopic mechanism driving magnetization dynamics due to their special properties. In particular, many Co-based Heusler alloys have been predicted to be half metallic ferromagnets, exhibiting a minority spin band gap at the Fermi level ($E_F$). Moreover, in the quaternary alloy $Co_2Mn_{1-x}Fe_xSi$ (CMFS), the size and position of the band gap with respect to $E_F$ can be tuned by changing the Fe content x [3]. This allows drawing direct conclusions about the influence of the band structure on magnetization dynamics. In this talk we will present the results of time-resolved MOKE experiments on CFMS and compare them to the results from Co and other Co-based Heusler alloys.

[1] Koopmans et al, PRL 95, 267207 (2005) [2] Cinchetti et al, PRL 97, 177201 (2006) [3] Balke et al, PRB 74, 104405 (2006)

MA 35.11 Thu 18:00 HSZ 04

**Characterizing half-metallicity via magnetization dynamics on ultrafast timescales** — •Andreas Mann[1], Henning Ulrichs[1], Jakob Walowski[1], Markus Münzenberg[1], Jan Schmalhorst[2], Andy Thomas[2], Andreas Hütten[2], and Günter Reiss[2] — [1]I. Physikalisches Institut, Universität Göttingen, Germany — [2]Department of Physics, Universität Bielefeld, Germany

We study the magnetization dynamics of potential half-metals probed by the time-resolved magneto-optical Kerr effect (TRMOKE) using a femtosecond laser pump-probe setup (temporal resolution: $50\,fs$). Half metals are promising candidates for the development of so called 'spintronic' devices, because they possess a minority-spin band gap at the Fermi level and are therefore 100 % spin-polarized. The magnetization dynamics in ferromagnetic metals are generally marked by two characteristic timescales, a short demagnetization time $\tau_m$ of several hundred $fs$ and a relaxation time $\tau_e$ in the $ps$ range. In the special case of a half metal, the minority-spin band gap blocks the Elliot-Yafet scattering and thus slows down the demagnetization. The enlarged $\tau_m$ of a few $ps$ to $ns$ which is governed by anisotropy fluctuations can be measured in our setup and indicates a half-metallic behaviour of the sample. More in detail, our experiments imply that the band gap of a half metal also has a subtle influence on the magnetization dynamics on the ultrafast timescale, evident in a steplike feature. We present an expansion of the three temperature model by Beaurepaire et al.. We gratefully acknowledge the support by the DFG SPP 1133: "Ultrafast magnetization processes".

MA 35.12 Thu 18:15 HSZ 04

**Thermally Induced Magnetization Reversal of Fe/W(110) Nanoislands Investigated by SP-STM** — •Stefan Krause[1], Gabriela Herzog[1], Luis Berbil-Bautista[2], Matthias Bode[3], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, Germany — [2]Materials Science Division, Lawrence Berkeley National Laboratory, USA — [3]Center for Nanoscale Materials, Argonne National Laboratory, USA

Spin-polarized scanning tunneling microscopy (SP-STM) is a well-established tool to investigate not only static but also dynamic magnetic properties of surfaces at lateral resolution down to the atomic scale [1]. Our variable-temperature STM is suitable to investigate the thermal switching behavior of single atomic-scale Fe/W(110) nanoislands over a temperature range between 30 K and 300 K.

Both the attempt frequency as well as the effective activation energy barrier of individual nanoislands can be determined from the Arrhenius-like switching behavior as a function of temperature. An analysis of the data reveals that magnetization reversal takes place via the nucleation and propagation of a domain wall. Furthermore, the attempt frequency is found to vary with island size and shape.

The results will be discussed in terms of domain wall nucleation and diffusion. For atoms at the center and the rim of a nanoisland the exchange stiffness and anisotropy energy contributions are to be quantified and compared to the results of earlier studies on the Fe/W(110) monolayer system.

[1] M. Bode *et al.*, Phys. Rev. Lett. 92, 067201 (2004).

MA 35.13 Thu 18:30 HSZ 04

**Thermally assisted magnetisation switching close to the Curie temperature: elliptical and linear reversal** — •Denise Hinzke[1], Natalia Kazantseva[2], Roy W. Chantrell[2], and Ulrich Nowak[1] — [1]Universität Konstanz, 78457 Konstanz — [2]University of York, York YO10 5DD, U. K.

Laser induced magnetic writing processes have been extensively studied recently as a possibility to improve the storage density as well as the writing speed in magnetic data storage. In our work, we focus on magnetisation reversal processes during laser heating in the presence of a magnetic field. This is important for the understanding of the dynamics of writing processes in the pico-second time scale and in relation to Heat Assisted Magnetic Recording. This technique has been proposed as a means of writing information on high anisotropy magnetic media.

We investigate the thermally assisted switching analytically within the framework of the Landau-Lifshitz-Bloch equation recently derived by D. Garanin [1]. Close to the Curie temperatures $T_c$ two different reversal modes appear: elliptical as well as linear reversal [2]. The latter one plays a crucial role for the dynamics of the magnetisation reversal close to and especially above $T_c$. We have calculated the coercive fields and the energy barriers for both reversal modes as well as the minimal switching time and field needed for thermally assisted switching below and above $T_c$.

[1] D. A. Garanin, Phys.Rev. B 55, 3050 (1997), [2] N. Kazantseva et al, submitted for publication

MA 35.14 Thu 18:45 HSZ 04

**Three-dimensional control of the antiferromagnetic order parameter in nickel oxide** — •Andrea Rubano[1], Takuya Satoh[2], and Manfred Fiebig[1] — [1]HISKP, University of Bonn, Germany — [2]Institute of Industrial Science, University of Tokyo, Japan

A three-dimensional switching of the antiferromagnetic (AFM) order parameter has been achieved in the exchange-bias compound NiO by means of an intense optical excitation. By controlling the power and pulse length of the pump pulse the AFM order parameter was tran-

siently oriented into the easy(1) axis, the easy(2) axis, or the hard axis direction. The reorientation was evidenced by optical second harmonic generation beating processes. The relation between the pump-pulse parameters and the induced direction of the AFM order parameter was investigated in detail. At constant pump-pulse energy we tuned its temporal duration: "short pulse" ($\approx$ 110 fs) switch the AFM order parameter into the hard axis direction, while longer pulses ($\approx$ 130 fs) set the order parameter along the easy(2) axis. We ascribe the observed phenomenon to the competition between "hot carrier" creation modifying the magnetic anisotropy and electron-electron relaxation processes occurring on the same timescale.

MA 35.15 Thu 19:00 HSZ 04

**Magnetization Dynamics in Interlayer Exchange Coupled Magnetic Microstructures** — •Alexander Kaiser, Carsten Wiemann, Stefan Cramm, and Claus M. Schneider — Forschungszentrum Jülich, Institut für Festkörperforschung IFF-9 und JARA-FIT, 52425 Jülich, Deutschland

Photoemission Electron Microscopy (PEEM) combined with soft x-rays with variable polarization and a pulsed time structure offered at modern storage rings is a powerful tool for investigating magnetization dynamics with high spatial and temporal resolution. Tuning the photon energy to the absorption edges of the appropriate elements and exploiting the XMCD effect offers the possibility to probe the micromagnetic structure of different layers in magnetic heterostructures independently. Thus the influence of coupling phenomena on the micromagnetic behavior can be studied in magnetic heterostructures.

We have investigated the magnetization dynamics in interlayer exchange coupled CoFe/Cr/NiFe structures for different Cr thicknesses spanning parallel, antiparallel and 90°-coupling of the ferromagnetic layers. The films have been grown epitaxially by MBE on GaAs substrates with Ag buffer layers. We present time-resolved PEEM measurements of the magnetodynamic response on a short magnetic field pulse in both ferromagnetic films. The influence of the interlayer exchange coupling on the magnetodynamic behaviour will be discussed.

*This work was supported by the DFG within SFB 491.*

MA 35.16 Thu 19:15 HSZ 04

**Ultrafast Spin Noise Spectroscopy** — •Sebastian Starosielec and Daniel Hägele — AG Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, D-44801 Bochum, Germany

Optical spin noise spectroscopy based on cw laser probe has proved to be a powerful method for determining e.g. spin lifetimes with only minimally perturbing the electronic system [1]. The accessible frequency range is however limited to typically below 1 GHz by the detection electronics. Here we propose a new scheme based on pairs of fs laser pulses that allows for measuring noise spectra up to 10 THz [2]. Monte-Carlo-simulations including photon shot noise show that smooth spectra can be obtained within a total observation time of only a few seconds. In addition, ultrafast noise spectroscopy can measure broad signals that are centered around zero frequency where traditional Raman- or Brillouin spectroscopy is notoriously difficult or even impossible. We give analytic expressions for the quality of ultrafast spin noise spectra in terms of observation time, photon shot noise, electrical noise, and the spin-noise level. A time-resolved version of noise spectroscopy for detecting noise after a pump event follows naturally from the scheme.

[1] M. Oestreich, M. Römer, R. J. Haug and D. Hägele, Phys. Rev. Lett. **95**, 2166003 (2005).
[2] S. Starosielec and D. Hägele, Appl. Phys. Lett. **93**, 051116 (2008).

## MA 36: Magnetic Particles and Clusters II

Time: Thursday 15:15–18:15 Location: HSZ 401

MA 36.1 Thu 15:15 HSZ 401

**Ligand-dependence of longterm stability of cobalt nanoparticles** — •Britta Vogel, Axel Dreyer, Nadine Mill, Anna Regtmeier, Inga Ennen, Daniel Ebke, Simone Herth, and Andreas Hütten — Department of Physics, University of Bielefeld, D-33615 Bielefeld, Germany

Cobalt nanoparticles with a diameter of 12nm have initially been prepared with TOPO. Subsequently a ligand exchange was carried out so as to employ the ligand of choice to the nanoparticles. The effect of different ligands on the change of the magnetic moment of the particles was investigated systematically by using ligands with two different head groups, several different chain lengths with and without double bond, several numbers of chains and two ligands with benzene rings. The samples were stored at different temperatures to gain insight into the temperature dependence of the oxidation.

MA 36.2 Thu 15:30 HSZ 401

**Imaging magnetic responses of different Fe nanocube configurations** — •Nina Friedenberger[1], Katharina Ollefs[1], Florian Kronast[2], Hermann Dürr[2], and Michael Farle[1] — [1]Experimentalphysik-AG Farle, Fachbereich Physik, Universität Duisburg-Essen, Germany — [2]BESSY GmbH, Berlin, Germany

While structural properties of self-assembled particles can be studied using electron microscopy, a magnetic characterization is presently mostly based on ensemble averaging. Here we use high lateral resolution photoemission electron microscopy (PEEM) and x-ray magnetic circular dichroism (XMCD) spectroscopy to overcome this limitation. We studied Fe nanoparticles with a cubic shape [1] in the PEEM with a lateral resolution of typically 30nm. In order to identify the local coordination of the particles we matched the PEEM images to scanning electron microscopy (SEM) images of higher lateral resolution. PEEM images were taken in an applied magnetic field of up to +/- 33mT which allowed us to extract the hysteresis behavior of different configurations at temperatures down to 110K. Our results demonstrate that the magnetic properties of the investigated Fe nanoparticles depend strongly on their local coordination. Obviously strong magnetic dipolar coupling between neighboring particles influences their magnetic response. Financially supported by: DFG (SFB 445) and EC: MC-RTN "SyntOrbMag". [1] A. Shavel, et al. Adv. Funct. Mat. 17 (2007) 3870-3876

MA 36.3 Thu 15:45 HSZ 401

**Micro Hall Magnetometry on individual iron filled carbon nanotubes** — •Kamil Lipert[1], Franziska Wolny[1], Thomas Mühl[1], Pintu Das[2], Jens Müller[2], Rüdiger Klingeler[1], and Bernd Büchner[1] — [1]Leibniz-Institute for Solid State and Materials Research (IFW) Dresden — [2]Max Planck Institute for Chemical Physics of Solids (MPI-CPfS) Dresden

We present the fabrication and structural characterization of a gated (Al,Ga)As Micro- Hall device and its application for studying the magnetic properties of iron filled carbon nanotubes. The nanomagnets have been positioned in the center of the active area of 800*800nm$^2$ by means of a Scanning Electron Microscope (SEM) equipped with micromanipulators. The Hall-voltage was measured under applied magnetic fields up to 1T at temperatures 5K $\leq T \leq$ 90K in the ballistic regime. The $z$-component of the stray field of the nanomagnet has been extracted and the magnetisation reversal has been studied in detail. Interestingly, we found unusual multi-step hysteresis curves which can be tentatively explained by magnetic field induced bending of the free-standing carbon nanotube. This might open the possibility of practical application as for example a nano-switch.

MA 36.4 Thu 16:00 HSZ 401

**Decoupling of the surface and core magnetic contribution in antiferromagnetic nanostructures** — •Maria Jose Benitez[1,2], Oleg Petracic[1], Harun Tüysüz[2], Florin Radu[3], Ferdi Schüth[2], and Hartmut Zabel[1] — [1]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Max-Planck Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr — [3]BESSY GmbH, Albert-Einstein Strasse 15, D-12489 Berlin

Ferromagnetic particles enter superparamagnetism upon decreasing their size. However, antiferromagnetic nanoparticles are governed by core-shell behavior. We present a systematic magnetometry study on antiferromagnetic $Co_3O_4$ and CoO nanowires with various structure sizes between 5 and 10nm. We identify two different magnetic contributions, viz. one being governed by the antiferromagnetically ordered wire cores. The second one is attributed to the antiferromagnetic sur-

face. We demonstrate that the surface behaves as a two-dimensional diluted antiferromagnet in a field (DAFF) [1]. Furthermore we show that measurements of the thermoremanent (TRM) and isothermoremanent magnetization (IRM) can serve as a magnetic fingerprint of particularly the surface contribution to the magnetization.

[1] M. J. Benitez et al., Phys. Rev. Lett. 101, 097206 (2008).

MA 36.5 Thu 16:15 HSZ 401

**Surface energies of Fe, Co, Mn, Pt and their alloys: An *ab initio* study** — •Antje Dannenberg, Markus Ernst Gruner, and Peter Enetl — Universität Duisburg-Essen, 47048 Duisburg, Germany

$L1_0$-ordered FePt and CoPt nanoparticles are considered as promising materials for ultra-high density magnetic recording applications. Since the energies of surfaces and internal interfaces play an important role in determining the equilibrium shape of the particles, their analysis is of fundamental interest.

We here show the results of a systematic study of the energies and magnetism of low-indexed surfaces for the monoatomic systems Fe, Co, and Pt, as well as for the binary alloys FePt, CoPt, and MnPt. For $L1_0$-ordered, stoichiometric alloys we present a method which is based on surface energy phase diagrams in order to evaluate the surface energy contributions of the single material components. For transition metals this has not been done before. We find, that especially platinum covered {111} facets show extraordinary low surface energy while the (001) surface, which is needed for the desired $L1_0$-cuboctahedron, lays higher in energy. This gives rise to the appearance of multiply twinned icosahedra in gas phase experiments. The energies are calculated within density functional theory using the VASP code and the surfaces were modeled within the slab approach.

MA 36.6 Thu 16:30 HSZ 401

**Effect of Pt capping on the magnetic anisotropy of 3*d* clusters** — •Sanjubala Sahoo[1], Peter Entel[1], and Manuel Richter[2] — [1]Physics Department, University of Duisburg-Essen, 47048 Duisburg, Germany — [2]IFW Dresden e.V., D-01171 Dresden, Germany

Clusters show large magnetic anisotropy compared to bulk because of spatial confinement. The enhanced anisotropy in clusters is a favorable property explored by the data storage technologies, which aim to develop miniature devices. Systems like FePt alloys are active candidates for the same. We study the magnetic anisotropy of 13 atom icosahedral clusters of Fe, Co and Ni, respectively, using the density functional theory. In our studies, the anisotropy is treated by including the spin-orbit interaction in a scalar relativistic approximation in the density functional Hamiltonian. Our studies show that the spin and orbital moments of clusters are larger than that of bulk. The magnetic anisotropy is also enhanced as compared to the corresponding bulk values. The role of Pt in the magnetic anisotropy of clusters is studied by capping Fe cluster with Pt atoms. Capping such a 5*d* element on a 3*d* cluster is observed to change the cluster's anisotropy energy, which will be discussed in our contribution.

MA 36.7 Thu 16:45 HSZ 401

**Antiferromagnetic finite nanowires: Heisenberg spin model revisited** — •Mohammed Ahsanul Hoda Ahsan[1,2], Jamal Berakdar[1], and Mohammed Mahfoozul Haque[2] — [1]Institute of Physics, Martin-Luther University, Halle-Wittenberg, Heinrich-Damerow Str.-4, 06120 Halle, Germany. — [2]Department of Physics, Jamia Millia Islamia(Central University), New Delhi 110025, India.

In line with a recent experimental work on antiferromagnetic finite nanowires[1] and its subsequent theoretical discussions[2,3], we present here exact diagonalization calculations on the one-dimensional antiferromagnetic Heisenberg spin-$\frac{1}{2}$ chain on a magnetic substrate. The chain-substrate coupling $\Gamma$ is assumed to be ferromagnetic. Numerical diagonalization is performed for chains of up to 25 spins to find the ground state and the first five excited states. The critical value of $\Gamma$ at which the ground state first changes its spin symmetry is found to be consistently higher for the odd chains as compared to the even chains considered. In odd chains, the ground state and the first excited state have the same total spin equal to $\frac{1}{2}$ whereas for even chains the ground state and the first excited state have spins 0 and 1 respectively. These bring in the premise of an odd-even effect on the ground state and low lying excited states of finite antiferromagnetic nanowires.

[1] C. F. Hirjibehedin, C. P. Lutz, A. J. Heinrich, Science **312**, 1021(2006).
[2] S. Lounis, P. H. Dederichs, and S. Blugel, Phys. Rev. Lett. **101**, 107204(2008).
[3] P. Politi and M. G. Pini, arXiv:0811.1687v1 [cond-mat.mtrl-sci].

MA 36.8 Thu 17:00 HSZ 401

**Mapping of ultrafast magnetic-switch scenarios to infrared spectroscopy** — •Georgios Lefkidis, Chun Li, and Wolfgang Hübner — Department of Physics and Research Center OPTIMAS, Kaiserslautern University of Technology, Box 3049, 67653 Kaiserslautern, Germany

We present a first-principles controlled ultrafast magnetooptical switch and transfer mechanism in small two-magnetic-center clusters exploiting spin-orbit-coupling enabled $\Lambda$-processes [1-4]. By attaching CO to one of the magnetic centers of the $[CoMg_2Ni]^+$ and $[CoNi]^+$ clusters and optimizing the structure we detect a mapping of the laser-induced spin manipulation to the IR spectrum of CO. The predicted spin-state-dependent CO frequencies can facilitate experimental monitoring of the processes. The lower electronic states of the clusters exhibit a very high degree of spin localization either at the Co or the Ni site. Spin flip on one magnetic atom and transfer from one magnetic center to the other are realized in structurally optimized magnetic clusters with fidelities that reach 99.8%.

[1] C. Li, G. Lefkidis and W. Hübner, arXiv:0811.4042v1 [cond-mat.other]
[2] R. Gomez-Abal, O. Ney, K. Satitkovitchai and W. Hübner, PRL 92, 227402 (2004)
[3] G. Lefkidis and W. Hübner, PRB 76, 014418 (2007)
[4] T. Hartenstein, C. Li, G. Lefkidis and W. Hübner, JPD 41, 164006 (2008).

MA 36.9 Thu 17:15 HSZ 401

**Electronic theory of ultrafast spin dynamics: Towards magnetic nanologic elements** — •Wolfgang Hübner[1], Sander Kersten[1,2], and Georgios Lefkidis[1] — [1]Dept. of Physics and Research Center OPTIMAS, University of Kaiserslautern, Box 3049, 67653 Kaiserslautern, Germany — [2]Dept. of Applied Physics, Eindhoven University of Technology, Box 513, 5600 MB, Eindhoven, The Netherlands

We present a fully *ab initio* theory of ultrafast nanologic elements and show that controlled spin manipulation is feasible with the inclusion of spin-orbit coupling thus realizing a $\Lambda$-process [1-3]. We discuss the requirements of such elements and we devise realistic 3-magnetic-center clusters. Out of a multitude of clusters we show, using high-level quantum chemistry, that in $Ni_2Na_3$ both spin flips and spin transfers are possible within a hundred femtoseconds. An external **B**-field and the state of one magnetic center serve as input bits, while the magnetic state of the cluster after a controlled laser pulse can be mapped to the result of a logic operation induced by the laser pulse. We are able to construct an OR, an XOR (CNOT) and two AND gates [4]. Thus multicenter magnetic clusters form suitable objects for extending spin dynamics to optically triggered and properly functionalized magnetic transport on a subpicosecond timescale and nanometer spatial scale.

[1] R. Gómez-Abal *et al.*, PRL 92, 227402 (2004)
[2] G. Lefkidis and W. Hübner, PRB 76, 014418 (2007)
[3] T. Hartenstein *et al.*, JPD 41, 164006 (2008)
[4] W. Hübner, S. Kersten and G. Lefkidis (unpublished)

MA 36.10 Thu 17:30 HSZ 401

**Highly sensitive detection of magnetic markers by tunneling magnetoresistance sensors** — •Camelia Albon, Karsten Rott, and Andreas Hütten — Thin Films and Physics of Nanostructures, Department of Physics, Bielefeld University, P.O. Box 100131, 33501 Bielefeld, Germany

Tunneling magneto-resistance (TMR) sensors are employed in the detection of magnetic markers for biological applications. An array of sensors is constructed by e-beam lithography means and consists of 20 elements placed on an 18.2 micrometer squares area. Each element has the size of 100nm on the transversal axis and 400nm on the longitudinal axis, the distance between two adjacent sensors being 1.2 micrometers. The sensors have been proved to be eligible for the detection of 1 micrometer magnetic beads by providing different detection signals with respect to the bead orientation at the sensor surface. Also, TMR sensors are able to detect the threshold of magnetic coupling between the 14nm Co nanoparticles situated on top of the sensor surface. By integrating the sensors with microchannels technique it has been proved their suitability for real time detection of magnetic markers.

MA 36.11 Thu 17:45 HSZ 401

**Magnetism in homonuclear transition metal dimers** — •Daniel

Fritsch, Klaus Koepernik, Manuel Richter, and Helmut Eschrig — IFW Dresden, PO Box 270116, D-01171 Dresden, Germany

The present work gives an overview over calculated structural and magnetic properties of homonuclear transition metal dimers. All the calculations have been performed utilizing the full-potential local-orbital program package FPLO [1] for the solution of the Kohn-Sham equations. The ground state spin multiplicity, bond length, and harmonic vibrational frequency are obtained by scalar-relativistic calculations within the local spin-density (LSDA) and generalized gradient (GGA) approximations to the density functional. Applying the fixed-spin moment method stabilizes the convergence and helps to identify the lowest spin state. In the next step, orbital magnetic properties are obtained from spin polarized full-relativistic calculations. Since orbital moments are usually underestimated in such calculations, we have additionally studied the influence of orbital polarization corrections (OPC) [2]. The results will be compared with available experimental and other theoretical data [3].

[1] K. Koepernik and H. Eschrig, Phys. Rev. B **59**, 1743 (1999); http://www.fplo.de (version 8.00-31-WS).

[2] O. Eriksson, M. S. S. Brooks, and B. Johansson, Phys. Rev. B **41**, 7311 (1990).

[3] D. Fritsch, K. Koepernik, M. Richter, and H. Eschrig, J. Comp. Chem. **29**, 2210 (2008).

MA 36.12 Thu 18:00 HSZ 401

**Stability of the magnetic domain structure of nanoparticle thin films against external fields** — •Kai-Felix Braun[1], S. Sievers[1], M. Albrecht[1], U. Siegner[1], K. Landfester[2], and V. Holzapfel[2] — [1]Physikalisch-Technische Bundesanstalt, 38116 Braunschweig. — [2]Max Planck Institute for Polymer Research, 55128 Mainz.

We investigate the influence of an external magnetic field on the magnetic ordering of single-layer and multi-layer thin films of magnetic nanoparticles (MNP). It is shown that the dipolar interaction results in a larger stability of multi-layer films as compared to single-layer films when exposed to inhomogeneous fields generated, e.g. by the magnetized tip of a magnetic force microscope (MFM). Numerical calculations and experimental MFM studies are presented. The calculations show that unperturbed single-layer MNP films display an in-plane domain pattern which is induced by dipolar interaction. Yet, even in the presence of this collective effect, external fields can rotate the spins of the MNPs out of plane. In MFM images an out-of-plane configuration manifests itself by a contrast enhancement at the film edge. This theoretical prediction is confirmed by the experimental MFM images of a single-layer film. Multi-layer films are found to be more robust against external fields than monolayers. Both calculated and measured MFM images show that the domain pattern of multi-layer films is still oberved under external fields that prevent the observation of the domain pattern of single-layer films. The nature of the collective reaction on the external perturbation will be discussed in detail and will be compared to non-interacting MNPs.

## MA 37: Spin Dependent Transport Phenomena

Time: Thursday 15:15–19:45 Location: HSZ 403

MA 37.1 Thu 15:15 HSZ 403

**Spin-polarized tunneling through $SrTiO_3$ and $BaTiO_3$ barriers** — •Daniel Wortmann and Stefan Blügel — Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

With the increased experimental control in growing transition-metal oxides in thin films of high quality, the fabrication of tunneljunctions containing e.g. $SrTiO_3$ and $BaTiO_3$ barriers became possible. Such junctions can be viewed as the prototype of new oxide-electronic devices employing the rich physics of transition-metal oxides for novel functionalities. In particular the large dielectric response of e.g. $SrTiO_3$ or even the ferroelectricity of $BaTiO_3$ can be exploited for innovative tunneling setups.

We present *ab initio* calculations of spin-polarized transport in tunneljunctions with magnetic $SrRuO_3$ leads and $SrTiO_3$ and $BaTiO_3$ insulating barriers. These calculations have been performed within the FLAPW method as implemented in the Jülich `FLEUR` code (www.flapw.de) and utilize the newly developed linearly scaling Greenfunction method that will presented in another presentation of this conference [1]. Detailed studies of the electronic structure of the barrier, i.e. of their complex bandstructure, will be presented demonstrating that these materials form significantly more complex barriers than simple oxides like $MgO$.

Support from the SPP-1243 of the DFG is gratefully acknowledged.

[1] F. Freimuth, D. Wortmann, S. Blügel, *Embedding based order-N implementation of the FLAPW method*

MA 37.2 Thu 15:30 HSZ 403

***Ab initio* study of antiferromagnetic Cr interlayers in Fe/MgO/Fe junctions** — •Peter Bose[1], Peter Zahn[1], Ingrid Mertig[1], and Jürgen Henk[2] — [1]Martin Luther University Halle-Wittenberg, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

One important issue for spintronics applications is the ability to tune the tunnel magnetoresistance (TMR) ratio, for example by insertion of metallic buffers into Fe/MgO/Fe tunnel junctions. Promising candidates are antiferromagnetic chromium interlayers which are intensively investigated experimentally and thus lend themselves support for a theoretical investigation.

We show by first-principles electronic-structure and transport calculations that the desired increase of the TMR ratio is not achieved. Instead, a strong exponential decay with Cr thickness is observed. Further, the conductances—and so the TMR ratio—oscillate with a period of 2 monolayers, which can be traced back to the layerwise antiferromagnetic structure of bcc Cr(001). A detailed analysis of layer-resolved and symmetry-decomposed spectral densities reveals that the electronic transport is mainly determined by the Cr/MgO interface.

MA 37.3 Thu 15:45 HSZ 403

**Electronic Transport Properties of Magnetic Tunnel Junctions at High Temperatures** — •Markus Meinert, Jan Schmalhorst, Daniel Ebke, Andy Thomas, and Günter Reiss — Department of Physics, Bielefeld University, Germany

In this contribution the results of electronic transport measurements on magnetic tunnel junctions (MTJs) at high temperatures will be presented. Two types of magnetic tunnel junctions were invesigated. First, junctions based on the half-Heusler alloy CoMnSb with a Curie-temperature of about 500K. And second, CoFeB/MgO/CoFeB junctions, which were characterized *in-situ* during an annealing process and after a conventional annealing.

The evolution of the TMR effect with temperature and bias voltage of the CoMnSb based junctions will be discussed as well as the temperature dependence of the TMR effect and the resistance of CoFeB/MgO/CoFeB-junctions.

MA 37.4 Thu 16:00 HSZ 403

**ZnO-based magnetic tunnel junctions** — •Shengqiang Zhou[1], Qingyu Xu[2], L. Hartmann[3], A. Muecklich[1], M. Helm[1], G. Biehne[3], H. Hochmuth[3], M. Lorenz[3], M. Grundmann[3], and H. Schmidt[1] — [1]Forschungszentrum Dresden-Rossendorf, Bautzner Landstraße 128, 01328 Dresden — [2]Southeastern University, Nanjing 211189, China — [3]Universität Leipzig, Linnéstraße 5, 04103 Leipzig

Spin-polarized tunnel magnetoresistance (TMR) effects occur when two ferromagnets are separated by a thin insulator. The resistance of the tunneling current changes with the relative magnetization orientation of the magnetic bottom and top electrode. The research is fuelled by the demanding of magnetoresistive random access memory (MRAM) devices. Novel MRAM cells are based on magnetic tunnel junctions with current-induced switching. It has been shown that semiconductors need a current pulse for switching which is two orders of magnitude smaller in comparison to metals [1]. In this talk, we report the clearly observed tunneling magnetoresistance at 5 K in magnetic tunnel junctions with Co-doped ZnO as the bottom electrode and Co as the top electrode prepared by pulsed laser deposition and thermal evaporation [2], respectively. Spin-polarized electrons were injected from Co-doped ZnO to the crystallized Al2O3 separation layer and tunnelled through the amorphous part of the Al2O3 barrier. Our studies demonstrate the spin polarization in Co-doped ZnO and its

possible application in future ZnO-based spintronics devices. [1] M. Yamanouchi et al., Nature 428, 539 (2004). [2] Q. Xu et al., Phys. Rev. Lett. 101, 076601 (2008).

MA 37.5 Thu 16:15 HSZ 403

**Hot electron transport in thin bcc FeCo spin valves - Room temperature Magnetocurrent exceeding 1200%** — Christoph Kefes, •Emanuel Heindl, Johann Vancea, and Christian Back — Department of Physics, University of Regensburg, 93040 Regensburg, Germany

We use the tip of a scanning tunneling microscope to create a nonequilibrium unipolar electron distribution in a metal layer and measure the subsequent perpendicular ballistic hot electron transport through thin single crystalline metallic spin valves by employing ballistic electron emission microscopy (BEEM). By variation of the thickness of one of the ferromagnetic layers we can determine the spin dependent attenuation lengths which reflect the bulk hot electron transport along the [100]-axis of the bcc FeCo-layers. While the minority spin attenuation length is found to be energy independent and about 0.8 nm, the majority spin attenuation length is about 6 times larger within the measured energy interval of 1.3 up to 2 eV above the Fermi level. Consequently, a magnetocurrent effect exceeding 1200 % accompanied by a monotonic bias voltage behavior is observed at room temperature.

MA 37.6 Thu 16:30 HSZ 403

**Temperature dependent non local spin precession in lateral all-metal spin valves** — •Jeannette Wulfhorst, Andreas Vogel, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

All-metal spin-valve devices are studied to determine spin-dependent effects in normal metals. The non local spin-valve effect has been measured with spin-valve devices consisting of permalloy, copper or aluminum, and aluminumoxide. With a perpendicular external magnetic field the Hanle effect, i.e. spin precession of the electrons injected into a normal metal, is observed [1]. Transport measurements at various temperatures have been performed. Spin-dependent phenomena, namely the non local spin-valve effect and spin precession, are observed. A theoretical description of spin-dependent transport is presented including spin diffusion, spin relaxation, spin precession, and tunnel barriers. From the comparison of the experimentally observed spin precession to the theoretical description, we obtain a spin-relaxation time of 78 ps and a spin-relaxation length of 703 nm in aluminum. In copper a spin-relaxation time of 68 ps and a spin-relaxation length of 2571 nm are determined.

[1] A. van Staa, J. Wulfhorst, A. Vogel, U. Merkt, and G. Meier, Phys. Rev. B **77**, 214416 (2008)

MA 37.7 Thu 16:45 HSZ 403

**Time dependent dielectric breakdown in Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions.** — •Ayaz Arif Khan, Jan Schmalhorst, Karsten Rott, Andy Thomas, and Günter Reiss — Thin films and physics of Nano structures Department of Physics, Bielefeld university, P. O. Box 100131, 33501 Bielefeld germany.

The reliability of magnetic tunnel junctions (MTJs) is a key issue for their application in sensing or storing devices. We have investigated the time dependent dielectric breakdown in Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions deposited on thermally oxidized silicon wafers and focused on its dependence on the barrier thickness(1.8 to 4nm), junction area, polarity of the applied voltage, ramp speed and annealing temperature. Measurements with positive and negative polarities are carried out by a voltage ramp method. The junctions with an area from $15 \times 15$ to $25 \times 25 \mu m^2$ were patterned using laser lithography process, leading to a tunneling magneto resistance (TMR) up to 174% with a 1.8 nm thick barrier. It is found that the TMR decreases with increasing barrier thickness and a 4 nm thick barrier shows no TMR at room temperature. The observed intrinsic failure due to voltage stress-induced degradation of an insulator is characterized by an abrupt decrease in resistance at the breakdown voltage. The junction studied show an average DC breakdown voltage from 1.72 to 3.48 V depending on barrier thickness and on polarity of the applied voltage.The breakdown voltage increases linearly with the MgO thickness and the resistance area product increases from $96 k\Omega\mu m^2$ to $461 M\Omega\mu m^2$ in this investigated thickness range.

MA 37.8 Thu 17:00 HSZ 403

**Examination of manipulation of domain walls by pure diffusive spin currents** — •Andreas Lörincz[1], Dennis Ilgaz[1], Lutz Heyne[1], Jan Rhensius[1,2], Stephen Krzyk[1], Mathias Kläui[1], Laura J. Heyderman[2], and Ulrich Rüdiger[1] — [1]Universität Konstanz, 78462 Konstanz — [2]Paul Scherrer Institut, 5232 Villigen, Schweiz

Non local spin valves (NLSV) have drawn much attention over the last years, due to their physical porperties and behaviour as well as the perspective of application in different ultra-low power dissipation devices. The advantage of the NLSV is the ability to examine purely the effects of spin currents without contributions from charge currents, which entail Joule heating.

By separating the charge current from the spin current we can study the effects of spin current absorption by a ferromagnet with a domain wall. Using transport measurements at variable temperature, we determine the domain wall depinning properties as a function of the spin accumulation. We then compare the effect to Oersted field-induced domain wall depinning [1].

References: [1] D. Ilgaz et al., Appl. Phys. Lett. 93, 132503 (2008)

MA 37.9 Thu 17:15 HSZ 403

**Magnetoresistance effects of Co/Pt layered structures** — •André Kobs, Simon Hesse, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

We have investigated the current in plane (CIP) magnetoresistance (MR) of Co/Pt single and multilayers at room temperature. In case of multilayers with 4 fold repetition, the Pt interlayer thickness has been varied from 1 nm to 10 nm with a fixed Co thickness of 0.7 nm (perpendicular magnetization). In case of single layers, the Co thickness has been varied between 0.5 nm (perpendicular magnetization) and 5 nm (in plane magnetization). The MR of the samples has been measured in three different geometries, with the magnetic field applied in plane parallel and perpendicular to the current direction, respectively, as well as perpendicular to the film plane (out of plane geometry). In all geometries the anomalous Hall effect (AHE), which is sensitive to the perpendicular component of magnetization, has been measured simultaneously. In contradiction to the anisotropic MR (AMR) of bulk materials we find, that the perpendicular in plane saturation resistance is significantly smaller than the perpendicular out of plane resistance. For Co single layers the opposite effect was found [1]. In case of samples with perpendicular magnetization, antisymmetric peaks at the fields of magnetization reversal occur [2].

[1] W. Gil et al., Phys. Rev. B **72**, 134401, (2005)
[2] X. M. Cheng et al., Phys. Rev. Lett. **94**, 017203 (2005)

**15 Min. break**

MA 37.10 Thu 17:45 HSZ 403

**Magnetoresistance of iron thin films on facetted $Al_2O_3$-substrates** — •Sebastian Mooser and Martin Jourdan — Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

$Al_2O_3$(100) substrates are annealed at high temperatures in air which results in a facetted surface. A layer of iron is deposited via molecular beam epitaxy. The deposition temperature, the thickness, the angle of the beam respective to the sides of the facets as well as the annealing process after the deposition are varied. The shape of the facets is analysed via in-situ STM and ex-situ AFM after Al-capping, respectively. The growth of iron on facetted $Al_2O_3$ is analysed via four-circle-diffractometry. Finally, the resistance depending on the applied magnetic field is measured at different temperatures. A change in resistance up to 0.5% has been achieved yet. A possible morphological origin of the observed magnetoresistance is proposed. Small iron grains building sorts of nano-wires give rise to the resistance being dependent on the applied magnetic field.

MA 37.11 Thu 18:00 HSZ 403

**Current induced resistance change of magnetic tunnel junctions** — •Patryk Krzysteczko[1], Xinli Kou[1,2], Karsten Rott[1], Andy Thomas[1], and Günter Reiss[1] — [1]Thin Films and Physics of Nanostructures, Bielefeld University, 33615 Bielefeld, Germany — [2]School of Physical Science and Technology, Lanzhou Universuty, Lanzhou, China

Ultra-thin magnetic tunnel junctions with low resistive MgO tunnel barriers are prepared to examine their stability under large current stress. The devices show magnetoresistance ratios of up to 110 % and an area resistance product of down to 4.4 $\Omega\mu m^2$. If a large current is

applied, a reversible resistance change is observed, which can be attributed to two different processes during stressing and one relaxation process afterwards. Here, we analyze the time dependence of the resistance and use a simple model to explain the observed behavior. The explanation is furter supported by numerical fits to the data in order to quantify the timescales of the involved phenomena.

MA 37.12 Thu 18:15 HSZ 403

**Resistance of domain walls in epitaxial Fe wires on GaAs(110)** — •Christoph Hassel[1], Florian M. Römer[1], Nathalie Reckers[1], Sven Stienen[1], Florian Kronast[2], Günter Dumpich[1], and Jürgen Lindner[1] — [1]Fachbereich Physik, AG Farle, CeNIDE, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Bessy GmbH, Berlin

From epitaxial Fe films grown on GaAs (110) wires of different widths are prepared using electron beam lithography and Ar sputtering. Since the coercive field of longitudinally magnetized wires depends on the width of the wires, it is possible to pin a domain wall at the transistion between a smaller and a wider wire. The resistance of this domain wall is measured and contains contributions from the anisotropic magnetoresistance (AMR) and the domain wall resistance. Micromagnetic calculations are performed to study the structure of the domain wall and estimate contributions of the AMR. Furthermore, a magetic force microscope tip is used to create a different number of domain walls in transversally magnetized wires in a controlled way. The additional resistance contribution due to the presence of the domain walls is measured and the contributions from AMR are estimated by micromagnteic calculation. This work is financially supported within the SFB 491.

MA 37.13 Thu 18:30 HSZ 403

**Transport through Single Molecule Magnets with Magnetic Field and Polarized Electrodes** — •Nikolaos P. Konstantinidis[1,2,3] and Maarten R. Wegewijs[1,2,3] — [1]Institut für Theoretische Physik A, Physikzentrum, RWTH Aachen, 52056 Aachen, Germany — [2]Institut für Festkörperforschung-Theorie III, Forschungszentrum Jülich, Leo-Brandt-Strasse, 52425 Jülich, Germany — [3]JARA-Fundamentals of Future Information Technology

We investigate transport through single molecule magnets (SMMs) contacted by non-colinear magnetic and non-magnetic electrodes in the single electron tunneling regime. We show that an external magnetic field splits the negative differential conductance (NDC) that originates in weakly allowed spin-transitions between states in different charge sectors. The resulting current oscillations as a function of the applied voltage depend on the direction of the magnetic field relative to the easy axis of the molecule. We also show how Berry-phase interference appears as crossing and anticrossing lines in conductance maps in magnetic field and applied voltage. We analyze the detailed dependence of the current on the electrode polarizations and the arbitrary angles with each other and the easy axis of the SMM.

MA 37.14 Thu 18:45 HSZ 403

**Femtosecond spin dynamics induced by ballistic transport of spin-polarized carriers in Au/Fe/MgO(001)** — A. Melnikov[1], I. Razdolski[2], T. Wehling[3], A. Lichtenstein[3], E. Papaioannou[1], Ch. Rüdt[1], P. Fumagalli[1], O. A. Aktsipetrov[2], and •U. Bovensiepen[1] — [1]Freie Universität Berlin, Fachbereich Physik, 14195 Berlin, Germany — [2]Physics Department, Moscow State University, Moscow, 119992, Russia — [3]Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany

Scattering of hot carriers can be studied by ballistic electron microscopy. Here, we present a complementary approach using femtosecond laser pulses in a pump-probe experiment. We demonstrate an all-optical back-pump front-probe scheme to analyze the transport of spin-polarized hot carriers through Au/Fe/MgO(001). We excite hot carriers in 15 nm thick Fe by absorption of an 800 nm laser pulse. The spin-polarized hot carriers propagate subsequently at the Fermi velocity through the layer stack. A time-delayed second laser pulse generates its optical second harmonic (SH) in reflection at the opposite Au surface. We monitor the SH intensity as a function of pump-probe delay for opposite Fe magnetization directions, which facilitates an analysis of the spin and carrier propagation through Au. From the observed transfer time and its broadening we conclude that the carriers propagate ballistically for 50 nm Au and diffusively for 100 nm. Interestingly, the magneto-optical signal changes its sign after 500 fs, which is discussed in terms of local spin reorientation and different propagation velocities for minority and majority carriers.

MA 37.15 Thu 19:00 HSZ 403

**Hall effect and electronic structure of half metallic $Co_2Fe_xMn_{1-x}Si$ films** — •Gerhard Jakob[1], Horst Schneider[1], Enrique Vilanova[1], Stanislav Chadov[2], Gerhard Fecher[2], and Claudia Felser[2] — [1]Institute of Physics, Johannes Gutenberg-University, 55099 Mainz, Germany — [2]Institute of Anorganic and Analytical Chemistry, Johannes Gutenberg-University, 55099 Mainz, Germany

Half metals are defined by the existence of an energy gap at the Fermi energy for one spin direction. Keeping half metallicity at room temperature requires not only a large gap but also the Fermi energy to be far away from the band edges. As a model system we chose the system $Co_2Fe_xMn_{1-x}Si$, where the Fermi energy was calculated to move from the valence band edge of the minority states to the conduction band edge with increasing x. On high quality laser ablated epitaxial films we observe a sign change of the normal and anomalous Hall effect with doping. The experiments are discussed in comparison to band structure calculations done in the LSDA+U scheme.

Financial support by the DFG through project Ja821/2-3 within research unit 559 is gratefully acknowledged

MA 37.16 Thu 19:15 HSZ 403

**Spin-filtering in thin magnetic insulator barriers: EuO** — •Martina Müller[1,2], Guo-Xing Miao[1], and Jagadeesh S. Moodera[1] — [1]Francis Bitter Magnet Laboratory, Massachusetts Institute of Technology, Cambridge, USA — [2]Institute of Solid State Research, Research Center Jülich, Jülich, Germany

The magnetic insulator Europium Oxide (EuO) has been recognized as a promising material for the generation of highly spin-polarized currents. Its spin-filtering property is due to exchange splitting of the conductance band below the ferromagnetic transition temperature $T_c$. Especially challenging is to achieve sizable magnetic ordering and exchange splitting in thin (< 6 nm) EuO films, which is the thickness regime of spin-filter tunnel barriers.

In this work, we studied the magnetic and transport properties of 1 – 6 nm EuO films to explore their spin filtering efficiency. We found the EuO thickness being one of the primary factors scaling the Curie temperature $T_c$ and the onset of the metal-insulator transition. We show, that the reduced magnetic ordering at interfaces due to structural and chemical intermixing becomes particularly relevant in the low thickness regime. Current-voltage measurements of EuO-based tunnel junctions showed a strongly bias-dependent, two-step Fowler-Nordheim-type tunneling characteristics. Moreover, we could determine an exchange splitting of $\phi$=0.5 eV of the conduction band (CB) of 4nm EuO barriers by fully electrical means. The results show a direct correlation of the temperature-dependent change of the CB height with the EuO magnetic state.

MA 37.17 Thu 19:30 HSZ 403

**Measurement of the spin polarisation of $Co_2FeSi$ with Andreev reflection point-contact spectroscopy** — •Samuel Bouvron[1], Michael Marz[1], Gernot Goll[1], and Claudia Felser[2] — [1]Physikaliches Institut, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität, 55099 Mainz, Germany

With a theoretical spin polarisation $P$ of 100 % at the Fermi level, a Curie temperature of 1100 K and a high magnetic moment of 6 $\mu_B$, the ferromagnetic Heusler alloy $Co_2FeSi$ exhibits advantageous properties for magnetoelectronic or spin-electronic devices. Spin polarisation measurements were performed on polycrystalline and single-crystalline $Co_2FeSi$ and $Co_2FeAl_{1-x}Si_x$ samples, using Andreev reflection spectroscopy in ferromagnet/superconductor (F/S) point contacts which were realized with the needle-to-anvil method with a mechanical control of a superconductive Pb tip. Analyses of the conductance spectra were carried out by the Cuevas modell, which is based on the Landauer-Büttiker formalism with spin dependent transmission coefficients $\tau_{\uparrow(\downarrow)}$ with $P = (\tau_\uparrow - \tau_\downarrow)/(\tau_\uparrow + \tau_\downarrow)$. The extracted polarisation was lower than expected from band-structure calculations, the maximal measured value being 56 %. A decrease of the polarisation both with increasing size of the contact and increasing potential barrier at the F/S interface hints at possible origins of the reduced current spin polarisation among which spin-orbit scattering in the contact region [1] is the most prominent candidate.

[1] M. Stokmaier *et al.*, Phys. Rev. Lett. 101, 147005 (2008)

# MA 38: Multiferroics

Time: Thursday 15:15–19:30 Location: HSZ 103

MA 38.1 Thu 15:15 HSZ 103

**Interface modification in LCMO-BTO superlattices** — •Kai Gehrke, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

At perovskite interfaces, electric, magnetic and multiferroic (MF) properties can be different from those in bulk. Especially in manganite thin films and superlattices (SL) it is well known that breakage of symmetry at interfaces lead to orbital, charge and spin reconstructions[1]. Moreover, interfacial stress, which leads to lattice distortions, greatly influences ferromagnetic as well as ferroelectric polarizations. $(LaCa)MnO_3-BaTiO_3$ SL have been grown by a metalorganic aerosol deposition technique on MgO and STO substrates. Besides the magnetic properties, Magnetocapacitance as well as third harmonic Voltages have been measured to clarify the influence of the interfaces and their relation to the formation of correlated polaros. We show that compositional grading of the $(LaCa)MnO_3$ at the interfaces modifies the magnetic, electric and MF properties in a positive way. The magnetisation is increased, the manganite resistance is strongly reduced and third harmonic voltages are depressed. The work was supported by the Deutsche Forschungsgemeinschaft via SFB 602, project A2.

[1] Luis Brey, "Electronic phase separation in manganite-insulator interfaces", PHYSICAL REVIEW B 75, 104423 (2007)

MA 38.2 Thu 15:30 HSZ 103

**Colossal elastoresistance of phase separated $(Pr_{1-y}La_y)_{0.7}Ca_{0.3}MnO_3$ thin films** — •Maartje Dekker, Steffen Oswald, Ludwig Schultz, and Kathrin Doerr — IFW-Dresden, Germany

The use of a piezoelectric substrate [1], PMN-PT (001) $(PbMg_{1/3}Nb_{/3}O_3)_{0.72}(PbTiO_3)_{0.28}$, allows us to biaxially compress as grown epitaxial films by as much as 0.2%. This reversible dynamic strain process gives a unique insight into the effect of strain on perovskite oxides, eliminating effects such as varying oxygen concentration, which may occur when several substrates with different lattice mismatch are used.

We have prepared phase separated PLCMO $(Pr_{1-y}La_y)_{0.7}Ca_{0.3}MnO_3$ films on PMN-PT for a range of $y$ values. Around $y = 0.6$, the system exhibits a transition from an insulating to a metallic ground state. When partially releasing the as grown tensile strain of the PLCMO film by piezo-compression of the substrate, we find a huge reduction of the resistance, or "colossal" elastoresistance. The relaxed films show an enhanced magnetisation and an increase in magnetic transition temperature. Thus we can conclude that tensile strain efficiently suppresses the ferromagnetic conducting phase and favours the charge ordered state.

[1] C. Thiele et al., Phys. Rev. B 75, 054408 (2007)

MA 38.3 Thu 15:45 HSZ 103

**Magnetism and magnetotransport of strained epitaxial $La_{1-x}Sr_xCoO_3$ (x = 0.18; 0.3) films** — •Orkidia Bilani-Zeneli, Andreas Herklotz, Diana Rata, Ksenia Boldyreva, Ludwig Schultz, Nadja Kozlova, and Kathrin Dörr — IFW Dresden, Postfach 270116, 01171 Dresden

Perovskite cobaltites $La_{1-x}A_xCoO_3$ (A = Sr, Ca) have been investigated in bulk form for the temperature- and pressure-dependent spin state of Co ions for decades. Magnetic studies of epitaxially grown films are rare, but recent work on $LaCoO_3$ has indicated the potential for strain-controlled magnetism [1].

In this work, films of $La_{1-x}Sr_xCoO_3$ (x = 0.18; 0.3) have been grown epitaxially on substrates of various lattice mismatch ($SrTiO_3$, $LaAlO_3$, LSAT, PMN-PT) by off-axis pulsed laser deposition. Film lattice parameters reveal that large strains can be maintained up to thicknesses beyond 60 nm. The films (x = 0.18; 0.3) are ferromagnetic with huge coercive fields indicating large magnetic anisotropy. The effect of biaxial strain on the Curie temperature and the magnetization has been derived from statically strained films and from reversibly strained films on piezoelectric PMN-PT(001). Interestingly, the strain strongly affects the electrical conduction: tensile strain leads to reduced conductivity and a strain-induced insulator state (x = 0.3) [2]. Data on strain-dependent resistance and magnetoresistance in magnetic fields up to 50 T will be discussed. [1] D. Fuchs et al., PRB 75, 144402 (2007); PRB 77, 014434 (2008) [2] A. D. Rata et al., PRL 100, 076401 (2008)

MA 38.4 Thu 16:00 HSZ 103

**Ising magnetism and ferroelectricity in $Ca_3CoMnO_6$** — •Hua Wu[1], T. Burnus[1], Z. Hu[1], C. Martin[2], A. Maignan[2], J. C. Cezar[3], A. Tanaka[4], N. B. Brookes[3], D. I. Khomskii[1], and L. H. Tjeng[1] — [1]II. Phys. Inst, Uni Köln — [2]Lab. CRISMAT, Caen, France — [3]ESRF Grenoble, France — [4]Hiroshima University, Japan

Among a variety of multiferroic materials discovered so far, see review articles [1,2], ferroelectric Ising chain magnet $Ca_3CoMnO_6$ is quite unique, because the ferroelectricity is driven by a magnetostriction in a collinear Ising spin chain consisting of the charge ordered transition-metal ions [3]. In this work, the origin of both the Ising chain magnetism and ferroelectricity in $Ca_3CoMnO_6$ is studied by *ab initio* electronic structure calculations and x-ray absorption spectroscopy. We find that $Ca_3CoMnO_6$ has the alternate trigonal prismatic $Co^{2+}$ and octahedral $Mn^{4+}$ sites in the spin chain. Both the $Co^{2+}$ and $Mn^{4+}$ are in the high spin state. In addition, the $Co^{2+}$ has a huge orbital moment of 1.7 $\mu_B$ which is responsible for the significant Ising magnetism. The centrosymmetric crystal structure known so far is calculated to be unstable with respect to magnetostriction in the experimentally observed ↑↑↓↓ antiferromagnetic structure for the Ising chain. The calculated inequivalence of the Co-Mn distances accounts for the ferroelectricity. [1] S. W. Cheong and M. Mostovoy, Nat. Mater. **6**, 13 (2007). [2] D. I. Khomskii, J. Magn. Magn. Mater. **306**, 1 (2006). [3] Y. J. Choi *et al.*, Phys. Rev. Lett. **100**, 047601 (2008).

MA 38.5 Thu 16:15 HSZ 103

**Quantum paraelectric-like behavior and giant magnetodielectric coupling in $NdFe_3(BO_3)_4$** — •Umut Adem[1], Liran Wang[1], Norman Leps[1], Rüdiger Klingeler[1], Christian Hess[1], Alexander Vasiliev[2], Leonard N. Bezmaternykh[3], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany — [2]Moscow State University, Moscow, 119992, Russia — [3]Kirensky Institute of Physics, Siberian Division, Russian Academy of Sciences, Akademgorodok, Krasnoyarsk, 660036, Russia

We have measured the dielectric constant in addition to specific heat, magnetostriction, and magnetization of magnetoelectric $NdFe_3(BO_3)_4$ single crystals and observed rare quantum paraelectric-like behavior. The dielectric constant increases with decreasing temperature in the temperature range 300 to 5K, more sharply upon the magnetic ordering of Fe spins below 30 K. Application of magnetic field strongly suppresses the additional increase below $T_N$, resulting at 5K, 8 % change in the dielectric constant under 3 Tesla. We speculate that the dielectric behavior originates from soft phonon mode behavior and the coupling of this soft phonon mode to the magnetic ordering causes the giant magnetodielectric coupling. We compare the quantum paraelectric (incipient ferroelectric) behavior and the magnetodielectric coupling of $NdFe_3(BO_3)_4$ to that of $TbFe_3(BO_3)_4$ single crystals.

MA 38.6 Thu 16:30 HSZ 103

**Multiferroicity in $Cu_2OSeO_3$ studied by Raman scattering** — •Vladimir Gnezdilov[1,2], Peter Lemmens[2], Yurii Pashkevich[3], Dietrich Wulferding[2], and Hemuth Berger[4] — [1]ILTP, Kharkov, Ukraine — [2]IPKM, TU Braunschweig, Germany — [3]Donetsk Physteh, Ukraine — [4]IPMC, Lausanne, Switzerland

The lone pair piezoelectric ferrimagnet $Cu_2OSeO_3$ is a unique example of a metrically cubic material that allows linear magnetoelectric coupling as well as piezoelectric and piezomagnetic coupling [1]. The metric cubic lattice excludes a magnetoelectric coupling mechanism involving spontaneous lattice strains. Raman spectra show drastic changes below Tc, namely the appearance of new lines, the splitting of some lines, and anomalies in their temperature behaviour. These observations are discussed in terms of a symmetry reduction and magnetic excitations.

[1]. J.-W. G. Bos, C.V. Colin, and T.T.M. Palstra, arXiv:0808.5955.

MA 38.7 Thu 16:45 HSZ 103

**Magnetic phase transition at a biferroic interface predicted from first principles** — •Michael Fechner[1], Igor Maznichenko[2], Sergey Ostanin[1], Arthur Ernst[1], Jürgen Henk[1], Patrick Bruno[3], and Ingrid Mertig[1,2] — [1]MPI für Mikrostrukturphysik

Halle, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Germany — [3]European Synchrotron Radiation Facility Grenoble, France

On the basis of first-principles electronic-structure calculations we predict that epitaxial multiferroic films—fabricated as ultrathin Fe films deposited on $TiO_2$-terminated (001) surfaces of $ATiO_3$ perovskites (A = Pb, Ba)—exhibit an unexpected change of their magnetic structure with increasing Fe-film thickness. The magnetic order changes from ferromagnetic, with a magnetization of about $3\mu_B/atom$ for the 1-monolayer system, to ferrimagnetic with almost vanishing magnetization upon deposition of a second Fe layer. Ferromagnetic order is restored for thicker Fe films but with significantly reduced magnetization as compared to Fe bulk. The effect is understood in terms of hybridization of electronic states and geometric structure. The magnetoelectric coupling affects the size of the magnetic moments moderately, a spin-reorientation transition is not found.

MA 38.8 Thu 17:00 HSZ 103

*Ab-initio* **prediction of room temperature multiferroic materials** — •Marjana Ležaić[1] and Nicola A. Spaldin[2] — [1]Institut für Festkörperforschung and Institute for advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Materials Department, University of California, Santa Barbara, California 93106-5050, USA

Recently a new ordered double perovskite, $Sr_2CrOsO_6$ was synthesized [1]. This compound is an insulating ferrimagnet with an unusually high Curie temperature of 725 K. With this experiment in mind, we investigate double perovskite compounds ($A_2BB'O_6$) from first principles, focusing on one of the main challenges for the applications of multiferroics: ferroelecticity accompanied by a net magnetization at room temperature. We demonstrate that ferroelectricity can be induced in these compounds by utilizing an A-site cation possessing a stereochemically active lone pair of electrons. Combining a 3*d* and a 5*d* element at the B and B′ sites in an ordered fashion leads to the increase of the magnetic ordering temperature of these ferrimagnets. We also indicate the possibility of strain-assisted switching between antiferroelectric and ferroelectric states.

[1] Y. Krockenberger *et al.*, Phys. Rev. B **75**, 020404(R) (2007).

**15 min. break**

MA 38.9 Thu 17:30 HSZ 103

**X-ray diffraction studies on multiferroic *R*MnO3 compounds in high magnetic fields** — •Jörg Strempfer[1], Britta Bohnenbuck[2], Ioannis Zegkinoglou[2], Nadir Aliouane[3], Dimitri N. Argyriou[3], Alexander Krimmel[4], and Martin von Zimmermann[1] — [1]HASYLAB at DESY, Notkestr. 85, 22603 Hamburg, Germany — [2]MPI/FKF, Heisenbergstr. 1, Stuttgart, Germany — [3]Helmholtz-Zentrum für Materialien und Energie, Glienicker Str. 100, Berlin, Germany — [4]Experimentalphysik V, Universität Augsburg, Augsburg, Germany

Investigations of the multiferroic compounds $TbMnO_3$, $DyMnO_3$ and $Y_{0.2}Eu_{0.8}MnO_3$ by x-ray diffraction in high magnetic fields, oriented along the *a* and *b*-directions of the crystal, are presented. The relation of the behaviour of first and second harmonic reflections to changes in ordering of the rare earth moments in applied field for $TbMnO_3$ and $DyMnO_3$ is discussed [1-3]. Observations below the ordering temperature of the rare earth moments without and with applied magnetic field suggests a strong interaction of the rare earth moments, the Mn moments and the lattice. Since structural first harmonic reflections are absent in $Y_{0.2}Eu_{0.8}MnO_3$, these reflections in the other compounds reflect the ordering of the rare earth moments.

[1] N. Aliouane et al. Phys. Rev. B 73, 020102 (2006)
[2] J. Strempfer et al. Phys. Rev. B 75, 212402 (2007)
[3] J. Strempfer et al. Phys. Rev. B 78, 024429 (2008)

MA 38.10 Thu 17:45 HSZ 103

**Multiferrocity in $MnWO_4$: anomalous ultrasonic dissipation and spin phonon coupling** — •Alexander Doering[1], Peter Lemmens[1], Dietrich Wulferding[1], Sergei Zherlitsyn[2], Christophe Payen[3], Jubo Peng[4], and Chengtian Lin[4] — [1]IPKM, TU Braunschweig, Germany — [2]FZD, Dresden, Germany — [3]IMN, CNRS, Nantes, France — [4]MPI-FKF, Stuttgart, Germany

Ultrasound spectroscopy on the multiferroic $MnWO_4$ show anomalies in the magnetic phase diagram crossing the PM/AF and the AF/spiralAF-polar phase. The scaling of the temperature dependence of the sound velocity is comparable to $YMnO_3$. The sound attenuation show an anomalous, strongly asymmetric peak attributed to excitations with coupled spin-polar character. Work supported by DFG and ESF-HFM.

MA 38.11 Thu 18:00 HSZ 103

**Analysis of ferroelectric and magnetic chiral order in $MnWO_4$** — •Naëmi Leo[1], Dennis Meier[1], Thomas Lottermoser[1], Michael Maringer[1], Petra Becker[2], Ladislav Bohatý[2], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn — [2]Institut für Kristallographie, Universität zu Köln

Spin spiral systems form a particularly interesting subgroup of magnetoelectric multiferroics since violation of inversion symmetry by long-wavelength magnetic order is responsible for the spontaneous electric polarisation. Such intrinsic coupling of magnetism and ferroelectricity is not only promising with respect to future spintronic applications. It also enables fascinating physical effects like the magnetic-field-induced polarisation flop in $TbMnO_3$ or $MnWO_4$.

In our studies we focus on $MnWO_4$, which is a remarkable example of a spin-spiral multiferroic because a single transition-metal ion is responsible for the coexistence of magnetic and electric order. We present a spectral analysis of its multiferroic phase by means of optical second harmonic generation (SHG). With respect to symmetry dependent selection rules we distinguish between crystallographic, antiferromagnetic (AFM) and ferroelectric (FE) SHG contributions of different multipole order. Characteristic temperature dependencies of the associated FE and AFM order parameters further support the attribution. This work is supported by the DFG through SFB 608.

MA 38.12 Thu 18:15 HSZ 103

**First principle calculations of domain boundaries in multiferroic BiFeO3** — •Axel Lubk[1], Nicola Spaldin[2], Sibylle Gemming[3], and Hannes Lichte[1] — [1]Institute for Structure Physics, Technische Universität Dresden, Germany — [2]Materials Department, University of California, Santa Barbara, USA — [3]Institute of Ion Beam Physics and Materials Research,Forschungszentrum Dresden-Rossendorf, Germany

Domain boundaries in ferroic materials deviate from the bulk in both the structural and electronic properties. Their presence in the material influences the total energy of the system, the band structure and the magnetic and electric polarization. We report on a Density Functional Theory (DFT) approach within the Local Density Approximation on domain boundaries in multiferroic BiFeO3 (space group: R3c). Our model systems consist of the experimentally observed 71°, 109° and 180° domain walls. The calculations were performed within the DFT software VASP, incorporating standard pseudopotentials and a plane wave basis set. A complete electronic and ionic relaxation of the model structures has been performed to yield details of the charge and structure modulation at the boundary including the deformation of the Fe-centered oxygen octahedron, the formation of electric dipole layers leading to a jump in the electrostatic potential, band gap narrowing and a domain wall dependent modification of the small ferromagnetic effect present in BiFeO3.

MA 38.13 Thu 18:30 HSZ 103

**Many-particle Approach to Multiferroic Bulk Systems** — •Thomas Michael[1], Steffen Trimper[1], and Julia M. Wesselinowa[2] — [1]Institute of Physics, Martin-Luther-Universitaet, Halle (Saale), Germany — [2]Department of Physics, University of Sofia, Sofia, Bulgaria

Multiferroic bulk systems are studied in a many-particle approach. The magnetization, polarization, excitation energies, associated dampings of ferroelectric and magnetic modes are presented as a function of temperature. An anomaly in the ferroelectric quantities close to the magnetic phase transition is observed. The analysis of the ferroelectric subsystem is based on a two-state quantum model, the Ising model in a transverse field. The magnetic moments interact via the Heisenberg model. The corresponding multiferroic coupling term differs for hexagonal and orthorhombic materials. A Green's function technique in reciprocal space provides the static and dynamic properties. Furthermore, we present the dielectric function of the coupled model. The theoretical result are compared with experimental data.

MA 38.14 Thu 18:45 HSZ 103

**Controlled manipulation and coupling of domains in a spin spiral multiferroic** — •Dennis Meier[1], Michael Maringer[1], Naëmi Leo[1], Thomas Lottermoser[1], Petra Becker[2], Ladislav

Bohatý[2], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn — [2]Institut für Kristallographie, Universität zu Köln

The intrinsically strong cross coupling between magnetism and ferroelectricity in spin spiral multiferroics suggests these systems as prime candidates for novel multifunctional devices. Comprehension and controlling of the correlated antiferromagnetic (AFM) and ferroelectric (FE) domain structures by external fields is an indispensible prerequisite for future device design. However, very few is know about the domain topology and switching of AFM spin spirals and the magnetically induced FE domains. Here we discuss the correlation of AFM domains and FE domains under external electric and magnetic fields in the spin spiral multiferroic $MnWO_4$. Correlations are revealed by optical second harmonic generation. Electric fields are used to uniquely control the magnetic domain structure, leading to an E-field driven hysteresis of the magnetic order parameter. Application of a magnetic field allows to conceal a ferroelectrically stored information, which reemerges as the field is removed. This work is supported by the DFG through SFB 608.

MA 38.15 Thu 19:00 HSZ 103

**Strain-coupled multiferroic model system of magnetic films on piezoelectric PMN-PT(001)** — •Andreas Herklotz, Diana Rata, Ksenia Boldyreva, Orkidia Bilani-Zeneli, Martina Cornelia Dekker, Ludwig Schultz, and Kathrin Dörr — IFW Dresden, Postfach 270116, 01171 Dresden

In many multiferroic composites the interrelation of magnetic and polar electric properties originates from joined elastic strain of the components. A straightforward model system for quantitative investigations of strain-modulated magnetic properties comprises of magnetic films epitaxially grown on high-strain piezoelectric single crystals [1,2].

In this work, we report on structural, ferroelectric and elastic properties of $Pb(Mg_{1/3}Nb_{2/3})O_3$-$PbTiO_3$ (PMN-PT) (001) single crystals utilized as thin film substrates for dynamical strain control of up to 0.25% in complex oxide films [2]. A tunable buffer layer system of solid solutions of perovskite-type $LaScO_3$ and $LaAlO_3$ has been developed that serves to adjust the in-plane parameter of buffered PMN-PT in a range of several percent. Thus, various as-grown strain states of a given magnetic film can be prepared and studied under reversible strain. First examples for $La_{1-x}Sr_xBO_3$ (B = Co or Mn) films under both statically and dynamically varied biaxial strain will be discussed.

[1] C. Thiele et al., PRB 75, 054408 (2007)

[2] M. D. Biegalski, K. Dörr, H. M. Christen (submitted); A. Herklotz et al. (submitted)

MA 38.16 Thu 19:15 HSZ 103

**Voltage controlled inversion of magnetic anisotropy in Ni thin films** — •Mathias Weiler[1], Andreas Brandlmaier[1], Stephan Geprägs[1], Matthias Althammer[1], Matthias Opel[1], Christoph Bihler[2], Hans Huebl[2], Martin S. Brandt[2], Rudolf Gross[1,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Walter Schottky Institut, TU München, 85748 Garching, Germany — [3]Physik-Department, TU München, 85748 Garching, Germany

The control of magnetic properties by means of an electric field is an important aspect in magnetism and magnetoelectronics. We here demonstrate a voltage control of magnetization orientation in Ni thin film/piezoelectric actuator hybrids via magnetoelastic coupling at room temperature [1]. Ferromagnetic resonance (FMR) spectroscopy shows that the in-plane uniaxial magnetic anisotropy of the Ni film is inverted upon changing the polarity of the voltage $V_p$ applied to the actuator. Using SQUID magnetometry, we find that the magnetization orientation can be reversibly rotated in the Ni film plane within a range of approximately 70° by changing $V_p$ alone – even at static external magnetic field strengths well below the Ni coercive field. All magnetometry data can be quantitatively modelled in a Stoner-Wohlfarth approach using the magnetic free energy determined from FMR.

We gratefully acknowledge financial support by the DFG via SPP 1157 (GR 1132/13), GO 944/3 and the German Excellence Initiative via the "Nanosystems Initiative Munich".

[1] M. Weiler *et al.* (2008) arXiv:0810.0389

## MA 39: Invited Talk Hillebrands

Time: Friday 10:15–10:45 Location: HSZ 04

**Invited Talk** MA 39.1 Fri 10:15 HSZ 04

**Magnon gases and condensates** — •Burkard Hillebrands — FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, Germany

A magnon gas is an excellent model system for the investigation of interacting bosonic particles and thus for correlated systems in general. Its potential is due to the wide controllability of the magnon density as well as of the spectral properties influencing the magnon-magnon interaction. The recent observation of Bose-Einstein condensation of magnons at room temperature demonstrates this clearly.

The most effective mechanism to inject magnons into the gas is parametric pumping which creates a condensate of photon-coupled magnon pairs. Formation, thermalization and disintegration of this condensate as well as its interaction with the Bose-Einstein condensate of magnons constitute a hot topic of research.

We use time-, space-, phase- and wave-vector sensitive Brillouin light scattering spectroscopy in combination with conventional microwave techniques to reveal the dynamics of magnon gases and condensates. It is a powerful instrument to investigate the energy transfer inside of the parametrically driven magnon gas, to determine the exact spectral positions of the involved magnon groups, and to observe the pumping-free evolution of the condensates. The role of the electromagnetic pumping field in the behaviour of the magnon gas is of particular interest.

Financial support by the DFG (SFB/TRR 49) is acknowledged.

## MA 40: Poster II: Bio- and Molecular Magnetism (1-9); Magnetic Coupling Phenomena/Exchange Bias (10-15); Magnetic Particlicles and Clusters (16-29); Micro and Nanostructured Magnetic Materials (30-51); Multiferroics (52-64); Spin Injection in Heterostructures (65-67); Spin-Dyn./Spin-Torque (68-93); Spindependent Transport (94-108)

Time: Friday 11:00–14:00 Location: P1A

MA 40.1 Fri 11:00 P1A

**Functionalized multiwalled carbon nanotubes as container for Mn2+-based Molecular Magnets** — •Janet Leschner, Christine Taeschner, Manfred Ritschel, Gesine Kreuzer, Mohammed Yehia, Jorge Borrero, Anupama Parameswaran, Rüdiger Klingeler, Vladislav Kataev, Albrecht Leonhardt, and Bernd Buechner — Leibnitz Institute for Solid State and Material Research, IFW Dresden, 01069 Dresden

We present the hydrothermal synthesis of Mn2+-based molecular magnets, their detailed magnetic and structural characterisation and utility as potential packing material for carbon nanotubes (CNTs). The latter is realised by utilizing open ended diamagnetic CNT carriers which exhibit no residual catalyst particles. The magnetic properties of CNT-molecular magnet-complexes are discussed with respect to the pure material, e.g. manganese-di-mandelate, based on our magnetic susceptibility and ESR (Electron-Spin-Resonance) studies.

MA 40.2 Fri 11:00 P1A

**Magnetic properties of novel binuclear metal-organic com-**

**plexes** — •A. Parameswaran[1], Y. Krupskaya[1], R. Klingeler[1], V. Kataev[1], I. Bezkishko[2], V. Miluykov[2], O. Kataeva[2], O. Sinyashin[2], and B. Büchner[1] — [1]IFW Dresden, D-01171 Dresden, Germany — [2]Arbuzov Institute for Organic and Physical Chemistry, RAS, Kazan, Russia

We present static magnetization and ESR data on novel binuclear complexes containing two transition metal ions TM = Mn or Ni connected by two 1,2-diphosphocyclopentadienide bridges for different ligands L = CO, MeCN and PPh3. In the case of TM = Mn, the effective moment $p_{\mathrm{eff}}$ is in average close to that of the Mn(II) in the low spin state. However, we find a systematic substantial increase of $p_{\mathrm{eff}}$ by passing from L = CO ($p_{\mathrm{eff}} = 1.55\mu_{\mathrm{B}}$) via L = MeCN ($2.2\mu_{\mathrm{B}}$) to L = PPh3 ($p_{\mathrm{eff}} = 2.67\,\mu_{\mathrm{B}}$). The antiferromagnetic (AFM) Curie-Weiss temperatures amount to 1 K, 17 K and 18 K for these ligands, respectively. A systematic change of ESR spectra confirms these observations and reveals an appreciable anisotropy of the Mn - Mn AFM exchange due to the spin-orbit coupling effects. We conclude that by changing the ligand from a strong $\pi$-acceptor type (CO) to a weak one (PPh3) one can tune the electron density at the TM ion thereby affecting its local moment, the strength and the anisotropy of the intramolecurar magnetic exchange. Similarly strong effects are also visible in the Ni analogs. Surprisingly, however, for Ni complexes the magnetic interaction changes to ferromagnetic and is larger in magnitude compared to the Mn counterpart.

MA 40.3 Fri 11:00 P1A

**Mixed-valent maganese high-spin complexes studied by X-ray spectroscopy methods** — •Miriam Baensch[1], Manuel Prinz[1], Christian Taubitz[1], Karsten Kuepper[2], Andreas Scheurer[3], Stefan Sperner[3], Rolf W. Saalfrank[3], Andrei Postnikov[4], and Manfred Neumann[1] — [1]University of Osnabrück, Fachbereich Physik, D-49069 Osnabrück — [2]University of Ulm, Institut für Festkörperphysik, D-89069 Ulm — [3]Universität Erlangen Nürnberg, Department Chemie und Pharmazie, D-91058 Erlangen — [4]Paul Verlaine University, Institute de Physique Electronique et Chimie, 1 Bd Arago, F-57078 Metz, France

The investigations of transition metal containing polynuclear complexes are of current interest due to their relevance to various research areas like bioinorganic chemistry, molecular magnetism and catalysis. There are several manganese containing complexes comprising mixed-valent Mn ions, e.g. $Mn_{12}^{III/IV}$-acetate, the wheel-shaped $Mn_{12}^{II/III}$ and $Mn_{7}^{II/III}$ molecules. For the investigation of the electronic and magnetic structure of those mixed-valent high-spin complexes, it is important to have reference spectra of homonuclear manganese clusters with different Mn valencies. We present our X-ray spectroscopic and theoretical investigations of homo- and mixed-valent molecules, including X-ray photoelectron spectroscopy (XPS) and X-ray absorption spectroscopy (XAS), density functional theory and charge transfer multiplet model (CTM) calculations. We discuss the wheel-shaped, mixed-valent $Mn_{12}$ and $Mn_7$ complexes using our pure $Mn^{II}$ and $Mn^{III}$ reference spectra of the $Mn^{II}$Star, and $Mn_6^{III}$Salox compounds.

MA 40.4 Fri 11:00 P1A

**DFT studies of magnetic molecules** — •Stefan Leiding and Juergen Schnack — Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

The ability to tune the couplings between the spins of individual transition metal atoms by controlled attachment of molecular ligands is investigated with spin-dependent density functional theory. We use the SIESTA program to study the magnetic properties of molecules with single ion anisotropy. Vibrational spectra are evaluated as well.

MA 40.5 Fri 11:00 P1A

**DMRG studies of magnetic molecules** — •Joerg Ummethum and Juergen Schnack — Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

The DMRG technique provides a powerful tool for the investigation of ground state and dynamical properties of low-dimensional strongly correlated quantum systems [1]. The results are most accurate for one-dimensional systems with nearest neighbour interactions but an application to rather complex magnetic molecules described by the Heisenberg model is also possible [2].

We present new results of our DMRG studies of the antiferromagnetic Heisenberg icosidodecahedron for different spin quantum numbers. Special emphasis is laid on the lowest energy levels in the subspaces of total magnetic quantum number which possess a so-called rotational band structure for many systems [3].

[1] S. R. White, Phys. Rev. B **48**, 10345 (1993); U. Schollwöck, Rev. Mod. Phys. **77**, 259 (2005);
[2] M. Exler and J. Schnack, Phys. Rev. B **67**, 094440 (2003);
[3] J. Schnack and M. Luban, Phys. Rev. B **63**, 014418 (2000).

MA 40.6 Fri 11:00 P1A

**X-ray absorption spectroscopy of molecular magnets** — •Zoe Kugler[1], Patryk Krzysteczko[1], Carl-Georg Freiherr von Richthofen[1], Elke Arenholz[2], Andy Thomas[1], Thorsten Glaser[1], and Günter Reiss[1] — [1]Bielefeld University, Bielefeld, Germany — [2]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, USA

We investigated the $Mn_6Cr$ single-molecule magnet (SMM) using x-ray absorption spectroscopy (XAS). The $C_3$-symmetric $Mn_6Cr$ complex is based on three molecular building blocks and has a total spin ground state of $S_t = 21/2$. Any application for this molecuar magnets, such as molecular spintronic devices, require a fundamental understanding of the SMM's behavior on surfaces.

We investigated $Mn_6Cr$ molecules on different surfaces by using x-ray absorption spectroscopy. To investigate the SMMs structural behavior with respect to the conductivity of the surface we have adsorbed the molecules on top of 'half' magnetic tunnel junctions (MTJ), where the top layer is the insulating barrier of a conventional MTJ. By varying the thickness of the barrier we could influence the conductivity of the top layer and therefore the interaction of the SMM with the surface. We will present the temperature dependent XA spectra from 3K up to 300K.

MA 40.7 Fri 11:00 P1A

**Inelastic electron tunneling spectroscopy on single molecule magnets in MgO based magnetic tunnel junctions** — •Jana Münchenberger, Zoe Kugler, Andy Thomas, and Günter Reiss — Bielefeld University, Universitätsstraße 25, D-33615 Bielefeld

We investigated single molecule magnets (SMMs) on MgO based magnetic tunnel junctions (MTJs). The junctions are prepared by dc- and rf-magnetron sputtering in a vacuum system with a base pressure of $10^{-7}$mbar. The MTJs with MgO barrier are doped with SMMs to investigate their vibrational modes on the barrier's surface by IET-Spectroscopy.

We tested the MTJs with regard to the influence of several preparation parameters such as annealing temperature, solvent and solvent concentration on the barrier and the TMR ratio. We succeeded to produce MgO based MTJs doped with SMMs with a TMR ratio of about 34% at room temperature and 52% at 13 K (annealed at $170^0C$).

The vibrational modes are obtained by IETS-measurements at low temperature. The results are compared with IR-spectra of the molecules. First measurements showed a good agreement between the IET-spectra and the IR-spectra of the molecules.

MA 40.8 Fri 11:00 P1A

**Investigation of Electronic Spin Dynamics in the Giant Keplerat Molecule $Fe_{30}Mo_{72}$ by $^{57}$Fe Moessbauer Spectroscopy and Magnetisation Measurements** — •Til Dellmann[1,2], F. Jochen Litterst[1], H.-Henning Klauss[2], Jürgen Schnack[3], Bernd Büchner[4], Anupama Parameswaran[4], Rüdiger Klingeler[4], and Achim Müller[5] — [1]IPKM TU Braunschweig — [2]IFP TU Dresden — [3]Fakultät für Physik, Uni Bielefeld — [4]IFW Dresden — [5]Anorganische Chemie I, Uni Bielefeld

In the frustrated polyoxomolybdate nanomolecule $Fe_{30}Mo_{72}$, 30 Fe(III) ions (S=5/2) are located on the vertices of an icosidodecahedron coupled via nearest neighbor antiferromagnetic interactions $J_0$. However, recent ac suszeptibility measurements by Schröder et al. [1] show that the interactions are non-isotropic and can be described by a random distribution around $J_0$.

We performed $^{57}$Fe Moessbauer spectroscopy on this system down to 2 K. Dynamic magnetic hyperfine spectra with magnetically inequivalent sites appear below 6 K. We conclude slow paramagnetic relaxation in agreement with dc magnetisation measurements. Furthermore, the magnetic field dependence at low temperatures (T=50mK) has been studied by ac susceptibility measurements. No magnetsation steps could be observed as predicted by the quantum rotational band model [2]. The implications of our results on this low temperature quantum model are being discussed on the poster.

[1] C. Schröder et al., Phys.Rev.B 77 (2008), 224409
[2] J. Schnack et al., Europhys. Lett., 56 (6), pp. 863-869 (2001)

MA 40.9 Fri 11:00 P1A

**Spin states of a novel Ni(II) trimer complex** — •Y. Krupskaya[1], A. Parameswaran[1], A. Alfonsov[1], R. Klingeler[1], V. Kataev[1], B. Büchner[1], M. Gressenbuch[2], and B. Kersting[2] — [1]IFW Dresden, D-01171 Dresden — [2]Institute of Inorganic Chemistry, University of Leipzig, D-04103 Leipzig

We have investigated magnetic properties of a novel macrocyclic chelate trinuclear Ni(II)-Complex $[Ni_3(L)(OAc)_2]$ with $[O_3N_2\mathbf{Ni}(\mu\text{-}S)\mathbf{Ni}(N_2O_2)(\mu\text{-}S)\mathbf{Ni}N_2O_3]$ as the core by measurements of the static magnetization $M$ and high-frequency $\nu$ tunable electron spin resonance (HF-ESR). Both temperature $T$ and magnetic field $B$ dependences of $M$ reveal an appreciable antiferromagnetic coupling between three Ni(II) ($3d^8$, $S_{\rm Ni} = 1$) ions in the complex which is maintained by $\mu$-sulphur bridges. The data on the saturation magnetization at $T = 2\,\mathrm{K}$ give evidence that the ground state of the molecule can be characterized by a total spin $S_0^{\rm tot} = 1$. A strong nonlinear development of the inverse magnetic susceptibility $\chi(T)^{-1} = [M(T)/B]^{-1}$ in the range $T = 2 - 100\,\mathrm{K}$ measured at $B = 1$ and $5\,\mathrm{T}$ indicates a thermal activation of high energy spin multiplets $S_1^{\rm tot} = 2$ and $S_2^{\rm tot} = 3$. In this $T$-regime HF-ESR measured at $\nu = 92 - 350\,\mathrm{GHz}$ and $B$ up to $15\,\mathrm{T}$ reveals multiple excitations associated with the intramultiplet spin-flip transitions. The $\nu$-dependence of the resonance field of the ESR modes yields a magnetic anisotropy gap of the order of $50\,\mathrm{GHz}$ ($\sim 2.4\,\mathrm{K}$) and a $g$-factor of $\sim 2.2$. We propose a scheme of the energy spectrum of the spin states and discuss the relationship between magnetic interactions and the topology and chemical bonding in this spin trimer complex.

MA 40.10 Fri 11:00 P1A

**Tuning the static and dynamic magnetization properties of exchange bias modulated thin films** — •Christine Hamann[1], Jeffrey McCord[1], Jürgen Fassbender[2], Roland Mattheis[3], Rainer Kaltofen[1], Rudolf Schäfer[1], and Ludwig Schultz[1] — [1]IFW Dresden — [2]Forschungszentrum Dresden-Rossendorf — [3]IPHT Jena

Aiming for new magnetic properties, the lateral combination of different magnetic properties into hybrid magnetic thin film structures are of increasing interest. We investigated exchange bias patterned thin NiFe/IrMn films to correlate the static and dynamic magnetization processes of the artificial hybrid material to the intrinsic material properties. Arrays of stripes with modulated exchange bias, i.e. exchange bias strength and direction, and a periodicity of a few micrometers were created. Inductive magnetometry revealed a distinct influence of geometry and orientation on the magnetization loop yielding either single-step shifted hysteresis loops or two-step loops with exchange spring effect. By means of high resolution Kerr microscopy, this could be attributed to either coherently or separately reversed stripe magnetization. As for the dynamics, the films exhibited either multiple resonance frequencies (as superposition of the input properties) or a single hybrid resonance frequency. The acquired frequencies at zero bias field as well as according damping parameters could be varied by a factor of about two. The different phenomena are discussed in terms of direct exchange coupling via the extended NiFe film as well as quasi-magnetostatic interactions at the stripe interfaces.

MA 40.11 Fri 11:00 P1A

**Modification of the magnetostatic coupling in NiFe/Au/Co/Au multilayers by He-ion bombardment through a nanosphere mask** — •Oliver Buhl[1], Dieter Engel[1], Tanja Weis[1], Arno Ehresmann[1], W. Glapka[2], Piotr Kuswik[2], Maciej Urbaniak[2], M. Blaszczyk[2], Bogdan Szymanski[2], Feliks Stobiecki[2], Iosif Sveklo[3], Andrzej Maziewski[3], and K. Joszwiak[4] — [1]Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]Institute of Physics, Polish Academy of Sciences, Poznań, Poland — [3]Faculty of Physics, University of Białystok, Poland — [4]Poznań University of Technology, Institute of Materials Science, Poznań, Poland

He-ion bombardment through a nanosphere mask enables locally a defined modification of the magnetostatic coupling between the NiFe and the Co layers. A single layer of polystyrene nanospheres arranged in a regular hexagonal lattice on top of the layer system can be used as a lithography mask in combination with keV-He-ion bombardment, resulting in local anisotropy reductions around the spheres. This could be visualized by a regular artificially created domain structure with hexagonal symmetry, observed when a perpendicular-to-plane magnetic field of a certain value has been applied [1]. First results of VSM and MFM measurements will be presented.

[1] W. Glapka, P. Kuświk, I. Sveklo, M. Urbaniak, K. Jóźwiak, T. Weis, D. Engel, A. Ehresmann, M. Błaszczyk, B. Szymański, A. Maziewski, F. Stobiecki, Acta. Phys. Pol., (2008) at press

MA 40.12 Fri 11:00 P1A

**Controlled positioning of nanobeads by strayfields of artificial topographically flat magnetic patterns generated by keV-He-ion bombardment** — •Daniel Lengemann, Alla Albrecht, Jannick Langfahl-Klabes, Tanja Weis, Dieter Engel, 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

Ion bombardment induced lateral magnetic patterning (IBMP) has been used to generate different magnetic patterns (artificial domains) in an IrMn/NiFe bilayer system without changes in the surface topography. This technique enables to create areas with effective antiparallel magnetizations in adjacent patterns stable in remanence. In the resulting stray fields (essentially emitted by the artificial domain walls) it is possible to position nanobeads along these walls. The dependence of this positioning on the domain wall width, domain wall type and size of the nanobeads will be discussed and first results will be presented.

MA 40.13 Fri 11:00 P1A

**Comparison of the behaviour of Magnetic Force Microscopy tips in measurements in external in-plane magnetic fields** — •Christoph Schmidt[1], Tanja Weis[1], Dieter Engel[1], Arno Ehresmann[1], Volker Hoeink[2], Jan Schmalhorst[2], and Guenter Reiss[2] — [1]Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany — [2]University of Bielefeld, Department of Physics, Nano Device Group, P.O. Box 100131, 33501 Bielefeld, Germany

Magnetic Force Microscopy (MFM) measurements in external in-plane magnetic fields are influenced by the undesired effect of the field on the magnetic moment of the tip. A simple approach is to use the point dipole approximation and consider this effect as a tilt of the tip's magnetic dipole moment. By measuring a topographically flat calibration sample with an artificially created periodic magnetic pattern, stable in a certain external magnetic field range this tilt can be determined [1]. The fabrication procedure of ion bombardment induced magnetic patterning (IBMP) for such calibration samples and results of the calibration of two different kinds of commercial MFM tips will be discussed.

MA 40.14 Fri 11:00 P1A

**Study of interfacial spin glass layer in exchange coupled $\mathbf{Ni_{80}Fe_{20}/Ir_{19}Mn_{81}}$ bilayers** — •S. K. Mishra, F. Radu, H. A. Dürr, and W. Eberhardt — Albert-Einstein Str. 15, D-12489, Berlin, Germany

We report on an experimental study of the angular and antiferromagnet thickness dependence of exchange coupling in the $Ni_{80}Fe_{20}/Ir_{19}Mn_{81}$ polycrystalline bilayers. The longitudinal component of the magnetization yields a very rich phenomenology at critical thickness of antiferromagnet. The experimental study suggests a non monotonic behavior for both exchange bias and coercivity fields as the function of antiferromagnetic layer thickness. These results are discussed within the framework of the spin glass model of the exchange bias. Simulations of the magnetic hysteresis loops suggest a variation of the antiferromagnetic anisotropy and of the other interfacial exchange coupling parameters across the critical thickness of the antiferromagnet layer.

MA 40.15 Fri 11:00 P1A

**Highly ordered spin-states in epitaxial $\mathbf{[Co/Cr/Fe/Cr(001)]_n}$ spin-valve type superlattices** — •Frank Brüssing[1], Boris Toperverg[1], Maximilian Wolff[1], Hartmut Zabel[1], and Katharina Theis-Bröhl[2] — [1]Department of Physics, Ruhr-University Bochum, 44780 Bochum, Germany — [2]University of Applied Sciences Bremerhaven, 27568 Bremerhaven, Germany

We have grown $[Co/Cr/Fe/Cr(001)]_n$ epitaxial superlattices on MgO (001) by molecular beam epitaxy with spin valve properties. We adjusted the film thickness of Fe and Co layers such that their magnetization magnitudes are roughly equal. For a proper spin-valve type behavior the Cr spacer thickness was chosen as to provide a week antiferromagnetic coupling in remanence. The quality of the layering and

the epitaxial relationship were verified via x-ray methods. The layer resolved magnetization in the as-grown state and with an applied magnetic field was studied by olarized neutron reflectometry. Ferromagnetic and antiferromagnetic 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. Interestingly, additional half-order peaks appear in the asgrown state indicating a new possibly spiral magnetic state. Applying a magnetic field removes this state irreversibly. We speculate that a combination of magnetic anisotropy and dipolar coupling during growth governs the spiral state. This project was supported by the DFG via SFB491.

MA 40.16 Fri 11:00 P1A

**Superparamagnetic Switching of Two-dimensional Magnetic Islands Studied by Monte Carlo Simulation** — •Thim Stapelfeldt, Elena Y. Vedmedenko, Stefan Krause, Gabriela Herzog, and Roland Wiesendanger — Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

Small islands of magnetic material with strong uniaxial anisotropy can be used to store binary information. To maximize the bit density of storage devices consisting of magnetic islands, the size of these islands has to be shrunk as much as possible. A critical bit density is reached, when the islands become so small that they approach the superparamagnetic (SP) limit.

We present a theoretical investigation of the superparamagnetic behavior of two-dimensional Fe/W(110) islands by means of a Monte Carlo simulation based on a single flip Metropolis algorithm. In our simulations the SP region is defined by characteristic temperatures, that indicate the transitions between different magnetic states, i.e. from paramagnetic to SP and from SP to ferromagnetic state. We present the size dependence of the characteristic temperatures, the energy barriers $\Delta E$ and attempt frequencies $\nu_0$. We compare the energy barriers with energy barriers derived via SP-STM measurements and give a suggestion of the dominating switching mechanism.

MA 40.17 Fri 11:00 P1A

**Kondo effect in a magnetic trimer** — •Philipp Knake and Alexander Chudnovskiy — 1. Institut für Theoretische Physik, Universität Hamburg

The system under consideration is a magnetic trimer on a metallic substrate. To describe it, we use an Anderson model in the low energy sector and in mean field theory. The spin degrees of freedom are taken into account by a fermionisation method first suggested by Popov and Fedotov. While for one single magnetic impurity the physics will be governed by the Kondo-effect, in the case of the magnetic trimer there additionally occur geometric effects (related to the RKKY effect). Instead of just one Kondo-temperature characterising the system of a single atom, there arise three characteristic temperatures in the latter case, the highest determining the physics. For some special geometries of the trimer, like the equilateral triangle and the linear chain, one can solve the mean field equations analytically in some limiting cases and thus achieve analytical expressions for the characteristic temperatures.

MA 40.18 Fri 11:00 P1A

**Influence of magnetostatic interaction between nanoparticles on the magnetization behavior : Comparison between experiments and simulations** — •Srinivasa Rao Saranu, Brook Esseye Anshebo, and Ulrich Herr — Institute of Micro and Nanomaterials,Ulm University,89081 Ulm,Germany

To achieve high density data storage in pattern recording media the particles must arrange as close as possible. Influence of area coverage of the particles on magnetization behavior was studied. Co and Ni nanoparticles were prepared using plasma gas condensation technique. Diameter and area coverage of the particles were measured using SEM. To study the effect of magnetostatic interaction on magnetization behavior, particles was deposited on Si substrate and in-situ covered with Cu film. The area coverage of the particles varied from 3% to 20%. Hysteresis curves for these samples were recorded with field applied in-plane and perpendicular to the substrate using vibrating sample magnetometry (VSM). Co particles with an average diameter of 30nm show ferromagnetic behavior at room temperature. When the coverage exceeds 5 %, the remanent magnetization along the in-plane direction was larger than that perpendicular to the sample, whereas the saturation field was smaller, which can be attributed to the magnetostatic interaction between the particles. In 40 nm Ni particles, similar behavior was observed but effect of magneto static interaction was smaller than for the Co particles. Influence of interactions on switching field distribution of the particles was studied. The results are compared with micromagnetic simulations of suitable model systems.

MA 40.19 Fri 11:00 P1A

**The use of XMCD to determine the magnetic and structural composition of nanoparticles** — •Daniela Nolle[1], Eberhard Goering[1], Liberato Manna[2], Albert Figuerola[2], Thomas Tietze[1], Sebastian Brück[1], and Gisela Schütz[1] — [1]Max Planck Institute for Metal Research, Heisenbergstr. 3, 70569 Stuttgart, Germany — [2]National Nanotechnology Laboratory of CNR-INFM, Unità di Ricerca IIT, Distretto Tecnologico ISUFI, via per Arnesano km. 5, I-73100 Lecce, Italy

We have investigated different FePt/FeOx nanoparticles using X-ray magnetic circular dichroism (XMCD). All investigated nanoparticles are produced in a "one-pot"-synthesis and consist of a FePt core (fcc structure) and a FeOx shell (inverse spinell structure) in different volume ratios.To determine the structural and magnetic composition of the nanoparticles we performed XMCD measurements both in the surface sensitive total electron yield mode (TEY) and the bulk-sensitive transmission mode. The measured spectra have been analysed in terms of a linear superposition of suitable reference data of metallic FePt, Magnetite (Fe3O4), and Maghemite ($\gamma$-Fe2O3). A comparison between TEY and transmission measurements for the 18 nm hybrid system shows, that the iron oxide shell is mainly magnetite like, while the surface has predominantly maghemite character.This method demonstrates the strength of simultaneously performed XMCD experiments utilizing different scanning depth measurement modes and provides a detailed structural and magnetic model for the investigated nanoparticles, which is consistent to corresponding SQUID measurements.

MA 40.20 Fri 11:00 P1A

**Magnetic field effect on the assembly of FePt and CuAu nanoparticles from the gas phase on amorphous carbon** — •Ute Queitsch, Inge Lindemann, Darius Pohl, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden, P.O. Box 270116 D-01171, Germany

The key to successful applications of nanoparticles is their organization at the nanoscale, i.e. the creation of defined and regular nanostructures of particles with controlled morphology in highly ordered arrays. Gas phase preparation has proven to allow for the preparation of nanoparticles of various materials with narrow size distribution. A regular arrangement of the particles was accomplished by self organization on bacterial S layer templates [1]. One problem inherent to this approach is the agglomeration of the nanoparticles due to the statistical arrival at the substrate. The deposition of gas phase prepared FePt nanoparticles with 5 nm in size in the presence of a magnetic field of 1 T onto carbon-coated TEM grids leads to the formation of hexagonal-like particles patterns with interparticle distances of 7nm and thereby to a significant decrease of agglomeration [2]. Interestingly, comparable results are found for CuAu nanoparticles. The magnetic properties of the CuAu nanoparticles and the physical origin for the observed self-organization are discussed.

[1] U.Queitsch et al., Appl. Phys. Lett. 90, 113114 (2007)
[2] U.Queitsch et al., J. Phys. D: Appl. Phys., 41 (2008)

MA 40.21 Fri 11:00 P1A

**Synthesis and magnetic characterisation of MnAs nanoparticles on GaAs surfaces** — •Michael Wolff[1], Maria Messing[2], Knut Deppert[2], and Kornelius Nielsch[1] — [1]Univ Hamburg, Inst Appl Phys, D-20355 Hamburg, Germany — [2]Lund Univ, S-22100 Lund, Sweden

In order to explore the possibility to generate ferromagnetic nanoparticles via annealing of monodisperse aerosol particles, Mn particles are generated in a spark discharge and then, after being sintered and size-selected in an aerosol setup, deposited on (111)B-GaAs substrates. The Mn particles transform into MnAs particles by annealing them under an Arsine background pressure. The reaction takes place in a MOVPE chamber under hydrogen atmosphere. The particle diameter can be controlled and is varied between 15 and 40 nm. While the crystallographic orientation of the Mn particles before annealing is randomly distributed, the crystal structure of the MnAs particles after annealing seems to be determined by the GaAs surface. The magnetic properties are studied using a SQUID magnetometer. The coercive field is expected to depend on the particle diameter and the orientation of the applied field. The substrate's influence on the magnetic properties is investigated by comparing particles on different GaAs surfaces.

MA 40.22 Fri 11:00 P1A

**Tuning the Dimensionality and Magnetic Properties of Mixed Valence Mn(II)/Mn(III) Coordination Polymers** — Sudarshana Mukherjee[1], Yanhua Lan[1], •George Kostakis[2], Redolphe Clérac[3], Christopher Anson[1], and Annie Powell[1,2] — [1]Institut für Anorganische Chemie der Universität Karlsruhe, Engesserstr. 15, D-76131 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, Postfach 3640, D-76021 Karlsruhe, Germany — [3]Université de Bordeaux, UPR 8641, Pessac, F-33600, France

Four 3D metal organic frameworks and the 1D coordination polymer have been synthesized. The 3D frameworks of compounds can be described as diamondoid networks. Magnetic studies show that weak MnII-MnIII antiferromagnetic interactions (in the range of -0.55 - 0.22 K) mediated by syn-anti carboxylate bridges are present in all compounds. While the 1D coordiantion polymer remains paramagnetic down to 1.8 K, the 3D networks exhibit long-range ferrimagnetic ordering below 7.4 K (1), 4.6 K (2), 3.0 K (3) and 7.7 K for 4. The decrease of the critical temperature reflects the increase of the coordination sphere number around the Mn(II) site from four in 1, five in 2 and six in 3 that lower the bond strength and also the magnetic interactions. This result also reinforces the hypothesis that the structures of 1 and 4 are similar as also suggested by the X-ray analysis.

MA 40.23 Fri 11:00 P1A

**Magnetoelastic effects of magnetic nanoparticles in a copolymer matrix** — •W. Schirmacher[1], A. Omran[2], L. Schulz[3], S. Vallopilly[4], P. Böni[2], W. Petry[2], and P. Müller-Buschbaum[2] — [1]Institut für Physik, Universität Mainz — [2]Physik-Department E13, TU München — [3]Universite de Fribourg, Switzerland — [4]LENS Indiana Synchrotron Facility, Bloomington IN, USA

Magnetic properties of thin composite films, consisting of polystyrene-coated $\gamma$-$Fe_2O_3$ (maghemite) nanoparticles embedded into polystyrene-block-polyisoprene (PS-b-I) matrices, have been investigated. The magnetization measured as a function of external field and temperature show typical features of "super-paramagnets", including a hysteresis at low temperatures and dispersive blocking, as expected for polydispersive samples. However, the differential magnetic susceptibility depends only weakly on temperature between roomtemperature and 2K. This strongly contradicts the superparamagnetic model, for which a Curie law is expected. We are able to explain our findings if we assume a mechanical twist of the particle due to the applied field. This coupling mechanism yields a temperature-independent susceptibility which is inversely proportional to the shear modulus of the copolymer matrix. We are able to successfully fit the hysteresis curves of our samples with this model.

MA 40.24 Fri 11:00 P1A

**Templated self-assembly of $Fe_3O_4$ nanoparticles in lithographically nanopatterned lines** — •Maria Jose Benitez[1,2], Oleg Petracic[1], Mathias Feyen[2], Anhui Lu[2], and Hartmut Zabel[1] — [1]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum — [2]Max-Planck Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr

We report on self-assembled $Fe_3O_4$ nanoparticle films on silicon substrates. Furthermore, using electron beam lithography we fabricate patterned trenches of 100-1000nm width for the assisted self-assembly of magnetite nanoparticles. The nanoparticles with a diameter of 20 nm were synthesized by thermal decomposition of iron oleate complex in trioctylamine and oleic acid. Individual nanoparticle behavior is governed by superparamagnetism. Above the blocking temperature, the self-assembled films and the templated nanoparticles show collective behavior due to dipolar coupling as evidenced from magnetometry measurements.

MA 40.25 Fri 11:00 P1A

**The effect of the sputtering gas (Ar, Xe) on FePt clusters formation, structural and magnetic properties** — •valentina cantelli, jörg grenzer, johannes von borany, and jürgen fassbender — Institute of Ion Beam Physics and Materials Research, Forschungszentrum Dresden-Rossendorf, Dresden, Germany

$L1_0$ FePt phase is widely studied for magnetic recording media because of an excellent magnetocrystalline anisotropy ($K_U \sim 5\text{-}8 \times 10^{-7}$ erg/cm$^3$) and large magnetic moments. [1] We will report about the effect of the sputtering gases, Ar and Xe, on FePt clusters formation using magnetron sputtering deposition at high working pressures. Sequential monolayers or co-deposition have been investigated comparatively. 5 or 3 nm thick layers were deposited at RT onto $SiO_2$/Si substrates, subsequently annealed at 550°C in order to induce the A1-$L1_0$ ordering transformation. The highest $L1_0$ fraction was found using Xe as sputtering gas. Xe ions impact enhances layers coarsening in as-deposited films: 2 nm crystallites agglomerate in clusters having a lateral size of about 50 nm; and decreases the transformation activation energy reducing the critical thickness for the ordering transition. Layers deposited with Ar as sputter gas show an almost close morphology. Strong ferromagnetic behavior has been obtained only in the case of a sequential monolayers deposition, underlining the importance to reduce the diffusion path to an atomistic scale. [2]

[1] H. Kanazawa, G. Lanhoff, T. Suzuki, J. Appl. Phys. 87 (2000) 6143; [2] M. L. Yan, N. Powers, D. J. Sellmyer, J. Appl. Phys. 93 (2003) 8292

MA 40.26 Fri 11:00 P1A

**Influence of ligands on magnetic properties of chemically synthesized FePt-nanocrystallites** — •Thomas Traussnig[1], Stephan Landgraf[2], Klemens Rumpf[3], Petra Granitzer[3], Ilse Letofsky-Papst[4], Karin Wewerka[4], Gerald Kothleitner[4], Heinz Krenn[3], and Roland Würschum[1] — [1]Institut für Materialphysik, Technische Universität Graz, Petersgasse 16, A-8010 Graz, Austria — [2]Inst. f. Physikalische & Theoret. Chemie, TU Graz — [3]Inst. f. Physik, Karl-Franzens-Universität Graz — [4]Inst. f. Elektronenmikroskopie & Feinstrukturforschung, TU Graz

FePt-nanoparticles have attracted considerable interest recently with respect to possible application potentials for future storage media. FePt-particles were synthesized chemically by thermal decomposition of iron pentacarbonyl and reduction of platinum acetylacetonate. The spherical particles with a small diameter of 3.4 nm and a narrow size distribution are coated by oleic acid and oleylamine. Variation of the particle distance can be obtained by a ligand exchange process, substituting the oleic acid/oleylamine ligand shell by an octanoic acid/octylamine or an hexanoic acid/hexylamine ligand shell. The influence of the different ligand shells as well as of subsequent thermal annealing on the superpara- and ferromagnetic behaviour is studied by SQUID magnetometry.

Acknowledgement: Financial support by FWF - Austrian Science Fund (project S10405-N16) is appreciated.

MA 40.27 Fri 11:00 P1A

**Magnetische Nanopartikel als Ultraschall- / Viskositätssensoren.** — •Christian Höhl, Nouri Elmiladi und Karl Maier — Helmholtz-Institut für Strahlen- und Kernphysik, Rheinische Friedrichs-Wilhelm Universität, Bonn, Germany

Magnetische Nanopartikel (MNP) bestehen aus magnetischen Kernen die in nichtmagnetische Hüllen von einigen 10 nm eingelassen werden. Die Hülle kann weiter chemisch funktionalisiert werden und dazu dienen, die MNP kolloidal in Lösung zu bringen.

Durch eine asymmetrische Beschichtung der Hülle, z.B. mit organischen Molekülen, kann das MNP durch Ultraschall (US) in Kippschwingungen versetzt werden. Das aufgrund der magnetischen Anisotropie an das Partikel gebundene magnetische Moment sendet dann Radiosignale mit US Frequenz. Das so erzeugte lokale Wechselfeld kann über Kernspinresonz am Lösungsmittel ortsaufgelöst nachgewiesen werden. Die Amplitude des Wechselfeldes hängt über die Schwingungsamplitude der MNP von der Viskosität des Lösungsmittels und der Ultraschallamplitude ab.

Die Methode eignet sich auch, um chemische Reaktionen an den präparierten MNP's messtechnisch zu verfolgen. Umsetzung und Anwendung in medizinischer Diagnostik werden präsentiert.

MA 40.28 Fri 11:00 P1A

**Carbon coated Fe, Co and Ni Nanoparticles produced by High Pressure CVD and their potential for Medical Applications** — •A. A. El-Gendy, E. M. M. Ibrahim, V. Khavrus, Y. Krupskaya, A. Leonhardt, R. Klingeler, and B. Büchner — Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany

Fe@C, Co@C and Ni@C nanocapsules have been produced by high pressure chemical vapour deposition (HPCVD). Scanning electron microscopy images prove that most of the particles are coated with carbon. High resolution transmission electron microscopy imaging confirms that these particles have a broad size distribution and a core/shell structure. In addition, individual nanoparticles are found inside a carbon capsule as well as several particles together in one shell. X-ray diffraction confirms the phases and allows calculating the average par-

ticle size from the width of the peaks. Our magnetisation studies confirm that the coated particles are ferromagnetic up to 400 K. AC magnetic heating studies have been performed which imply the potential of carbon coated nanomagnets for applications in hyperthermia therapies.

MA 40.29 Fri 11:00 P1A

**Magnetically filled Carbon Nanotubes for Hyperthermia** — •Yulia Krupskaya[1], Christopher Mahn[1], Anupama Parameswaran[1], Arthur Taylor[2], Kai Krämer[2], Anja Wolter[1], Silke Hampel[1], Rüdiger Klingeler[1], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany — [2]Department of Urology, Medical Faculty, Dresden University of Technology, Germany

We present a detailed magnetic study of filled Carbon Nanotubes (CNT), which highlights their potential for contactless magnetic heating in hyperthermia cancer treatment. We have performed magnetic field and frequency dependent AC magnetic heating experiments on Fe- and Co-filled CNT dispersions. We observe a substantial temperature increase of CNT dispersions under applied AC magnetic fields in different media. DC and AC magnetization studies were done in order to elucidate the heating mechanism. We observe a different magnetic response of CNT powders compared to CNT dispersed in aqueous solution, e.g., ferromagnetic Fe-CNT in powder do not show any hysteresis when being dispersed in liquid. Differences in the AC susceptibility confirm this observation. Our data indicate the motion of Fe-CNT in liquid under applied magnetic fields.

MA 40.30 Fri 11:00 P1A

**Magnetotransport studies of the anisotropic and domain wall magnetoresistance in Co nanowires** — •Francis Bern, Jose Barzola-Quiquia, and Pablo Esquinazi — Division of Superconductivity and Magnetism, University of Leipzig, D-04103 Leipzig

Cobalt wires of width x thickness $\sim 300 \ldots 600$ nm $\times$ 35 nm and cross sectional area − length ratios between 1.3 and 4 nm were prepared by electron lithography. The magnetoresistance as a function of field, angle between field and current, and between 4 K and 250 K was measured. The observed domain wall magnetoresistance of $-0.65\%$ and an anisotropic magnetoresistance effect of 1.6% at 4 K are higher than in similar works reported in the literature. The measured angle and temperature dependences of the coercive field agree with theoretical expectations. The achieved resolution in the magnetotransport measurements allows us to study the influence of notches and constrictions on the behavior of the magnetoresistance of the nanowires.

MA 40.31 Fri 11:00 P1A

**Correlation of magnetic properties of electrodeposited Fe nanowires with deposition conditions and morphology** — Veronika Hähnel[1,2], •Heike Schlörb[1], Sebastian Fähler[1], and Ludwig Schultz[1,2] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]TU Dresden, Faculty of Mechanical Engineering, Institute of Material Science, 01062 Dresden, Germany

Periodic arrays of magnetic nanowires deposited in self-organised nanoporous templates have recently attracted much attention in fundamental and applied research. Scientific interest focuses on these low dimensional nanostructures, as significant changes in terms of chemical and physical properties compared to bulk material are expected.
In this study Fe nanowires were deposited using DC voltage into a nanoporous aluminum oxide membrane with a pore diameter of 70 nm and an interpore distance of 110 nm. By adjusting the deposition time the wire length was varied up to 10 $\mu$m. With increasing length we observe that the axis perpendicular to the wire axis becomes the magnetically hard axis due to shape anisotropy. In addition, two different slopes are observed in magnetisation curves measured along the wire axis for long wires. Since this behaviour is not expected for isolated wires, it is discussed with respect to magnetostatic interactions favouring an antiferromagnetic alignment of neighbouring wires. As these features are only observed for wires having a smooth morphology, the influence of varied deposition conditions like potential, $Fe^{2+}$ concentration and the electrolyte composition (e.g. adding $H_3BO_3$) on morphology and magnetic properties is analysed in detail.

MA 40.32 Fri 11:00 P1A

**Weak electron localization and enhanced electron electron interaction in epitaxial Fe wires on GaAs(110)** — •Christoph Hassel, Florian M. Römer, Günter Dumpich, and Jürgen Lindner — Fachbereich Physik, AG Farle, CeNIDE, Universität Duisburg-Essen, 47048 Duisburg, Germany

Epitaxial Fe films are prepared on GaAs(110) substrates. Structural investigations of these films are carried out using LEED and IV-LEED. After capping the Fe-films with Ag and Pt to prevent an oxidation, we determined the anisotropy constants of the Fe films using ferromagnetic resonance (FMR) and SQUID. The films are subsequently structured into wires using electron-beam lithography and Ar-ion beam etching. Fe wires in the range of 100 to 3000 nm are studied. Due to the interplay of uniaxial and fourfold anisotropy of Fe/GaAs(110), it is possible to structure the wires, so that the effective easy axis of magnetization is transversal to the long wire axis [1]. This is proven by magnetic force microscopy, magnetoresistance and by micromagnetic simulations using the OOMMF code. By varying the widths of the wires and thus the shape anisotropy, one can change this effective easy axis of magnetization. We measured the low temperature magnetoresistance behaviour of these wires in order to find contributions of the weak electron localization. However, our results can be quantitatively explained in the framework of enhanced electron-electron interaction and no effect of weak electron localization was found.

[1] C. Hassel, F. M. Römer, R. Meckenstock, G. Dumpich, and J. Lindner, Phys. Rev. B 77, 224439 (2008)

MA 40.33 Fri 11:00 P1A

**Competition of Shape and Magnetocrystalline Anisotropies in Electrodeposited Co Nanowires** — Ajeet K. Srivastav[1,2], •Heike Schlörb[1], Sebastian Fähler[1], and Ludwig Schultz[1] — [1]IFW Dresden, Germany — [2]IIT Kanpur, India

Ordered arrays of magnetic nanowires are of high interest for both fundamental understanding of magnetism in low dimensions as well as many applications ranging from biological, chemical to information storage systems. They allow studying unexpected effects of different magnetic anisotropies and magnetostatic interactions. Cobalt nanowires are expected to show a complex behaviour due to its hexagonal structure and the resulting high magnetocrystalline anisotropy. Cobalt nanowires were electrodeposited into AAO templates using a single sulphate electrolyte partly buffered by boric acid. The influence of different pH values on structure and temperature dependent magnetic properties was investigated. At high pH and room temperature the easy axis is aligned parallel to the wire axis as expected for high aspect ratio nanowires due to shape anisotropy. Competing effects of shape and magnetocrystalline anisotropies result in a nearly isotropic behaviour at low pH values, when the hexagonal c-axis is oriented perpendicular to the wire axis. Due to the strong temperature dependency of the magnetocrystalline anisotropy the easy magnetization direction in Co nanowires changes from parallel to perpendicular to the wire axis when decreasing temperature. The crossover temperature strongly depends on electrolyte pH indicating changes in both fraction and orientation of the hexagonal phase when pH is increased.

MA 40.34 Fri 11:00 P1A

**Magnetoresistance Measurements of Magnetic Nanowires Lithographically Contacted by an Optical Microscope** — •Tim Böhnert, Judith Moser, Kristina Pitzschel, Shadyar Farhangfar, Robert Zierold, Lars Bocklage, Ulrich Merkt, Guido Meier, and Kornelius Nielsch — Institut für Angewandte Physik, Universität Hamburg

We fabricate $\mu m$-sized structures using projection photolithography with a modified optical microscope. This setup provides a fast and simple way to four-point measurements on individual nanowires. A 2 x 2 $cm^2$ rotatable printed foil mask can be projected on an area down to 300 x 300 $\mu m^2$ allowing us to create $\mu m$-sized features. The technique grants complete visual control over the mask alignment, which is a huge advantage compared to conventional lithography techniques for contacting prepatterned structures. We define four probe low-ohmic contacts to electrochemically synthesized Ni nanowires of different diameters. The switching behavior of the wires is studied by anisotropic magnetoresistance measurements. We will present details of the sample processing and first magnetoresistance measurements. The goal of the project is investigating the field- and current-induced magnetization reversal in straight wires, in bent wires, and in wires with tailored pinning sites.

The authors gratefully acknowledge financial support by the SFB 668.

MA 40.35 Fri 11:00 P1A

**Preparation of Ni nanowires on Si gratings and their properties** — •Wolfgang Kreuzpaintner[1], Dieter Lott[1],

Michael Störmer[1], Volker Neu[2], Cristina Bran[2], and Andreas Schreyer[1] — [1]GKSS Forschungszentrum GmbH, Max-Planck-Str. 1, 21502 Geesthacht — [2]IFW Dresden, Institute for Metallic Materials, Dpt. Magnetic Microstructures, Helmholtzstr. 20, 01069 Dresden

Ni was e-beam evaporated under a shallow angle of incidence onto a lithographically structured Si substrate with submicrometer grating. By pure geometrical shading effects, 10nm wide Ni nanowires were deposited spaced at 750nm. In order to prevent the Ni from oxidization a 10nm thick Al capping layer was additionally sputter deposited.

The structural properties of the such prepared Ni nanowires were studied using x-ray scattering and atomic force microscopy techniques. Results on the magnetic behaviour were obtained by neutron scattering and magnetic force microscopy.

MA 40.36 Fri 11:00 P1A

**Magnetic nanowires and tubes with modulated diameter from a porous alumina template** — •Kristina Pitzschel[1], Josep M. Montero Moreno[1,2], Ole Albrecht[1], Julien Bachmann[1], and Kornelius Nielsch[1] — [1]Institute of Applied Physics and Microstructure Research Center Hamburg, University of Hamburg — [2]Electrodep, Dept. Physical Chemistry, Universitat de Barcelona

We utilize porous alumina membranes as templates in which mild and hard anodizations are combined to yield modulations in the pore diameter [1]. Filling the pores with Ni by electrodeposition delivers wires replicating the changes in diameter. Alternatively, atomic layer deposition allows for the preparation of $Fe_3O_4$ tubes with the same silhouettes [2]. Both types of structures are ferromagnetic. Ensemble magnetic measurements evidence a strong correlation between geometric parameters and magnetic properties. [1] W. Lee *et al.*, Nature Nanotech. **3**, 234 - 239 (2008). [2] J. Bachmann *et al.*, J. Am. Chem. Soc. **129**, 9554-9555 (2007). This research was financially supported by the SFB668.

MA 40.37 Fri 11:00 P1A

**Synthesis of hard magnetically terminated carbon nanotube systems** — •Franziska Schäffel, Christine Täschner, Mark H. Rümmeli, Christoph Schünemann, Albrecht Leonhardt, Bernd Rellinghaus, Bernd Büchner, and Ludwig Schultz — IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

We report on the synthesis of hard-magnetically terminated carbon nanotubes (CNT) from multilayer Fe-Pt thin film catalysts via plasma enhanced chemical vapour deposition (PECVD). Although FePt is rarely used as a catalyst for CNT synthesis it is of great interest due its special hard magnetic properties when in the chemically ordered $L1_0$ phase. The combination of such highly anisotropic nanomagnets with CNT opens up exciting possibilities to create novel CNT functionalities. The tailored growth of CNT with a hard magnetic particle at their tip is very promising for the realization of nanodevices, for example tips for magnetic force microscopy or magnetically actuated nanoelectronic systems.

MA 40.38 Fri 11:00 P1A

**Preparation and characterization of $Ni_2MnIn$ Heusler electrodes for spin valves** — •Hauke Lehmann, Jan M. Scholtyssek, Jeannette Wulfhorst, Ulrich Merkt, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

We grow $Ni_2MnIn$ films by thermal coevaporation of Ni and the alloy MnIn. The films are deposited on $Si_3N_4$ membranes for transmission-electron microscopy (TEM) as well as on Si, $SiO_2$, and $Si_3N_4$ for investigations of the electronic structure. We determine the transport spin polarization by point-contact Andreev reflection spectroscopy (PCAR) [1]. The resistivity of the films is measured using a four-terminal van der Pauw setup. Nanopatterned $Ni_2MnIn$ Heusler electrodes for spin-valve structures are prepared by electron-beam lithography. As a first test, the anisotropic magnetoresistance (AMR) of each individual electrode is measured. In a further step we want to investigate the spin-valve effect of the whole structure. In view of the temperature-sensitivity of the electron-beam resist, the electrodes are grown at low temperature and annealed afterwards. The post-growth annealing process is investigated in situ in the TEM using transmission-electron diffraction on films grown on $Si_3N_4$ membranes [2]. The change of the resistivity during the annealing process is analyzed.

[1] L. Bocklage, J. M. Scholtyssek, U. Merkt, and G. Meier, J. Appl. Phys. **101**, 09J512 (2007)
[2] J. M. Scholtyssek, G. Meier, and U. Merkt, J. Crystal Growth accepted (2008)

MA 40.39 Fri 11:00 P1A

**Tunable magnetic and magnetotransport properties of $Zn_xFe_{3-x}O_4$ epitaxial films** — •Michael Wagner, Deepak Venkateshvaran, Matthias Althammer, Andrea Nielsen, Sebastian Goennenwein, Matthias Opel, and Rudolf Gross — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

The structural, magnetic and transport properties of $Zn_xFe_{3-x}O_4$ are investigated in this work. Non-magnetic $Zn^{2+}$, when substituted for $Fe^{3+}$ in $Fe_3O_4$ allows one to tune the magnetic and electronic properties without losing mobility of the carriers [1]. We have grown coherently strained, epitaxial thin films of $Zn_xFe_{3-x}O_4$ on MgO (001) substrates using pulsed laser deposition. Two sets of $Zn_xFe_{3-x}O_4$ films were deposited, one with x = 0, 0.1, 0.5 and 0.9 grown in pure argon, and a second with x = 0, 0.1, 0.33 and 0.9 grown in an $Ar/O_2$ (99:1) mixture. X-ray diffractometry measurements indicate high crystallinity with an FWHM of 0.04° in the rocking curves for the $Zn_xFe_{3-x}O_4$ (004) reflection. Magnetization measurements were performed using a SQUID magnetometer and magnetotransport properties were studied using micro-patterned Hall bars in magnetic fields up to 14 T. Our results are discussed within the framework of Zn substitution on the tetrahedral sites of $Fe_3O_4$, Fe vacancies, oxygen stoichiometry, and the exchange mechanisms responsible for ferrimagnetism [2]. This work was funded by the DFG within SPP 1285 and the DAAD.

[1] J. Takaobushi et al., Appl. Phys. Lett. 89, 242507 (2006)
[2] D. Venkateshvaran et al., arXiv:0808.3642 (2008)

MA 40.40 Fri 11:00 P1A

**The effect of oxygen nonstoichiometry on (Sr/La)2FeMoO6-d double perovskite** — •Mikalai Kalanda[1], Anis Saad[2], Sergey Demyanov[1], and Alexander Petrov[1] — [1]Scientific-Practical Materials Research Centre NAS of Belarus, Minsk, Belarus — [2]Al-Balqua Applied University, Salt, Jordan

Layered magnetic semiconductors Sr2FeMoO6-d could be considered among the most prospective materials for spintronics. In this work we investigate synthesis of (Sr/La)2FeMoO6-d using semi-reduced precursors SrFeO3-x, SrMoO4-x as initial reagents. It is established that the temperature dependence of magnetization is determinedby the oxygen index and external magnetic field values. in dependence on oxygen index and external magnetic field. For the (Sr/La)2FeMoO6.00 compound during cooling from 300 K down to 170 K magnetization goes up and then decreases and magnetization at 77 K almost reaches the values of magnetization at 300 K. At the increase of the measured magnetic field up to 1 T magnetization of (Sr/La)2FeMoO6.00 constantly grows at 300 - 77 K. It is supposed that the presence of point defect influence the exchange interactions mechanism, changing ferromagnetic interaction in the Fe3+ - O - Mo5 chains to (Sr/La)2FeMoO5.87 to the ferromagnetic one for (Sr/La)2FeMoO6.00 at 300 - 170 K between iron cations with a subsequent appearance of ferromagnetic exchange interaction lower than 170 K.

MA 40.41 Fri 11:00 P1A

**Soft x-ray holography of FIB nanostructured Co/Pt multilayers** — •Daniel Stickler[1], Robert Frömter[1], Christian Menk[1], Holger Stillrich[1], Carsten Tieg[2], Simone Streit-Nierobisch[3], Christian Gutt[3], Lorentz-M. Stadler[3], Olaf Leupold[3], Gerhard Grübel[3], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11 A, 20355 Hamburg, Germany — [2]European Synchrotron Radiation Facility (ESRF), 38043 Grenoble, France — [3]Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg, Germany

Focused Ion Beam (FIB) milling is a powerful tool to produce ordered magnetic nanostructures. However, it is impossible to produce out-of-plane magnetized nanoscale structures from multilayer films by direct FIB writing. Co/Pt multilayers exhibit an out-of-plane easy axis due to strong perpendicular interface anisotropy. The interface contribution is known to be very sensitive to high energy ion irradiation. In case of 30 keV Ga ions it needs less than one ion per 100 surface atoms to destroy the perpendicular interface anisotropy. We demonstrate how this problem can be overcome by milling a Co/Pt multilayer, which has been deposited on a SiN membrane, from the rear side, through the SiN. The effect of the ions is determined as a function of applied dose utilizing the domain structure imaged by soft x-ray holography. When the magnetic material is removed we find only a very narrow

range of destruction around the holes in contrast to the observations when milling from the Co/Pt side. This behaviour can be explained by the shielding of the halo of the ion beam by the SiN membrane.

MA 40.42 Fri 11:00 P1A

**Magnetic viscosity in Co/Pt multilayers on nanospheres** — •Cristina Bran[1], Volker Neu[1], Ulrike Wolff[1], Till Ulbrich[2], Manfred Albrecht[3], and Ludwig Schultz[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]University of Konstanz, Department of Physics, D-78457 Konstanz, Germany — [3]Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany

Magnetic nanoparticles have attracted considerable interest in recent years due to the possible applications in high density data storage technology. Requirements are a well defined and localized magnetic switching behavior and a large thermal stability in zero fields. The thermal stability of $(Co/Pt)_N$ multilayers with different numbers of repeats (N), deposited on nanospheres [1] is studied by magnetic viscosity measurements. For this, the time dependent magnetization decay is recorded at different reversal fields. The linear evolution of magnetization with ln(t) is interpreted as a relatively large energy barrier distribution. By measuring recoil loops we determine the irreversible susceptibility, which, together with viscosity data, allows to calculate the activation volume and to correlate these results to the magnetic particle volume. The results show that the activation volume is much smaller than the particle's physical volume which indicates a non-uniform magnetic reversal within individual nanospheres. This finding is also a possible prerequisite for an individual particle switching expected from bit patterned media. [1] M. Albrecht et al, Nature Materials 4, 203 (2005).

MA 40.43 Fri 11:00 P1A

**Combining glancing angle deposition and atomic layer deposition towards complex magnetic nanostructures** — •Ole Albrecht[1], Robert Zierold[1], Christian Patzig[2], Detlef Görlitz[1], Bernd Rauschenbach[2], and Kornelius Nielsch[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg — [2]Leibniz-Institut für Oberflächenmodifikationen e.V. (IOM), Permoserstrasse 5, 04318 Leipzig

We present a new method for the fabrication of periodically ordered magnetic nanostructures by a combination of two established deposition techniques, namely Glancing Angle (GLAD) and Atomic Layer Deposition (ALD). Tilted Si columns with different tilt angles and zigzag structures were produced on Si surfaces by GLAD technique [1]. ALD, as a self-limiting deposition, has the ability to cover the Si structures conformally and without shadowing effects [2]. By subsequent reduction, a magnetic layer ($Fe_3O_4$) was obtained on the structures. The magnetic properties were investigated using a superconducting quantum interference device (SQUID) magnetometer at room temperature. The magnetic parameters remanence and coercivity are strongly affected by the orientation of the sample with respect to the applied field. Additionally, the three rotation axes are distinct, namely the curves $H(\theta, \phi, \psi)$ and $M_{rem}(\theta, \phi, \psi)$ reflect the geometry of each sample.

[1] M. Hawkeye *et. al.*, J. Vac. Sci. Technol. A, **129**, 9554 (2007)
[2] J. Bachmann *et. al.*, J. Am. Chem. Soc., **129**, 9554 (2007)

MA 40.44 Fri 11:00 P1A

**Fabrication and magnetic properties of CFO films and arrays** — •Sven Schnittger[1], Christian Jooss[1], and Sibylle Sievers[2] — [1]Institut für Materialphysik, Universität Göttingen — [2]Physikalisch-Technische Bundesanstalt, Braunschweig

Patterned arrays of magnetic dots are interesting model systems for the study of new types of magnetic ordering due to the competition of intra-dot and inter-dot interactions. Whereas various studies have been performed at arrays of soft magnetic materials with in-plane easy magnetization axis, arrays of materials with perpendicular easy axis and moderate magnetocrystalline anisotropy energy are not well studied. We choose ferrimagnetic cobalt ferrite (CoFe2O4) squares, which have moderate magnetocrystalline anisotropy. Thin film samples were prepared by ion sputtering and patterning was performed by electron beam lithography processes which were adapted to the patterning of highly insulating materials. The structural and magnetic properties of the samples were characterized by scanning electron microscopy, magneto-optical and SQUID measurements, atomic force and magnetic force microscopy. The magnetization distribution of the arrays is analyzed as a function of element shape and distance.

MA 40.45 Fri 11:00 P1A

**Hard magnetic films on nanoparticle templates: An approach towards patterned and percolated media** — •Christoph Brombacher[1], Christian Schubert[1], Andreas Teichgräber[1], Steffen Schulze[1], Michael Hietschold[1], Sara Romer-Urban[2], Denys Makarov[3], Marc Saitner[4], Christian Pfahler[4], Alfred Plettl[4], Paul Ziemann[4], and Manfred Albrecht[1] — [1]Institute of Physics, TU Chemnitz — [2]Nanoscale Materials Science, Empa — [3]Department of Physics, University of Konstanz — [4]Institute of Solid State Physics, University of Ulm

The superparamagnetic limit is one of the main aspects which leads to novel concepts to increase the storage density in magnetic data storage devices. Patterned media, a concept in which a magnetic bit is represented by one specific nanostructure within a perfectly ordered array can be achieved by depositing magnetic materials onto spherical particle arrays. Co/Pt multilayers on nanoparticles, as well post-annealed FePt nanoparticle caps in their $L1_0$ phase, serve as examples for the creation of single-domain magnetic cap structures and the prospects for application in patterned media will be explored. A percolated medium, where domain-walls are effectively pinned by defect sites can be either created by the deposition of CoPt alloys onto close-packed, or by the deposition of Co/Pt multilayers onto none-close-packed particle arrays. These film systems have been characterized both structurally by XRD and TEM and magnetically by SQUID magnetometry and MFM. The effective pinning of domain-walls was further investigated by in-field MFM.

MA 40.46 Fri 11:00 P1A

**Magnetic correlations in laterally patterned layered magnetic structures** — •Elisabeth Josten[1], Ulrich Rücker[1], Sandra Gilles[2], Artur Glavic[1], and Thomas Brückel[1] — [1]IFF-Streumethoden, Forschungszentrum Jülich, 52425 Jülich — [2]IBN-Bioelektronik, Forschungszentrum Jülich, 52425 Jülich

Laterally patterned magnetic structures are the basic elements of spintronic devices. With ongoing miniaturization the influence of neighboring cells becomes more and more important. We study the influence of the period of laterally striped magnetic multilayers on the magnetic properties and the magnetic domain formation.

Fe/Cr/Fe have been grown epitaxially on GaAs (100) single crystals by Molecular Beam Epitaxy (MBE). Cr interlayers that induce antiferromagnetic coupling between adjacent Fe layers were chosen to reduce the magnetic dipole moment and to induce a magnetic superstructure easily observable in polarized neutron reflectometry. The lateral structuring is performed by laser interference lithography or UV-nanoimprint lithography and Reactive Ion Etching. Structural characterization is carried out by Scanning Microscopy and X-Ray scattering under grazing incidence. The magnetic order and domain formation as a function of the applied magnetic field are determined by MOKE and polarized neutron reflectometry and off-specular scattering.

MA 40.47 Fri 11:00 P1A

**Tailoring particle arrays by reactive ion etching: A novel method to realize percolated media** — •Daniel Assmann[1], Christoph Brombacher[2], Marc Saitner[3], Christian Pfahler[3], Alfred Plettl[3], Paul Ziemann[3], Denys Makarov[1], Martin Siekman[4], Leon Abelmann[4], Hartmut Rohrmann[5], and Manfred Albrecht[2] — [1]Universitaet Konstanz — [2]Technische Universitaet Chemnitz — [3]Universitaet Ulm — [4]University of Twente, Enschede, The Netherlands — [5]OC Oerlikon, Balzers, Liechtenstein

Percolated perpendicular media (PPM) is a possible way to increase the storage density in magnetic hard discs by pushing the limit of superparamagnetism, so that the 1Tbit/in2-regime can be reached.

We present an approach to the realization of a PPM by generating arrays of sparsely distributed polystyrene (PS) nanospheres with adjustable diameters and periodicity as a template for the deposition of Co/Pt multilayers with perpendicular magnetic anisotropy.

The generation of the particle arrays is done by self assembled monolayers of particles which are isotropically plasma etched to reduce the size of the particles. After depostion of Co/Pt multilayers onto these patterns they form an exchange decoupled, single-domain magnetic nanostructure array surrounded by a continuous film.

The magnetic reversal characteristic of the film-particle system is dominated by domain nucleation and domain wall pinning at the particle locations creating a percolated perpendicular media system, which we illustrated by MFM imaging and MOKE hysteresis loops.

MA 40.48 Fri 11:00 P1A

**Template-based electrodeposition of magnetic nanostructures** — Iwona Dobosz[1,2], •Jakub Koza[1], Kristina Tschulik[1], Margitta Uhlemann[1], Annett Gebert[1], and Ludwig Schultz[1] — [1]Leibniz Institute for Solid State and Materials Research Dresden, PO Box 270116, 01171 Dresden, Germany — [2]AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Krakow, Poland

In the past years a demand for new types of materials with different structures and specific physical properties for miniaturized devices, like MEMS and micro-electronics, is increasing. The nanowire arrays seem to have a large potential for a variety of applications. The nanowire of Co, Fe and FeCo alloy were prepared by the electrodeposition process into the alumina oxide membrane (AAO). AAO's were prepared by the two step anodizing process in oxalic acid solution. The influence of the electrolyte composition, electrodeposition parameters and superimposition of the external magnetic field during the deposition was studied. The effect of above parameters on the nanowire properties were determined by means of XRD, TEM, SEM, VSM and SQUID techniques. It was found that the properties of the deposited wires could be tuned by the preparation parameters. Especially the magnetic properties were affected, which are known to be very sensitive on the preparation conditions.

MA 40.49 Fri 11:00 P1A

**Characterization of nanostructured PdFe-alloy dots** — •Alexandra Schumann, Melanie Ewerlin, Frank Brüssing, and Hartmut Zabel — Ruhr-Universität Bochum, Experimentalphysik 4

We have investigated the magnetic properties of PdFe alloy films and nanostructured PdFe-alloy dots. The dots were prepared by means of e-beam lithography and have diameters in the range of 200nm to 800nm and are placed on a grid with rectangular symmetry. Our aim is to investigate magnetic phase transitions in laterally structured dot arrays. As the critical temperature $T_c$ increases with increasing Fe-concentration of the alloy, we can tune $T_c$ of the individual dot as well as of the array. It is possible to "reset" the magnetic state of the film and/or the patterns by warming up the sample to the paramagnetic state. After cooling, the sample reaches a "virgin" demagnetized ferromagnetic state. To achieve a stable single domain state in each dot, it is necessary to develop a phase diagram, which shows the dependence of the single domain state on the film thickness and the dot diameter. This phase diagram will be shown here.

This work was supported by the SFB 491.

MA 40.50 Fri 11:00 P1A

**Vortex stabilization in magnetic trilayer dots** — •Philipp Szary, Oleg Petracic, and Hartmut Zabel — Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum

We have investigated the spin structure in $Co/Al_2O_3/Py$ ($Py=Ni_{80}Fe_{20}$) trilayer nanodots both via micromagnetic simulation and experimentally by MOKE, SQUID and MFM measurements. Depending on the dot size isolated Py layers would show either a vortex or single domain state during magnetization reversal. However, the Co layer stays always in the single domain state. After combining both dots in a stack separated by an insulating layer, we observe three scenarios of reversal processes in the soft ferromagnetic Py layer due to dipolar coupling to the hard ferromagnetic Co layer, i.e. (1) stabilization, (2) triggering of the vortex state and (3) occurrence of a 360° domain wall. We have constructed a phase diagram, where regions of vortex stabilization, triggering and occurrence of a 360° domain wall are marked. We also have studied the case of a polycrystalline Co layer. Here the phase diagram is more complex with additional regions, i.e. a vortex in the Co layer, a vortex in both Co and Py layer or a destabilization of the vortex due to dipolar coupling.

MA 40.51 Fri 11:00 P1A

**Synthesis of novel tubular shaped nanoparticles for application as a ferrofluid** — •Robert Zierold[1], Julien Bachmann[1], Zhenyu Wu[2], Carl Krill[2], and Kornelius Nielsch[1] — [1]Institute of Applied Physics and Microstructure Research Center Hamburg, University of Hamburg — [2]Institute of Micro- and Nanomaterials, University of Ulm

A novel, fully tunable preparation of short (aspect ratio <10) ferromagnetic nanotubes is presented. Combining porous alumina as a template with Atomic Layer Deposition (ALD) offers the possibility of producing magnetic nanotubes [1]. By reducing the anodization time of aluminum and implementing multilayer ALD of silica and iron oxide, it is possible to control all system parameters (e.g. length, wall thickness, magnetic moment) of the tubular nanoparticles. By releasing the embedded tubes a ferrofluid-like suspension is formed. A novel synthesis strategy has been implemented for recycling the supporting aluminum substrate. The fluid viscosity is studied as a function of the applied magnetic field and the shear rate with a piezo-membrane axial vibrator. Compared to spherical nanoparticles of conventional ferrofluids, the tubular structure-based solution is expected to suppress shear-thinning effects [2] at higher shear rates. [1] J. Bachmann *et al.*, J. Am. Chem. Soc., **129**, 9554 (2007). [2] S. Odenbach *et al.*, J. Magnet. Magnet. Mater., **183**, 188 (1998). The authors thank the DPG (SPP1165) for financial support.

MA 40.52 Fri 11:00 P1A

**Novel concepts for anisotropic Heisenberg modelling of multiferroic oxides** — •Tim Kunze and Sibylle Gemming — Forschungszentrum Dresden-Rossendorf, P.O. Box 51 01 19, D-01314 Dresden, Germany

Hexagonal manganites are oxides, in which structural, electronic, and magnetic degrees of freedom are coupled in a complex manner. Therefore, such materials have the potential for novel, nanoscale sensing and switching applications. Manganites are composed of dense-packed hexagonal manganese oxide layers with strong in-plane and weak interlayer coupling, thus the possible spin configurations may be studied with the help of a two-dimensional model Hamiltonian. Special focus is directed to the efficient sampling of the configuration space at low temperatures and concepts for improved importance sampling will be discussed.

MA 40.53 Fri 11:00 P1A

**Spectromicrosopy of Ferroelectric and Magnetoelectric Nanostructures** — •Ingo Krug[1,4], Nick Barrett[1], Adrian Petraru[2], Jean-Baptiste Moussy[1], Bertrand Vilquin[3], Hermann Kohlstedt[2], and Claus M. Schneider[4] — [1]CEA Saclay, DSM/IRAMIS/SPCSI, Gif-sur-Yvette, FRANCE — [2]FZ Jülich, IFF-6, Jülich, GERMANY — [3]Ecole Centrale de Lyon — [4]FZ Jülich, IFF-9, Jülich, GERMANY

We present a spectromicroscopy study (LEEM, XAS- and energy-filtered PEEM) of ferroelectric and magnetoelectric nanostructures written by Piezoforce Microscopy. In thin ferroelectric $PbZr_xTi_{1-x}O_3$ (PZT) and $BaTiO_3$ (BTO) layers, artificial ferroelectric 180° domains have been written by Piezoforce Microscopy. The opposite polarization states in the 180° domains produce strong changes in the surface electronic structure, which have directly been observed as lateral contrast in both threshold PEEM and LEEM in mirror and diffraction mode. Analyzing the energies of emitted/reflected electrons, the changes in the surface potential (workfunction) can be determined, allowing for a quantification of the ferroelectric state. Furthermore we present an energy-filtered PEEM study of nanostructured magnetoelectric BTO/CFO samples grown by MBE.

MA 40.54 Fri 11:00 P1A

**Electric field-control of remanent magnetization in multifunctional hybrids** — •Andreas Brandlmaier[1], Matthias Brasse[1], Matthias Opel[1], Georg Woltersdorf[2], Rudolf Gross[1], and Sebastian T. B. Goennenwein[1] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching — [2]Universität Regensburg, 93040 Regensburg

Multifunctional ferromagnetic/ferroelectric hybrid structures allow for novel magnetization control schemes. In particular, an electric field-control of remanent magnetization orientation becomes possible.

We have fabricated ferromagnetic/ferroelectric hybrids by evaporating ferromagnetic Ni thin films onto commercially available piezoelectric actuators. Due to magnetoelastic coupling, the expansion/contraction of the actuator as a function of the applied voltage $V_p$ allows for a voltage-control of the magnetization orientation. In addition, because the expansion/contraction of the actuator is hysteretic itself, there are two different strain states at zero applied voltage leading to two different magnetization orientations.

Using magneto-optical Kerr effect and anisotropic magnetoresistance measurements, we study the magnetization orientation as a function of strain. We demonstrate that upon the application of an appropriate voltage sequence to the actuator, the magnetization at $V_p = 0$ V can be deterministically switched between two distinct magnetization states without applying a magnetic field. This allows to realize an electrically controlled magnetic memory cell.

This work is supported by the DFG via SPP 1157 and GO 944/3.

MA 40.55 Fri 11:00 P1A

**Topology of the electric order in multiferroic orthorhombic $DyMnO_3$ by SHG spectroscopy** — •Tim Günter[1], Dennis Meier[1], Thomas Lottermoser[1], Dimitri Argyriou[2], and Manfred Fiebig[1] — [1]HISKP, University of Bonn, Germany — [2]Helmholtz Centre Berlin for Materials and Energy, Germany

Multiferroics where a spontaneous electric polarization forms as a direct consequence of magnetic spiral order are of great interest. However, essential aspects of their ferroicity and the precise nature of the large magnetoelectric effects displayed by these compounds remain unclear. One set of these so-called spin-spiral multiferroics are the perovskite manganites $R\mathrm{MnO_3}$ ($R$=Tb, Dy). Here we report on the investigation of orthorhombic $DyMnO_3$ by second harmonic generation (SHG) spectroscopy and topology. Due to its high absorption in the visible range a detectable SHG signal requires using femtosecond laser pulses in a reflection geometry. Performing SHG polarization analysis based on SHG selection rules allows the separation of crystallographic background and magnetically induced ferroelectric contributions. A clear evidence of the observation of the magnetically induced electric order below $\approx$ 19 K was given by the temperature dependence and the spectral distribution of the SHG contributions. In addition, first results on the imaging of magnetically induced ferroelectric domains are reported. A detailed investigation of $DyMnO_3$ allows to generalize results gained on other spin-spiral multiferroics displaying magnetically induced ferroelectricity like $MnWO_4$ and $TbMn_2O_5$.

MA 40.56 Fri 11:00 P1A

**Microstructure and magnetic properties of $BaTiO_3$-(Ni,Zn)$Fe_2O_4$ multiferroics** — •Michael R. Koblischka[1], Anjela Koblischka-Veneva[2], Michael Wick[1], Liliana Mitoseriu[3], and Uwe Hartmann[1] — [1]Experimental Physics, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany — [2]Functional Materials, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany — [3]Department of Solid State and Theoretical Physics, Al. I. Cuza University, Iasi 700506, Romania

The microstructures of $BaTiO_3$-(Ni,Zn)$Fe_2O_4$ (BT-NZF) multiferroics with various mixing ratios (70:30, 60:40 and 50:50) [1] are investigated by means of electron-backscatter diffraction (EBSD) [2] and magnetic force microscopy (MFM). The EBSD measurements reveal a change in the texture of the ferrite and the $BaTiO_3$ grains upon increasing the ferrite content in the sample. The 70:30 sample exhibits the best ferrite texture, where only some directions are present. Furthermore, the resulting grain sizes vary from several $\mu$m (50:50) to about 100 nm in the 70:30 sample. The MFM images reveal the presence of magnetic domains being extended over several adjacent grains, which according to the EBSD data may comprise different crystallographic orientations. In this way, we can explain the differences in the magnetic contrast obtained.

[1] L. Mitoseriu et al., JMMM 316, e603 (2007) [2] A. Koblischka-Veneva et al., IEEE Trans. Magn. 42, 2873 (2006)

MA 40.57 Fri 11:00 P1A

**Raman spectroscopy of the multiferroic manganite Eu(1-x)Y(x)MnO3** — •Sven Issing[1], Andrei Pimenov[2], Alexander A. Mukhin[3], and Jean Geurts[1] — [1]Universität Würzburg, Physikalisches Institut, Experimentelle Physik III, Am Hubland, 97074 Würzburg — [2]Universität Würzburg, Physikalisches Institut, Experimentelle Physik IV, Am Hubland, 97074 Würzburg — [3]General Physics Institute of the Russian Acad. of Sciences, 119991 Moscow, Russia

Quite recently the existence of a strong magnetoelectric coupling in Eu(1-x)Y(x)MnO3 has been shown [1]. As follows already from the first principles, this coupling would lead to appearance of elementary excitations of magnetoelectric origin - the so called electromagnons [2].

Investigations of the Raman active phonons can provide important information on the coupling of the electromagnons to the phonons. This motivated us to carry out systematic measurements of the polarized Raman spectra in Eu(1-x)Y(x)MnO3 for several Y contents $x \leq 0.5$. Our results show a good agreement with Raman spectra of other orthorhombic rare earth manganites [3]. Tuning of the A-site cation radius by increasing the Y content leads to a shift of the phonon frequencies, which can be explained by an increasing distortion from the ideal cubic perovskite structure.

[1] J. Hemberger et al., PRB 75, 035118 (2007)
[2] A. Pimenov et al., PRB 77, 014438 (2008)
[3] M. N. Iliev et al., PRB 73, 064302 (2006)

MA 40.58 Fri 11:00 P1A

**Anisotropy of antiferromagnetic 180° domains in magnetoelectric $LiMPO_4$** — •Anne Zimmermann[1], Bas B. van Aken[1], Jean-Pierre Rivera[2], Hans Schmid[2], and Manfred Fiebig[1] — [1]HISKP, University of Bonn, Germany — [2]Department of Inorganic, Analytical and Applied Chemistry, University of Geneva, Switzerland

The investigation of compounds forming 180° domains directly leads to the inherent magnetic effects determining the AFM domain topology. The group of lithium-orthophospates $LiMPO_4$ (M = Co, Fe, Mn, Ni) is a good system for studying the parameters determining the formation of 180° domains, because of its variety of magnetically similar but pronouncedly anisotropic compounds. The crystallographic symmetry of $LiMPO_4$ is mmm. As magnetic symmetry, mmm' (M = Co, Fe) and mm'm (M = Mn, Ni) are obtained.

Here we report on the observation of AFM 180° bulk domains in $LiMPO_4$ (M = Co, Fe, Ni) by optical second harmonic generation (SHG). SHG coupling linearly to the AFM order parameter was identified in spectroscopy measurements and used for imaging domains. In spite of their similar crystallographic and magnetic structure the three compounds display drastically different domain patterns. Possible explanations for this unexpected diversity are discussed. In addition, we observed domains of a magnetic vortex (so-called ferrotoroidic) state that coexist with the AFM domains in $LiCoPO_4$. For $LiNiPO_4$ we showed that a magnetic field is sufficient to orient the AFM 180° domains via the magnetoelectric effect. - Work supported by the SFB 608 of the DFG.

MA 40.59 Fri 11:00 P1A

**Investigation of the magnetic configuration of $LuFe_2O_4$ by means of XMCD and multiplet calculations** — •Christine Derks[1], Michael Raekers[1], Christian Taubitz[1], Karsten Kuepper[2], Stephen J. Blundell[3], Dharmalingam Prabhakaran[3], and Manfred Neumann[1] — [1]Universität Osnabrück, FB Physik, Osnabrück — [2]FZ Dresden-Rossendorf, Dresden — [3]Clarendon Laboratory, University of Oxford, Oxford, UK

The use of magneto electric coupling and multi ferroics in spintronics has led to an intense research of ferro electric magnets. The spinel $LuFe_2O_4$ is a very promising candidate for such applications. This compound exhibits giant room temperature magneto dielectric response, which suggests a strong coupling between spin moment und electric dipole. The resulting giant magneto capacitance is due to charge ordering of mixed valent iron ions. A complex two dimensional ferri magnetism plays an important role for the multi ferroic properties of $LuFe_2O_4$. We determine the magnetic configuration by means of XMCD. Experimental data are compared with multiplet calculations, which are performed with the TT multiplet program [1]. The trigonal bipyramidal crystal symmetry was included in these calculations. We suggest a local charge order with a ferrimagnetic structure as found by Mössbauer and neutron diffraction; The minority spin sub lattice exhibits 2/3 of total $Fe^{3+}$ ions whereas the majority spin subband contains 1/3 of $Fe^{3+}$ and all the $Fe^{2+}$ ions. [1] F.M.F. de Groot, High resolution x-ray emission and x-ray absorption spectroscopy, Chem. Rev., vol. 101, pp. 1779-1808, (2001).

MA 40.60 Fri 11:00 P1A

**Multiferroic hysteresis in $MnWO_4$** — •Thomas Finger[1], Alexander Komarek[1], Daniel Senff[1], Petra Becker-Bohaty[2], Ladislav Bohaty[2], Louis-Pierre Regnault[3], Karin Schmalzl[4], Wolfgang Schmidt[4], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln — [3]CNG-Grenoble / ILL, Grenoble — [4]JCNS / ILL, Grenoble

Multiferroic materials or compounds with a strong magnetoelectric effect posses a large application potential in data storage techniques: one would like to replace the common magnetic writing by an electric process, as the generation of the magnetic fields is energy expensive. Quite recently, systems with a peculiar spiral magnetic order were shown to directly induce a spontaneous electric polarization and to exhibit giant magnetoelectric and magnetocapacitance effects, among them $MnWO_4$, which crystallizes in a monoclinic structure and undergoes several magnetic phase transitions as a function of temperature. From these phases only the incommensurate non-collinear ordering in the "AF2"-phase induces an electric polarization and large magnetoelectric effects, fully consistent with recent theories. We have succeeded for the first time to observe a chirality hysteresis curve driven by the

electric field. These data can give important information about the pinning of the multiferroic order, which is relevant in view of future applications. We want to present our temperature dependent studies on the multiferroic hysteresis as well as a characterization of the second harmonics of the spiral.

MA 40.61 Fri 11:00 P1A

**Magnetic structure in multiferroic pyroxenes: (Na, Li)FeSi2O6** — •Max Baum[1], Alexander C. Komarek[1], Navid Qureshi[1], Petra Becker[2], Ladislav Bohatý[2], Martin Meven[3], M. Teresa Fernandez Diaz[4], Paul Steffens[4], and Markus Braden[1] — [1]II. Phys. Inst., Universität zu Köln, Zülpicher Str. 77, 50937 Köln, Germany — [2]Inst. für Geologie und Mineralogie, Universität zu Köln, Zülpicher Str. 49b, 50674 Köln, Germany — [3]Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), Lichtenbergstr. 1, 85747 Garching, Germany — [4]Institut Laue-Langevin, BP 156, 6 rue Jules Horowitz, 38042 Grenoble Cedex 9, France

(Na,Li)FeSi2O6 exhibit multiferroic properties. Previous neutron diffraction experiments on powder samples of both compounds were interpreted in a commensurate model with antiferromagnetically coupled FeO6 chains of anti- or ferromagnetic character. Our triple-axis result of a single crystal is at odds with the former published commensurate model for magnetic ordering: magnetic ordering is incommensurate in NaFeSi2O6 with a temperature independent modulation. Magnetic satellites appear at q-positions corresponding to an incommensurate modulation vector (0,0.23,0). Based on powder neutron diffraction data, Redhammer et al. propose the Shubnikov group P21/c as the magnetic space group for LiFeSi2O6. This corresponds in antiferromagnetic ordering within and between the FeO6 chains. Our measurement on a single crystal reveals the Shubnikov group P21/c' which is equivalent to ferromagnetic coupling within the chains and antiferromagnetic coupling between the chains.

MA 40.62 Fri 11:00 P1A

**Pulsed laser deposited $TbMnO_3$ thin films on $YAlO_3$ with high crystalline quality** — •Artur Glavic[1], Jürgen Schubert[2], Jörg Voigt[1], and Thomas Brückel[1] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH, 52425 Jülich — [2]Institut für Bio- und Nanosysteme, Forschungszentrum Jülich GmbH, 52425 Jülich

We have chosen to deposit $TbMnO_3$ on $YAlO_3$ substrates because it has almost the same lattice parameters in plane as $TbMnO_3$ and a large difference in out of plane direction. Additionally the propagation vector of the magnetic spiral in the multiferroic state points out of plane. These two properties are advantageous for the use of scattering methods as the substrate- and filmpeaks are separated from each other and the magnetic structure can be probed by neutron diffraction easier. Multiferroic thin films of $TbMnO_3$ have already been fabricated using PLD on other Substrates as $SrTiO_3$ and $LaAlO_3$ in the orthorhombic and for example on $ZrO_2$ in the hexagonal phase.

We will present data from X-Ray diffraction experiments which show high crystalline quality (FWHM of less than 0.1 degree) and the obtained lattice constants of the epitaxial grown films. Rutherford back scattering with channelling of 2% could be observed, too. The temperature dependent magnetic properties have been probed with a SQUID magnetometer and an enhancement of the features compared to bulk has been found. The surface quality has been investigated by X-Ray reflectometry and atomic force microscopy.

MA 40.63 Fri 11:00 P1A

**Propagating and standing acoustic waves in Oxide multilayers** — •Marc Herzog[1], Mareike Kiel[1,2], Ionela Vrejoiu[3], Marin Alexe[3], Dietrich Hesse[3], and Matias Bargheer[1,2] — [1]Institute of Physics and Astronomy, University of Potsdam, 14476 Potsdam-Golm, Germany — [2]Max Planck Institute of Colloids and Interfaces, Research Campus Golm, 14476 Potsdam-Golm, Germany — [3]Max Planck Institute of Microstructure Physics, 06120 Halle, Germany

We investigate the ultrafast optical response of oxide multilayers composed of ferromagnetic metals ($SrRuO_3$ = SRO and $(La,Sr)MnO_3$ = LSMO), ferroelectrics ($Pb(Zr,Ti)O_3$ = PZT and $BaTiO_3$ = BTO) and the dielectrics ($SrTiO_3$ = STO). Typically 10 double layers (superlattice) of approx. 10 nm thickness are sufficient to define a mini-Brillouin zone, giving rise to the zone-folding of phonons and phonon band gaps. A tunable femtosecond pulse (IR, vis or UV) excites coherent phonons (strain waves) with the wavevector given by the artificial periodicity. An ultrashort whitelight continuum probes the transient reflectivity and transmission. The spectral and temporal information is used to disentangle standing and propagating strain waves and, moreover, to understand the fundamental processes driving the strain waves, such as electron-phonon coupling. In particular, we study the temperature dependence of the ultrafast response when tuning through ferroelectric and ferromagnetic phase transitions. These studies may be relevant for devices exploiting the coupled dynamics of several functional nanolayers.

MA 40.64 Fri 11:00 P1A

**Structural investigations of complex perovskite oxide films with X-ray diffraction** — •Ksenia Boldyreva, Diana Rata, Andreas Herklotz, Orkidia Bilani-Zeneli, Ruben Hühne, Ludwig Schultz, and Kathrin Dörr — IFW Dresden, Postfach 270116, 01171 Dresden, Deutschland

The electronic and magnetic properties of many complex oxides are highly sensitive to external parameters which include mechanical deformation or strain. Thus, X-ray diffraction methods such as reciprocal space mapping are powerful and indispensable for the characterization of thin films, particularly for evaluating the in-plane strain state. The direct influence of strain on the magnetization of epitaxial $La_{1-x}Sr_xMnO_3$ (LSMO) films has been studied utilizing piezoelectric PMN-PT substrates [1]. On the other hand, $La_{1-x}Sr_xCoO_3$ (LSCO) films also reveal large strain-induced changes of the magnetization and the electrical conductivity [2]. Since the in-plane lattice parameter of the piezoelectric substrate, PMN-PT, of ∼4.02 Å is larger than that of most correlated oxides, $LaSc_{1-x}Al_xO_3$ (LSAO) has been explored as a buffer layer showing a lattice parameter that is tunable by the composition $x$. The lattice structure of (i) LSAO buffers depending on the composition and (ii) of magnetic films (LSMO, LSCO) grown in various strain states will be discussed.

[1] C. Thiele *et al.*, PRB **75**, 054408 (2007); [2] A. D. Rata *et al.*, PRL **100**, 076401 (2008).

MA 40.65 Fri 11:00 P1A

**Cobalt-InAs-hybrid-structures operated at ferromagnetic resonance** — •Philippe Klemm[1], Sebastian Neusser[1], Bernhard Botters[1], Andreas Wittmann[1], Christian Heyn[2], and Dirk Grundler[1] — [1]Lehrstuhl für Physik funktionaler Schichtsysteme, — [2]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Jungiusstraße 11, Hamburg D-20355, Germany

It has been predicted that a ferromagnet operated in ferromagnetic resonance emits a spin current into adjacent nonmagnetic contacts, i.e. spin battery effect [1]. Recent experiments on multilayers of magnetic and non-magnetic metals have shown a corresponding spin precession effect, the so called spin pumping [2]. We present our approach on measuring a spin-precession induced voltage using a hybrid system of Al-Co-InAs (high mobility two-dimensional electron gas [3]). Samples are prepared using optical lithography and cleaved edge overgrowth. We discuss characterization measurements on the Co and InAs heterostructure. Furthermore, we present our broadband probe station setup used for GHz measurements. We acknowledge financial support through the German Excellence Cluster "Nanosystems Initiative Munich".

[1] A. Brataas et. al., Phys. Rev. B 66, 060404 (2002)
[2] B. Heinrich et al., Phys. Rev. Lett. 90, 187601 (2003)
[3]C. H. Möller et al., Appl. Phys. Lett. 80, 3988 (2002)

MA 40.66 Fri 11:00 P1A

**Magnetic and nonmagnetic states in graphene** — •Zhen Gang Zhu[1], Kai He Ding[2], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Nanotechnikum-Weinberg, Heinrich-Damerow-Strasse 4, D-06120 Halle (Saale), Germany — [2]Department of Physics and Electronic Science, Changsha University of Science and Technology, Changsha 410076, People's Republic of China

We investigate the conditions necessary for the presence or absence of localized magnetic moments on adatoms in graphene by using the equation of motion method for the Green's function. After decoupling to the third order, a self-consistent integral equation can be obtained. Its analytical properties are discussed. A compact analytical solution for the Green*s function is derived from the integral equations in the infinite interaction limit, giving rise to a set of self-consistent equations for the occupation numbers with different spins. Magnetic and nonmagnetic states of the impurity are discussed accordingly.

MA 40.67 Fri 11:00 P1A

**Fabrication and analysis of Fe and Fe/MgO films on the**

**GaAs(110) cleaved edge of an LED structure for spin injection** — •Hasmik Harutyunyan[1], Carsten Godde[1], Sani Noor[1], Ulrich Köhler[1], Arne Ludwig[2], Dirk Reuter[2], and Andreas D. Wieck[2] — [1]Institut für Experimentalphysik IV, AG Oberflächen, Ruhr-Universität Bochum, Germany — [2]Lehrstuhl für angewandte Festkörperphysik, Ruhr-Universität Bochum, Germany

This project's aim is the spin injection via Fe and Fe/MgO on the GaAs(110) cleaved edge which can be detected optically by an LED structure in the sample. The geometry of cleaved edge samples allows a spin injection perpendicular to the quantum well in the LED structure using an in plane magnetized Fe film. The conductivity mismatch is minimized either by the Schottky barrier of the Fe/GaAs interface or by use of MgO as a tunnelling barrier. This contribution focuses on the technical aspects of the cleaving and evaporation processes which are not trivial especially due to the dangers of short-circuiting the LED structure. Structured samples are cleaved in UHV. Cleaved edge overgrowth (CEO) is carried out under variable angles with respect to the cleavage surface. Angular dependent MOKE measurements have been performed in both cases. For Fe/GaAs, the easy axis is [001] with a high remanence. However, under the use of an MgO tunnelling barrier, the easy axis rotates by 90° into the $[1\bar{1}0]$. Photoluminescence has been shown for electrons travelling from the ferromagnetic contact into the semiconductor. Optical and therewith spin polarisation has yet to be demonstrated.

MA 40.68 Fri 11:00 P1A

**Elliott-Yafet spin relaxation mechanism in metals: an ab initio approach** — Martin Gradhand[1,2], Dmitry Fedorov[1], Michael Czerner[1], •Peter Zahn[1], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

In metals the spin scattering is dominated by the Elliott-Yafet mechanism. The electronic structure of the host and the perturbation of the potential in the vicinity of the defects were calculated in the framework of the density-functional theory using a multiple scattering Green's function Korringa-Kohn-Rostoker scheme. Treating the spin-flip transition matrix in Born approximation provides a good agreement with conduction electron spin resonance experiments for Cu containing different types of substitutional non-magnetic impurities [1]. Nevertheless, this approach neglects the spin-orbit interaction in the host and is not suitable for materials which show spin hot spots on the Fermi surface, like Al, Mg, and Be. To investigate such systems, we calculated the electronic wave functions and the solution of the impurity problem in the framework of the Dirac theory. First results obtained for defects in Al are discussed.

[1] D.V. Fedorov, P. Zahn, M. Gradhand, and I. Mertig, Phys. Rev. B **77**, 092406 (2008)

MA 40.69 Fri 11:00 P1A

**Spin dynamics in ferromagnetic antidot lattices** — •Sebastian Neusser, Bernhard Botters, Georg Dürr, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department,James-Franck-Str. 1, D-85747 Garching b. München, Deutschland

Our recent work on spin dynamics in antidot lattices is presented. We present a semi-analytical approach allowing the identification of the distinct eigenmodes of antidot lattices [1]. We find, both, extended modes spanning through the lattice and localized modes residing in individual unit cells. The influence of these modes on spin-wave propagation is discussed in the light of the emerging research field of magnonics; we find for antidot lattices that propagation is tailored by the orientation of the external field. Furthermore, we present experimental data of broadband ferromagnetic resonance performed on such systems [2] in good agreement with our theoretical predictions. Mode localization for different angles of the external field with the antidot lattice unit cell axis is discussed.

[1] S. Neusser, B. Botters, and D. Grundler "Localization, confinement, and field-controlled propagation of spin waves in antidot lattices" Phys. Rev. B, 78, 054406 (2008).

[2] S. Neusser, B. Botters, M. Becherer, D. Schmitt-Landsiedel, and D. Grundler, "Spin wave localization between nearest and next-nearest neighboring holes in an antidot lattice" Appl. Phys. Lett. 93, 122501 (2008).

MA 40.70 Fri 11:00 P1A

**Magnetization dynamics of nanoparticles subject to continuous magnetic fields or ultra short magnetic pulses** — •Alexander Sukhov[1,2] and Jamal Berakdar[2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle/Saale — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle/Saale

We study the magnetization dynamics of a Stoner nanoparticle using the Landau-Lifshitz-Gilbert equation of motion extended for finite temperatures. In case of continuous static or time-dependent magnetic fields we are interested in switching properties of the nanoparticles: Critical fields and the corresponding reversal times as a function of damping and temperature for various anisotropy types [1]. In the scheme proposed for ultra short magnetic pulses we show both analytically and numerically that not only switching but also a certain stabilization of the magnetization ("freezing") can be achieved regardless the anisotropy type and temperature. In contrast to the continuous fields additional parameters arise: Dynamics and control strongly depend upon an angle shift between the magnetization and the pulse, the duration and the form of pulses.

[1] A. Sukhov and J. Berakdar, J. Phys.: Condens. Matter **20**, 125226 (2008).

MA 40.71 Fri 11:00 P1A

**Spin-transfer torque in tunnel junctions: Comparison of ab initio and simple models** — •Asma H. Khalil[1], Arne G. Christen[1], Paul M. Haney[2], Mark D. Stiles[2], and Christian Heiliger[1] — [1]I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany — [2]Center for Nanoscale Science and Technology, National Institute of Standards and Technology, Gaithersburg, MD 20899-6202, USA

Our reported ab initio calculations of the spin-transfer torque in Fe/MgO/Fe tunnel junctions are in excellent agreement with experimental results [1]. Simple model calculations give different results [2]. In particular, they show strong deviations from a linear bias voltage dependence of the in-plane torque even for small biases. In this contribution we analyze simple single band models for a large number of parameters to point out the difference between them and first principles calculation. With our results we show the importance of ab initio calculations. This work has been supported in part by the NIST-CNST/UMD-NanoCenter Cooperative Agreement.

[1] C. Heiliger and M.D. Stiles, Phys. Rev. Lett. **100**, 186805 (2008)
[2] I. Theodonis, N. Kioussis, A. Kalitsov, M. Chshiev, and W. H. Butler, Phys. Rev. Lett. **97**, 237205 (2008)

MA 40.72 Fri 11:00 P1A

**Tunneling of spin waves through a mechanical gap** — •Thomas Schneider[1], Alexander A. Serga[1], Andrii V. Chumak[1], Mikhail P. Kostylev[2], and Burkard Hillebrands[1] — [1]FB Physik und Forschungszentrum Optimas, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]School of Physics, M013, University of Western Australia, Crawley, WA 6009, Australia

We report on the investigation of spin-wave tunneling through a mechanical gap. Tunneling in this case happens due to the long range dipolar field created by the spin waves. Experiments were performed in yttrium iron garnet waveguides where gaps of different sizes were created perpendicular to the waveguide axis by chemical etching. Spin-wave excitation was performed using microwave pulses that were applied to a microstrip transducer. Brillouin light scattering spectroscopy as well as a conventional microwave technique were used to detect the spin waves. The use of two microstrip antennas allowed us to simultaneously observe the spin waves that tunnel through the gap as well as a reference spin wave that propagates in the continuous part of the same sample. By comparing the intensities of this two waves one can precisely determine the tunneling transmission coefficient. Realizing interference between them provides the possibility to measure the additional phase shift induced by the tunneling process.

Financial support by the DFG (Graduiertenkolleg 792 and SE 1771/1-1) and the Australian Research Council is gratefully acknowledged.

MA 40.73 Fri 11:00 P1A

**Spin wave generation by photon coupled exchange magnons** — •Vitaliy I. Vasyuchka, Christian Sandweg, Alexander A. Serga, and Burkard Hillebrands — FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, Germany

The behavior of a parametrically driven magnetic medium after the pumping source is switched off defines the important problem of pumping-free evolution of a non-equilibrium magnon gas.

A parallel electromagnetic pumping process creates pairs of photon coupled exchange magnons at half of the pumping frequency. These pairs induce a microwave magnetic field which is coherent with the pumping one but is shifted in phase. Thus the net pumping is effectively reduced in a stationary state. Switching the pumping source off is accompanied by an increase of the net magnetic field at the pumping frequency.

We report on the first observation of the energy transfer in the magnon gas caused by the influence of this field. The experiment was performed using a tangentially magnetized yttrium-iron-garnet (YIG) film. A microwave pumping pulse was supplied to the microstrip transducer. The signal irradiated by the YIG sample at half of the pumping frequency was picked up by the same microstrip. Just after the pumping pulse is switched off we detected a sharp peak at the end of this signal. The appearance of the peak is interpreted as a result of the parametric generation of long-wave spin waves by the non-compensated internal field, which acts as a pump.

Financial support by the DFG (SFB/TRR 49) is acknowledged.

MA 40.74 Fri 11:00 P1A

**Multiple spin-wave pulse recovery by parallel pumping** — •Volker Kegel, Sebastian Schäfer, Alexander A. Serga, and Burkard Hillebrands — FB Physik und Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We have studied the storage and parametrically stimulated recovery of microwave signals in a tangentially magnetized yttrium-iron-garnet (YIG) ferrite film. The microwave signal carried by a packet of magnetostatic surface spin waves (MSSW) is stored due to the excitation of dipolar-exchange standing spin-wave modes across the film thickness. A recovered MSSW packet appears in the film as a result of parametric amplification of one of these standing modes [1]. The recovery delay time as well as the duration and amplitude of the recovered signal are mostly controlled by the power of the pumping signal. Here we report on the behaviour of the spin-wave system under influence of multiple pumping pulses applied per one MSSW signal pulse. We demonstrate the ability of a multiple recovery process and discuss the dependence of its characteristics on the time interval between pumping pulses. Financial support by the DFG (SFB/TRR 49) is acknowledged.

[1] A.A. Serga, A.V. Chumak, A. Andre, G.A. Melkov, A.N. Slavin, S.O. Demokritov, and B. Hillebrands, PRL 99, 227202 (2007).

MA 40.75 Fri 11:00 P1A

**Improvement of the spin torque reversal by resonant microwave currents** — •Lukas Fricke, Santiago Serrano-Guisan, and Hans-Werner Schumacher — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

We study ultra fast spin torque (ST) magnetization reversal in magnetic tunnel junctions by numerical simulations in the macrospin (single-domain) approximation. Magnetization reversal by pulsed currents under a hard axis bias field is studied. We find optimized low current switching for low fields inducing a tilt of the free layer magnetization out of the easy axis by about 6°. Similar results are obtained with tilted pinned layer devices. Furthermore ST reversal assisted by resonant microwave currents is considered. Here, an AC oscillation with frequency close to the ST precession frequency of the free layer is superimposed on the DC current pulse. The efficiency and reversal time of such AC assisted ST reversal schemes is investigated.

MA 40.76 Fri 11:00 P1A

**Trajectory imaging of current-induced gyrotropic vortex motions** — •Martin Müller, Christian Dietrich, Christian Back, Dieter Weiss, and Josef Zweck — Institut für Experimentelle und Angewandte Physik der Universität Regensburg, Germany

Transmission Electron Microscopy (TEM) can be used to study current induced excitations in low dimensional magnetic systems. Lorentz microscopy, a special operating mode with switched-off objective lens, using a long focal length lens instead, yields information about domain wall structures and/or the vortex position of magnetic disk samples. In this work we investigate magnetic specimens with different geometries (Landau structures in thin-film square elements/vortex structures in disks) and lateral dimensions in the micrometer range. It is possible to excite the gyrotropic eigenmode of the vortex structure by a spin-polarized ac current with frequencies in the range between 40 to 400 MHz. Lorentz microscopy enables us to image the trajectory of the vortex motion. We demonstrate that the resonantly excited vortex core has a circular trajectory whereas in off-resonance the motion of the vortex core is elliptical as predicted by analytical calculations[1]. The shape and the size of the trajectory and its frequency distribution depends on the ratio of spin transfer torque and Oersted field and therefore on the spin polarization of Permalloy.

Modifications in the magnetic specimen, such as an artificially created hole or other defects have been investigated and show a different vortex motion.

[1] Ki-Suk Lee, Sang-Koog Kim, Phys. Rev. B **78**, 014405 (2008)

MA 40.77 Fri 11:00 P1A

**Spatially and Time-Resolved Scanning Kerr Microscopy on Permalloy Microstructures** — •Andreas Krohn, Sebastian Mansfeld, Felix H. R. Balhorn, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg

We report on microwave induced spin waves in narrow permalloy wires with typical thicknesses and widths of 20 nm and 5 $\mu$m, respectively. We have set up a novel experiment, where the microwave frequency is synchronized with the pulses of the laser used to detect the magnetization in the sample via the magneto optical Kerr effect. This enables time and spatially resolved measurements of spin waves in the permalloy structures. Due to the geometric boundary conditions in our samples spin waves underlie quantization effects and spin-wave modes are formed. We investigate the propagation of these spin-wave modes for several resonance conditions and find frequency dependant propagation velocities in the region of 100.000 m/s. We compare our findings with an analytical model based on spin waves in ferromagnetic films combined with quantization rules and micromagnetic simulations performed by OOMMF.

We thank the Deutsche Forschungsgemeinschaft for financial support via SFB 668 and 508.

MA 40.78 Fri 11:00 P1A

**Spin-wave excitation in Permalloy by oscillating pinned domain walls** — •Christopher Rausch, Sebastian Hermsdörfer, Helmut Schultheiss, Sebastian Schäfer, Philipp Pirro, Britta Leven, and Burkard Hillebrands — FB Physik und Landesforschungszentrum OPTIMAS, Erwin-Schrödinger-Str. 56, TU Kaiserslautern, 67663 Kaiserslautern, Germany

This poster presents a new mechanism for the spin-wave excitation. The excitation of spin waves by oscillating pinned domain walls is an alternative approach to the well-known excitation via an antenna or, as another example, via vortex-anti-vortex-annihilation. The investigations have been carried out using micromagnetic simulations (LLG-code). The basic idea of the mechanism is to deflect a pinned domain wall out of its equilibrium position within the limits of the domain wall pinning. The following relaxation caused by the pinning potential which is driving the wall back towards the equilibrium position occurs as a damped oscillation with characteristic eigenfrequency. In case that the domain wall is excited by an external field with this eigenfrequency, a "steady-state" oscillation forms out with the eigenfrequency and an amplitude determined by the energy balance between the dissipation processes due to damping and the external triggering by the applied field. The energy pumped into the system by the external field leads not only to the compensation of the damping but also to the radiation of spin waves.

Financial support by the DFG within the SPP1133 is gratefully acknowledged.

MA 40.79 Fri 11:00 P1A

**2D approach to the k-vector resolution of the Brillouin light scattering spectroscopy** — •Benjamin Jungfleisch, Christian W. Sandweg, Vitaliy I. Vasyuchka, Alexander A. Serga, and Burkard Hillebrands — FB Physik und Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

In this poster we report on our progress towards k vector sensitivity using Brillouin light scattering spectroscopy which enables us to detect and resolve the whole range of magnon wave vectors occurring during the formation of magnon gases and condensates. We overcome this challenge by varying the angle of incident light with respect to the orientation of magnetization. The improvement of our approach consists of expanding this k-vector sensitivity to two dimensions such that spin-wave wave vectors oriented both parallel and perpendicular to the external field can be resolved and measured. The proper operation of this setup is demonstrated by showing the results both for directly excited spin waves near the ferromagnetic resonance and for magnons at the lowest energy state of a parametrically driven magnon gas in yttrium-iron-garnet ferrimagnetic film.

MA 40.80 Fri 11:00 P1A

**Laser-Induced Generation and Quenching of Magnetization on FeRh Investigated with Time-Resolved X-ray Magnetic Circular Dichroism** — •Ilie Radu[1,2], Christian Stamm[2], Niko Pontius[2], Torsten Kachel[2], Paul Ramm[1], Jan-Ulrich Thiele[3], Hermann Dürr[2], and Christian Back[1] — [1]Regensburg University, Regensburg, Germany — [2]BESSY GmbH, Berlin, Germany — [3]Hitachi Global Storage, San Jose, CA, USA

Upon heating, the equiatomic FeRh alloy exhibits a first-order magnetic phase transition from the antiferromagnetic (AFM) to the ferromagnetic (FM) state around room temperature. Here, we study the fs laser-induced AFM-FM phase transition as well as the transition from FM towards the paramagnetic state by employing the time-resolved X-ray magnetic circular dichroism. Both Fe and Rh elements show a gradual growth of the magnetic moment within 200 ps after laser excitation. Temperature-dependent data, measured at intermediate temperatures between AFM and FM state, provide evidence for the rapid nucleation and subsequent slow expansion of the FM regions within an AFM matrix, supporting the magnetization growth model proposed in [1]. Once in the FM state, FeRh can be optically demagnetized on a few ps time scale (limited by the X-ray probing pulse). Further time-resolved magneto-optics measurements done in the visible spectral range reveal a demagnetization time constant of ˜200 fs. For the photo-induced demagnetization process we consider a mechanism that follows the transient electronic structure of the system.

[1] B. Bergmann et al., PRB 73, 060407(R) (2006)

MA 40.81 Fri 11:00 P1A

**Current induced switching of MgO-based MTJs at different temperatures** — •Markus Schäfers, Andy Thomas, Karsten Rott, and Günter Reiss — Bielefeld University, Universitätsstrasse 25, D-33615 Bielefeld, Germany

A spin-polarized current injected into a nanomagnet applies a torque to the magnetization and induces a precession or even a reversal of the magnetization direction. This spin-torque effect has generated much interest because it can be used as writing mechanism to store information in magnetic random access memory (MRAM). An extensive understanding of the switching process is necessary to produce high performance memory cells.

Here, we prepared sub-$\mu$m-sized MTJs with different free layer thicknesses based on CoFeB/MgO/CoFeB by e-beam lithography and argon ion beam etching. We compare the critical current densities for switching the free layer of these samples at different temperatures.

Samples were provided by Singulus Nanodeposition Technologies GmbH.

MA 40.82 Fri 11:00 P1A

**Interdigital transducers for surface acoustic wave radiation onto ferromagnetic films** — •Rupert Huber, Bernhard Botters, Sebastian Neusser, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme Technische Universität München, Physik Department, James Franck Straße 1, 85747 Garching

We introduce our work on the design and fabrication of an emitter-receiver configuration of interdigital transducers (IDT). This system is assembled on the piezoelectrical crystal Lithium Niobate as substrate material, radiating surface acoustic waves (SAW). Encouraged by simulations with SYNC [1] we design IDTs matched to a 50 Ohm circuit. We test them at frequencies from 100 MHz up to the GHz regime by a vector network analyzer (VNA). In the propagation path of the SAWs we introduce a ferromagnetic film. We control the magnetic state with an external magnetic field. The SAWs are expected to distort the ferromagnetic film. We aim at measuring the transmitted SAWs depending on the magnetization state oft he film. We acknowledge support from the German Excellence Cluster "Nanosystems Initiative Munich".

[1] http://www.sawlab.te.chiba-u.ac.jp/˜ken/freesoft.html

MA 40.83 Fri 11:00 P1A

**Observation of reversible current-induced vortex core displacements in magnetic disks** — •Lutz Heyne, Jan Rhensius, Dennis Ilgaz, Mathias Kläui, and Ulrich Rüdiger — Universität Konstanz, Germany

The understanding of the interplay between spin-polarized currents and the magnetization is of high scientific interest and many proposed applications relay on the ability of controlled manipulation of the magnetization by currents. Here especially the influence of the so called non-adiabatic contribution on the interaction is to the present point poorly understood. Vortex cores exhibit large magnetization gradients and it has been predicted that the non-adiabatic contribution will be large in these systems. Thus their study can reveal important information concerning the non-adiabatic term.

We present new results on the interaction between injected current and magnetic vortex cores. Moreover we calculate the vortec core response theoretically as well as numerically to compare with the experimental results.

With direct imaging using X-ray photo emission electron microscopy we directly measure the current-induced vortex core displacement as a function of the current density. The results allow us to estimate the influence of the non-adiabatic term to the magnetization dynamics.

MA 40.84 Fri 11:00 P1A

**Electron Spin Resonance in 2D triangular Cr-spin lattices** — •Mamoun Hemmida, Hans-Albrecht Krug von Nidda, and Alois Loidl — Experimentalphysik V, Elektronische Korrelationen und Magnetismus, Universität Augsburg, 86135 Augsburg, Germany

The spin dynamics in some two-dimensional (2D) triangular Cr-antiferromagnetic lattices, i.e. the rock salt compounds $HCrO_2$, $LiCrO_2$, and $NaCrO_2$ as well as the delafossite compounds $CuCrO_2$ and $AgCrO_2$, have been investigated by electron spin resonance (ESR). In these oxides, the divergence of the temperature dependent linewidth, on approaching the Néel temperature $T_N$ from above, is well described in terms of a Berezinskii-Kosterlitz-Thouless (BKT) scenario [1-3] due to magnetic vortex-antivortex pairing. Except for $LiCrO_2$, where $T_{KT}$ is close to $T_N$, the broad fluctuation regime $T_{KT} < T < T_N$ suggests an intermediate 2D liquid antiferromagnetic state in analogy to the melting scenario of a 2D triangular lattice described by Nelson, Halperin, and Young in the framework of a modified Kosterlitz-Thouless model [4,5].

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[2] J. M. Kosterlitz and D. J. Thouless, J. Phys. C **6**, 1181 (1973).
[3] J. M. Kosterlitz, J. Phys. C **7**, 1046 (1974).
[4] B. I. Halperin and D. R. Nelson, Phys. Rev. Lett. **41**, 121 (1978).
[5] A. P. Young, Phys. Rev. B **19**, 1855 (1979).

MA 40.85 Fri 11:00 P1A

**Dissipation and coupling of spin-wave eigenmodes in nanoscaled magnetic ring structures** — •Katrin Vogt, Helmut Schultheiss, Björn Obry, Christian Sandweg, Sebastian Hermsdörfer, Sebastian Schäfer, Britta Leven, and Burkard Hillebrands — Fachbereich Physik and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Small magnetic ring structures magnetized in the onion state exhibit two spin-wave eigenmode systems confined at the pole and equatorial positions, respectively. With time-resolved Brillouin light scattering microscopy we analyzed the decay of these spin-wave eigenmodes after the resonant excitation with a microwave pulse. A strong dependency on the position within a single ring was found for the lifetime of the excited spin-wave eigenmodes showing that the damping of the magnetization dynamics is not constant within a single magnetic element. Furthermore, we demonstrate that the eigenmode frequencies can be tuned by means of an externally applied field. For certain frequency ratios of the eigenmode frequencies at the pole and equatorial position a nonlocal coupling of spin-wave eigenmodes is observed. Energy is transferred from spin-wave eigenmodes confined in the poles of the ring to spin waves at the equator if the frequency ratio is an integer number. Financial support by the DFG (SPP1133) is acknowledged.

MA 40.86 Fri 11:00 P1A

**Time resolved field induced domain wall excitations in permalloy wires** — •Jan Rhensius[1,2], Lutz Heyne[2], Dirk Backes[1,2], Stephen Krzyk[2], Dennis Ilgaz[2], Mathias Kläui[2], Laura J. Heyderman[1], Ulrich Rüdiger[2], Frithjof Nolting[1], and Arantxa Fraile-Rodriguez[1] — [1]Paul Scherrer Institut, 5232 Villigen, Switzerland — [2]Universität Konstanz, 78457, Germany

Micromagnetic systems are predicted to be useful for future magnetic storage devices. Therefore the investigation of the fundamental mechanisms of magnetization dynamics is essential. Field induced domain wall excitations are investigated with time and spatially resolved XMCD-PEEM (X-ray Magnetic Circular Dichroism - Photoemmission Electron Microscopy). We study the domain configurations in permalloy wires with a width of 2 $\mu$m, fabricated by electron beam lithography. Using a 10 *m wide stripline, connected to a laser triggered diode, well defined sub-ns field pulses were applied to move the domain wall. By triggering the channel plate of the PEEM at a well defined delay

time, this pump-probe experiment achieves a time resolution of below 100 ps and a spatial magnetic resolution of about 50 nm. With this we can quantitatively analyze the response of the domain wall to the field pulse and we find domain wall displacements with velocities of hundreds of m/s. To understand the results, we compare the experimental data with results of micromagnetic simulations and find good agreement.

MA 40.87 Fri 11:00 P1A

**Field- and Current-induced Domain Wall Motion in Ho-doped Permalloy Nanowires probed by single shot Kerr-microscopy** — •Philipp Möhrke[1], Thomas A. Moore[1,2], Mathias Kläui[1], Stephen Krzyk[1], Jan Rhensius[1,3], Dirk Backes[1,3], Laura J. Heyderman[3], and Ulrich Rüdiger[1] — [1]Universität Konstanz, Fachbereich Physik, Universitätsstraße 10, 78457 Konstanz, Germany — [2]SPINTEC, CEA Grenoble, 17 rue des Martyrs, 38054 Grenoble Cedex 9, France — [3]Paul Scherrer Institut, 5232 Villingen PSI, Switzerland

We present single shot measurements of field- and current-induced DW dynamics in pure and Holmium-doped Permalloy ($Ni_{80}Fe_{20}$) nanowires (thickness 20-25 nm, width $\geq$ 500 nm) by nanosecond time-resolved Kerr-microscopy. We probe the velocity of single DW displacements across a 1 $\mu$m spot size located at various positions along the wire and determine the depinning fields and currents.
Results obtained from 1500 nm-wide and 25 nm-thick pure and Ho-doped Py-wire with the laser focused at a position 10 $\mu$m away from the starting point of the DWs are presented. DWs were repeatedly prepared at the kinks in the wire, the field ramped from 0 G with a speed of in 1 G/$\mu$s and the arrival times / depining fields measured. Measurements on samples, which by doping with Ho, have a different damping constant $\alpha$ show a significant drop of the average velocity with increasing $\alpha$. These velocities are compared by results obtained from micromagnetic simulations.

MA 40.88 Fri 11:00 P1A

**Current induced domain wall motion in out-of-plane magnetized magnetic nanowires characterized by high resolution magnetic imaging** — •Olivier Boulle, Lutz Heyne, Jan Heinen, Jan Rhensius, Mathias Kläui, and Ulrich Rüdiger — Fachbereich Physik, Universität Konstanz, Universitätsstrasse 10, 78457 Konstanz, Germany

Current driven domain motion (CIDM) in perpendicularly magnetized multilayers attracts currently much interest due to the simple and narrow Bloch DWs observed in these materials and the more efficient spin transfer compared to previously studied in-plane magnetized permalloy nanowires. Here we report on current induced DW propagation in promising out-of-plane magnetized materials, such as low coercivity $(CoFeB(0,6nm)/Pt)_n$ multilayers and highly spin polarized $(Co/Ni)_n$ multilayers. Current-induced magnetization switching was studied in these materials for the first time by high resolution magnetic imaging using XMCD-PEEM. In $(CoFeB(0,6nm)/Pt)_n$, for wide wires (2 $\mu$m) and/or high current densities, current induced domain nucleation is observed. The analysis of the domain patterns indicate that the Oersted field plays a major role in the domain nucleation. In particular, the domain structure can be reversibly switched from one domain configuration to another by current by the sole effect of the Oersted field [1]. For smaller wire width and lower current, current induced DW motion is observed and the interplay between Oe field and spin torque results in a strongly geometry-dependent behaviour.

[1] Boulle et al, Jour. of Appl. Phys., (in press 2008)

MA 40.89 Fri 11:00 P1A

**Microwave-Assisted Magnetization Reversal in $Ni_{80}Fe_{20}$ Nanowires: Reduced Critical Fields in Arrays with sub 100 nm Spacing** — •Jesco Topp[1], Stefan Mendach[1], Detlef Heitmann[1], and Dirk Grundler[2] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany — [2]Physik-Department E10, Technische Universität München, James-Franck-Straße, 84747 Garching b. München, Germany

We studied microwave-assisted switching (MAS) in densely packed arrays of $Ni_{80}Fe_{20}$ nanowires. We used electron-beam lithography and lift-off processing to prepare arrays of 300 nm wide and 20 nm thick ferromagnetic nanowires with an edge-to-edge spacing of 90 nm. To study MAS the nanomagnets were irradiated with a microwave (rf) of fixed frequency and power and the linear eigenmode spectrum was used to probe the magnetization configuration inside the array.

We observe microwave-assisted switching for rf fields of less than 2 mT, a factor 3 lower than reported previously for individual nanowires of similiar dimensions. The phase-diagram of the switching efficiency is a complex function of rf amplitude and frequency. The switching process is most efficient at frequencies below linear eigenfrequency, which we attribute to the non-linear nature of the precession that leads to the magnetization reversal. For higher rf amplitude the regime of MAS is severely broadened by several GHz. Under optimal conditions the switching field can be reduced by more than 50%.

This work is supported by the DFG via "SFB 668" and the "Nanosystems Initiative Munich" (NIM).

MA 40.90 Fri 11:00 P1A

**Magnetization dynamics in curved permalloy nanowires** — •Sandra Motl-Ziegler, Lars Bocklage, Toru Matsuyama, Jesco Topp, Markus Bolte, and Guido Meier — Universität Hamburg, Institut für Angewandte Physik, Jungiusstr. 11, D-20355 Hamburg

Magnetization dynamics in nanostructures is an interesting field of research as magnetization patterns like domain walls and vortices form on these length scales. We investigate field-induced magnetization dynamics in curved permalloy nanowires placed on a waveguide. The dependence of spin-wave modes on an external magnetic field and on the excitation frequency is studied by a broadband ferromagnetic resonance setup [1]. After saturating a nanowire the field is reduced resulting in a domain wall in the curved part of the wire. In magnetic fields between -90 mT and 90 mT the frequency is swept from 45 MHz to 20 GHz by a network analyzer. Spectra are normalized with a reference measurement at a saturating field to improve the visibility of the spin-wave modes. For a wire of 6 $\mu$m length, 200 nm width, and 20 nm thickness with an outer radius of 3 $\mu$m we identify five modes. The measurements are compared with numerical simulations based on the Landau-Lifshitz-Gilbert equation to support the experimental results. Permalloy stripes and wires with different radii are also studied.
[1] J. Podbielski et al., Phys. Rev. Lett. **96**, 167207 (2006)

MA 40.91 Fri 11:00 P1A

**Inductive detection of spin wave propagation in permalloy thin films** — •Georg Dürr, Sebastian Neusser, Bernhard Botters, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Str. 1, D-85747 Garching b. München, Germany

Spin wave propagation in permalloy thin films is investigated, both in the frequency and the time domain. Different configurations of two coplanar waveguides used as emitter and receiver of spin waves are presented. Using a broadband vector network analyzer we measure the spin wave eigenfrequencies in the frequency domain. In a further experiment the transmission of pulsed induced spin waves in the time domain is detected using a digital sampling oscilloscope. All measurements are performed at room temperature with an external field applied in different directions. We discuss the data in the light of the spin wave propagation based on dispersion relations of permalloy thin films. We acknowledge financial support through the German excellence cluster "Nanosystems Initiative Munich".

MA 40.92 Fri 11:00 P1A

**Effect of a DC current on the magnetization dynamics in spin-valve nanocontacts** — •Abdelghani Laraoui[1], Florin Ciubotaru[1], Helmut Schultheiss[1], Alexander Serga[1], Sebastian Hermsdörfer[1], Maarten van Kampen[2], Liesbet Lagae[2], Britta Leven[1], Andrei N. Slavin[3], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]IMEC, Kapeldreef 75, Leuven, Belgium — [3]Oakland University, Rochester, Michigan, USA

We have studied the magnetization dynamics in spin-valve nanocontact devices under the influence of an applied microwave ac and dc current by means of Brillouin light scattering (BLS) microscopy. To obtain an idea of the possible modes of spin waves that can be excited, the 80 nm point contact was subjected to an ac current of varying frequencies and powers. The BLS spectra of the extended Py free layer of the spin-valve stack were recorded at a fixed position near to the point contact (˜ 200 nm) and for various amplitudes of an external magnetic field. Strong nonlinear spin waves are excited with the ac current and discussed within the framework of three magnon scattering. In the presence of a dc current the efficiency of the direct excited modes is enhanced. This effect can be explained by both spin transfer torque and Oersted field effects. In addition, the threshold properties for nonlinear spin-waves (non-integer modes) excitation are mainly controlled by the Oersted field created by the dc current injected through the nanocontact. Sup-

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MA 40.93 Fri 11:00 P1A

**Anisotropy dependence of domain structure and magnetization dynamics in magnetic thin film elements** — •Claudia Patschurek, Jeffrey McCord, Rainer Kaltofen, Rudolf Schäfer, and Ludwig Schultz — IFW Dresden, Inst. f. Metallische Werkstoffe, Helmholtzstr. 20, 01069 Dresden

Patterned multilayered samples of polycrystalline Ni81Fe19 and amorphous Co60Fe20B20 with and without a 5 nm MgO interlayer were deposited under an applied field using dc magnetron sputtering. While the total stack thickness of 80 nm was kept constant, the thickness ratio of the individual layers was systematically varied in order to achieve a linear change of magnetic anisotropy. Static and dynamic properties were investigated by quasi-static magnetometry and pulsed inductive microwave magnetometry (PIMM).

Magneto-optical Kerr microscopy studies reveal that the patterning leads to the formation of characteristic, anisotropy-dependent non-Landau closure domain structures in the non-laminated elements, while no anisotropy dependence is obvious for the domain structure of laminated thin film elements. Irregular contributions to the effective field and thus the dynamic magnetic response, originating from the domain structures, were identified.

MA 40.94 Fri 11:00 P1A

**Tunnel magnetoresistance and spin dependent shot noise in carbon nanotube quantum dot in the Kondo regime** — •Stanislaw Lipinski and Damian Krychowski — Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland

The out of equilibrium transport properties of carbon nanotube quantum dot coupled to ferromagnetic electrodes are studied by means of the non-equilibrium Green functions using equation of motion method. Polarization of electrodes introduces the spin dependence of tunneling rates and exchange splitting of the dot level. We point out on the possibility of achieving giant values of tunnel magnetoresistance in the Kondo range and discuss a prospect of gate control of this quantity. Change of the gate enables a control of the value and sign of polarization of conductance. For parallel orientation of polarizations of electrodes a significant decrease of the Fano factor is observed for gate potentials corresponding to vanishing exchange splitting. The exchange induced Kondo satellites reflect in the bias or gate dependences of spin resolved Fano factors.

MA 40.95 Fri 11:00 P1A

**AC Transport in thin manganite films** — •Sebastian Hühn, Kai Gehrke, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37707 Göttingen

We have studied the metal-insulator (MI) transition in perovskite manganite films by means of a.c. electric transport technique. The films of $La_{1-x}Sr_xMnO_3$ (LSMO), $La_{1-x}Ca_xMnO_3$ (LCMO) and $(La_{1-y}Pr_y)_{1-x}Ca_xMnO_3$ (LPCMO) were prepared by a metalorganic aerosol deposition technique. The linear $R_\omega$ and nonlinear 3$^{rd}$ harmonic resistance $R_{3\omega}$ were measured simultaneously as a function of temperature (4-300K), current (1-1000$\mu$A), frequency (1-1000Hz) and magnetic field (0-7T). We show that the MI transition temperature ($T_{MI}$) is frequency dependent. The nonlinear resistance $R_{3\omega}$ is strongly enhanced mostly in the vicinity of $T_{MI}$ and shows a peculiar magnetic field dependance. The results on LPCMO film are compared with LCMO and LSMO and discussed within correlated polarons approach and phase separation scenario.

Deutsche Forschungsgemeinschaft via SFB 602, TPA2 is acknowledged

MA 40.96 Fri 11:00 P1A

**Electronic structure in mesoscopic systems under finite bias** — •Steven Walczak[1,2], Michael Czerner[2], Christian Heiliger[3], and Ingrid Mertig[2] — [1]Max Planck Institute of Microstructure Physics, D-06120 Halle (Saale), Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, D-06120 Halle (Saale), Germany — [3]I. Physikalisches Institut, Justus Liebig University, D-35392 Giessen, Germany

The understanding of the I-V-characteristics is a key issue in ballistic transport. In particular, the voltage drop within the scattering region depends strongly on the geometry of the system. For example in a tunnel junction one expects a simple linear voltage drop over the barrier but for atomic contacts, nanowires, or molecules the voltage drop is expected to be more complicated. To account for these systems we extend our implementation of the Keldysh formalism in the Korringa-Kohn-Rostoker Green's function method [1]. Furthermore, a real space formulation of the Keldysh equation is used to describe open systems which exhibit broken translational symmetry like atomic contacts or nanowires.

Our extension includes the self-consistent treatment of the system under applied bias using the non-equilibrium density between the chemical potentials of the left and the right lead. The voltage drop within the system is then proportional to the difference of the densities with and without an applied voltage.

[1] C. Heiliger, M. Czerner, B. Yavorsky, I. Mertig, M. Stiles, J. Appl. Phys. 103, 07A709 (2008)

MA 40.97 Fri 11:00 P1A

**Direct measurement of the spin polarization of Co-Fe and Co-Fe-B** — •Savio Fabretti[1], Oliver Schebaum[1], Andy Thomas[1], Günter Reiss[1], and Jagadeesh Moodera[2] — [1]Universität Bielefeld — [2]MIT Cambridge

We investigated the spin polarization of Co-Fe and Co-Fe-B thin films with the Meservey-Tedrow method. Superconductor/insulator/ferromagnet (S/I/F) structures were fabricated using shadow masks and DC- and RF-magnetron sputtering in an automatic sputtering system. The samples have been post annealed in a vacuum furnace. The superconducting electrode consists of $Al_{95}Si_5$ while the insulator is MgO. For optimization of the superconducting tunnel junctions the properties of the Al-Si films on MgO buffer layers have been investigated in dependence of the Al-Si thickness and the annealing temperature. The dI/dV measurements were done in a $^3$He cryostat at a temperature of 0.46K with magnetic fields applied in the range of 2T to 2.8T. Finally, the results were compared with conventional MgO magnetic tunnel junctions with Co-Fe and Co-Fe-B electrodes.

MA 40.98 Fri 11:00 P1A

**Measurement of the spin polarisation of the current through nanostructured Al/Fe and Nb/Fe point contacts** — •Konstantin Mirlin[1], Samuel Bouvron[1], Michael Marz[1,2], Gernot Goll[1], Christoph Sürgers[1,2], and Hilbert v. Löhneysen[1,2,3] — [1]Physikalisches Institut, Universität Karlsruhe, 76128 Karlsruhe — [2]DFG-Zentrum für funktionelle Nanostrukturen der Universität Karlsruhe, 76128 Karlsruhe — [3]Institut für Festkörperphysik, Forschungszentrum Karlsruhe, 76021 Karlsruhe

Point-contact spectroscopy can be used to determine the spin polarisation $P$ of the current through a S/F point contact. We used this method to study nanostructured Al/Fe and Nb/Fe contacts produced by electron-beam lithography. We measured the differential conductance spectra $G(V) = dI/dV(V)$ of the Nb/Fe contacts in a $^4$He cryostat down to 1.5 K and described the spectra within two different theoretical models, the Mazin model [1] and the Cuevas model [2]. The first one considers the current through the F/S contact as composed of a fully polarised and an unpolarised part. The second one is based on the Landauer-Büttiker formalism with spin dependent transmission coefficients $\tau_{\uparrow(\downarrow)}$ with a single $P = (\tau_\uparrow - \tau_\downarrow)/(\tau_\uparrow + \tau_\downarrow)$. $P$ depends on the contact size and is reduced with increasing contact size, possibly due to spin-orbit scattering in the contact region [3]. This scenario is supported by a larger decrease of $P$ for Nb/Fe contacts compared to Al/Fe contacts, as expected for spin-orbit scattering.

[1] I.I. Mazin, PRL 83(7), 1427 (1999); [2] J.C. Cuevas et al., PRB 69, 140502 (2004); [3] M. Stokmaier et al., PRL 101(14), 147005 (2008)

MA 40.99 Fri 11:00 P1A

**In-situ Preparation and Characterization of Tailored Magnetic Nanocontacts** — Stephen Krzyk, Ajit Patra, •Andre Bisig, Mathias Kläui, and Ulrich Rüdiger — Fachbereich Physik, Universität Konstanz, 78457 Konstanz

It has been shown that magnetoresistance measurements can be used to investigate domain walls spin structure and pinning characteristics [1], and that the type and pinning behavior of domain walls is strongly dependant on the geometry of the investigated structures [2]. So far, the accessible lateral size regime has been limited by the finite resolution of the lithographic preparation process. An innovative approach to overcome this limitation and leading down to atomic size of a contact is the electromigration technique [3].

We use a combination of electron- and focussed-ion-beam lithography to pre-pattern nanoscale ring-structures with notches on a $Si_3N_4$

surface, and Permalloy ($Ni_{80}Fe_{20}$) films are grown on the structures in UHV. Controlled electromigration is used to reduce the size of the notch. By alternating deposition and electromigration, the resistance and correspondingly the cross-section of the notch can be reversibly changed by several orders of a magnitude. In-plane magnetic fields are used to nucleate and move magnetic domain walls in the nanostructure and magnetoresistance measurements are used to probe the influence of the notch geometry on the behavior of the domain wall.

[1] D. Bedau et al., J. Appl. Phys. 101, 09F509 (2007).
[2] M. Laufenberg et al., Appl. Phys. Lett. 88, 052507 (2006).
[3] R. Hoffmann et. al., Appl. Phys. Lett. 93, 043118 (2008).

MA 40.100 Fri 11:00 P1A

**Annealing behaviour of CoFeB/MgO/CoFeB magnetic tunnel junctions** — Sebastian Ringer[1,2], Michael Vieth[2], Ludwig Bär[2], Manfred Rührig[2], and •Günther Bayreuther[1] — [1]Universität Regensburg, 93040 Regensburg, Germany — [2]Siemens AG, Corporate Technology CT T MM1, 91050 Erlangen, Germany

With CoFeB/MgO/CoFeB magnetoresistive tunnel junctions, annealing is commonly used to increase the TMR ratio. The annealing process simultaneously affects the antiferromagnetic pinning layer as well as the tunnel barrier and the ferromagnetic contacts. In particular, the role of diffusion of B into the MgO barrier has been considered recently. By a systematic variation of annealing time and temperature the present study aims to achieve a better understanding of the relevant diffusion processes and an optimization of the annealing procedures. Junctions with a barrier thickness of 1.5 nm showed a TMR ratio of 30% at room temperature before annealing which increased to a maximum value of 150% after annealing for 4 h at 350° C. Measurement of the high resistance state (i.e. for antiparallel magnetizations), the low resistance state (parallel magnetizations) and the TMR ratio versus annealing time at different temperatures allows for the calculation of temperature dependent time constants and activation energies of the processes involved. A comparison of room temperature and low temperature resistance values is used to separate different effects of the annealing process.

MA 40.101 Fri 11:00 P1A

**Magnetoresistance and electroresistance in $BiMnO_3$ based tunnel junctions** — •Nicki Hinsche[1], Michael Fechner[1,2], Igor Maznichenko[1], Peter Bose[1,2], Sergei Ostanin[2], Arthur Ernst[2], Juergen Henk[2], Peter Zahn[1] und Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

The tunneling magnetoresistance (TMR) and electroresistance (TER) of $BiMnO_3$ based tunnel junctions are investigated by means of a combined ab initio and model calculation. The structural relaxation of the barrier material was performed using the VASP package. The electronic structure, and especially the complex band structure of the barrier, are calculated within density functional theory in self-interaction-corrected local density approximation (SIC-LDA) using a KKR multiple scattering scheme. The potential profile in the barrier is determined by the material polarization and the different screening lengths in the electrodes. We assumed a half-metallic and a nobel metal electrode. The influence of the barrier polarization, the $BiMnO_3$ complex band strucure, and the screening properties of the electrodes on the TMR and TER will be discussed.

MA 40.102 Fri 11:00 P1A

**Dielectric Breakdown and inelastic electron tinneling spectroscopy of top pinned and bottom pinned Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions** — •Ayaz Arif Khan, Jan Schmalhorst, Karsten Rott, Andy Thomas, and Günter Reiss — Thin films and physics of Nano structures, Department of Physics, Bielefeld university, P. O. Box 100131, 33501 Bielefeld germany.

We present a detailed investigation into the intrinsic tunnel barrier reliability in Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions (MTJ). The intrinsic reliability is measured as the ramped breakdown voltage ($V_{bd}$) at room temperature for both positive and negative polarity. The measurements were done for two types of junctions: one set of junctions had exchange biased (pinned) bottom electrodes, one set exchange biased (pinned) top electrodes with an additional artificial ferrimagnet. We found a significant polarity dependence in the dielectric breakdown: top as well as bottom pinned tunnel junctions showed higher breakdown voltage when the top electrode was biased positively compared to negative bias. In contrast to this the differential resistance $\frac{dV}{dI} - V$ spectra revealed an asymmetry for the top pinned junctions which was reversed in comparison to the bottom pinned system. This indicates that both asymmetries have different origins. Additionally the bottom pinned junctions showed in general slightly lower breakdown voltages and stronger magnon excitation in the inelastic electron tunneling $\frac{d^2I}{dV^2} - V$ spectra than the top pinned junctions.Possible reasons for these correlations are discussed.

MA 40.103 Fri 11:00 P1A

**Preparation and characterization of sputtered CoFeB/MgO/CoFeB based TMR magnetic tunnel junctions (MTJs)** — •Neda Sadrifar[1], Senthilnathan Mohanan[1], Sören Selve[2], Ute Kaiser[2], and Ulrich Herr[1] — [1]Institut für Mikro- und Nanomaterialien, Universität Ulm, 89081 Ulm — [2]Materialwissenschaftliche Elektronenmikroskopie, Universität Ulm

MTJs with amorphous aluminum oxide tunnel barrier are currently used in magnetoresistive random access memory (MRAM) and the read heads of hard disk drives. MTJs with crystalline MgO tunnel barrier and body centered cubic (bcc) Fe, Co or CoFe ferromagnetic electrodes are predicted to exhibit over 1000% magnetoresistance due to coherent tunneling of fully spin polarized electrons. MTJs with MgO barrier sandwiched between CoFeB electrodes are recently developed for practical applications and found to have TMR ratios up to 500% at RT. Crystallization of amorphous CoFeB into (001)-oriented bcc structure results in a good lattice matching with (001)-oriented MgO and a very sharp and smooth interface and consequently to highly spin polarized tunneling current and high TMR effect. In this study, CoFeB/MgO/CoFeB-based MTJs were prepared by magnetron sputtering and characterized with respect to their microstructure and roughness by XRD, AFM, SEM and TEM. The main focus is on the effect of underlayers on the morphology of the MTJ stack and formation of (001)-oriented MgO and bcc-CoFeB.

MA 40.104 Fri 11:00 P1A

**Properties of ferromagnetic tunnel junctions with organic spacer layers** — •Hartmut Vinzelberg, Joachim Schumann, Dieter Elefant, Jürgen Thomas, and Bernd Büchner — IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany

Within the spintronics/optoelectronics communities the search for alternative materials with improved properties for coherent spin transport recently has initiated strong activities in the field of organic spintronics and related materials. The realization of spin injection into organic semiconductors and the coherent spin transport over distances on the nanometer scale are discussed controversy in the literature. [1-3] Therefore, in this work ferromagnetic sandwich devices with $Alq_3$-spacer are prepared and studied in order to find out which mechanism controls the observed spin-dependent transport effects: spin propagation in the organic film or tunneling over a barrier between the ferromagnetic electrodes. Spin-valve effects at low temperatures have been observed in a broad resistance interval from kΩ to MΩ-range without systematic area dependence. In some samples the magneto-resistance changes the sign as a function of the bias voltage. Additional SQUID and TEM studies suggest as transport mechanism tunneling processes between ferromagnetic electrodes separated by an organic barrier.

[1] J.S. Jiang, et al., Phys. Rev. B 77, 035303 (2008)
[2] H. Vinzelberg, et al., J. Appl. Phys., 103, 093720 (2008)
[3] V. Dediu, et al., Phys. Rev. B 78, 115203 (2008)

MA 40.105 Fri 11:00 P1A

**Tunnel magnetoresistance in $Al_2O_3$ – MgO composite magnetic tunnel junctions** — •Oliver Schebaum, Volker Drewello, Alexander Auge, Andy Thomas, and Günter Reiss — Bielefeld University, Germany

In the recent years TMR ratios of up to 500% at room temperature (RT) have been observed for magnetic tunnel junctions with MgO tunnel barriers, while the TMR ratio of $Al_2O_3$ based MTJs seems to be limited to 70% to 80%. This has been explained by coherent tunneling in the crystalline FM/MgO/FM systems. With our investigation we wanted to find out, if also an increased spin polarization could be the reason for this high TMR ratios. We therefore investigated MTJs with MgO, $Al_2O_3$ and MgO – $Al_2O_3$ composite tunnel barriers and Co-Fe-B magnetic electrodes. The samples have been prepared by DC and RF magnetron sputtering and optical UV lithography. The characteristics of these tunnel junctions have been investigated for different annealing temperatures by transport measurements. The highest observed TMR

ratio for the composite barrier MTJs is 74% at room temperature. The prepared reference MTJs with an MgO tunnel barrier exhibit a maximum TMR ratio of 176% at room temperature. The highest observed TMR ratio for the composite tunnel barrier MTJs is in the range of the highest reported values for amorphous single layer $Al_2O_3$ tunnel barriers, but still much lower than the observed and reported values for MgO based MTJs. This gives evidence that the high tunnel magnetoresistance ratios obtained in MgO based tunnel junctions might be attributed to coherent tunneling.

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**Inelastic electron tunneling spectroscopy of magnetic tunnel junctions with different electrode designs and barrier materials** — •Volker Drewello, Markus Schäfers, Oliver Schebaum, Andy Thomas, and Günter Reiss — Bielefeld University, 33615 Bielefeld, Germany

MgO based magnetic tunnel junctions with up to 230 % tunnel magneto resistance ratio at room temperature and up to 345 % at 13 K are prepared. The lower electrode is either exchange biased or free, while the top electrode is free or an exchanged biased artificial ferrimagnet, respectively. Additionally, a pseudo spin valve (hard soft switching) design with two unpinned electrodes is used. Inelastic electron tunneling spectra for each of these systems show a strong variation of the zero bias anomaly with a reduced peak for some of the junctions. At voltages around 200 mV additional structures are found which are not known from junctions with lower magneto resistance, such as alumina based junctions. We discuss the spectra for the different electrode types and compare our findings with respect to barrier material and magneto resistance ratio.

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**Investigation of thermally evaporated Fe/MgO/Fe MTJs and NaCl layers** — •Jan Rogge, Anna Regtmeier, and Andreas Hütten — Thin Films and Physics of Nanostructures, Department of Physics, Bielefeld University, Universitätsstr. 25, 33615 Bielefeld, Germany

A high tunnel magnetoresistance effect (TMR) in magnetic tunnel junctions (MTJs) is the key for developing new spinelectronic devices like MRAM or magnetic sensors.

In order to enhance the level of crystalinity and epitaxy, we have fabricated Fe/MgO/Fe MTJs using molecular beam epitaxy (MBE). By applying the Brinkman fit to the investigated IV-curves a very low barrier height can be observed, which indicates oxygen vacancy defects in the thermally evaporated MgO barrier. Further electrical transport properties will be discussed considering the MTJs' crystal features obtained from XRD measurements.

Due to the recently predicted huge MR ratio of up to 600% for Fe/NaCl/Fe MTJs [1], we will also show preliminary results of growth studies on NaCl thin films deposited by MBE regarding its practicability as a barrier in MTJs.

[1] P. Vlaic, Third Seeheim Conference on Magnetism, (2007)

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**Magnetic properties of $Co_2FeSi$ thin films deposited by magnetron sputtering using different target compositions** — •Daniel Ebke, Jan Schmalhorst, Andy Thomas, Andreas Hütten, and Günter Reiss — Bielefeld University, Thin Films and Physics of Nanostructures, D-33615 Bielefeld, Germany

The Heusler alloy $Co_2FeSi$ is predicted to show 100% spin polarization at the Fermi energy $E_F$ and a high magnetic moment of $6\mu B$ as well as a high Curie temperature of 1100K [1]. Therefore it is a promising material for spintronic applications. In experiments a lower spin polarization and a lower magnetic moment are reported by different groups [2,3].

Sputtered thin films from stoichiometrical targets show off-stoichiometrical layers which might be the reason for lowering the spin polarization of the Heusler alloy. However, a correct film composition is required to enhance the spin polarization and so the tunneling magneto resistance (TMR) ratio.

We have studied the growth conditions and the magnetic properties of $Co_2FeSi$ thin films which were deposited by using different target compositions. The electrical transport properties were investigated and will be discussed in combination with the magnetic properties and XRD measurements.

[1] S. Wurmehl et al., Phys. Rev. B, 72, 184434 (2005)
[2] Z. Gercsi et al., Appl. Phys. Lett., 89, 082512 (2006)
[3] T. Daibou et al., IEEE Trans. on Magn., 42, 2655-2657 (2006)