Magnetism Division
Fachverband Magnetismus (MA)

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Overview of Invited Talks and Sessions

(lecture rooms H3, H10, H22 and H23; poster A and B1)

Invited Talks

MA 1.1	Mon	10:15–10:45	H10	**The magnetic compass of migratory birds: from behaviour to molecules and cognition** — •Henrik Mouritsen
MA 3.1	Mon	10:15–10:45	H3	**Antiferromagnetic interlayer coupling in $La_{0.7}Sr_{0.3}MnO_3$ / $SrRuO_3$ superlattices** — •Ionela Vrejoiu
MA 6.1	Mon	14:00–14:30	H10	**Heusler alloy films for spintronics** — •Terunobu Miyazaki, Daisuke Watanabe, Shigemi Mizukami, Feng Wu, Takahide Kubota, Sumito Tsunegi, Hiroshi Nagahama, Mikihiko Oogane, Yasuo Ando
MA 6.2	Mon	14:30–15:00	H10	**Heusler alloy based magnetic read heads** — •Stefan Maat
MA 14.1	Wed	9:30–10:00	H10	**Ultrafast spin-orbit excitations in ferromagnets probed by fs x-ray pulses** — •Hermann A. Dürr
MA 17.1	Wed	14:00–14:30	H10	**Current-induced magnetization dynamics** — •Mathias Kläui
MA 17.2	Wed	14:30–15:00	H10	**Ultrafast switching of magnetic vortex cores – The role of the internal energy** — •Riccardo Hertel
MA 22.1	Thu	9:30–10:00	H10	**Tailoring the spin functionality of a hybrid metal-organic interface by means of alkali metal doping** — •Mirko Cinchetti, Sabine Neuschwander, Jan-Peter Wüstenberg, Alexander Fischer, Martin Aeschlimann
MA 26.1	Thu	14:00–14:30	H10	**Magnonics - Exploring spin waves on the nanoscale** — •Dirk Grundler
MA 26.2	Thu	14:30–15:00	H10	**Spin dynamics of complex metallic magnets** — •Paweł Buczek, Arthur Ernst, Leonid Sandratskii
MA 32.1	Fri	10:15–10:45	H10	**Light-Induced Magnetization in Colloidal Semiconductor Nanocrystals** — •Gerd Bacher, Lars Schneider, Remi Beaulac, Paul I. Archer, Daniel R. Gamelin

Invited and Topical Talks of the Focused Session "Topological Defects in Electronic Systems" (with TT)

Organization: Roderich Moessner (MPI-PKS Dresden)

TT 13.1	Tue	9:30–10:00	H20	**Skyrmions in Chiral Magnets** — •Ulrich K. Rössler, Andrei A. Leonov, Anna B. Butenko, Alexei N. Bogdanov
TT 13.2	Tue	10:00–10:30	H20	**Dirac Strings and Magnetic Monopoles in the Spin Ice, $Dy_2Ti_2O_7$** — •David Jonathan Pryce Morris, Alan Tennant, Santiago Grigera, Bastian Klemke, Claudio Castelnovo, Roderich Moessner, Clemens Czternasty, Michael Meissner, Kirrily Rule, Jens-Uwe Hoffmann, Klaus Kiefer, Damien Slobinsky, Robin Perry
TT 13.3	Tue	10:30–11:00	H20	**Manifestations of monopole physics in spin ice materials** — •Claudio Castelnovo, Roderich Moessner, Shivaji Sondhi
TT 13.4	Tue	11:00–11:30	H20	**Skyrmion Lattices in Pure Metals and Strongly Doped Semiconductors** — •Christian Pfleiderer
TT 13.5	Tue	11:45–12:15	H20	**Skyrmion lattice in MnSi** — •Achim Rosch
TT 13.6	Tue	12:15–12:45	H20	**Topological Insulators in Applied Fields: Magnetoelectric Effects and Exciton Condensation** — •Joel Moore

TT 13.7	Tue	12:45–13:15	H20	**Probing non-Abelian statistics with quasiparticle interferometry** — •Kirill Shtengel
TT 13.8	Tue	13:15–13:45	H20	**Spin Hall effects in HgTe Quantum Well Structures** — •Laurens W. Molenkamp

Topical Talks of the Focused Session "Single Nanomagnets"

Organization: Michael Farle (Universität Duisburg-Essen)

MA 12.1	Tue	10:45–11:15	H22	**Exploring the frontiers in cluster magnetism from a theorist's perspective** — •Gustavo Pastor
MA 12.2	Tue	11:15–11:45	H22	**Magnetic chirality in the electron microscope: Progress and Applications** — •Peter Schattschneider
MA 12.3	Tue	11:45–12:15	H22	**Stochastic resonance of a nanomagnet excited by spin transfer torque** — •Ilya Krivorotov
MA 12.4	Tue	12:15–12:45	H22	**Exploring single nanomagnets with photoelectron microscopy** — •Florian Kronast

Invited Talks of the Joint Symposium "Spin-Orbit Coupling and Spin Relaxation in Graphene and Carbon Nanotubes" (SYGN)

See SYGN for the full program of the Symposium.

SYGN 1.1	Mon	14:00–14:35	H1	**Models for spin-orbit coupling in graphene** — •Francisco Guinea
SYGN 1.2	Mon	14:35–15:10	H1	**Spin-orbit coupling and spin relaxation in carbon nanotube quantum dots** — •Ferdinand Kuemmeth
SYGN 1.3	Mon	15:10–15:45	H1	**Spin-orbit interaction in carbon nanotubes probed in pulsed magnetic fields** — •Sungho Jhang, Magdalena Marganska, Yurii Skourski, Dominik Preusche, Benoit Witkamp, Milena Grifoni, Herre van der Zant, Joachim Wosnitza, Christoph Strunk
SYGN 1.4	Mon	16:00–16:35	H1	**Wigner molecules and spin-orbit coupling in carbon-nanotube quantum dots** — •Massimo Rontani
SYGN 1.5	Mon	16:35–17:10	H1	**Spin relaxation and decoherence in graphene quantum dots** — •Guido Burkard
SYGN 1.6	Mon	17:10–17:45	H1	**Spin transport in graphene field effect transistors** — •Bart van Wees

Invited Talks of the Joint Symposium "Magnetism and Medicine" (SYMM)

See SYMM for the full program of the Symposium.

SYMM 1.1	Wed	9:30–10:00	H1	**Magnetic resonance imaging: an ongoing success story** — •Jens Frahm
SYMM 1.2	Wed	10:00–10:30	H1	**Biomedical nanomagnetics: A spin through new possibilities** — •Kannan Krishnan
SYMM 1.3	Wed	10:30–11:00	H1	**Recent SQUID applications in medicine** — •Hans Koch
SYMM 1.4	Wed	11:00–11:30	H1	**Biomedical Magnetic Resonance using Hyperpolarized Gases and Liquids** — •Laura Schreiber
SYMM 1.5	Wed	11:30–12:00	H1	**Recent Developments in Healthcare Biomagnetics** — •Quentin Pankhurst
SYMM 1.6	Wed	12:00–12:30	H1	**SQUIDs for Noninvasive Magnetogastrography** — •Alan Bradshaw, Leo Cheng, Andrew Pullan, William Richards

Invited Talks of the Joint Symposium "Density Functional Theory and Beyond for Real Materials" (SYDF)

See SYDF for the full program of the Symposium.

SYDF 1.1	Thu	14:45–15:15	H1	**Downfolded Self-Energy of Many-Electron Systems and the Hubbard U** — •Ferdi Aryasetiawan
SYDF 1.2	Thu	15:15–15:45	H1	**LDA+Gutzwiller method for correlated electron systems** — •Zhong Fang

SYDF 1.3	Thu	15:45–16:15	H1	**Localized and itinerant states in *d/f*-electron systems unified by *GW*@LDA+*U*** — •Hong Jiang
SYDF 1.4	Thu	16:30–17:00	H1	**Giant polaronic effects in solids and nanstructures** — •Andrea Marini
SYDF 1.5	Thu	17:00–17:30	H1	**Excitation energies with time-dependent density *matrix* functional theory** — •Evert Jan Baerends, Klaas J. H. Giesbertz, Oleg Gritsenko, Katarzyna Pernal
SYDF 1.6	Thu	17:30–18:00	H1	**Calculations of multipoles in magnetic metals and insulators** — •Lars Nordström

Sessions

MA 1.1–1.1	Mon	10:15–10:45	H10	**Bio- and Molecular Magnetism**
MA 2.1–2.10	Mon	10:45–13:15	H10	**Bio- and Molecular Magnetism**
MA 3.1–3.9	Mon	10:15–12:45	H3	**Multiferroics I (with DF, KR, DS)**
MA 4.1–4.9	Mon	11:00–13:15	H22	**Magnetic Coupling Phenomena/ Exchange Bias**
MA 5.1–5.8	Mon	11:00–13:00	H23	**Micro- and Nanostructured Magnetic Materials I**
MA 6.1–6.17	Mon	14:00–19:00	H10	**Magnetic Thin Films I (Heusler Alloys)**
MA 7.1–7.14	Mon	14:00–17:45	H3	**Multiferroics II (with DF, KR, DS)**
MA 8.1–8.14	Mon	15:15–19:00	H22	**Magnetic Shape Memory Alloys**
MA 9.1–9.16	Mon	15:15–19:30	H23	**Magnetic Particles, Clusters**
MA 10.1–10.80	Tue	10:45–13:45	Poster A	**Poster I**
MA 11.1–11.8	Tue	9:30–13:45	H20	**FS: Topological Defects in Electronic Systems (with TT)**
MA 12.1–12.4	Tue	10:45–12:45	H22	**FS: Single Nanomagnets**
MA 13.1–13.4	Tue	14:00–16:15	H3	**ThyssenKrupp Dissertationspreis der AG Magnetismus**
MA 14.1–14.12	Wed	9:30–12:45	H10	**Spin Dynamics / Spin Torque I**
MA 15.1–15.11	Wed	10:15–13:00	H22	**Magnetic Half-metals and Oxides I**
MA 16.1–16.10	Wed	10:15–12:45	H23	**Micro- and Nanostructured Magnetic Materials II**
MA 17.1–17.15	Wed	14:00–18:30	H10	**Spin Dynamics / Spin Torque II**
MA 18.1–18.15	Wed	15:15–19:15	H3	**Magnetic Thin Films II**
MA 19.1–19.6	Wed	15:15–16:45	H22	**Magnetic Half-metals and Oxides II**
MA 20.1–20.5	Wed	17:00–18:15	H22	**Micromagnetism / Computational Magnetics**
MA 21.1–21.10	Wed	15:15–18:00	H23	**Magnetic Materials**
MA 22.1–22.12	Thu	9:30–12:45	H10	**Spin Dynamics / Spin Torque III**
MA 23.1–23.10	Thu	10:15–12:45	H3	**Micro- and Nanostructured Magnetic Materials III**
MA 24.1–24.10	Thu	10:15–12:45	H22	**Spinelectronics / Spin Injection in Heterostructures**
MA 25.1–25.10	Thu	10:15–12:45	H23	**Surface Magnetism / Magnetic Imaging I**
MA 26.1–26.10	Thu	14:00–17:00	H10	**Spin Dynamics / Spin Torque IV**
MA 27.1–27.6	Thu	17:15–18:45	H10	**Spin Structures and Magnetic Phase Transitions**
MA 28.1–28.14	Thu	15:15–19:00	H3	**Spin-dependent Transport Phenomena**
MA 29.1–29.6	Thu	15:15–16:45	H22	**Magnetic Semiconductors I**
MA 30.1–30.5	Thu	17:00–18:15	H22	**Electron Theory of Magnetism**
MA 31.1–31.15	Thu	15:15–19:15	H23	**Surface Magnetism / Magnetic Imaging II**
MA 32.1–32.1	Fri	10:15–10:45	H10	**Magnetic Semiconductors II**
MA 33.1–33.95	Fri	11:00–14:00	Poster B1	**Poster II**

Assignment of the Posters to the Topics

MA 10.1-10.12: Bio- and Molecular Magnetism
MA 10.13-10.28: Multiferroics
MA 10.29-10.35: Magnetic Coupling Phenomena/Exchange Bias
MA 10.36-10.59: Magnetic Thin Films
MA 10.60-10.63: Magnetic Shape Memory Alloys
MA 10.64-10.71: Magnetic Particles/Clusters
MA 10.72-10.76: Magnetic Half-metals and Oxides
MA 10.77-10.80: Magnetic Materials
MA 33.1-33.2: Electron Theory of Magnetism
MA 33.3-33.11: Magnetic Semiconductors
MA 33.12-33.29: Micro- and Nanostructured Magnetic Materials
MA 33.30-33.37: Micromagnetism / Computational Magnetics

MA 33.38-33.47: Surface Magnetism / Magnetic Imaging
MA 33.48-33.55: Spin Structures and Magnetic Phase Transitions
MA 33.56-33.58: Spinelectronics / Spin Injection in Heterostructures
MA 33.59-33.83: Spin Dyanmics / Spin Torque
MA 33.84-33.96: Spin-dependent Transport Phenomena

Annual General Meeting of the Magnetism Division

Mittwoch 18:45–19:45 H10

- Bericht des Vorsitzenden
- Aussprache
- Verschiedenes

MA 1: Bio- and Molecular Magnetism

Time: Monday 10:15–10:45 Location: H10

Invited Talk MA 1.1 Mon 10:15 H10

The magnetic compass of migratory birds: from behaviour to molecules and cognition — •Henrik Mouritsen — IBU, University of Oldenburg, Oldenburg, Germany

Migratory birds can use a magnetic compass to find their way, but how do they sense the reference direction provided by the geomagnetic field? Two biophysical mechanisms have become established as the most promising candidates: (1) iron-mineral-based sensors in the upper beak connecting to the brain through the ophthalmic branch of the trigeminal nerve and/or (2) light-dependent radical-pair processes in the eyes converting the magnetic signal into a visual signal, which is then processed in visual brain areas. In my talk, I will introduce the two hypotheses. Then, I will present our most recent findings strongly suggesting that the magnetic compass of night-migratory songbirds is part of the birds' visual system. This conclusion is based on a number of combined experiments involving molecular biology, anatomy, chemical analyses, neurobiology and behaviour. For instance, we have shown that potentially magnetosensitive molecules called cryptochromes are found in highly active neurons of the retina of night-migratory birds and that these cryptochromes possess a number of key biophysical prerequisites that makes them ideally suited as magnetodetectors. We have also located a specific forebrain area, named Cluster N, which we have demonstrated to be needed for magnetic compass orientation. In contrast, information transmitted through the ophthalmic branch of the trigeminal nerve is neither necessary nor sufficient for magnetic compass orientation in European Robins, a migratory bird.

MA 2: Bio- and Molecular Magnetism

Time: Monday 10:45–13:15 Location: H10

MA 2.1 Mon 10:45 H10

Quantum control and entanglement in an avian chemical compass — •Jianming Cai[1,2], Gian Giacomo Guerreschi[1,2], and Hans Briegel[1,2] — [1]University of Innsbruck, Innsbruck, Austria — [2]Institut for Quantenoptik und Quanteninformation, Innsbruck, Austria

The contribution has been withdrawn.

MA 2.2 Mon 11:00 H10

Electric quantum control of spins in molecular magnets — •Mircea Trif[1], Dimitrije Stepanenko[1], Filippo Troiani[2], and Daniel Loss[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland — [2]CNR-INFM National Research Center S3 c/o Dipartimento di Fisica via G. Campi 213/A, 41100, Modena, Italy

Single molecule magnets show clear signatures of coherent behavior. The control of the spins can allow for the quantum information processing and study of quantum dynamics. Electric fields fields are good for quantum control at the nanoscale. There are many SMMs and it is hard to predict which ones are suitable for control. Here, we provide two tools for the search for suitable SMMs. We analyze the form and mechanisms that lead to spin-electric coupling in the molecules with the shape of regular polygons. We find that the SEC in triangles is governed by the modification of the exchange interaction, while in pentagon the spin-electric coupling proceeds via spin-orbit interaction. The symmetry analysis leaves the coupling constant undetermined, and we apply a Hubbard model to single-molecule magnet to find a connection between the spin-electric coupling and the properties of the chemical bonds in a molecule. We study the experimental signatures of spin-electric coupling in the standard experiments, NMR, ESR, and thermodynamics.

MA 2.3 Mon 11:15 H10

Ultra-low temperature x-ray magnetic circular dichroism of TM-Ni binuclear molecular magnets. — •Karsten Kuepper[1], Ulf Wiedwald[1], Florian Mögele[2], Bernhard Rieger[3], and Paul Ziemann[1] — [1]Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm — [2]Institut für Materialien und Katalyse, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm — [3]WACKER-Lehrstuhl für Makromolekulare Chemie, Technische Universität München, Lichtenbergstraße 4, 85747 Garching bei München

Molecular magnets display a large variety of new and complex chemical and physical properties. We have investigated three planar TM-Ni-$C_{46}H_{68}N_2O_6$ (TM=Mn,Fe,Co) molecules, which show uncompensated magnetic moments [1] by means of ultra-low temperature XMCD. The experiments have been performed at a temperature of 0.6K in order to probe the magnetic ground state properties. For all three complexes we find Ni to be divalent, also Mn and Co are in a 2+ valence state, whereas mainly Fe^{3+} ions are present in the Fe-Ni molecule. We find different internal magnetic structures. In the Co-Ni molecule the Ni appears to be in a low spin state, thus no dichroic signal is present, whereas Co shows a strong MCD. A similar result is observed for the Mn-Ni complex, only a very small dichroic Ni signal is present. However, for the Fe-Ni complex both, the Fe and Ni spectra are dichroic, revealing a ferromagnetic alignment of the Ni and Fe ions in this molecule.

[1] F. Mögele et al., Langmuir **25**, 13606 (2009).

MA 2.4 Mon 11:30 H10

Approximate eigenvalue determination of geometrically frustrated magnetic molecules — •Roman Schnalle — Universität Bielefeld, Fakultät für Physik, Universitätsstraße 25, D-33615 Bielefeld

Geometrically frustrated magnetic molecules have attracted a lot of interest in recent years. Interesting physical phenomena related to frustration that have been observed in zero-dimensional systems directly link the research fields of molecular and highly frustrated magnetism. In order to further investigate frustration effects in finite-size systems like magnetic molecules numerical exact diagonalization would be the method of choice. Having calculated the full energy spectra of such systems all thermodynamic and spectroscopic properties can be deduced.

Unfortunately, although not affected by conceptual problems arising from geometrical frustration, the application of numerical exact diagonalization is limited to rather small molecular systems. Especially, the magnetic behavior of the zero-dimensional representation of the Kagomé lattice – one of the most investigated extended antiferromagnetic systems – cannot be resolved by a numerical exact diagonalization. Nevertheless, an approximate numerical method that is based on a diagonalization within a reduced but carefully chosen set of basis states can be used to get insight into the physics of rather large frustrated systems [1].

[1] R. Schnalle, A. Läuchli, J. Schnack, Cond. Mat. Phys. **12**, 331 (2009).

MA 2.5 Mon 11:45 H10

Magnetic response of magnetic molecules with non-collinear local d-tensors — •Jürgen Schnack — Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

Investigations of molecular magnets are driven both by prospective applications in future storage technology or quantum computing as well as by fundamental questions. Nowadays numerical simulation techniques and computer capabilities make it possible to investigate spin Hamiltonians with realistic arrangements of local anisotropy tensors. In this contribution I will discuss several recently synthesized molecules and their magnetic properties [1-3].

[1] Ian S. Tidmarsh, Luke J. Batchelor, Emma Scales, Rebecca H. Laye, Lorenzo Sorace, Andrea Caneschi, Jürgen Schnack and Eric J. L. McInnes, Dalton Trans. (2009) 9402-9409

[2] J. Schnack, Condens. Matter Phys. 12 (2009) 323-330

[3] Thorsten Glaser, Maik Heidemeier, Hubert Theil, Anja Stammler, Hartmut Bögge and Jürgen Schnack, Dalton Trans. (2010) in print

MA 2.6 Mon 12:00 H10

Magnetization measurements of a novel family of heteronuclear Mn_2Ni_3 SMM clusters — •Klaus Gieb[1], Animesh Das[2], Yulia Krupskaya[3], Wolfgang Kroener[1], Serhiy Demeshko[2], Rüdiger Klingeler[3], Vladislav Kataev[3], Bernd Büchner[3], Franc Meyer[2], and Paul Müller[1] — [1]Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany — [2]Institut für Anorganische Chemie, Georg-August-Universität Göttingen, Germany — [3]Leibniz-Institute for Solid State and Materials Research IFW Dresden, Germany

We report on magnetic measurements of two hetrometallic $Mn_2^{III}Ni_3^{II}X_2L_4(LH)_2(H2O)_2$ (X = Cl, Br) complexes. These compounds have a ground state spin of $S = 7$ and show an easy-axis type of anisotropy. DC and AC susceptibility measurements were performed with a commercial SQUID magnetometer. A home-made micro-Hall-probe magnetometer was used to perform the characterization at mK temperatures. We found an uniaxial anisotropy parameter of $D \simeq -0.5$ K. Magnetic hysteresis and quantum tunneling of magnetization was observed at temperatures below a blocking temperature $T_B \simeq 1.5$ K. The shape of the hysteresis loop is influenced by intermolecular interactions. The signature of these interactions can be modified by the variation of the Mn coordination partner X.

MA 2.7 Mon 12:15 H10

High-field ESR on the Mn_2Ni_3 single molecular magnet — •Y. Krupskaya[1], A. Das[2], K. Gieb[3], W. Kroener[3], S. Demeshko[2], S. Dechert[2], R. Klingeler[1], V. Kataev[1], P. Müller[3], F. Meyer[2], and B. Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research (IFW) Dresden, D-01171 Dresden, Germany — [2]Institut für Anorganische Chemie, Georg-August-Universität Göttingen, D-37077 Göttingen, Germany — [3]Lehrstuhl für Experimentalphysik, Universität Erlangen-Nürnberg, D-91058 Erlangen, Germany

Magnetic properties of a novel metal-organic molecular complex with $[Mn(III)_2Ni(II)_3(\mu\text{-}O)_8]$ core have been studied by means of high-field electron spin resonance (HF-ESR) spectroscopy and magnetization measurements. We observe a ferromagnetic coupling between three Ni(II) and two Mn(III) ions which yields a high spin magnetic ground state with $S_{\rm tot} = 7$. Frequency-tunable HF-ESR spectroscopy reveals a substantial magnetic anisotropy gap with a negative axial anisotropy $D = -0.55$ K which gives evidence for a bistable (easy axis) magnetic ground state of the molecule. The analysis of the ESR data by means of a minimal effective spin Hamiltonian enables an accurate description of the energy level scheme and the spin states of the complex. The observed high spin ground state and the negative axial anisotropy ensure necessary prerequisites for the realization of a single molecular magnet. Indeed, at low temperatures ($T < 1$ K) magnetization measurements reveal a single molecular magnet behavior such as hysteresis and tunnelling of the magnetization.

MA 2.8 Mon 12:30 H10

Magnetic coupling between Fe phthalocyanine molecules and ferromagnets — •Claudia Weis, Bernhard Krumme, Frank Stromberg, Anne Warland, Carolin Antoniak, Werner Keune, and Heiko Wende — Fakultät für Physik and CeNIDE, Universiät Duisburg-Essen

On the road towards molecular spintronic devices magnetic organic molecules on ferromagnetic surfaces play an important role. Going beyond earlier investigations on Fe porphyrin (FeOEP) molecules [1-2] the present work aims to study the influence of changes in the ligand field on the magnetic coupling. From Mössbauer spectra of bulk-like samples, it is obvious that a considerable difference occurs between Fe phthalocyanine (FePc) and FeOEP. We investigate sub-monolayer coverages of magnetic FePc molecules on ultrathin ferromagnetic films of Ni and Co on Cu(100) by X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD). We find that also the FePc molecules couple to ferromagnets similar to the FeOEP molecules [1-2]. The magnetic coupling between the molecules and the magnetic substrate turns from ferromagnetic to antiferromagnetic if an interlayer of oxygen is introduced by oxygen surfactant-assisted growth of the ferromagnetic film. Similarities and differences in the fine structure of the spectra will be discussed in detail.

[1] H. Wende et al., Nature Materials **6**, 516 (2007).
[2] M. Bernien et al., Phys. Rev. Lett. **102**, 047202 (2009).
– Supported by DFG (Sfb 491) and BMBF (05 ES3XBA/5).

MA 2.9 Mon 12:45 H10

Preparation and characterization of Mn_6Cr single-molecule-magnets on surfaces — •Marc Sacher[1], Andreas Helmstedt[1], Aaron Gryzia[1], Peter Koop[1], Sebastian Steppeler[1], Norbert Müller[1], Armin Brechling[1], Ulrich Heinzmann[1], Veronika Höke[2], Thorsten Glaser[2], Mikhail Fonin[3], and Ulrich Rüdiger[3] — [1]Fak. f. Physik, Uni Bielefeld — [2]Fak. f. Chemie, Uni Bielefeld — [3]Fak. f. Physik, Uni Konstanz

The single-molecule-magnet (SMM) Mn_6Cr consists of two bowl-shaped Mn_3-salen complexes, bridged by a complex containing a Cr atom. Three counterions are coupled to the SMM to ensure charge neutrality. To study the influence of the molecule-substrate-interaction on the electronic and the magnetic properties a homogeneous preparation of the SMM on the substrate is necessary. The preparation is done by dropping SMM, dissolved in methanol with certain concentration. Depending on the choice of the substrate, the Mn_6Cr concentration, the substrate inclination and the droplet size the arrangement of the SMM strongly varies. This will be visualized in videos of the drying process obtained by optical microscopy with a magnification of up to 1000. The electronic properties of the deposited SMM are investigated by X-ray absorption spectroscopy. These properties change with exposure time due to a low stability of the SMM against X-rays. These changes can be accelerated or slowed down via the choice of the counterions and the SMM concentration on the substrate. Possible reasons will be discussed.

MA 2.10 Mon 13:00 H10

Understanding the Composition of the Ground-State Spin - Subtle Structural Differences lead to Spin Maximization in Mn_7 Disks — •Joscha Nehrkorn[1], Oliver Waldmann[1], Shreya Mukherjee[2], George Christou[2], Thierry Strässle[3], and Hannu Mutka[4] — [1]Physikalisches Institut, Universität Freiburg, 79104 Freiburg, Germany — [2]Department of Chemistry, University of Florida, Gainesville, Florida 32611-7200, USA — [3]LNS, ETH Zürich & Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [4]Institut Laue-Langevin, 38042 Grenoble, France

The magnetic properties of molecular nanomagnets depend strongly on the ground-state spin S of the molecule. For instance, a large value of S can give rise to quantum tunneling of the magnetization, while systems with small S can show quantum tunneling of the Néel vector. S depends on the magnetic exchange couplings between the spin centers in the molecule. Small differences in the ligands should only have a small effect, however, for two related Mn_7 disks a big effect on S was observed: in $Mn_7$11 the ground-state spin is $S = 11$ while in $Mn_7$16 it has the maximal value S =16. To understand the spin maximization we studied the magnetic interactions in the two Mn_7 disks by inelastic neutron scattering, which allowed us to determine the magnetic exchange couplings and weak magnetic anisotropy. The small perturbation in the ligand shell leads to slightly different exchange coupling constants, which, however, due to the frustrating nature of some of these couplings, leads to very different energy schemes and ground states.

MA 3: Multiferroics I (with DF, KR, DS)

Time: Monday 10:15–12:45 Location: H3

Invited Talk MA 3.1 Mon 10:15 H3

Antiferromagnetic interlayer coupling in $La_{0.7}Sr_{0.3}MnO_3$ / $SrRuO_3$ superlattices — •Ionela Vrejoiu — Max Planck Institute of Microstructure Physics, Halle, Germany

Perovskite oxides are versatile materials with a broad spectrum of physical properties, such as (anti)ferromagnetism, (anti)ferroelectricity, superconductivity, and multiferroicity. As illustrating examples, $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) and $SrRuO_3$ (SRO) are both ferromagnetic perovskites with bulk ferromagnetic Curie temperatures of 370 K and 160 K, respectively. LSMO is a 3d transition metal double exchange ferromagnet, whereas SRO is a rare case of a 4d

itinerant metallic ferromagnet and, in contrast to LSMO, SRO shows exceptionally strong magneto-crystalline anisotropy. Such differences make the interlayer coupling between LSMO and SRO epitaxial thin films an intriguing case. We report on LSMO / SRO superlattices (SLs) grown by pulsed-laser deposition on vicinal TiO_2-terminated $SrTiO_3$ (100) (STO) substrates. These SLs exhibit strong antiferromagnetic (AF) interlayer coupling at temperatures below 140 K, where the SRO layers become ferromagnetic. SLs in which an ultrathin nonmagnetic perovskite spacer was grown in between all the LSMO and SRO layers (so that the LSMO and SRO have no mutual interfaces) exhibited ferromagnetic coupling below 140 K. This indicates that the AF coupling occurs only in SLs with direct interfaces between LSMO and SRO. A joint study of structural characterization, SQUID magnetometry as well as first principles calculations was performed, in order to unravel the origin of this strong AF coupling.

MA 3.2 Mon 10:45 H3

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], and Ingrid Mertig[1,2] — [1]MPI für Mikrostrukturphysik Halle, Germany — [2]Fachgruppe Theoretische Physik, Martin-Luther-Universität Halle-Wittenberg

The interface magnetoelectric effect mediates the change of the magnetization at a ferromagnetic/ferroelectric interface when the electric polarization is modified. Using first principle methods, we investigate different ultrathin ferromagnetic films (Co and Fe) on top of ferroelectric $ATiO_3$ (A=Pb,Ba) perovskites upon the occurrence of it. The calculations show that at the interface a moderately change of the size of the total magnetization takes place [1]. Further the magnetic ordering of the Fe film is sensitive to its thickness, so an unexpected antiferrimagnetic ordering appears for 2ML Fe whereas for all other thicknesses ferromagnetic ordering is preferred. Hybridization and strain effects at the interface can explain all observations. An interesting perspective for further studies will be the investigation of thin films of a CoFe alloy. This may allow gaining control of the magnetic ordering by the electric polarization.

[1] Fechner et al.. PRB 78, 212406(2008)

MA 3.3 Mon 11:00 H3

Magnetoelectric coupling at modified Fe/$BaTiO_3$ interfaces — •Martin Hölzer[1], Michael Fechner[2], Sergey Ostanin[2], and Ingrid Mertig[1,2] — [1]Martin-Luther-Universität Halle-Wittenberg, Fachbereich Physik, D-06900 Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

Two-component multiferroics are gaining attention within the last years. These compound materials, consisting of ferromagnetic and ferroelectric layers, combine the advantages (e. g. high curie temperatures) of their components in a tuneable magnetoelectric structure.

Ab initio DFT studies of ultrathin Fe films on ferroelectric $BaTiO_3$ show that their magnetoelectric coupling can be enhanced considerably by means of interface alloying.

In these systems, the magnetoelectric coupling is related to structural changes in the interface region under polarisation reversal of the $BaTiO_3$ substrate. In one of the considered cases, a magnetic phase transition with high change in the total magnetization is triggered under polarization reversal.

MA 3.4 Mon 11:15 H3

Towards ferroelectric tunneling barriers with magnetic electrodes — •Daniel Pantel, Dietrich Hesse, and Marin Alexe — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

The tunneling magnetoresistance (TMR) is a well-established quantum phenomenon in oxide electronics [1]. Recently, tunneling electroresistance was experimentally investigated in an oxide ferroelectric tunneling barrier [2, 3]. Combining both functionalities in one device, i.e. a ferroelectric barrier sandwiched in between two ferromagnetic electrodes, yields interesting properties, e.g. different effects of the ferroelectric polarization on the two spin channels [4]. However, experimental results are still lacking.

In this talk we report on the growth and the properties of perovskite oxide heterostructures consisting of a pulsed laser deposition-grown thin ferroelectric barrier layer sandwiched between two magnetic electrodes. First electrical measurements on capacitor-like tunneling junctions are presented.

[1] De Teresa, J.M., *et al.*, Science **286**, 507 (1999)
[2] Contreras, J.R., *et al.*, Appl. Phys. Lett. **83**, 4595 (2003)
[3] Garcia, V., *et al.*, Nature **460**, 81 (2009)
[4] Velev, J.P., *et al.*, J. Appl. Phys. **103**, 07A701 (2008)

MA 3.5 Mon 11:30 H3

Multiferroic materials with a non-collinear spin structure - A many-particle approach — •Thomas Michael[1], Julia M. Wesselinowa[2], and Steffen Trimper[1] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Germany — [2]Department of Physics, University of Sofia, Sofia, Bulgaria

Multiferroic bulk materials with a conical spin structure are investigated in the framework of a many-particle approach. The analysis of the ferroelectric subsystem is based on a two-state quantum model. Magnetic moments interact via the Heisenberg model. The canting of the spins is incorporated by the Dzyaloshinski-Moriya interaction. A representation of the spin operators with an arbitrary quantization axis is chosen. Minimizing the free energy yields the direction of the quantization axis. The multiferroic coupling term is discussed. A Green's function technique in reciprocal space provides the temperature dependence of the magnetization, polarization and the energy of the excitations.

MA 3.6 Mon 11:45 H3

Manipulating ferroelectric domains of multiferroic $DyMnO_3$ by soft X-rays — •Victor Soltwisch, Enrico Schierle, Detlef Schmitz, Dimitri Argyriou, Fabiano Yokaichiya, Ralf Feyerherm, and Eugen Weschke — Helmholtz Zentrum Berlin

In multiferroic $DyMnO_3$, ferroelectricity is induced by cycloidal magnetic structures of a chirality coupled to the direction of the electric polarization. XRMS at the Dy-M5 resonance allows to distinguish surface regions of different chirality of the Dy-4f magnetic cycloid and, hence, can be used to image ferroelectric domains. Furthermore, the x-ray beam itself can be utilized to manipulate the distribution of domains at the crystal surface.

MA 3.7 Mon 12:00 H3

Evidence of electro-active excitation of the spin cycloid in $TbMnO_3$ — •Alexey Shuvaev[1], Viktor Travkin[2], Vsevolod Ivanov[2], Alexander Mukhin[2], and Andrei Pimenov[1] — [1]Experimentelle Physik 4, Universität Würzburg, D-97074 Würzburg, Germany — [2]General Physics Institute, Russian Academy of Science, 119991 Moscow, Russia

The coupling between the magnetic and ferroelectric orders in multiferroics is currently a topic of intense study. The materials of particular interest are those where the incommensurate cycloidal ordering of the spins drives the ferroelectricity. One of the consequences of multiferroicity is the existence of novel coupled magnon-phonon excitations called electromagnons. In addition to the electromagnon along the a-axis, the polarization analysis of the experimental spectra suggests the existence of an electro-active excitation for ac electric fields along the crystallographic c-axis. This excitation is possibly the electro-active eigenmode of the spin cycloid in $TbMnO_3$, which has been predicted within the inverse Dzyaloshinskii-Moriya mechanism of magnetoelectric coupling.

MA 3.8 Mon 12:15 H3

Neutron scattering studies on chiral multiferroics: magnetic structure and excitations — •T. Finger[1], M. Baum[1], A. C. Komarek[1], D. Senff[1], P. Link[6], K. Hradil[5], K. Schmalzl[4], W. Schmidt[4], L.-P. Regnault[3], D. N. Argyriou[7], P. Becker-Bohaty[2], L. Bohaty[2], and M. Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln — [3]CNG-Grenoble / ILL, Grenoble — [4]FZ Jülich, JCNS at ILL, Grenoble — [5]Universität Göttingen / FRM2 München — [6]FRM2, TU München, München — [7]HMI, Berlin

We present neutron-scattering experiments on IN12 and on IN14 using spherical polarization analysis directly documenting the poling of the elastic magnetic chiral terms for the spiral magnets $MnWO_4$ and $TbMnO_3$ by cooling in an electric field. In addition, we were able to observe a multiferroic hysteresis curve as function of electric field in both compounds and succeeded to switch the spiral at constant temperature, which is the central issue in view of future applications. Additionally, measurements of the diffuse scattering slightly above the multiferroic transition show some small chiral terms remaining in the collinear phase. The close coupling of ferroelectricity and magnetism in the multiferroic materials also results in new collective excitations,

predicted almost 20 years ago: hybridised spin-phonon excitations, referred to as "electromagnons". After the first observations of potential electromagnon modes in infra-red and in neutron studies a conclusive interpretation is still missing. Our most recent neutron scattering measurements will be discussed.

MA 3.9 Mon 12:30 H3

Topological magnetoelectric memory effect in the spin-spiral multiferroic $MnWO_4$ — •Dennis Meier[1], Naemi 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

Within the field of multiferroics, i.e. compounds with coexisting magnetic and electric order, so-called spin-spiral ferroelectrics attract tremendous attention. In these systems magnetic long-range order violates the inversion symmetry and induces a spontaneous electric polarization. Magnetic and electric domains are thus rigidly coupled so that "giant" magnetoelectric effects are obtained. However, up to now nearly nothing is know about the topology of the domain state in these systems. We report spatially-resolved measurements of the multiferroic domain topology in $MnWO_4$. For the first time, the full three-dimensional domain structure in a spin-spiral system is imaged. Our study reveals that the multiferroic domains in magnetically-induced ferroelectrics unify features that are associated to a magnetic domain state and others that point unambiguously to ferroelectric domains. Hence, a description in terms of ferroelectric or antiferromagnetic domains is incomplete and no longer appropriate. The novel concept of "multiferroic hybrid domains" is introduced. Annealing cycles reveal a topological memory effect: Due to phase coexistence at one phase boundary limiting the multiferroic state in $MnWO_4$, the entire multiferroic multidomain state can be reconstructed subsequent to quenching it. This work is supported by the DFG through SFB608.

MA 4: Magnetic Coupling Phenomena/ Exchange Bias

Time: Monday 11:00–13:15 Location: H22

MA 4.1 Mon 11:00 H22

The origin of exchange bias, Observation of pinned orbital moments at iron L2,3 in FeMn/Co — •Patrick Audehm[1], Sebastian Brück[2], Gisela Schütz[1], and Eberhard Goering[1] — [1]Max Planck Institute for Metals Research, Heisenbergstrasse 3, 70569 Stuttgart, Germany — [2]University of Würzburg, Physikalisches Institut. IV Am Hubland, D-97074 Würzburg, Germany

The exchange anisotropy was discovered by Meiklejohn and Bean in 1956. Since then there have been many attempts to model the behavior of a system with exchange bias effect. Exchange bias (EB) results in a shift of the hysteresis loop and secondly in an increase of the coercive field. We investigated a widely studied EB-system, consisting of polycrystalline iron (Fe)-manganese (Mn) as an antiferromagnet and cobalt as a ferromagnet. We used X-ray magnetic circular dichroism (XMCD) and x-ray resonant magnetic reflectivity (XRMR) at the Fe L2,3 and Mn L2,3 edges, simultaneously performed in surface sensitive total electron yield (TEY) and bulk sensitive total fluoresence yield (TFY) at room and low temperatures. For the first time, we measured pinned magnetic Fe moments in iron-manganese. Mn shows nearly no XMCD effect, while the Fe provides a sizeable signal from the rotatable moments and a very small (about 0.7 per mill of the total signal) signal from the pinned uncompensated moments. According to the well established sum rules of XMCD the non-rotatable Fe L2,3 edge spectra reveal nearly pure orbital character. These results suggest a different view on the origin of exchange bias, based on locally loaded spin-orbit-coupling, and new possibilities understanding the origin of EB.

MA 4.2 Mon 11:15 H22

Antiferromagnetic coupling in Fe/Si/Fe structures with interfacial Co "dusting" — •Rashid Gareev[1], Matthias Buchmeier[2], Matthias Kiessling[1], Georg Woltersdorf[1], and Christian Back[1] — [1]Uni Regensburg, Universitätsstrasse 31, 93053 Regensburg — [2]Uni Münster, Corrensstraße, 48149 Münster

Epitaxial Fe/Si/Fe structures demonstrate strong antiferromagnetic coupling (AFC) reaching 8mJ/m2 and resonant-type tunnelling magnetoresistance (TMR) [1]. A promising way to increase spin polarization is to insert Co *dusting* layers at interfaces [2]. We present AFC in Fe/Co/Si/Co/Fe epitaxial structures with 0.2 nm-thick Co *dusting* layers and different thickness of Si spacer. We extracted AFC from fitting experimental FMR data as well as from the MOKE hysteresis. The AFC is near 0.1mJ/m2 with the maximum of coupling near 2.0 nm of spacer thickness. For spacers thinner than 1.7 nm coupling is ferromagnetic indicating an increased inter-diffusion. Temperature dependence of magnetization above T0˜50K corresponds to the Bloch*s law characteristic for spin-wave parameters of iron films. We revealed regions with different temperature dependence of AFC. Below T0˜50K and above T˜100K saturation field and, accordingly, coupling strength show increase with decreasing temperature. In the intermediate region coupling is not stable. We relate observed features to formation of interface magnetic iron-cobalt silicides with Tc˜50K. This work is supported by the project DFG 9209379.[1]. R.R. Gareev et al: JMMM 240, 235 (2002), APL 81, 1264 (2002), JAP 93, 8038 (2003), APL 88, 172105 (2006); [2]. Y. Wang et al, APL 93, 172501 (2008).

MA 4.3 Mon 11:30 H22

Effect of re-entrant spin glass transition on the exchange bias in Fe/Cr bilayers — •Syed Rizwan Ali[1], Muhammad Bilal Janjua[1], Dieter Lott[2], Marian Fecioru-Morariu[1], Coen J. P. Smits[1], and Gernot Güntherodt[1] — [1]Physikalisches Institut (IIA), RWTH Aachen University, 52056 Aachen, Germany — [2]GKSS Forschungszentrum, 21502 Geesthacht, Germany

The exchange bias (EB) field H_{EB} in polycrystalline Fe/Cr bilayers is found to exhibit sign reversal and enhancement at low temperature due to competing ferromagnetic and antiferromagnetic interfacial couplings. The interface roughness as examined by x-ray reflectivity is considerably large indicating significant alloying at the Fe/Cr interface. Our results indicate that the interface alloying drives Cr into an Fe-cluster spin glass (SG) phase. After field cooling below the SG transition temperature the Fe clusters give a net ferromagnetic coupling to the adjacent Fe layer and hence result in an enhanced negative H_{EB}. With increasing temperature the net ferromagnetic interfacial coupling progressively decreases as the alloy undergoes a temperature-driven re-entrant SG-to-antiferromagnet phase transition. Thereafter, antiferromagnetic interfacial coupling between the uncompensated Cr moments and the Fe layer dominates. This yields the temperature driven sign reversal of H_{EB}. The H_{EB} of samples containing the intentionally deposited $Cr_{1-x}Fe_x$ SG-alloy underneath the Fe layer show all the features observed in our nominal Fe/Cr bilayer samples, thereby confirming our arguments.

MA 4.4 Mon 11:45 H22

Influence of ferromagnetic–antiferromagnetic coupling on the antiferromagnetic ordering temperature in Ni/Fe_xMn_{1-x} bilayers — •Miriam Stampe, Paul Stoll, Tobias Homberg, Kilian Lenz, and Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

We present a detailed study on epitaxial bilayers made up of ferromagnetic (FM) Ni and antiferromagnetic (AFM) Fe_xMn_{1-x} layers. The AFM ordering temperature (T_{AFM}) and the coupling at the interface of FM and AFM layer are deduced from polar magneto-optical Kerr effect measurements at different temperatures. The enhancement of coercivity for samples with different Fe_xMn_{1-x} layer thickness, Fe concentration and FM–AFM interface roughness reveals that T_{AFM} only depends on the layer thickness. The FM–AFM coupling strength is determined by the Fe concentration of the Fe_xMn_{1-x} layer and the interface roughness, but as the measurement series clearly show, these do not affect the ordering temperature. The different behaviour of our out-of-plane measurements compared to earlier results for in-plane magnetization [1,2] leads us to the assumption that the spin structure in Fe_xMn_{1-x} is distorted from the 3Q structure in bulk material, depending on the magnetization direction of the adjacent FM layer.

[1] F. Offi *et al.*, Phys. Rev. B **66**, 064419 (2002).
[2] K. Lenz *et al.*, Phys. Rev. Lett. **98**, 237201 (2007).
Financial support by the DFG (KU1115/9-1) is acknowledged.

MA 4.5 Mon 12:00 H22

Ab initio exchange constants for the Heisenberg model — •Adam Jakobsson[1,2], Stefan Blügel[1], Marjana Ležaić[1], and Biplab Sanyal[2] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Department of Physics and Materials Science, Uppsala University, Box 530, SE-75121 Uppsala, Sweden

Ab initio total energies of spin spirals in selected metals and insulators have been mapped to Heisenberg Hamiltonian in order to extract the exchange constants as well as Curie temperatures through a Monte Carlo algorithm. The full potential linearized augmented plane wave code `FLEUR` [1] was employed. A comparison is made between extracting exchange constants from a set of Fourier transforms and a least square fit to total energies. The calculations of total energy differences are approximated by the use of Andersen's force theorem. The validity and the precision of the calculations are discussed. For strongly correlated systems such as MnO a Hubbard U is applied and additional attention is required when the force theorem is used. The benchmark materials bcc Fe, fcc Ni and rock salt MnO are covered. Fe is a metal and has long ranged interactions with Ruderman-Kittel-Kasuya-Yosida behaviour. In contrast the insulator MnO has mainly short ranged interactions. For Ni longitudinal fluctuations of magnetic moments are substantial. Finally we discuss a Hamiltonian with higher order terms and the influence they might have on magnetism of some compounds. [1] www.flapw.de

MA 4.6 Mon 12:15 H22

Magnetic and transport properties of spin-valve elements based on iron oxide nanoparticles — •Giovanni Andrea Badini Confalonieri[1], Philipp Szary[1], Maria Jose Benitez[1,2], Durga Mishra[1], Matthias Stadlbauer[1], Frank Brüssing[1], Matthias Feyen[2], Anhui Lu[2], Oleg Petracic[1], and Hartmut Zabel[1] — [1]Experimentalphysik IV, Ruhr-Universität Bochum, D-44780 Bochum — [2]Max-Planck Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr

Spin-valve elements based on magnetic nanoparticles are prepared by a combination of self-organization, ion etching and thin film growth. Highly monodisperse magnetic iron oxide nanoparticles are prepared by a chemical synthesis route, suspended in a toluene solution and spin coated on a Si substrate to form a well ordered self-assembled hexagonal close-packed monolayer. A Co bias-layer is evaporated on top of the nanoparticles after ion milling. Several cases are investigated: biasing via an unoxidized Co layer or via an exchange bias CoO layer. Surface characterisation is performed by means of Scanning Electron Microscopy and Atomic Force Microscopy. The magnetic characterisation presented includes field-cooling/zero-field cooling M(T) curves and magnetic hysteresis curves, in the temperature range from 15 K to 380 K, as well as surface magnetic properties studies by means of Magneto Optic Kerr Effect and Magnetic Force Microscopy. The transport properties of the spin-valve devices are measured by conventional four-probe technique. The effect of the device geometry on the magnetic and transport properties will be discussed.

MA 4.7 Mon 12:30 H22

Perpendicular FePt-based exchange-coupled composite media — •Denys Makarov[1], Jehyun Lee[2], Christoph Brombacher[1], Christian Schubert[1], Markus Fuger[2], Dieter Suess[2], Josef Fidler[2], and Manfred Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Institute of Solid State Physics, Vienna University of Technology, A-1040 Wien, Austria

To increase storage density in magnetic recording, FePt alloys in the $L1_0$ phase are under study as promising candidates for a recording layer [1]. However, due to the strong magnetic anisotropy, the magnetic field required to reverse the magnetization of the media may become higher than the field provided by a recording head. To solve this issue, the concept of exchange-coupled composite (ECC) media was suggested to reduce the switching field of a hard magnetic layer [2].

We fabricated ECC media which consisted of a hard FePtCu alloy film and a softer $[Co/Pt]_N$ multilayer stack both revealing an out-of plane easy axis of magnetization. We demonstrated that the switching field could be efficiently reduced by increasing the thickness of the soft magnetic layer and by tuning the interlayer exchange coupling. These studies were supported by theoretical modeling revealing the relevant factors to reduce the switching field of the hard layer which are important for future media design.

[1] D. Makarov et al., J. Appl. Phys. 103 (2008) 053903.
[2] D. Suess et al., Appl. Phys. Lett. 87 (2005) 012054.

MA 4.8 Mon 12:45 H22

Magnetization in a epitaxial $[Fe/Cr/Co/Cr]_{20x}$ spin valve system — •Frank Brüssing[1], Boris Toperverg[1], Kirill Zhernenkov[1], Maximilian Wolff[1], Hartmut Zabel[1], Katharina Theis-Bröhl[2], Carsten Wiemann[3], Alexander Kaiser[3], and Claus M. Schneider[3] — [1]Department of Physics, Ruhr-University Bochum — [2]University of Applied Sciences Bremerhaven — [3]Institut für Festkörperforschung, Forschungszentrum Jülich GmbH

Magnetic heterostructures containing different magnetic layers, such as Co and Fe, are essential elements for modern spintronic devices. As a model system we have chosen $[Co/Cr/Fe/Cr(100)]_{20x}$ epitaxial superlattices with spin valve properties. The thicknesses of the Fe and Co layers were adjusted such that their magnetization magnitudes are roughly equal. The quality of the layering and the epitaxial relationship were verified via x-ray methods. Via PEEM and PNR the ground state and the magnetization reversal were studied. In this work we mainly focused on the magnetic correlation between Co and Fe mediated by Cr spacer layer and its dependence on the Co bcc-hcp martensitic transition. The 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. For a certain thickness of the Co and Fe layers in the as grown state additional half-order peaks can be recognized, which indicate a spiral like magnetic ordering in the sample. A combination of the magnetic anisotropy of the different layers and interlayer exchange coupling is most likely the reason for the spiral state. This project was supported by the DFG via SFB491.

MA 4.9 Mon 13:00 H22

Magnetic circular dichroism in the angular distribution of electrons emitted from buried layers observed by hard X-ray photoelectron spectroscopy. — •G. Stryganyuk[1], E. Ikenaga[2], X. Kozina[1], S. Ouardi[1], T. Sugiyama[2], N. Kawamura[2], M. Suzuki[2], K. Kobayashi[3], K. Inomata[4], M. Yamamoto[5], C. Felser[1], and G.H. Fecher[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany — [2]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan — [3]National Institute for Materials Science, SPring-8, Hyogo, Japan — [4]NIMS, Tsukuba 305-0047, Japan — [5]Hokkaido University, Sapporo, Japan

This work reports on measurements of the magnetic dichroism in photoemission from core levels and valence band of magnetised buried thin films. The high bulk sensitivity of hard X-ray photoelectron spectroscopy allows to study the magnetic multilayers. High resolution photoelectron spectroscopy was performed with an excitation energy of $h\nu = 7.938$ keV. The circularly polarised photons were produced by an in-vacuum phase retarder at undulator BL-47XU beamline of SPring-8. The experiments were performed on exchange biased magnetic layers covered by insulators of 1 nm to 3 nm thickness. Two types of structures were used with the MnIr (10 nm) exchange bias layer either on top or below the ferromagnetic layer.

This work is financially supported by DfG-JST (FE633/6-1).

MA 5: Micro- and Nanostructured Magnetic Materials I

Time: Monday 11:00–13:00 Location: H23

MA 5.1 Mon 11:00 H23

Microresonator setup for Ferromagnetic Resonance investigations of nanoobjects — •Anja Banholzer[1], Ryszard Narkowicz[2], Dieter Suter[2], Ralf Meckenstock[1], Jürgen Lindner[1], and Michael Farle[1] — [1]Fakultät für Physik and Center for Nanointegration Duisburg-Essen, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Institut für Physik, Universität Dortmund, 44227 Dortmund, Germany

For Ferromagnetic Resonance (FMR) experiments a minimum number of spins on the order of 10^{12} (e.g. for Permalloy) are necessary. To enhance the sensitivity of the FMR detection, we have designed a microresonator setup with very high sensitivity, which allows for investigating small nanoobjects, for which conventional FMR detection would fail. The microresonators are prepared using Electron Beam Lithography. The constant microwave field is generated within the resonator at the position of the sample. Due to the resonator geometry, the resonance frequency for our measurements is fixed at 14 GHz. To observe the FMR, we sweep the externally applied magnetic field. With the microresonator we show the detection of a single Permalloy stripe with the size of 5 μm x 0.5 μm x 0.05 μm. The measured spectra are in good agreement with theoretical calculations. We achieve a sensitivity of $4 \cdot 10^6$ $spins/(G \cdot \sqrt{Hz})$. To demonstrate the flexibility of the approach, FMR measurements are performed on an epitaxial iron disc containing about 10^{10} spins. Financial support by DFG and SFB 491 is acknowledged.

MA 5.2 Mon 11:15 H23

Magnetic Reversal in Iron Thin Films Interspersed with Non-Magnetic Pinning Sites — •Stefan Nau, Ulf Wiedwald, Stefan Wiedemann, Alfred Plettl, and Paul Ziemann — Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany

Magnetic switching of continuous iron thin films is tailored by structuring a periodic array of nonmagnetic holes acting as pinning centers for domain walls. Contrary to common lithographically prepared antidots, nanostructures are prepared by deposition of densely packed monolayers of polystyrene (PS) spheres on silicon and silicon nitride substrates. Isotropic plasma etching leads to adjustable PS diameters between 20% and 80% of the initial value while conserving the particle spacing. The influence on the magnetic reversal process is studied as a function of diameter and distance of the PS spheres. Iron films are deposited by pulsed laser deposition. Antidot arrays of 100 nm period lead to up to 15 times increased in-plane coercive fields at 300 K, depending on dot diameters and film thicknesses. The magnetic reversal is imaged by scanning transmission x-ray microscopy accompanied by micromagnetic simulations in order to understand domain nucleation and propagation in varying external fields.

MA 5.3 Mon 11:30 H23

Analysis of Permalloy films prepared on anodized alumina templates — •Saleh Getlawi, Michael R Koblischka, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, D-66123 Saarbrücken, Germany.

The magnetic properties of Permalloy (Py) systems have been extensively studied for thick films due to the important role in many technological applications, e.g., in magnetoresistive-based sensors and devices. Nanopatterned magnetic media are important for various current approaches in magnetoelectronics and magnetic recording. Commercially available anodized aluminia templates with pore diameters of 100 mm and 30 mm were employed as substrates for Py thin films. The films were prepared by dc-magnetron sputtering. The film thickness was between 7 nm and 30 nm. The obtained antidot patterns were observed by electron and force microscopy. The resulting magnetic domain structures were characterized by means of magnetic force microscopy performed in externally applied magnetic fields. Additionally, the magnetic parameters were characterized by means of SQUID magnetometry.

MA 5.4 Mon 11:45 H23

Effects of hexagonal hole structures on magnetization dynamics in thin nickel films — •Fabian Garbs, Benjamin Lenk, Andreas Mann, Henning Ulrichs, Darius G. Vahdat-Pajouh, and Markus Münzenberg — I. Physikalisches Institut, Georg-August Universität Göttingen

The spin-wave modes in hexagonal magnonic structures in thin nickel films are investigated by ultra short laser pulses (60 fs). In an all optical pump-probe setup the pulses are used both to excite the sample and to observe the magnetic relaxation on the picosecond timescale up to 1 ns. By using the time resolved magneto-optical Kerr effect (TRMOKE) the magnetic oscillations are observed in external fields up to $\mu_0 H_{\text{ext}} = \pm 150\,\text{mT}$, under an angle of up to 30° out of plane.

The magnetic films are structured with periodic micron-sized holes to produce a magnetic metamaterial using a focused ion beam (FIB). Hole structures with different parameters (hole radius and periodic distance) were investigated. The hexagonal structure was chosen because of high symmetry and in comparison to results of rectangular structure experiments. Measurements under different in-plane angles reflect the structural symmetry in terms of the obtained field-dependent dispersion.

Furthermore a missing row in hole structures was investigated in order to find analogies to photonic waveguide behavior, which could be used prospectively for magnonic circuits.

MA 5.5 Mon 12:00 H23

Qualitative and quantitative imaging of magnetic stray fields in $RECo_5$ thin films — •Ulrike Wolff[1], Sven Schnittger[2], Jonas Norpoth[2], Christian Jooss[2], Ludwig Schultz[1], and Volker Neu[1] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]Institut für Materialphysik, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

The contribution has been withdrawn.

MA 5.6 Mon 12:15 H23

Spin-wave propagation in a microstructured magnonic crystal — •Andrii V. Chumak[1], Philipp Pirro[1], Alexander A. Serga[1], Mikhail P. Kostylev[2], Robert L. Stamps[2], Helmut Schultheiss[1], Katrin Vogt[1], Sebastian J. Hermsdoerfer[1], Bert Laegel[1], P. Andreas Beck[1], and Burkard Hillebrands[1] — [1]FB Physik, Nano+Bio Center, and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]School of Physics, University of Western Australia, Crawley, Western Australia 6009, Australia

The transmission of spin waves through a magnonic crystal fabricated as permalloy (Py) waveguide with a periodically variable width was studied experimentally and theoretically. Electron beam lithography, molecular beam epitaxy, and lift-off process were used to fabricate the magnonic crystal in the form of a 40 nm thick Py stripe of periodically variable width between 2.5 μm and 1.5 μm. The lattice constant of the magnonic crystal is 1 μm. A bias magnetic field was applied perpendicularly to the waveguide in the film plane. Spin waves were excited by a 1 μm wide copper antenna and their characteristics were measured by spatially-resolved Brillouin light scattering microscopy. A rejection frequency band, where spin waves are not allowed to propagate, was clearly observed. The band gap frequency can be tuned in the range from 6.5 to 9 GHz by varying the applied magnetic field. The measured spin-wave intensity as a function of frequency and propagation distance is in good agreement with model calculations.

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

MA 5.7 Mon 12:30 H23

Magnetization dynamics of a CrO_2 grain studied by micro-Hall magnetometry — •Pintu Das[1,2], Jens Müller[1,2], Ashna Bajpai[3], Fabrizio Porrati[2], Franziska Wolny[3], Steffen Wirth[1], Thomas Mühl[3], Michael Huth[2], Rüdiger Klingeler[3], and Bernd Büchner[3] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, Dresden, — [2]Instiute of Physics, Goethe University, Max von Laue Str. 1, Frankfurt am Main — [3]Instiute for Solid State and Materials Research, Helmholtz Str. 20, Dresden

In the field of magnetism, it is often difficult to gain a complete quantitative understanding of magnetization dynamics in bulk or multigrain systems. Studying the magnetic behaviour of single magnetic entities is thus very important in order to understand the process of magnetization reversal in complex magnetic materials. In this work, we have studied the magnetization reversal of a single CrO_2 grain of size

$\sim 8 \times 2 \times 2\,\mu m^3$ using micro-Hall magnetometry technique. CrO_2 is ferromagnetic and has a T_c of $\sim$ 393 K. The grain has an antiferromagnetic Cr_2O_3 layer of thickness $\sim$ 2-5 nm. We observe that the magnetization in this grain switches through a series of Barkhausen jumps of stochastic nature. In the temperature range of 5 K - 60 K, simultaneously measured magnetization at both ends (along the long axis) of the grain show that these jumps are correlated. The data may allow us to infer the nature of the magnetic domains inside the grain and the behaviour of the domain walls for externally applied magnetic fields. We discuss the results and compare them with micro-magnetic simulations for the magnetic behaviour of this sample.

MA 5.8 Mon 12:45 H23

Magnetization Reversal in Arrays of Gold Nanoparticles Covered with Co/Pt Multilayers — •Carsten Schulze[1], Denys Makarov[1], Herbert Schletter[1], Alan Craven[2], Sam McFadzean[2], Michael Hietschold[1], Ulrike Wolff[3], Volker Neu[3], and Manfred Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Department of Physics and Astronomy, University of Glasgow, Glasgow G12 8QQ, UK — [3]IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany

The reversal process of Co/Pt multilayers with perpendicular magnetic anisotropy deposited on arrays of self assembled gold nanoparticles with sizes down to 20 nm has been investigated. The magnetic caps on 60 and 40 nm particles show a well defined single domain state. The observed magnetization reversal process suggests, that the neighboring caps are exchange coupled. In this respect, the single domain caps observed in an exchange coupled magnetic film are suggested to occur through the formation of metastable domain patterns such as bubble domains. The reversal behavior on magnetic films on planar substrate and on assemblies of 20-nm-sized particles was found to be similar, but with substantially different size of the magnetic domains. Careful investigation of the magnetization reversal suggests the presence of strong pinning of domain walls on inhomogeneities in the magnetic material due to the particles. The latter indicates that the dense assemblies of gold particles could be considered as a template to realize the concept of perpendicular percolated media [1].

[1] D. Suess et al., J. Appl. Phys. 99 (2006) 08G905

MA 6: Magnetic Thin Films I (Heusler Alloys)

Time: Monday 14:00–19:00 Location: H10

Invited Talk MA 6.1 Mon 14:00 H10

Heusler alloy films for spintronics — •Terunobu Miyazaki[1], Daisuke Watanabe[1], Shigemi Mizukami[1], Feng Wu[1], Takahide Kubota[2], Sumito Tsunegi[2], Hiroshi Nagahama[2], Mikihiko Oogane[2], and Yasuo Ando[2] — [1]WPI Advanced Institute for Materials Research Tohoku Univ. Sendai Japan — [2]Department of Applied Physics Tohoku Univ. Sendai Japan

Half-metallic ferromagnets are an ideal material for obtaining high tunnel magnetoresistance (TMR) ratio because they have an energy gap at the Fermi level only in the up or down spin channel. Especially, Heusler alloys show a high Curie temperature and relatively high value of saturation magnetization and they are expected as an ideal material for spintronics. However, the realization of high TMR ratio and high spin polarization experimentally shown is in recent years. In my talk, first historical study of Heusler electrode tunnel junction including our past data will be explained. Then, transport properties of Co2FexMn1-xSi/Al-O/Co75Fe25 tunnel junctions and Gilbert damping constant in Co2FexMn1-xSi films for x of 0-1.0 will be explained in detail. Finally, I will explain an experiment for epitaxial Mn2.5Ga films, which are tetragonal (non-cubic Heusler type alloy) and exhibit perpendicular magnetic anisotropy of the order 107 erg/cc and low saturation magnetization about 250 Gauss. One can expect for the MnGa film as one candidate for the electrode material of MTJ of Spin-RAM. A quite recent experiments related to memory materials will be also included.

Invited Talk MA 6.2 Mon 14:30 H10

Heusler alloy based magnetic read heads — •Stefan Maat — Hitachi, 5601 Great Oaks Parkway, San Jose, CA 95119 (USA)

All-metal current perpendicular-to-the-plane giant magneto-resistive sensors are an attractive follow-on reader technology to tunnel-magneto-resistance sensors as magnetic recording densities continue to increase. With low resistance-area products in the range 0.05 Ohm*um2, CPP-GMR sensors exhibit low impedance and therefore low noise even at sensor dimensions below 30 nm. Although the magneto-resistance (dR/R) of CPP-GMR sensors increases with thicker magnetic layers due to spin-diffusion length effects their thickness is limited by the desired shield-to-shield spacing determining the maximum linear recording density. Among the challenges that CPP-GMR sensors face are low dR/R for thin magnetic layers as well as current-induced noise and magnetic instability from spin-torque effects, which arise from the interaction of spin-polarized electron current with the magnetization of the electrodes. Highly spin-polarized Heusler based alloys are promising candidates to achieve high dR/R. However, these alloys are challenging to synthesize with full order in a thin film form within the low growth and annealing temperature limitations. Although film-level dR/R of ~ 8 % has been obtained in spin-valves with CoFeGe and Co2MnGe electrodes (compared to 2% with CoFe), these alloys give rise to a high level of spin-torque excitation due to their high spin-polarization and low magnetic damping resulting in sensor noise. Thus, new multilayer structures to suppress excessive spin-torque excitations need to be implemented.

MA 6.3 Mon 15:00 H10

Wachstum und Charakterisierung ferromagnetischer Co_2FeSi-Filme auf Galliumarsenid(110)-Substraten — •Thomas Hentschel, Claudia Herrmann, Hans-Peter Schönherr, Bernd Jenichen und Jens Herfort — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

Die ferromagnetische Heusler-Legierung Co_2FeSi gilt aufgrund der theoretisch vorhergesagten hohen Spinpolarisation (bis zu 100%) und der hohen Curie-Temperatur (>980 K) als vielversprechendes Material zur Realisierung spinpolarisierter Elektroneninjektion in einen Halbleiter. Von besonderem Interesse ist das Wachstum von Co_2FeSi auf der GaAs(110) Oberfläche, da hier theoretischen Berechnungen zufolge im Gegensatz zur (001)-Orientierung die hohe Spinpolarisation an der Ferromagnet/Halbleiter-Grenzfläche erhalten bleibt und eine deutlich längere Spinlebensdauer im Halbleiter zu erwarten ist. In unserer Arbeit wurden 15 bis 40 nm dicke stöchiometrische Co_2FeSi-Filme auf GaAs(110) mittels Molekularstrahlepitaxie gewachsen. Rasterkraftmikroskopie-Aufnahmen zeigen bei Wachstumstemperaturen zwischen T_G=100 °C und 225 °C ausgeprägte Stufen und Terrassen, was auf zweidimensionales Wachstum schließen lässt. Röntgenbeugungsexperimente an (220)- und (440)-Reflexen zeigen bis etwa 250 °C neben dem Substrat- und Schichtpeak ausgeprägte Oszillationen (Fringes), die auf eine atomar scharfe Grenzfläche hinweisen. Oberhalb von 250 °C setzen Grenzflächenreaktionen ein. Das Vorhandensein ordnungsabhängiger Reflexe bei $T_G \approx 200$ °C weist zudem auf eine geordnete $B2$- bzw. sogar $L2_1$-Struktur hin.

MA 6.4 Mon 15:15 H10

Thin films of the ferrimagnetic Heusler compound Mn_2VAl — •Arbelo Jorge Elena, Brose Daniel, Jourdan Martin, Klaer Peter, and Elmers Hans Joachim — Institute of Physics, Johannes-Gutenberg University, Staudinger Weg 7, 55099 Mainz, Germany

Half-metallic ferrimagnetic materials are interesting candidates for spintronic applications. In comparison with ferromagnetic compounds, their values of the total magnetic moments are small which provides additional benefits. They are less affected by an external magnetic field and do not cause strong stray fields in devices.

First experimental studies on thin films of the ferrimagnetic Heusler compound Mn_2VAl are presented here. The Heusler Mn_2VAl thin films are prepared by rf-sputtering on MgO substrates at room temperature followed by an annealing step. The crystallographic and magnetic properties are analysed by using X-ray diffraction, SQUID magnetometry and X-ray Magnetic Circular Dichroism (XMCD), respectively.

The structural analysis shows B2 order for films annealed at 550^{o}C. Concerning magnetic properties, first XMCD results at RT show a spin moment of 1.06 μ_B/f.u and -0.9 μ_B/f.u for Mn and V, respectively in the bulk and a reduction to 0.46 μ_B/f.u and -0.22 μ_B/f.u at the sur-

face. The values in the bulk are in certain agreement with theoretical predictions which are 1.5 μ_B/f.u and -0.9 μ_B/f.u, giving rise to a total spin moment of -2 μ_B/f.u.

First results of this compound implemented in Magnetic Tunneling Junctions are shown.

MA 6.5 Mon 15:30 H10

Growth of epitaxial thin films of Co_2MnSi and Cu_2MnAl by solid-state crystallization from the x-ray amorphous state. — •Denise Erb, Gregor Nowak, Kurt Westerholt, and Hartmut Zabel — Ruhr-Universität Bochum

Ferromagnetic Heusler alloys have attracted considerable interest recently, since the full spin polarization at the Fermi level in some of these compounds makes them promising candidates for spintronic applications. Using UHV magnetron sputtering at room temperature and subsequent annealing we have prepared thin films of the Heusler phases Co_2MnSi and Cu_2MnAl on MgO (100) and Al_2O_3 (a-plane) substrates. The structural properties were studied by synchrotron-based x-ray diffraction; the magnetic properties were investigated by vibrating sample magnetometry. In the as-prepared state the films are atomically disordered and non-magnetic. Upon annealing ferromagnetism develops together with the crystalline structure. Co_2MnSi films grown on Al_2O_3 (a-plane) and different seedlayers exhibit only the (220) Bragg reflection, indicating a long-range order of the A2-type after annealing. However, the ferromagnetic quality of these samples evidences a short-range $L2_1$ order. Cu_2MnAl can be grown directly on MgO (100) with the in-plane [100]-direction rotated by 45° from the [100]-direction in MgO. The presence of the (111) Bragg reflection in Cu_2MnAl samples proves the epitaxial quality and a long-range $L2_1$ order in the annealed state.

MA 6.6 Mon 15:45 H10

Transport spin polarization of thin MBE-grown Co_2FeSi-films — •Hauke Lehmann[1], Jan M. Scholtyssek[1,2], Jens Herfort[3], Claudia Herrmann[3], Guido Meier[1], and Ulrich Merkt[1] — [1]Inst. f. Angew. Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Inst. f. Elekt. Messtechnik und Grundlagen der Elektrotechnik, TU Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig — [3]Paul-Drude-Institut f. Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin

The predicted half-metallicity of Co_2FeSi in combination with its high Curie temperature of above 980 K [1] makes this Heusler alloy very interesting for spintronic applications. Thin Co_2FeSi films grown by molecular-beam epitaxy are fabricated on GaAs substrates with a close lattice match. We determine the transport spin polarization at the Fermi energy by point-contact Andreev-reflection (PCAR) spectroscopy. A systematic study of PCAR measurements on different films, varying in thickness between 18 and 48 nm and in substrate temperature at the deposition process between 100 and 350^{o}C is presented. The highest polarizations of about 60% can be observed for films grown at substrate temperatures of 200 to 300^{o}C. At higher temperatures Cobalt might diffuse into the substrate [2], leading to a decrease of the polarization. A repetition of the measurements on samples stored in vacuum and in air after one year also shows a measurable decrease of the spinpolarization, presumably caused by oxidation.

[1] V. Niculescu et al., J. Magn. Magn. Mater. **5**, 60 (1977)
[2] M. Hashimoto et al., J. Phys. D: Appl. Phys. **40**, 1631 (2007)

MA 6.7 Mon 16:00 H10

Thin magnetic films of the Heusler compound $Co_2FeAl_{0.4}Si_{0.6}$ — •Frederick Casper[1], Tanja Graf[1], Johannes Paul[2], Gerhard Jakob[3], and Claudia Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, 55099 Mainz, Germany — [2]SENSITEC GmbH, 55131 Mainz, Germany — [3]Institute of Physics, Johannes Gutenberg - University, 55099 Mainz, Germany

Half-metallic compounds which are fully spin polarized near the Fermi level (E_F) due to an energy gap in the minority-spin channel have attracted great attention as key materials for creating spintronic devices. Co-based Heusler compounds have been predicted to have a high spin polarization even at room temperature due to their high Curie temperature of around 1000 K. To overcome the problem of narrow energy separation between the Fermi level and the bottom edge of the conduction band, $Co_2FeAl_{1-X}Si_X$ (CFAS) has been predicted to be more stable against the influence of temperature. For X = 0.5, several reports show promising results with CFAS in magnetic tunnel junctions using MgO and Al_2O_3 as tunnel barrier. Here we show the first results of $Co_2FeAl_{0.4}Si_{0.6}$ films on MgO and SiO_X substrates. Depending on the annealing temperature, buffer layer and substrate, CFAS shows B2 and/ or $L2_1$ type of order. Magnetic moments ranging from 3.8 to 5.1 μ_B/f.u. depending on the degree of ordering. AFM measurements show smooth surfaces, and XPS reveal the right stoichiometry for all films. This work is supported by the Federal Ministry for Education and Research BMBF, project "'Multimag"'.

MA 6.8 Mon 16:15 H10

Fe-rich Heusler/semiconductor hybrid structures: An ab initio study of the electronic and magnetic structure of the interface — •Heike C. Herper and Peter Entel — Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany

Ferromagnet(FM)-semiconductor(SC) hybrid structures have attracted much interest concerning the fabrication of spintronic devices. Fe and Co based Heusler alloys seem to be suitable for this purpose, because they are often half-metallic or have at least a high spin-polarization and a high T_C. Though, some of the stoichiometric systems have been intensively studied only few results exist for the nonstoichiometric systems and for the magnetic structure of the FM/SC interface. We focus on $Fe_2Fe_{1-x}Y_xSi$ (Y = Co, Ni) Heusler alloys. Fe_3Si and Fe_2CoSi are known to have high T_Cs and being close to half-metallicity. In agreement with experiment we observe that the replacement of Fe by Co or Ni leads to an inverse Heusler ordering instead of the $L2_1$ structure. However, it turns out that the magnetic properties are sensitive to strain which may occur at interfaces.

First, we investigate the dependence on the concentration x and the structural ordering for the bulk phases. In a second step we perform calculations for the Fe-rich Heuslers on GaAs(001) and MgO(001) to study the polarization, the band gap etc. We observe that the polarization not only increases but also layer dependent oscillations of the polarization are reduced if Co is added to the system. The calculations are performed by using the VASP [Mater. Sci.**6**,15 (1996)] and SPR-KKR [by H. Ebert et al.] code.

MA 6.9 Mon 16:30 H10

X-ray diffraction studies of Co_2MnSi and Co_2FeAl Heusler compounds in magnetic tunnel junctions — •Patrick Thomas, Daniel Ebke, Markus Schäfers, Oliver Schebaum, Andreas Hütten, and Andy Thomas — Thin Films and Physics of Nanostructures, Physics Department, Bielefeld University, Germany

Recently, we have shown high room temperature tunnel magnetoresistance values of about 150% for magnetic tunnel junctions containing the Heusler compound Co_2FeAl.

In this work, we will present the structural properties of the Co_2FeAl electrode that were determined by x-ray diffraction (XRD) as a function of annealing temperature. A B2 type structure can be achieved for all annealing temperatures. This is compared to (XRD) studies of similar layer stacks based on the Heusler compound Co_2MnSi.

It will be discussed if a Co_2FeAl buffer layer underneath another Heusler compound, e.g. Co_2MnSi can induce a lower crystallization temperature as it was previously reported for Co_2FeSi/Co_2MnSi multilayers.

MA 6.10 Mon 16:45 H10

Disorder-induced sign reversal of spin polarization in Co_2FeSi — •Pawel Bruski[1], Oliver Brandt[1], Steve Erwin[2], Rouin Farshchi[1], Klaus-Jürgen Friedland[1], Jens Herfort[1], and Manfred Ramsteiner[1] — [1]Paul-Drude-Institut für festkörperelektronik, 10117 Berlin — [2]Center for Computational Materials Science, Naval Research Laboratory, Washington, DC 20375, USA

The ferromagnetic Heusler alloy Co_2FeSi is closely lattice matched to GaAs and is predicted to be halfmetallic, meaning electrons at the Fermi level are 100% spin-polarized. We investigated spin light emitting GaAs/(Al,Ga)As diodes (spin-LEDs) with Co_2FeSi injection layers grown by molecular-beam epitaxy at different substrate temperatures T_S. An opposite sign of the electroluminescence polarization (ca. 20%), i.e., spin polarization of injected electrons has been observed for spin-LEDs grown at $T_S = 100$ °C and $T_S = 280$ °C, respectively. Previous structural studies revealed that the partially disordered $B2$ phase of Co_2FeSi dominates near the interface for lower T_S while the fully ordered $L2_1$ phase dominates for higher T_S. Consequently, the experimentally observed sign reversal is attributed to a different spin orientation dominating at the Fermi energy of the two different Co_2FeSi phases. This conclusion is supported by first-principles calculations of the density of states by the LDA+U method. For intermediate T_S, Co_2FeSi layers consist of a spatially inhomogeneous distribution of the $L2_1$ and the $B2$ phases compensating each other by the injection of

oppositely spin-polarized electrons. Consequently, the corresponding spin-LEDs exhibit a comparatively small total spin-injection efficiency.

MA 6.11 Mon 17:00 H10

Determination of magneto-optical coupling constant of ferromagnetic metals — •Kahming Mok[1], Nan Du[1], Maciej Oskar Liedke[1], Shengqiang Zhou[1], Mathias Schubert[2], Manfred Helm[1], and Heidemarie Schmidt[1] — [1]Forschungszentrum Dresden Rossendorf, Dresden, Germany — [2]University of Nebraska-Lincoln, Nebraska, USA

Magneto-optical generalized ellipsometry (MOGE) is the most general approach to characterize the magneto-optical response of multilayer materials. One of the most basic mechanism in magneto optics is the spin nature of the electrons and the spin dependent selection rules. The characterization of magneto-optical materials typically requires 3 independent complex-valued parameters in its purely magneto-optical tensor description [1]. In our work, we measured the Mueller matrix of MBE grown ferromagnetic thin films (Co, Fe, Ni) using a variable angle spectroscopic ellipsometer (VASE) combined with a 3D 0.5 T vector magnet which can operate as a vector MOGE. We probed the Mueller matrix of reflected and transmitted light in the spectral range from 1 to 4 eV and modeled it by the 4 x 4 matrix method. From that we determined the complex magneto-optical coupling constants Q of Co, Fe, and Ni. [1] M. Schubert, "Infrared ellipsometry on semiconductor layer structures: Phonons, plasmons, and polaritons", Springer, Berlin, 2004.

15 min. break

MA 6.12 Mon 17:30 H10

Dependence of domain width on second order anisotropy — •D. Stickler[1], R. Frömter[1], H. Stillrich[1], C. Menk[1], C. Tieg[2], C. Gutt[3], S. Streit-Nierobisch[3], L.-M. Stadler[3], O. Leupold[3], G. Grübel[3], and H. P. Oepen[3] — [1]Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Str. 15, 12489 Berlin — [3]Deutsches Elektronen-Synchrotron (DESY), Notkestr. 85, 22607 Hamburg

The domain width of magnetic films with uniaxial perpendicular anisotropy is a consequence of the interplay between magnetostatic and domain wall energy. We fit the analytical solution for the magnetostatic energy of single layers[1] to numerical results for multilayers[2], with the thickness and scaling factor for the magneto-static energy as fit parameters. With the achieved analytical description, we calculate the energy minimum as a function of domain width, by utilizing the domain wall energy expression for systems with considerable K_2-contribution[3]. The model is applied to our findings on soft x-ray Fourier transform holography of anisotropy modulated films of constant thickness[4]. The anisotropy was tuned via ion beam bombardment. The analysis reveals that close to reorientation K_2 determines the domain width, while changes in K_1 are responsible for the transitions of the magnetization from vertical to in-plane orientation.

[1]Kaplan and Gehring, JMMM**128**, 111 (1993) [2]Draaisma and de-Jonge, J.Appl.Phys.**62**, 3318 (1987) [3]Träuble et al., Phys.Stat.Sol.**10**, 283 (1965) [4]Streit-Nierobisch et al., J.Appl.Phys.**106**, 083909 (2009)

MA 6.13 Mon 17:45 H10

Interface properties of spin injection systems and tunnel barrier systems: Fe_3Si on GaAs(001) and MgO(001) — •Sergey Makarov, Frank Stromberg, Bernhard Krumme, Claudia Weis, Werner Keune, and Heiko Wende — Fakultät für Physik and CeNIDE, Universität Duisburg-Essen

For spintronic applications, not only the charge transfer to the semiconductor, but also the spins of the electrons are of interest. Ferromagnet/semiconductor interfaces allow controlling the spin orientation of injected electrons. The degree of spin polarisation depends on the structural quality of the interface. Furthermore, the spin injection efficiency can be improved by introducing a tunnel barrier at the interface.

The quasi-Heusler system Fe_3Si is a promising candidate for such applications. It grows well ordered on MgO(001) with a low lattice mismatch to semiconducting GaAs(001). We have investigated the chemical ordering of Fe_3Si by conversion electron Mössbauer spectroscopy (CEMS) using the ^{57}Fe tracer layer technique. From CEMS we obtain the long-range order parameters S($D0_3$) and S(B2) together with the Si concentration. Strong interdiffusion occurs at the Fe_3Si/GaAs interface. Introducing a MgO tunnel barrier hinders the interdiffusion. Fe_3Si/MgO/GaAs(001) suprisingly shows an almost ordered $D0_3$-structure with 26% Si-content. However, the $^{57}Fe_3Si$ tracer layer at the MgO-buffer layer displays the B2-ordered structure with randomly distributed Si atoms on Fe sites. On the MgO tunnel barrier, the chemical order of Fe_3Si is comparable to Fe_3Si grown directly on a MgO(001) single crystal. – Supported by the DFG (Sfb491).

MA 6.14 Mon 18:00 H10

Magnetic properties of PdFe alloys — •Melanie Ewerlin[1], Stefan Buschhorn[1], Bastian Pfau[2], Christian Günther[2], Stefan Heinze[2], Stefan Eisebitt[2], and Hartmut Zabel[1] — [1]Institut für Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 14109 Berlin

We investigate the itinerant ferromagnetic system Pd1-xFex for different compositions with x=3.4-7.2. The Fe atoms provide a strong molecular field and trigger the alloy to a ferromagnetic state by polarization of the Pd atoms. This polarization effect is directly proven by x-ray magnetic circular dichroism experiments, which allow element specific magnetization measurements by resonantly tuning the x-ray energy. We are able to detect a clear magnetic dichroism signal both at the Fe L-edge and the Pd M-edge. Magnetic small angle x-ray scattering experiments at the Fe L-edge reveal a domain size of approximately 150nm in the samples. The shape of the hysteresis loops, magnetization curves and magnetization relaxation measurements measured with SQUID indicate the coexistence of long range ferromagnetism and also cluster magnetism in the alloy. Soft x-ray photon correlation spectroscopy measurements are performed to reveal both domain fluctuations and also possible spin fluctuations of Fe nanoclusters embedded in the Pd-matrix.

MA 6.15 Mon 18:15 H10

Hard X-ray photoelectron spectroscopy studies of buried magnetic multilayers at PETRA III. — •Andrei Gloskovskii[1], Gerhard H. Fecher[1], Claudia Felser[1], Sebastian Thiess[2], Heiko Schulz-Ritter[2], Wolfgang Drube[2], Götz Berner[3], Michael Sing[3], and Ralph Claessen[3] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [2]Hasylab/DESY, Hamburg — [3]Experimental Physics 4, University of Würzburg, Würzburg

We report on the first hard X-Ray photoelectron spectroscopy (HAXPES) experiments at the undulator beamline P09 of the PETRA III storage ring, currently being commissioned at DESY in Hamburg. With the combination of high-flux undulator radiation from a brilliant third generation hard X-ray source and high-resolution electron spectrometers operating at high voltages (kinetic energies up to 15 keV) HAXPES becomes a powerful tool for the investigation of electronic and magnetic properties of bulk materials and buried layers. Here, the properties of several promising candidates for tunnel magnetoresistive devices were investigated. Pinned MnIr-CoFe thin film multilayers show large dichroism in the angular distribution (LMDAD). The LMDAD effect has a $cos^2\theta$ dependence, where θ is the angle between the projection of the light polarisation and the sample magnetisation direction. This gives direct information about the magnetisation direction with respect to the plane of incidence of the p-polarised synchrotron beam. This work is funded by BMBF (05KS7UM1)

MA 6.16 Mon 18:30 H10

Kinetically controlled growth of iron oxides — •Mehrdad Baghaie Yazdi, David Bierwagen, and Lambert Alff — TU Darmstadt, Materialwissenschaft, Darmstadt, Deutschland

Magnetite is a promising material for spintronics applications due to its high Curie-temperature of 858 K, predicted half-metallicity and fairly low resistivity of 5.2 $\times 10^{-3}$ Ωcm. We have deposited magnetite thin films using reactive rf-magnetron sputtering on MgO and c-cut Al_2O_3 substrates. Furthermore the aforementioned substrate materials can also act as an insulating tunneling barrier in magnetic tunnel junction structures, making the epitaxial growth of all-oxide heterostructures possible.

The thin film samples were characterized by x-ray diffraction and reflectometry, superconducting quantum interference magnetometry, Raman spectroscopy and temperature dependent resistivity. The sample properties were compared to bulk magnetite, which acts as a quality standard. In particular, the Verwey transition is highly sensitive to material stoichiometry and defects. Optimized thin films exhibit an extremely sharp Verwey transition, in both magnetic and resistive measurments, between 119 K and 132 K. We have further established

a sputtering process, which allows for a kinetically controlled growth of iron oxide phases ranging from α-Fe_2O_3 to Fe_3O_4+ Fe.

The authors thank *LOEWE-Centre of Excellence AdRIA* for financial support and Dr. Emanuel Ionescu for his time and help with Microraman measurements.

MA 6.17 Mon 18:45 H10

Perpendicular magnetic anisotropy in Co_3Pt thin films — •Christian Schubert, Denys Makarov, Christoph Brombacher, Katja Neupert, Mirko Kehr, Walter Hoyer, and Manfred Albrecht — Chemnitz University of Technology, Institute of Physics, D-09107 Chemnitz, Germany

Binary alloys of M_xPt_{1-x} (M = Fe, and Co) prepared as thin films tend to show a strong perpendicular magnetic anisotropy (PMA), making them good candidates for magnetic recording media or sensoric devices. The magnetic response of M_xPt_{1-x} films can be strongly modified by the degree of composition, film thickness, deposition temperature, and nature of substrate. Thus, chemically disordered CoPt alloys with (111) texture exhibit an unexpected PMA related to an anisotropic short-range order (SRO) effect [1]. Here we present an investigation of structural and magnetic properties of Co_3Pt alloy films in the thickness range from 5 to 20 nm. The magnetic layers were deposited using magnetron co-sputtering on thermally oxidized Si(100) wafers. Interestingly, even when deposited at room temperature, these films reveal the presence of a strong PMA (K_U = 0.6 MJ/m^3) with a full remanence in the out-of-plane direction. Furthermore, owing to the high Co content, the alloy has a rather high value of saturation magnetization of about 0.8 T. To access the structural properties of the alloy, a x-ray diffraction study was carried out. However, no superstructure peaks which might be attributed to a chemical long range order have been observed indicating that SRO is the origin for the PMA. [1] Y. Yamada et al., *J. Appl. Phys.* **83** (1998) 6527.

MA 7: Multiferroics II (with DF, KR, DS)

Time: Monday 14:00–17:45 Location: H3

MA 7.1 Mon 14:00 H3

Switching of a spin-spiral-induced polarization in multiferroic $MnWO_4$ — •Tim Hoffmann[1], Dennis Meier[1], Petra Becker-Bohatý[2], Ladislav Bohatý[2], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn — [2]Institut für Kristallographie, Universität zu Köln

Coexisting ferroic orders become interesting when there is an interaction between them. Especially applying an electric field and thus changing the magnetic order is highly desirable for possible applications. In spite of the declared interest in multiferroics to switch a magnetization by an electric field nothing is known about the dynamics of the actual switching process.

The coupling of ferroelectric and magnetic order is intrinsically strong in spin-spiral multiferroics, where ferroelectricity emerges as a consequence of complex magnetic long-range order. Here we observe the manipulation of magnetically-induced ferroelectric domains in $MnWO_4$ by optical second harmonic generation (SHG). Application of an electric field allows to transform the sample to an electric as well as magnetic single-domain state. Moreover we obtained images of the domain structures during the transition revealing the growth of the domains. When cooled in zero-field, the domains have a bubble-like topology. Interestingly, after recovery from a single domain state the shape changes to a stripe structure and the domain size is significantly increased. Effects of the shape and duration of the electric-field poling pulses are investigated. Furthermore, in contrast to typical ionic ferroelectrics the spontaneous polarization can be switched without fatigue – no defects or pinning effects constrain the movement of domain walls.

MA 7.2 Mon 14:15 H3

Single Crystal X-ray diffraction studies on multiferroic $YMn_{2-x}Fe_xO_5$ — •Sven Partzsch[1], Jochen Geck[1], Norman Leps[1], Roberto Kraus[1], Dmitr Souptel[1], Bernd Büchner[1], and Enrico Schierle[2] — [1]IFW Dresden — [2]Helmholz-Zentrum Berlin

Temperature dependent single crystal X-ray diffraction studies of $YMn_{2-x}Fe_xO_5$ are presented. Upon cooling, the undoped material (x=0) orders antiferromagnetically below $T_N \approx 45$ K and becomes multiferroic below $T_{CE} \approx 39$ K. This multiferroic phase is destabilized rapidly with increasing Fe-content and we address here the reasons for this dramatic effect. The crystallographic study implies that the doped Fe mainly occupies the square pyramidal coordinated Mn position instead the octahedral one, which shows that these lattice sites are crucial for the MF properties.

In order to further characterize the electronic ordering in the ferroelectric phase of the undoped samples, we also applied soft resonant X-ray diffraction, which clearly shows that the oxygen states play an important role as well.

MA 7.3 Mon 14:30 H3

Electronic structure and magnetism in $YFeMnO_5$ — •Torsten Weissbach[1], Tilmann Leisegang[2], Axel Lubk[2], Dirk C. Meyer[3], and Sibylle Gemming[4] — [1]Inst. f. Theoretische Physik, TU Bergakademie Freiberg — [2]Inst. f. Strukturphysik, TU Dresden — [3]Inst. f. Experimentelle Physik, TU Bergakademie Freiberg — [4]Inst. f. Ionenstrahlphysik u. Materialforschung, Forschungszentrum Dresden

$YFeMnO_5$ crystallizes in the structure type of the orthorhombic RMn_2O_5 class of oxides. These show a series of antiferromagnetic phases with propagation vectors (1/2-δ, 0, 1/4+ϵ) below $T_N \approx 45$ K. For several of these phases, magnetism coexists with ferroelectricity. In $YFeMnO_5$, only one commensurable ferrimagnetic phase was found below $T_N = 165$ K, and ferroelectricity is absent. We apply crystallographic and quantum chemical methods to compare the Fe-substituted and the mangenese-only compounds. Diffraction experiments show slight displacements of the atom sites with increasing Fe content. The largest effects are related to crystal-field repulsion acting on the local metal 3*d* orbitals. The interaction between the magnetic metal ions is studied using DFT calculations starting with a bias magnetization of the atoms.

MA 7.4 Mon 14:45 H3

Ab initio **calculations of the magnetic properties of perovskites under deformation** — •Igor Maznichenko[1], Corina Etz[2], Arthur Ernst[2], Martin Lüders[3], Ingrid Mertig[1,2], Zdzislawa Szotek[3], and Walter Temmerman[3] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle (Saale), Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle (Saale), Germany — [3]Daresbury Laboratory, Daresbury, Warrington WA4 4AD, Cheshire, United Kingdom

Materials with perovskite and perovskite-like structures demonstrate a broad spectrum of physical properties. Colossal magnetoresistance, ferroelectricity, multiferroicity, superconductivity, charge ordering, metal-insulator transition, Jahn-Teller and other effects are observed in perovskites. These properties of the mentioned materials with the common formula ABO_3 are very sensitive to the type of the cations *A* and *B*. $La_{2/3}Sr_{1/3}MnO_3$ (LSMO) is a strongly correlated 3*d* transition metal oxide with a Curie temperature (T_C) above RT (370 K). For other La/Sr ratios different types of antiferromagnetism are observed. Other perovskite, ruthenate $SrRuO_3$ (SRO) is a 4*d* ferromagnet with T_C = 160 K.

Here we perform *ab initio* calculations for LSMO and SRO in ideal cubic, tetragonally distorted, and different orthorhombic structures. We focus on magnetic order and Curie temperature of the above mentioned structures in the different structural phases.

MA 7.5 Mon 15:00 H3

Electric field induced magnetization switching in strained EuO — •Marjana Ležaić, Konstantin Rushchanskii, Frank Freimuth, and Stefan Blügel — Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

EuO is one of the rare materials combining a semiconducting gap and ferromagnetic ordering. Due to this property, EuO was suggested as a spin-filter in magnetic tunnel junctions [1]. It was shown that its ordering temperature T_C of 69 K can be increased further by doping with Gd [2], or by a reduction of the lattice parameter [3]. Recently, it has also been shown that a spin-polarized 2-dimensional electron gas can be formed at the EuO/LaAlO3 interface [4]. The list of properties

that are not only interesting from the point of view of basic research, but also indicate possible applications, does not end here. A newly discovered property, ferroelectricity in strained EuO [5] puts this material into the class of multiferroics with relatively high T_C. Employing *ab-initio* calculations, we demonstrate how the ferroelectric property can be exploited in EuO films under tensile strain in order to achieve electric control of the magnetization direction.

[1] T. Santos and J. S. Moodera, Phys. Rev. B **69**, 241203 (2004).
[2] R. Sutarto, *et al*, Phys. Rev. B **80**, 085308 (2009).
[3] N. J. C. Ingle and I. S. Elfimov, Phys. Rev. B **77**, 121202(R) (2008).
[4] Y. Wang, *et al*, Phys. Rev. B **79**, 212408 (2009).
[5] E. Bousquet, N. A. Spaldin, Ph. Ghosez, arXiv:0906.4235v1.

MA 7.6 Mon 15:15 H3

Ferroelectric properties of $BiFeO_3$ thin films under mechanical stress — •Martin Hoffmann, Oliver Mieth, and Lukas M. Eng — Institut für Angewandte Photophysik, Technische Universität Dresden, D-01062 Dresden

Since ferroelectric properties (polarization, coercive field, etc.) of thin films can differ dramatically from the corresponding bulk values due to lattice-mismatch-induced strain, the systematic investigation of the impact of mechanical stress on the nm-length-scale is an indispensable step towards the general understanding of ferroic thin film physics.

In the present study, 150-nm-thick multiferroic $BiFeO_3$ films grown on (001)-oriented $SrTiO_3$ substrates were inspected with piezoresponse force microscopy (PFM) towards their ferroelectric domain distribution and their local ferroelectric hysteresis behavior under both tensile and compressive stress.

The systematic variation of the externally applied mechanical stress by substrate bending allowed us to compensate or to enhance the strain effect, which can be quantified by monitoring the coercive field as a function of the bending angle.

MA 7.7 Mon 15:30 H3

Strain effects in spinel ferrite thin films from first principles calculations — •Daniel Fritsch and Claude Ederer — School of Physics, Trinity College Dublin, Ireland

We present density functional theory calculations of the structural and magnetic properties of the inverse spinel systems $CoFe_2O_4$ (CFO) and $NiFe_2O_4$ (NFO). Both are insulating magnets with high magnetic ordering temperatures and large saturation magnetization, which have been of particular interest over the past few years as building blocks of multiferroic heterostructures [1]. In order to effectively design the magneto-electric response of such multiferroic heterostructures, a clear picture of strain-induced changes in the magnetic properties of CFO and NFO is particularly important. Here we present results for the structural and magnetic properties of both CFO and NFO, with special emphasis on strain-induced changes in the magnetocrystalline anisotropy energy (MAE). Our results are representative for (001)-oriented thin films of CFO and NFO, grown on different lattice-mismatched substrates. We find a large and strongly strain-dependent MAE for CFO, and a significantly smaller but also strongly strain-dependent MAE for NFO. We discuss the influence of cation order within the inverse spinel structure and analyze the effect of different exchange correlation functionals on the structural and magnetic properties.

[1] H. Zheng et al., Science 303, 661 (2004).

15 min. break

MA 7.8 Mon 16:00 H3

Mechanism of ferroelectric instabilities in non-d^0 perovskites: $LaCrO_3$ versus $CaMnO_3$ — Tim Harris, Roman Kovacik, and •Claude Ederer — School of Physics, Trinity College Dublin, Ireland

The incompatibility of partial d occupation on the perovskite B-site with the standard charge transfer mechanism for ferroelectricity has been a central paradigm in multiferroics research [1]. Nevertheless, it was recently shown by density functional theory calculations that $CaMnO_3$ exhibits a polar instability that even dominates over the octahedral tilting for slightly enlarged unit cell volume [2]. Here, we present similar calculations for $LaCrO_3$, which has the same d^3 B-site electron configuration as $CaMnO_3$. We show that $LaCrO_3$ exhibits a similar, albeit somewhat weaker, volume-dependent polar instability as $CaMnO_3$, but while the Born effective charge (BEC) for the Mn^{4+} cation in $CaMnO_3$ is highly anomalous, the BEC for Cr^{3+} in $LaCrO_3$ is only slightly enhanced. We decompose the BECs for both systems in contributions of individual Wannier functions to elucidate the different driving force behind the polar instability in these systems.

[1] N. A. Hill, J. Phys. Chem. B 104, 6694 (2000). [2] S. Bhattacharjee et al., Phys. Rev. Lett. 102, 117602 (2009).

MA 7.9 Mon 16:15 H3

Multiferroicity in $EuTiO_3$ and $Eu_{1-x}Ba_xTiO_3$: *ab initio* characterization of crystalline, magnetic and electronic structure — •Konstantin Z. Rushchanskii[1], Marjana Ležaić[1], and Nicola A. Spaldin[2] — [1]Institut für Festkörperforschung, Quanten-Theorie der Materialien, Forschungszentrum Jülich GmbH, 52425 Jülich, and JARA-FIT, Germany — [2]Materials Department, University of California, Santa Barbara, CA 93106-5050, USA

We report a systematic study of possible structural transitions in $EuTiO_3$ and ordered $Eu_{1-x}Ba_xTiO_3$ mixed compounds. We investigated phonon spectra of $EuTiO_3$ and found strong M- and R-point instabilities, indicating antiferrodistortive structural deformations. In the ordered $Eu_{0.5}Ba_{0.5}TiO_3$ compounds, the antiferrodistortive deformation is replaced by significant ferroelectric distortions, involving not only Ti, but also the magnetic Eu cation. We will discuss several scenarios of ferroelectric and antiferrodistortive transitions and their coupling with the magnetic structure. Corresponding changes in the phonon structure will be compared with available experimental data.

MA 7.10 Mon 16:30 H3

Electronic and magnetic properties of $LuFe_2O_4$ — •Karsten Kuepper[1], Michael Raekers[2], Christian Taubitz[2], Manuel Prinz[2], Christine Derks[2], Manfred Neumann[2], Andrei V. Postnikov[3], Frank M. F. de Groot[4], Cinthia Piamonteze[5], Dharmalingam Prabhakaran[6], and Stephen J. Blundell[6] — [1]Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [2]Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49069 Osnabrück, Germany — [3]LPMD, Paul Verlaine University and Institute Jean Barriol, Metz, France — [4]Department of Inorganic Chemistry and Catalysis, Utrecht University, Sorbonnelaan 16, 3584 CA Utrecht, Netherlands — [5]Swiss Light Source, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [6]Department of Physics, University of Oxford, Clarendon Laboratory, Parks Road, Oxford, OX1 3PU, United Kingdom

$LuFe_2O_4$ is a compound showing fascinating magneto electric coupling via charge ordering. Electronic and magnetic properties of the charge ordered phase of $LuFe_2O_4$ are investigated by means of x-ray spectroscopic and theoretical electronic structure approaches [1]. We identified the electronic states of the valence band by means of valence band XPS-, and XES-spectroscopies, and GGA+U first principles calculations. Moreover, by applying XMCD, we are able to identify the spin ground state of $LuFe_2O_4$ in the charge ordered phase to be a 2:1 ferrimagnetic configuration, ruling out a frustrated magnetic state.

[1] K. Kuepper et al., Phys. Rev. B, Rapid Commun., in press.

MA 7.11 Mon 16:45 H3

Influence of Fe-substitution in $LiNi_{(1-x)}Fe_xPO_4$ on the antiferromagnetic structure — •Elke Künzel[1], Anne Zimmermann[1], Jiying Li[2], David Vaknin[2], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn — [2]Ames Labatory and Department of Physics, Iowa States Univerity, Ames, USA

The LiMPO$_4$ system (M=Fe, Ni, Co, Mn) includes crystallographically isostructural compounds with antiferromagnetic (AFM) order differing in the spin direction only. Thus, the system offers the opportunity to study fundamental mechanisms of AFM 180° domain formation in a range of similar but not identical compounds. In spite of their structural similarity, drastic differences in the domain topology are observed by optical SHG. Domains in $LiNiPO_4$ form anisotropic platelets whereas in $LiFePO_4$ they are isotropic and amoeba-like. It is yet unclear whether this surprising behaviour is due to the properties of the nickel ion or to the spin direction which points along z in $LiNiPO_4$ and along y in $LiFePO_4$.

In order to clarify this, samples with different mixing ratios of nickel and iron were studied. The domain structure of $LiNiPO_4$ was found to become aboeba-like for an iron substitution of «50%. An anomalous temperature dependence of the AFM order parameter and indications for a spin structure different from that of the end compounds was observed.

MA 7.12 Mon 17:00 H3

Non-Resonant Magnetic X-ray Scattering on Rare-Earth Iron Borates $RFe_3(BO_3)_4$ — •Jorge E. Hamann-Borrero[1], Martin Philipp[1], Olga Kataeva[2], Martin von Zimmermann[3], Christian Hess[1], Ruediger Klingeler[1], Alexander Vasiliev[4], Leonard Bezmaternykh[5], and Bernd Buechner[1] — [1]IFW Dresden, 01171 Dresden, Germany — [2]A.E.Arbuzov Institute of Organic and Physical Chemistry of the Russian Academy of Sciences, Kazan, Russia — [3]HASYLAB at DESY, Hamburg, Germany. — [4]Low Temperature Physics department, Faculty of Physics, Moscow State University, Moscow, Russia. — [5]L.V Kirensky Institute of Physics, Russian Academy of Sciences, Krasnoyarsk, Russia.

Non-resonant magnetic XRD (NRMXRD) experiments with photon energy of 100keV where performed on selected compounds of the $RFe_3(BO_3)_4$ family as a function of temperature and applied magnetic field. The results show the existence of several unexpected diffraction features, in particular the presence of a magnetic super-lattice peak, and the appearance of two reflections that violate the diffraction conditions for the low temperature phase $P3_121$ of the iron borates. The magnetic nature of the former is concluded from analysing the scattering cross section at high energies and the magnetic structure of the different compounds. It is shown that the magnetic reflection reveals the magnetic properties of the material. For $GdFe_3(BO_3)_4$, values for the component of the spin moment perpendicular to the scattering plane ($S_\perp$) have been determined as well as the angle between the spin moment and the hexagonal basal plane.

MA 7.13 Mon 17:15 H3

Electronic structure, magnetic and dielectric properties of the edge-sharing copper-oxide chain compound NaCu2O2 — •Philippe Leininger[1], Martin Rahlenbeck[1], Markus Raichle[1], Britta Bohnenbuck[1], Andrey Malyuk[2], Chengtian Lin[1], Bernhard Keimer[1], Eugen Weschke[2], Enrico Schierle[2], Shinichiro Seki[3], Yoshi Tokura[3], and John Freeland[4] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstr. 1, D-70569 Stuttgart, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, D-12489 Berlin, Germany — [3]University of Tokyo, Dept. of Applied Physics, Bunkyo-ku, Tokyo 113-8656, Japan — [4]Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439, USA

We report an experimental study of NaCu2O2, a Mott insulator containing chains of edge-sharing CuO4 plaquettes, by polarized x-ray absorption spectroscopy (XAS), resonant magnetic x-ray scattering (RMXS), magnetic susceptibility, and pyroelectric current measurements. The XAS data show that the valence holes reside exclusively on the Cu2+ sites within the copper-oxide spin chains and populate a d-orbital polarized within the CuO4 plaquettes. Our results also demonstrate a new orbital selection rule for RMXS that is of general relevance for magnetic structure determinations by this technique. Dielectric property measurements reveal the absence of significant ferroelectric polarization below TN, which is in striking contrast to corresponding observations on the isostructural compound LiCu2O2. The results are discussed in the context of current theories of multiferroicity.

MA 7.14 Mon 17:30 H3

Magnetoelectric effect in diluted antiferromagnet $PbFe_{0.5}Nb_{0.5}O_3$ — •Vladimir Shvartsman[1], Pavel Borisov[2], Wolfgang Kleemann[2], and Antoni Kania[3] — [1]Institut für Materialwissenschaft, Fakultät für Ingenieurwissenschaften, Universität Duisburg-Essen, Essen, Germany — [2]Angewandte Physik, Fakultät für Physik, Universität Duisburg-Essen, Duisburg, Germany — [3]Institute of Physics, University of Silesia, Katowice, Poland

Multiferroics, i. e. materials where two primary ferroic order parameters of magnetic and electric nature coexist, are of significant scientific and practical interest nowadays. Especially attractive are the multiferroics with enhanced magnetoelectric (ME) properties, which relate changes of polarization/magnetization to external magnetic/electric fields, respectively. While the linear ME effect has strong symmetry requirements and is rare, higher order ME couplings are allowed in all multiferroics. We report on investigations of magnetic and ME properties of (001)-oriented $PbFe_{0.5}Nb_{0.5}O_3$ (PFN) single crystals in the temperature range 5-300 K. PFN is ferroelectric below 385 K and antiferromagnetic below the Néel temperature, T_N=154 K. Temperature dependences of the magnetization exhibit a step like anomaly at T_N and a maximum on zero-field cooled curves at 8 K. Below T_N, the system manifests a spontaneous second order ME effect (electrobimagnetic effect), which reaches a peak value around 20 K. Moreover, after field cooling the linear ME effect has been observed, which disappears above 8 K. The nature of the low-temperature magnetic anomaly and the temperature dependences of the ME effects are discussed.

MA 8: Magnetic Shape Memory Alloys

Time: Monday 15:15–19:00 Location: H22

MA 8.1 Mon 15:15 H22

Lattice dynamics and static displacements in Fe-based magnetic shape memory alloys — •Markus E. Gruner and Peter Entel — Faculty of Physics and Center for Nanointegration, CeNIDE, University of Duisburg-Essen, 47048 Duisburg

Within the framework of density functional theory, we provide a comparison between stoichiometrically ordered Fe_3Pt and disordered Fe-Pd magnetic shape memory alloys. We compare the analytic modelling of disorder within the coherent potential approximation (CPA) referring to the ideal lattice positions with an explicit description by supercell calculations allowing for the relaxation of the atomic positions. The calculations demonstrate that static displacements provide an important contribution to the variation of the total energy along the Bain path and are thus essential for the correct prediction of the ground state lattice structure. Distinct static relaxations are also present in all $L1_2$ ordered Fe-rich alloys with Ni-group elements, which can be described by an orthorhombic distortion of the Fe-octahedra encaged by the Ni-group sublattice. These manifest in a complete softening in the phonon dispersion at the M-point which we relate to nesting features of the Fermi surface.

MA 8.2 Mon 15:30 H22

Anomalous phonon behaviour in Ni-based Heusler alloys — •Mario Siewert, Markus E. Gruner, Peter Entel, and Alfred Hucht — Faculty of Physics and CeNIDE, University of Duisburg-Essen, 47048 Duisburg, Germany

Ferromagnetic shape memory alloys (FSMAs) are of large scientific interest due to their applicability in actuators and sensors based on magnetic fields. The martensitic transformation in the Ni_2MnGa reference system to a modulated low symmetry phase that is responsible for the magnetic shape memory behaviour is preceeded by anomalous temperature dependent phonon softening along the [110] direction in the parent phase. The occurence of the soft mode has been linked to Fermi surface nesting in the past. In this work we report systematic studies of magnetic Ni-Mn-X (X=Al, Si, Zn, Ga, Ge, In, Sn, Sb) based Heusler alloys by means of density functional theory. Our calculations reveal that a phonon softening along the [110] direction up to imaginary frequencies can be found for all compounds in the cubic phase. Furthermore, an inversion of the optical modes can be observed. A systematic investigation of the reconstruction of the Fermi surface as a function of the valence electron number per atom (e/a) allows to predict materials with particular nesting behaviour.

MA 8.3 Mon 15:45 H22

Dynamical properties of Ni-Mn-Ga alloys — •Semih Ener[1], Jürgen Neuhaus[1,2], Klaudia Hradil[2,3], Richard Mole[2], Peter Link[2], and Winfried Petry[1,2] — [1]Technische Universität München, Physik Department E13, Garching, Germany — [2]Technische Universität München, Forschungsneutronenquelle Heniz Maier-Leibnitz (FRM II), Garching, Germany — [3]Georg-August-Universität Göttingen, Institut für Physikalische Chemie, Göttingen, Germany

In this work we investigate the vibrational properties of Ni-Mn-Ga alloys by using the Three Axis Spectrometers (TAS) PUMA (for thermal neutrons) and PANDA (for cold neutrons) which are located in FRM II, Garching. To approve the first principle calculations the whole dispersions of stoichiometric sample were measured in high temperature austenite and low temperature martensite phases. The temperature dependence of the vibrational properties in both stoichiomet-

ric and off-stoichiometric sample were investigated. In the austenite phase we observe a softening at TA2[q q 0] branch in both stoichiometric and off-stoichiometric samples. In stoichiometric sample the softening is more prominent than the off-stoichiometric one and the minimum of the softening is at 0.33 and 0.27 for stoichiometric and off-stoichiometric samples, respectively. The temperature dependence of vibrational properties of TA2[q q 0] branch in pre-martensitic phase were investigated in stoichiometric sample. The results showed that in the vibrational point of view the 5-layered martensite phase and the pre-martensite phase have the same behavior but it is not the case in low energy excitations.

MA 8.4 Mon 16:00 H22

Ab initio characterization of new ferromagnetic Fe-Ni-Co-Zn-Ga shape memory alloys — •Antje Dannenberg[1], Markus Ernst Gruner[1], Manfred Wuttig[2], and Peter Entel[1] — [1]Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Materials Science and Engineering, University of Maryland, College Park, MD 20742, USA

Ferromagnetic shape memory alloys (FSMA) have received increasing interest, due to their potential use as smart materials for actuator and sensor applications, but for a technological breakthrough the operation temperatures are still too low.

In this report, we present a systematic investigation of the structural, electronic and magnetic properties of various systems based on Fe-Co-Ni-Ga-Zn. The results of our ab initio and Monte Carlo calculations predict high Curie temperatures for the Fe-based systems and show competing ordering between the conventional X_2YZ Heusler and the inverse (XY)XZ Heusler structure. The new Zn-based alloys may be promising new FSMA as they combine high T_C and the required structural properties but at the expense of structural stability.

MA 8.5 Mon 16:15 H22

A phase-field model for twin boundary motion in martensitic microstructures — •Christian Mennerich, Marcus Jainta, Frank Wendler, and Britta Nestler — Karlsruhe University of Applied Sciences, Karlsruhe, Germany

Magnetic shape memory (MSM) alloys are of great interest, e.g. for building actuators providing large deformations and rapid responses. Fundamental for the magnetic shape memory effect is the microstructure evolution in the twinned martensitic state of MSM materials under applied external magnetic fields. An existing phase-field model, basing on a free energy functional of the Ginzburg-Landau type, is extended by micromagnetic and elastic energy contributions, with the aim to model and predict the magnetically induced twin boundary evolution in martensitic microstructures. Assuming an isothermal setting below the Curie temperature and the martensitic start temperature, this model is appropriate to describe the diffusionless phase transition responsible for twin boundary motions. We give the derivation of the model extensions, resulting in a system of coupled partial differential equations, and solution strategies for a scheme using finite differences. With this model, the time-spatial evolution of the volume fractions of martensitic variants, of the displacement field for elasticity and of the micromagnetic domain wall structure can be described. Finally, we present simulation results demonstrating magnetically induced twin boundary motions.

MA 8.6 Mon 16:30 H22

Magnetization processes during field and stress induced twin boundary motion in NiMnGa — •Andreas Neudert, Yiu-Wai Lai, Rudolf Schäfer, and Jeffrey McCord — IFW Dresden, Helmholtzstr. 20, 01069 Dresden

We have studied the twin boundary motion in bulk single crystals of the ferromagnetic shape memory alloy NiMnGa using polarized light microscopy. Magnetic domains were imaged by using magnetic indicator films that are placed on top of the sample. Those indicator films consist of a soft-magnetic garnet film that senses the out of plane stray field of the sample. Twin boundaries can be moved by either applying a magnetic field or a mechanical stress to the sample, but there are qualitative differences between the two mechanisms. After moving a twin boundary by applying an external magnetic field, the domain state consists of wide antiparallel domains with 180° domain walls. Moving the twin boundary by applying external stress results in a different domain state. Here the magnetization rotates as the twin boundary passes through and a patchy domain structure is created. After demagnetizing the sample in a decaying ac magnetic field the domain state consists of mainly 180° domain walls again. This suggests that the magnetization after stress-induced reversal is not in a global energy minimum and rather trapped in local minima. The involved energies and effective fields for the two mechanisms will be discussed in the presentation.

MA 8.7 Mon 16:45 H22

Free-standing epitaxial Ni_2MnGa films — •Tobias Eichhorn, Peter Klaer, Hans-Joachim Elmers, and Gerhard Jakob — Institut für Physik, Universität Mainz, Deutschland

Among the compounds crystallizing in the Heusler structure many systems are of interest due to their predicted high spin polarization making them potential materials for spintronic devices. On the contrary Ni_2MnGa is attracting high scientific interest by presenting a ferromagnetic shape memory effect in the low temperature phase (martensite). Moderate magnetic fields can induce large reversible length changes up to 10 % in martensitic single crystals. Thereby actuators and sensors with a compact design can be realised using single crystalline thin films of the material. The investigated films are prepared on heated Al_2O_3(11-20) and MgO(100) substrates by dc-magnetron sputtering from alloy targets of different stoichiometry. Samples deposited from a Mn-rich target are martensitic at room temperature and show a modulated orthorhombic structure (7M). The complex crystal structure is studied by x-ray diffraction in 4-circle geometry. Magnetic properties are investigated by magnetometry, x-ray absorption spectroscopy and magnetic circular dichroism measurements. Since rigid substrates block magnetically induced strains free-standing films will be needed. One route is to deposit on NaCl(100) substrates that can be easily dissolved in water. The released films are strongly textured, but not single crystalline as desired. Improved crystal quality can be reached by another approach, i.e. introducing a buffer layer on MgO(100) that can be etched selectively. This work is part of SPP 1239.

MA 8.8 Mon 17:00 H22

Microstructure of adaptive martensite in Ni-Mn-Ga — •Sebastian Fähler[1,2], Stefan Kaufmann[1,2], Robert Niemann[1,2], Tom Thersleff[1], Oleg Heczko[3,1], Bernhard Holzapfel[1,2], and Ludwig Schultz[1,2] — [1]IFW Dresden, PO Box 270116, 01171 Dresden — [2]Institute for Solid State Physics, Department of Physics, Dresden University of Technology, 01062 Dresden — [3]Institute of Physics, Czech Academy of Science, Na Slovance 2, CZ-182 21 Praha 8

Recently we showed that modulated phases in the Ni-Mn-Ga magnetic shape memory alloy can be interpreted within Khachaturyan's concept of adaptive martensite and described as a nanotwinned microstructure of a basic tetragonal martensite [S. Kaufmann et al. arXiv:0906.5365v1]. The observed coexistence of austenite, 14M and NM martensite in thin films indicated that the transition between 14M and NM proceeds through coarsening of twin boundaries. Here we present a detailed study of the microstructure of an epitaxial film using FIB, AFM and SEM. At the first glance, the microstructure images appear more like modern art than physics. However, it can be shown that this microstructure arises from simple geometrical concepts. A quantitative analysis demonstrates that branching of twin boundaries occurs down to atomic scale and it controls twin width and periodicity over lengthscales more than 3 orders of magnitude.

MA 8.9 Mon 17:15 H22

A comparison of substrate-constraint and freestanding thin Ni-Mn-Ga films — •Anja Backen[1,2], Srinivasa Yeduru Reddy[3], Manfred Kohl[3], Anett Diestel[1,2], Ludwig Schultz[1,2], and Sebastian Faehler[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Dresden University of Technology, Department of Mechanical Engineering, Institute of Materials Science, 01062 Dresden, Germany — [3]Karlsruhe Institute of Technology, Institute of Microstructure Technology, Herrmann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

The magnetic shape memory alloy Ni-Mn-Ga belongs to a class of active materials where an external magnetic field can cause a maximum strain of 10 % in bulk single crystals. In order to use this effect for microsystems, scaling down from bulk dimensions is a key issue and thus epitaxial thin films are of particular interest. Recently we have reported on epitaxial growth of Ni-Mn-Ga on single crystalline MgO (100) substrates, however, the substrate constraints hinder elongation by magnetically induced reorientation. Hence, it is crucial to release films from the substrates. We report on successfully releasing thin Ni-Mn-Ga films grown on MgO (100) by using Chromium as sacrificial layer. We observe epitaxial growth of both Cr on MgO (100) and Ni-Mn-Ga on Cr without interdiffusion. After deposition, Cr can

be etched selectively without affecting the Ni-Mn-Ga film properties. In order to understand the influence of substrate constraint on the film properties, structure, microstructure and magnetic properties are analyzed and compared for films before and after their release.

15 min. break

MA 8.10 Mon 17:45 H22

High resolution imaging of epitaxial Ni-Mn-Ga films with STM — •Philipp Leicht[1], Aleksej Laptev[1], Mikhail Fonin[1], Yuansu Luo[2], and Konrad Samwer[2] — [1]Fachbereich Physik, Universität Konstanz — [2]I. Physikalisches Institut, Universität Göttingen

Magnetic shape memory (MSM) alloys are of great interest due to their possible application as actuators or sensors. Upon cooling from the high temperature austenite phase a structural phase transformation to a distorted martensite phase occurs. MSM films deposited on substrates accommodate the strain associated with the martensite transition by formation of twin boundaries [1]. Here epitaxial off-stoichiometric Ni-Mn-Ga films were grown on MgO substrates by dc-magnetron sputtering. The surface of the films was investigated in ultra high vacuum conditions by means of scanning tunneling microscopy (STM) at room temperature. Austenitic areas reveal atomically flat terraces separated by steps with an average height corresponding to the distance between equivalent atomic planes of the bulk $L2_1$ structure. STM images on martensitic areas reveal a wavy-like structure due to the formation of twin boundaries. An additional superstructure on every second variant in form of narrow stripes running perpendicular to the twin boundaries was observed. The latter structure is explained on the basis of a structural model taking into account the twinning and the shuffling of atomic planes in layered martensites (5M, 7M) [2]. This work is supported by BMBF-projects MSM-Sens 13N10061 and 13N10062.

[1] J. Buschbeck et al., Acta Materialia **57**, 2516-2526 (2009)
[2] V. V. Martynov et al., J. Phys. III France **2**, 739-749 (1992)

MA 8.11 Mon 18:00 H22

Preparation and characterization of textured Ni-Mn-Ga to show MFIS — •Martin Pötschke, Claudia Hürrich, Stefan Roth, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden

Ni-Mn-Ga alloys are interesting 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, which are easier to produce. To achieve magnetic field induced twin boundary motion in polycrystals, directional solidification was applied to a 5M Ni-Mn-Ga alloy 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 preferred solidification-induced growth direction was determined by EBSD. Annealing is necessary for homogenization and stress relaxation. 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. After a mechanical training process MFIS was observed.

Financial support by the DFG within SPP 1239.

MA 8.12 Mon 18:15 H22

Training of polycrystalline NiMnGa alloys — •Robert Chulist[1], Martin Pötschke[2], Andrea Böhm[3], Carl - Georg Oertel[1], Werner Skrotzki[1], and Erik Rybacki[4] — [1]Institut für Strukturphysik, Technische Universität Dresden, D-01062 Dresden, Germany — [2]Institut für Metallische Werkstoffe, Leibniz-Institut für Festkörper- und Werkstoffforschung, D-01069 Dresden, Germany — [3]Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik, D-01187 Dresden, Germany — [4]Geoforschungszentrum Potsdam, D-14473 Potsdam, Germany

In order to achieve magnetic field induced strain in NiMnGa alloys a training process is applied. This process consists of successively compressing the sample along two or three axes. As a result the twinning stress is reduced and the strain is maximized. To study the effect of training, two samples with 5M modulated structure were used: bicrystal and polycrystal deformed by high pressure torsion. Within the individual parent austenitic grains the initial orientation is characterized by three different martensitic variants separated by twin boundaries. Compression of the samples results in the motion of the twin boundaries changing the volume fraction of particular variants. Local orientation measurements by electron backscatter diffraction directly confirm twin boundary motion. The training process finally leading to a single variant state will be discussed with respect to initial microstructure and number of martensitic variants.

MA 8.13 Mon 18:30 H22

Training effects of polycrystalline Ni50Mn29Ga21 magnetic shape memory alloy — •Claudia Hürrich, Martin Pötschke, Stefan Roth, Bernd Rellinghaus, and Ludwig Schultz — IFW Dresden, Institute for Metallic Materials, P. O. Box 270116, 01069 Dresden, Germany

The alloy Ni-Mn-Ga arose great interest for its application as a magnetic shape memory material. This effect is caused by reorientation of twin variants by an external magnetic field. So far most of the experiments were concentrated on single crystals. But, this effect can also be realised in polycrystals which can be prepared much more efficiently. Here, polycrystalline samples were prepared by directional solidification with a <100> fibre texture of the high temperature cubic phase parallel to the heat flow. Afterwards a heat treatment was applied for chemical homogenization and stress relaxation in the austenitic state. Then the samples were heated up to the austenitic state and cooled down under load. The microstructure was analysed by Electron Back Scatter Diffraction (EBSD) before and after that treatment. Mechanical training in three directions was tracked by recording stress-strain curves. With increasing the number of training cycles the strain also increases. This work is supported by DFG within SPP 1239.

MA 8.14 Mon 18:45 H22

Magnetic field induced strain in Ni_2MnGa-Polymer-Composites — •Sandra Weiss[1], Nils Scheerbaum[1], Jian Liu[1], Ludwig Schultz[1], Oliver Gutfleisch[1], Edith Mäder[2], and Gert Heinrich[2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden — [2]Leibniz-Institut für Polymerforschung e.V., Hohe Straße 6, 01069 Dresden

Ni-Mn-Ga single- and polycrystals show large magnetic field induced strain (MFIS) but are in general difficult and expensive in preparation and also very brittle. An alternative to single- and polycrystals are Ni-Mn-Ga/polymer-composites. Here, small single-crystalline $Ni_{50.9}Mn_{27.1}Ga_{22.0}$-particles, produced by gently crushing melt-extracted and subsequently annealed fibres, were embedded in a soft polymer matrix. The particles have a 5M martensitic structure. The Young's Modulus of the polymer-matrix is 2 MPa and 175 MPa, for polyurethane and epoxy respectively. In response to the applied magnetic field, the MSM particles are prone to relocation within the polyurethane due to its low Young's modulus, leading to a very little effect of magnetic field-induced twin boundary motion. By contrast, the Ni_2MnGa-epoxy-composite shows a pronounced MFIS up to 0.1 % because the stiffness of epoxy fits better the one for Ni-Mn-Ga. Furthermore, the interface stability between Ni-Mn-Ga and epoxy-matrix was investigated by quasistatic Pull-Out Tests. First tests with silan-coupling-agent treated fibres indicate significant improvements of interface.

MA 9: Magnetic Particles, Clusters

Time: Monday 15:15–19:30 Location: H23

MA 9.1 Mon 15:15 H23

Magnetic properties of NiO nanoparticles investigated by SQUID and magnetic Raman scattering — •Farrakh Shahzad[1], Peter Knoll[1], Karl Ettinger[2], Kashif Nadeem[1], Heinz Krenn[1], Gabor Kozma[4], Akos Kukovecz[4], Zoltan Konya[4], Ilse Letofsky-papst[3], Karin Pressl[1], and Petra Granitzer[1] — [1]Institute of Physics , Karl-Franzens University, graz, austria — [2]institute of earth sciences, karl-franzens university, Graz, Austria — [3]Technical University, Graz, Austria — [4]Department of applied and environmental chemistry, University of Szeged, Hungary

We have measured the magnetization of NiO Nanoparticles with sizes ranging from 4nm-85nm by SQUID magnetometer. The Nanoparticles were prepared by Sol-gel and ball milling techniques. However, these measurements are very sensitive to induced small magnetic moments but do not directly measure the anti-ferromagnetic ordered spin pairs. This can be done by magnetic Raman scattering. Temperature-dependent magnetic Raman spectra for NiO single crystal are well known and understood, in which two-magnon peak (2M) is due to the anti-ferromagnetic nature of this material. In our measurements for Nanoparticles of diameter 40nm, 2M peak is not present at room temperature but appears at certain lower temperature range and then again disappears at very low temperature. For Nanoparticles of diameter 85nm, this peak is present at room temperature but still not present at very low temperature. 2M peak is not observed at any temperature for particles having diameter less than 40nm. These new experimental results will be presented within the so for established models.

MA 9.2 Mon 15:30 H23

Alloying of Co nanoparticles on differently oriented films and its influence on magnetic properties — •Luyang Han[1], Ulf Wiedwald[1], Johannes Biskupek[2], Ute Kaiser[2], and Paul Ziemann[1] — [1]Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm, Germany — [2]Materialwissenschaftliche Elektronenmikroskopie, Universität Ulm, Albert-Einstein-Allee 11, 89081 Ulm, Germany

It has been reported previously [1,2] that ultra-thin Co film deposited on top of a Pt single crystal at elevated temperature will form a $Co_{1-x}Pt_x$ alloy near the surface. Here, we investigate the local formation of $Co_{1-x}Pt_x$ alloys starting from a self assembled array of Co nanoparticles (diameter 3 nm and 8 nm) deposited on Pt(001) and Pt(111) films by micellar method [3]. AFM and SEM investigations show a gradual decrease of particle sizes when the particles are annealed above 500 K, while TEM reveals that a few monolayer thick alloy is formed around the particles, whose crystalline orientation is defined by underlying Pt film. The magnetic properties are characterized by means of SQUID magnetometry and XMCD. We observe an increase of both the coercive field and induced Pt magnetic moment after annealing at 570 K. XPS and XMCD reveals a reduced amount of Co after annealing at 770 K, indicating the start of long range diffusion.

[1]S. Ferrer et al., *Phys. Rev. B*, **56**, 9848, (1997)
[2]M. Pan et al., *J. Vac. Sci. Technol. A*, **23**, 790, (2005)
[3]A. Ethirajan et al., *Adv. Mater.*, **19**, 406, (2007)

MA 9.3 Mon 15:45 H23

Spin and orbital moments of small size-selected FePt clusters — •Torben Beeck, Ivan Baev, Kai Chen, Steffen Fiedler, Michael Martins, and Wilfried Wurth — Institute for Experimental Physics, University of Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany

Size-selected Fe_xPt_y alloy clusters ($x, y = 1, 2$) were deposited in situ under UHV conditions and soft landing. The substrate was a well defined and remanent magnetized Ni thin film evaporated upon a small Cu(100) crystal. The system was investigated in an element specific way at the Fe $L_{2,3}$ absorption edges by means of x-ray magnetic circular dichroism (XMCD) at the UE52 SGM beamline, BESSY II. Our aim was to determine separately the size and composition dependent spin and orbital moments by applying sum rules.

The results show an increase of the magnetic moments by adding Pt ligands to the Fe cluster. Especially the orbital moment is enhanced.

Because of the limited cluster sizes the experimental results are, in contrast to bigger systems, good candidates for complex theoretical calculations.

This work is supported by the DFG in the framework of the SFB 668 subproject A7.

MA 9.4 Mon 16:00 H23

Cross-over between spin-glass freezing and blocking in $NiFe_2O_4$ nanoparticles — •Kashif Nadeem and Heinz Krenn — Institute of Physics, Karl-Franzens University Graz, Universitätsplatz 5, A-8010 Graz, Austria

Single-phase $NiFe_2O_4$ nanoparticles (8-27nm) dispersed in SiO_2 matrix have been prepared by sol-gel method. Disorder and core-shell interaction induces surface spin-glass like freezing which is manifested by a low temperature peak in the AC susceptibility well separated from magnetic blocking peak. The spin-glass freezing peak vanishes as the particle size grows (>18nm). Exchange bias is present down to 8nm particle sample which indicates the existence of core-shell interactions. For 8nm sample, Arrhenius model is fitted to the frequency dependent AC susceptibility data and it gives spin-flip time τ_o~2.10^{-12} sec and activation energy E_A/k_B = 370 K. The dynamic scaling law is also fitted to the same data and it yields: T_o = 11 K, τ_o~10^{-05} sec and zv = 7.5 (which lies in spin-glass regime zv = 4-12). In the presence of DC field (10-500 Oe) in AC susceptibility, the freezing peak (T_f = 13 K) does not shift but the blocking peak (T_b = 233 K) moves towards lower temperature and finally collapses into the freezing peak as the DC field is increased. Time dependent TRM shows a non-monotonic behaviour in the vicinity of freezing peak which is consistent with the sharp increase of coercivity in the same temperature regime. Our system also exhibits memory effects. All these measurements demonstrate the presence of blocking/unblocking at high temperatures and core-shell mediated spin-glass like freezing at low temperatures.

MA 9.5 Mon 16:15 H23

Structural and Magnetic Deconvolution of $FePt/FeO_x$-Nanoparticles using X-Ray Magnetic Circular Dichroism — •Daniela Nolle[1], Eberhard Goering[1], Giesela Schütz[1], Albert Figuerola[2], and Liberato Manna[2] — [1]MPI for Metals Research, Heisenbergstrasse 3, 70569 Stuttgart, Germany — [2]IIT, Via Morego, 30 16163 Genova, Italy

In order to analyse the related magnetic and structural properties of bi-component nanoparticular systems we present XAS and XMCD studies at the Fe $L_{2,3}$-edges simultaneously performed in surface sensitive total electron yield (TEY) and bulk sensitive transmission mode, at room and low temperatures. This provides the separation of volume and surface related properties especially. The investigated systems were made up of $FePt/FeO_x$ hybrid nanoparticles of different diameters. A detailed deconvolution in terms of a linear superposition of suitable reference spectra (FePt, γ-Fe_2O_3, and Fe_3O_4) is presented. Absolute magnetic moments, determined by XMCD sum rule analysis, provide reliable and consistent magnetization values, in contrary to SQUID related results, due to the unknown size of the organic ligand shell around each nanoparticle. For the necessary magnetic characterization of these nanoparticles, SQUID results must be renormalized by the complementary XAS/XMCD investigations. Finally this method demonstrates the strength of simultaneously performed XMCD experiments using different scanning depth measurement modes for the investigation and characterization of nanoparticular systems, which are consistent and supplemental to corresponding SQUID measurements.

MA 9.6 Mon 16:30 H23

Templated self-assembly of Iron oxide nanoparticles in lithographically prepatterned tracks — •Oleg Petracic[1], Maria Jose Benitez[1,2], Durga Mishra[1], Philipp Szary[1], Frank Brüssing[1], Giovanni Badini Confalonieri[1], Matthias Feyen[2], Anhui Lu[2], Leonardo Agudo[3], Günther Eggeler[3], and Hartmut Zabel[1] — [1]Experimentalphysik IV, Ruhr-Universität Bochum, D-44780 Bochum — [2]Max-Planck Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr — [3]Institute for Materials, Department of Materials Science, Ruhr-Universität Bochum, 44780 Bochum

Magnetic nanostructures hold the potential for numerous applications, e.g., in magnetic data storage, logic devices, sensors or bio-medical applications. In particular, magnetic nanoparticles are in the focus of huge interest, because they could serve as building blocks for future

high-density data storage media and spintronics. We report on self-assembled Iron oxide nanoparticle films on silicon substrates. Furthermore, using electron beam lithography we fabricate patterned trenches of 40-1000nm width for assisted self-assembly. The nanoparticles with a diameter of 20 nm +/- 1.6 nm were synthesized by thermal decomposition of iron oleate complexes in trioctylamine in presence of oleic acid. Samples with different track widths and nanoparticle concentration have been characterized by magnetometry, X-ray diffraction and high resolution transmission electron microscopy.

MA 9.7 Mon 16:45 H23

NdFeB nanoparticles prepared by wet-milling — •Juliane Thielsch, Julia Lyubina, Thomas Woodcock, Ludwig Schultz, and Oliver Gutfleisch — IFW Dresden, P.O. Box 27 01 16, D-01171 Dresden

Since the prediction of a giant energy product of textured nanocomposite magnets [1] those materials where believed to be the next generation of permanent magnets. For effective exchange-coupling in such two-phase magnets grain sizes need to be in the range of the domain wall width of the hard magnetic phase. That makes a homogenous phase distribution and a microstructure with nanograins necessary. One option of preparing such materials is the synthesis of magnetic nanoparticles which further could be aligned and compacted to a bulk magnet. For this we performed wet-milling experiments of a NdFeGaNbB alloy. XRD studies revealed that by using a surfactant and a solvent during the high energy ball milling process amorphization sets in later than compared to dry milling experiments under the same conditions. Dynamic Light Scattering investigations showed a Gauss distribution of the particle size with a mean diameter of about 12nm which was also proven by TEM. Magnetic properties were measured with SQUID and showed so far rather poor coercivity values.

[1] R. Skomski and J.M.D. Coey, Phys. Rev. B, 1993, 48:15812

MA 9.8 Mon 17:00 H23

Magnetic nanoparticle arrays in 2-D and 3-D investigated with specular and diffuse X-ray scattering — •Durga Mishra[1], Maria Jose Benitez[1,2], Oleg Petracic[1], Frank Brüssing[1], Philipp Szary[1], Giovanni Badini Confalonieri[1], Matthias Feyen[2], Anhui Lu[2], Leonardo Agudo[3], Günther Eggeler[3], and Hartmut Zabel[1] — [1]Experimental Physik IV, Ruhr Universität Bochum, D-44780 Bochum — [2]Max-Planck-Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr — [3]Institute for Materials, Department of Materials Science, D-44780 Bochum

Magnetic (single domain) nanoparticles show promising potential for future nanotechnology applications. The novel applications manifest itself depending on the size and shape distribution of the nanoparticles which in turn affects the arrangement in 2-D or 3-D lattice structure. We report here the X-ray investigation of continuous array of 20nm diameter Iron Oxide nanoparticles spin coated on Si substrate (monolayer and multilayer). The in-plane hexagonal ordering and the out of plane superlattice structure were investigated with GISAXS and X-ray reflectivity measurements. A Grazing Incidence Diffraction (GID) study shows a mixed phase of iron oxide with different crystal structures (fcc and inverse spinel) due to annealing. The Zero Field Cooling (ZFC) and Field Cooling (FC) magnetization curves support the X-ray observation and show an exchange bias effect due to a core/shell structure, which was confirmed by TEM dark field imaging. This paves a way for tuning the magnetic and electronic properties without changing the ordering of the self organization.

MA 9.9 Mon 17:15 H23

Manipulation of the magnetic properties of Co nanoparticles by Pt or Pd capping — •Astrid Ebbing[1], Oleg Petracic[1], Olav Hellwig[2], Leonardo Agudo[3], Gunther Eggeler[3], and Hartmut Zabel[1] — [1]Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum — [2]San Jose Research Center, Hitachi Global Storage Technologies, San Jose, California 95135, USA — [3]Institute for Materials, Department of Materials Science, Ruhr-Universität Bochum, 44780 Bochum

We have prepared self-assembled Co nanoparticles with a diameter of approximately 3 nm by sputter-deposition on alumina buffer layers and investigated the effect of capping with different amounts of Pt or Pd. The magnetic properties have been studied using a superconducting quantum interference device (SQUID) magnetometer and magneto-optic Kerr effect as function of the nominal thickness of the capping material. Structural characterization has been performed by employing transmission electron microscopy (TEM) and atomic force microscopy (AFM). Co particles covered only by the Al2O3 protection layer show regular superparamagnetic behavior with a blocking temperature of $T_B = 22$ K. However, the Pt or Pd cap layer strongly modifies the magnetic properties and shifts the blocking temperature to higher values. E.g. for a nominal Pt capping thickness of 0.7 nm the system becomes even ferromagnetic with a Curie temperature of approx. 487 K.

15 min. break

MA 9.10 Mon 17:45 H23

Magnetic Properties of Fe and Co Clusters on Aluminum Oxide on $Ni_3Al(111)$ — •Andreas Buchsbaum[1], Pardeep Kumar Thakur[2], Alexei Preobrajenski[3], Edvin Lundgren[4], Michael Schmid[1], and Peter Varga[1] — [1]Institut für Angewandte Physik, Technische Universität Wien, Austria — [2]ID08, ESRF, Grenoble, France — [3]MAX-lab, Lund — [4]Division of Synchrotron Radiation Research, Lund University, Sweden

The structure of the aluminum oxide on $Ni_3Al(111)$ with a $(\sqrt{67} \times \sqrt{67})R12.2°$ unit cell can be used to grow well ordered arrays of Fe and Co clusters [1]. The size of these clusters can range from 1 up to ≈1000 atoms before reaching the limit of coalescence. We have investigated the magnetic properties of Fe clusters (≈900 atoms/cluster) and Co clusters (≈500 atoms/cluster) using x-ray magnetic circular dichroism (XMCD), assisted by scanning tunnelling microscopy (STM). This technique allowed us to measure the orbital and spin contribution to the magnetic moment per Fe or Co atom, as well as hysteresis curves down to temperatures of 7 K and up to fields of 5 T. From fitting the hysteresis curves we found clusters with a tilted easy axis in both cases and contributions of different cluster species in accordance to STM. Co clusters are superparamagnetic down to 7 K and Fe clusters are ferromagnetic below ≈50 K. The anisotropy energy is slightly higher than for bulk Fe or Co.

[1] M. Schmid, et.al., Phys. Rev. Lett. 99, 196104 (2007).

MA 9.11 Mon 18:00 H23

Magnetism of small Cr clusters: Structure, magnetic order and electron correlation effects — •Pedro Ruiz Díaz, Jose Luis Ricardo Chávez, Jesús Dorantes Dávila, and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Heinrich Plett Str. 40, 34132 Kassel, Germany

The magnetic properties of small Cr_N clusters ($N \leq 6$) are investigated in the framework of density-functional theory (DFT). The interplay between electron correlations, cluster structure and magnetic order is quantified by performing fully non-collinear spin-unrestricted calculations. Results obtained using the spin-polarized local density approximation (LDA) and the generalized-gradient approximation (GGA) are contrasted. A dimer-based growth pattern is found in all considered low-lying isomers, with very short equilibrium bond lengths (typically $d_{eq}^{\rm GGA}$ =1.55-1.65 Å) alternating with relative long ones (typically $d_{eq}^{\rm GGA}$ =2.75-2.85 Å). Strong local magnetic moments $\vec{\mu}_i$ are obtained for the relaxed geometries which show a *collinear* magnetic order with antiparallel (parallel) alignment of the $\vec{\mu}_i$ along the short (long) bonds. Despite quantitative differences, both LDA and GGA functionals yield collinear ground-state solutions for the fully relaxed structures, non-collinear spin arrangements are found only for particular highly symmetric (non dimerized) geometries. The present work demostrates that the magnetic frustration in compact Cr clusters, is solved by *dimerization* rather than by non-collinearity of the local moments. Finally, implications of the present trends for the ground-state structure and magnetism of larger Cr_N clusters are discussed.

MA 9.12 Mon 18:15 H23

Magnetism, structure and chemical order in small FeRh clusters — •Junais Mokkath and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Heinrich Plett Straße 40, 34132 Kassel, Germany.

The structural, electronic and magnetic properties of small Fe_mRh_n clusters having $N = m+n \leq 8$ atoms are investigated in the framework of a generalized gradient approximation to density-functional theory. The optimized cluster structures are compact with a clear tendency to maximize the number of nearest-neighbor FeRh pairs. For very small sizes the low-lying isomers present a different topology than the optimal structure, while for larger clusters the lowest-energy isomerizations imply mainly changes in the chemical order. The correlation between structure, chemical order, and magnetic behavior is analyzed as a func-

tion of size and composition. For all clusters having the optimized most stable structure the magnetic order is found to be Ferromagnetic-like, Antiferromagnetic-like spin arrangements were found in some low-lying isomers. The average magnetic moment per atom $\overline{\mu}_N$ increases approximately linearly with Fe content. A remarkable enhancement of the local Fe moments is observed as result of Rh doping. This is a consequence of the increase in the number of Fe d holes, due to FeRh charge transfer, combined with the extremely reduced local coordination. The Rh local moments, which are important already in the pure clusters ($N \leq 8$) are not significantly enhanced by Fe doping. However, the overall stability of magnetism– as measured by the total energy gain upon spin polarization at $T = 0$– increases when Rh is replaced by Fe.

MA 9.13 Mon 18:30 H23

Magnetic properties and anisotropy energies of deposited transition metal clusters on Pt(001) and Pt(111) surfaces — •Sanjubala Sahoo, Markus E. Gruner, Alfred Hucht, and Peter Entel — Faculty of Physics, University of Duisburg-Essen, Lotharstr. 1, 47057 Duisburg, Germany

Magnetic properties of transition metal (TM) clusters of Fe, Co, Ni and in particular, Fe-Pt deposited onto (001) and (111) surfaces of Pt are studied because of their importance in technology as possible data storage devices. We perform ab-initio structure optimization and finite temperature molecular dynamics using the Vienna Ab-initio Simulation Package (VASP) [1]. In addition, We have studied the magneto-crystalline anisotropy energy of free and deposited Fe, Co and Ni clusters. Calculations on free clusters show that for small elemental clusters of 13 atoms, (distorted) icosahedral structures are energetically favorable. We have studied supported icosahedral and cuboctahedral clusters on Pt(001) and Pt(111) surface for different starting orientations of clusters. Binary Fe-Pt clusters have large magneto-crystalline anisotropy in $L1_0$ structure. It is hence interesting to see whether this structure is stable when deposited on Pt surface, keeping in mind that Pt(001) and Pt(111) have different surface energies [2], which can influence the structure and magnetic properties of the deposited clusters. [1] G. Kresse, and J. Joubert, Phys. Rev. B. 59, 1758 (1999). [2] A. Dannenberg, M. E. Gruner, A. Hucht, and P. Entel, Phys. Rev. B (2010), in print

MA 9.14 Mon 18:45 H23

Synthesis and magnetic properties of carbon-coated FeRu, CoRu, and NiRu nanoalloys — •A.A. El-Gendy, V.O. Khavrus, S. Hampel, A. Leonhardt, R. Klingeler, and B. Büchner — Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany

Carbon coated FeRu, CoRu and NiRu nanoalloys have been synthesised by high pressure chemical vapour deposition (HPCVD). The formation of the core-shell nanoalloys with a mean diameter around 8 nm has been confirmed by means of high resolution transmission electron microscopy imaging (HRTEM), energy dispersive X-ray (EDX) analysis, and X-ray diffraction (XRD. We show the effect of the synthesis parameters on the actual composition of the nanoalloys and on their magnetic properties and we discuss their feasibility for applications in medical hyperthermia.

MA 9.15 Mon 19:00 H23

Magnetic and structural properties of TiO2 - FeCo nanocomposite — •Amit Kulkarni[1], Vladimir Zaporojtchenko[1], Thomas Stunkus[1], Franz Faupel[1], Eckhard Quandt[2], Venkata sai kiran Chakravadhanula[3], and Lorenz Kienle[3] — [1]Institute for Materials Science - Multicomponent Materials, Faculty of Engineering, Christian-Albrechts University at Kiel — [2]Institute for Materials Science - Synthesis and Real Structures, Faculty of Engineering, Christian-Albrechts University at Kiel — [3]Institute for Materials Science - Inorganic Functional Materials, Faculty of Engineering, Christian-Albrechts University at Kiel

Composite films of TiO2 as an insulator and FeCo as a ferromagnetic component with different metal volume fractions (MVF) were prepared by co-sputtering. High resolution transmission electron microscopy (HRTEM) analysis reveals that the microstructure of the TiO2/FeCo nanocomposites depends on the MVF. Amorphous nanocomposites are formed at lower MVF whereas FeCo crystallites are present at higher MVF. Likewise, the magnetic characteristics of these films depend on the MVF. At low MVF, composite films contain single domain particles exhibiting superparamagnetism whereas at high MVF FeCo forms percolating network of crystallites resulting in enlargement of the hysteresis loop. These composite films show a considerable tunnel magneto resistance of 5 % at RT and could be interesting as low cost magnetic field sensors.

MA 9.16 Mon 19:15 H23

The role of the tip material for switching fields measured by spin polarized STM — •yasmine nahas[1], safia ouazi[1], marco corbetta[1], fabio donati[1,2], hirofumi oka[1], sebastian wedekind[1], guillemin rodary[1], dirk sander[1], and jürgen kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [2]CNISM, NEMAS and Dipartimento di Energia - Politecnico di Milano, Milano, Italy

Spin polarized scanning tunneling microscopy (SP STM) enables us to probe the magnetism of single objects down to the single atom level. Switching fields of individual Co islands on Cu(111) were already measured using Cr coated W tips [1]. We study the same system using bulk Cr tips fabricated by standard electrochemical etching [2]. The switching fields of Co islands measured with a bulk Cr tip are consistently larger as compared to those obtained with Cr coated W tips. Whereas we measured with the Cr coated W tip a typical switching field of 0.6 T for a Co island with 1800 atoms at 8 K, we measure 1.2 T for an island of the same size using the bulk Cr tip. This surprising result is discussed in view of the role of the island size, temperatures, the island environment and tip material for the magnetic switching field.

[1] G. Rodary et al., Jpn. J. Appl. Phys. 47, 9013 (2008).
[2] A. Li Bassi et al., Appl. Phys. Lett. 91, 173120 (2007).

MA 10: Poster I

Time: Tuesday 10:45–13:45 Location: Poster A

MA 10.1 Tue 10:45 Poster A

Theorectical study of the influence of Ni-bridge-Ni angles on magnetic anisotropy and exchange — •Claudia Loose and Jens Kortus — TU-Bergakademie Freiberg, Institut for Theoretical Physics, Leipziger Str. 23, 09599 Freiberg, Germany

We studied the effect of distortions in the Ni-brigde-Ni angles of 5 small Ni-dimers by means of density functional theory calculations. In three cases we observed a decrease of the magnetic exchange coupling constant J with increasing magnetic anisotropy D. However, one of the Ni-dimers showed the opposite behaviour. The last discussed complexe displays an abrupt change from easy-axis to easy-plane as soon as one leaves the experimental geometry.

These results suggest that the development of simple guiding rules for rational design of magnetic anisotropy, similar to the well known Goodennough-Kanamori rules, may be difficult and a more detailed description based on electronic structure information may be required.

MA 10.2 Tue 10:45 Poster A

Magnetic anisotropy of paramagnetic porphyrin molecules on non-magnetic surfaces: an angle-dependent XMCD investigation — •Matthias Bernien[1], Jorge Miguel[1], Wolfgang Kuch[1], Adrian D. Ward Cherrier[2], Carsten Tieg[2], Claudia Weis[3], Carolin Antoniak[3], Dietger Bovenschen[3], and Heiko Wende[3] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]ESRF, BP 220, F-38043 Grenoble Cedex, France — [3]AG Wende and Center for Nanointegration (CeNIDE), Universität Duisburg-Essen, Lotharstrasse 1, 47048 Duisburg

Metal complexes on surfaces are a topic of intensive scientific investigations since the properties of their central metal ion, determined by the adjacent ligands, can be widely tuned by the chemical design of the molecule. Here we report on the electronic structure and the magnetic properties of paramagnetic Fe and Co octaethylporphyrin molecules adsorbed on non-magnetic Cu(100) and oxygen-covered $(\sqrt{2} \times 2\sqrt{2})$R45° O/Cu(100) surfaces. The magnetic moments of the metal centers of the molecules are aligned by an external mag-

netic field of 5 T at a temperature of 8 K. The magnetic anisotropy of the metal centers is probed by XMCD measurements along the easy and hard magnetization direction. For Fe porphyrin molecules on the bare Cu(100) substrate a negligible magnetic anisotropy is found. In contrast, a huge magnetic anisotropy of the Fe ion can be obtained by placing half a monolayer of atomic oxygen between the molecules and the Cu(100) surface. This work has been supported by DFG (Sfb 658 and Sfb 491) and ESRF (HE 2700).

MA 10.3 Tue 10:45 Poster A

Electron spin dynamics in novel binuclear Mn molecular complexes — •Y. Krupskaya[1], R. Zaripov[2], E. Vavilova[1,2], A. Parameswaran[1], V. Miluykov[3], I. Bezkishko[3], D. Krivolapov[3], O. Kataeva[3], O. Sinyashin[3], E. Hey-Hawkins[4], V. Voronkova[2], K. Salikhov[2], R. Klingeler[1], V. Kataev[1], and B. Büchner[1] — [1]IFW Dresden, Dresden, Germany — [2]Zavoisky Physical-Technical Institute of the RAS, Kazan, Russia — [3]A.E. Arbuzov Institute of Organic and Physical Chemistry of the RAS, Kazan, Russia — [4]Institute of Inorganic Chemistry, Leipzig University, Leipzig, Germany

We present a study of electron spin dynamics in novel Mn-dimer molecular complexes which show strong dependence of the electron density distribution at the Mn sites on the ligand surrounding. Using the pulsed electron spin resonance (ESR) technique we have detected electron spin echo and determined spin-lattice relaxation (T_1) and phase-coherence (T_2) times which systematically depend on the ligand type. Interestingly, we observe an electron spin echo envelope modulation (ESEEM) associated with the coupling of the Mn electron spins to nearby proton moments. Moreover, we show that the spin-relaxation times can be substantially increased by reducing intermolecular interactions, for instance, by dissolving the crystals in a liquid media.

MA 10.4 Tue 10:45 Poster A

Incoherent Slow Magnetisation Dynamics in the Giant Keplerat Molecule $Fe_{30}Mo_{72}$ — •T. Dellmann[1], H.-H. Klauss[1], J. Schnack[2], and B. Büchner[3] — [1]Institut für Festkörperphysik, TU Dresden — [2]Fakultät für Physik, Univ. Bielefeld — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden

In the geometrically frustrated polyoxomolybdate nanomolecule $Fe_{30}Mo_{72}$ a distinct slowing down of the magnetisation dynamics is observed at temperatures of about 5K depending on the observation method [1, 2]. These dynamics still persist at very low temperatures down to 20 mK as shown by local probe techniques. Furthermore, no magnetisation steps could be found in the field dependent magnetisation at these temperatures as predicted by the quantum rotational band model [3].

We present recent low temperature ac-susceptibility results for different frequencies (200 Hz < f < 10 kHz) and external fields (0 < B < 2 T) and discuss them in comparison with results from μ^+SR, NMR and ^{57}Fe moessbauer spectroscopy. The origin of decoherence at lowest temperatures is focussed in this discussion.

[1] Chr. Schröder et al., Phys.Rev.B 77, 224409 (2008)
[2] J. Lago et al., Phys.Rev.B 76, 064432 (2007)
[3] J. Schnack et al., Europhys. Lett., 56 (6), pp. 863-869 (2001)

MA 10.5 Tue 10:45 Poster A

High-field measurements of a spin-frustrated trinuclear copper (II) complex — •Wolfgang Kroener[1], Aksana Zharkouskaya[2], Eike T. Spielberg[2], Daniel Plaul[2], Klaus Gieb[1], Winfried Plass[2], and Paul Müller[1] — [1]Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg, Germany — [2]Institut für Anorganische und Allgemeine Chemie, Universität Jena, Germany

We present magnetic measurements of a trinuclear copper II complex based on triaminoguanidin (TAG): $[Cu_3(bipy)_3(^H\text{TAG})](ClO_4)$. A home-made micro-Hall-bar magnetometer and a commercial SQUID magnetometer were used to perform angle-resolved single crystal measurements. As the triangular structure of the complex suggests, we can conclude from our measurements, that we deal with a spin-frustrated system. Following a proposal of Trif et al.[1] we investigated the magnetization under high electric fields.

[1] M. Trif, F. Troiani, D. Stepanenko, D. Loss, Phys. Rev. Lett. 101, 217201 (2008).

MA 10.6 Tue 10:45 Poster A

Reinvestigation of the electronic and magnetic structure of the ferric star — •Daniel Taubitz[1], Karsten Kuepper[2], Rolf Saalfrank[3], Andreas Scheurer[3], Stefan Sperner[3], Jürgen Schnack[4], and Manfred Neumann[1] — [1]Department of Physics, University of Osnabrück, Barbarastrasse 7, D-49069 Osnabrück, Germany — [2]Department of Solid State Physics, University of Ulm, Albert-Einstein-Allee 11, D-89069 Ulm, Germany — [3]Institute for organic chemistry, Universität Erlangen-Nürnberg, Henkestr. 42, 91054, Erlangen, Germany — [4]Department of Physics, University of Bielefeld, Universitätsstr. 25, D-33615 Bielefeld

Large polynuclear complexes which contain transition metal and/or rare earth metal ions are of current interest due to their tunable magnetic properties and the possibility to act as single molecule magnets (SMM). The use of SMMs for information technology (e.g. molecular memory arrays) is a main target in the field of molecular spintronics. Simplest inorganic Systems, that show SMM behaviour like for example the ferric star $Fe^{III}[Fe^{III}(L^1)_2]_3$ have attracted much interest, since they can be investigated as model systems.
We investigated the ferric star with different X-ray spectroscopic techniques. The experimental results obtained by different groups using different methods will be compared and discussed.

MA 10.7 Tue 10:45 Poster A

Accuracy of the DMRG method applied to the antiferromagnetic Heisenberg icosidodecahedron — •Jörg Ummethum and Jürgen Schnack — Universität Bielefeld, Fakultät für Physik, Postfach 100131, D-33501 Bielefeld

Geometrically frustrated spin systems show a variety of fascinating properties like magnetization jumps or an enhanced magnetocaloric effect. There are many methods to study such systems like exact diagonalization, quantum Monte Carlo, or DMRG. Exact diagonalization is limited to rather small systems and quantum Monte Carlo suffers from the so-called negative sign problem. The DMRG method [1] is in principle free of such limitations but the accuracy is rather limited for systems with more than one dimension.

We present results of our DMRG studies of the antiferromagnetic Heisenberg icosidodecahedron and focus on the lowest energy levels in subspaces of total magnetic quantum number which form so-called rotational bands for many antiferromagnetic spin systems [2]. The accuracy of the results and possibilities to improve it, like different orderings of the spins, are discussed.

[1] S. R. White, Phys. Rev. B **48**, 10345 (1993)
[2] J. Schnack and M. Luban, Phys. Rev. B **63**, 014418 (2000)

MA 10.8 Tue 10:45 Poster A

DFT Studies Of A Magnetic Heptanuclear High-Spin Complex — •Stefan Leiding[1], Andrei Postnikov[2], Jürgen Schnack[1], and Dirk Andrae[1,3] — [1]Bielefeld University, Germany — [2]Paul Verlaine University Metz, France — [3]Freie Universität Berlin, Germany

The synthesis of molecular magnets has undergone rapid progress in recent years, therefore the ability to tune the couplings between the spins of individual transition metal atoms by controlled attachment of molecular ligands is examined using spin-dependent density functional theory. $[\{(\text{talen}^{\text{t-Bu}_2})\text{-}\{Mn^{III}(solv)_n\}_3\}_2\{Fe^{III}(CN)_6\}]^{3+}$ is a heptanuclear complex built via molecular recognition from three building blocks: two trinuclear manganese triplesalen units and one hexacyanometallate. In order to investigate the geometric and electronic effects on ferromagnetic coupling via the spin-polarization mechanism (well established in organic chemistry), we applied this mechanism to transition metal complexes. First of all we focus on much smaller fragments of the heptanuclear complex, e.g., the triplesalen ligand with three Mn^{III} centers and the [(N,N'-ethylenebis(salicylaldimine)) $Mn^{III}(H_2O)_2]^+$ which contains only a single Mn^{III} ion. The influence of the ligand folding in these complexes causes a change in the orientation of the magnetic orbitals and in the spin-polarizations. These properties are examined by Kohn-Sham DFT calculations with the SIESTA and the TURBOMOLE programs.

MA 10.9 Tue 10:45 Poster A

Magnetic coupling of Co porphyrin molecules to ferromagnetic substrates — •Felix Hermanns, Alexander Krüger, Matthias Bernien, Jorge Miguel, and Wofgang Kuch — Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Metalorganic compounds are promising candidates for spintronic devices. In this context, the interaction of the central transition metal ion of Fe-octaethyl-porphyrin molecules with underlying ferromagnetic substrates has been studied and found that it can be changed from parallel to antiparallel [1].

Here, we report on X-ray absorption spectroscopy (XAS) measurements of submonolayers of Co-octaethyl-porphyrin on bare and oxygen-covered Ni films grown on Cu(001). By means of angle-dependent XAS measurements at the N K-edge, a parallel orientation of the quasi-planar molecule is found with respect to the surface.

The Co $L_{3,2}$ XAS and XMCD spectra display significant differences for the two substrates. Angle-dependent spectral changes are explained by the distinct contributions of the individual Co 3d orbitals. The modification of the Co oxidation state by the adsorption on the two substrates is discussed. XMCD investigations yield a ferromagnetic coupling at room temperature between the Ni substrate and the Co ion only in the case of the bare metal surface. From the temperature dependence of the Co-XMCD signal, the magnetic coupling energy is evaluated.

This work is supported by the DFG (Sfb 658).

[1] M. Bernien et al., Phys. Rev. Lett. 102, 047202 (2009)

MA 10.10 Tue 10:45 Poster A

Stability of Mn_6Cr single-molecule-magnets adsorbed on surfaces: The influence of X-ray exposure, layer thickness, choice of substrate and counterions — •Andreas Helmstedt[1], Aaron Gryzia[1], Sebastian Steppeler[1], Norbert Müller[1], Marc D. Sacher[1], Ulrich Heinzmann[1], Veronika Höke[2], Thorsten Glaser[2], Mikhail Fonin[3], and Ulrich Rüdiger[3] — [1]Fak. f. Physik, Uni Bielefeld — [2]Fak. f. Chemie, Uni Bielefeld — [3]Fak. f. Physik, Uni Konstanz

The single-molecule-magnet (SMM) Mn_6Cr consists of three main components: Two bowl-shaped Mn_3-salen complexes are bridged by a complex containing one Cr atom. Three counterions are coupled to the triply charged SMM to ensure charge neutrality. Mn_6Cr-SMM have a low stability against X-ray exposure, which adversely affects a study of the electronic properties by X-ray absorption- and photoelectron spectroscopy. With increasing exposure time, the spectral features of trivalent Mn representing intact molecules disappear while Mn(II)-typical features increase. This degradation process and its dependence on the photon flux, the substrate and the SMM concentration were observed during beamtimes at BESSY II and MAXLAB III. The rate of degradation shows also a strong dependence on the choice of counterions. The choosen preparation method allows the adsorption of Mn_6Cr-SMM with varying layer thickness on various substrates. This study reveals an influence of the substrate and the molecule layer thickness on the initial electronic state of the adsorbed molecule layer, i.e. the molecules seem to degrade already during the adsorption process.

MA 10.11 Tue 10:45 Poster A

Homogenous adsorption of Mn_6Cr single-molecule-magnets on substrates — •Peter Koop[1], Aaron Gryzia[1], Andreas Helmstedt[1], Wiebke Hachmann[1], Armin Brechling[1], Marc Sacher[1], Ulrich Heinzmann[1], Veronika Höke[2], and Thorsten Glaser[2] — [1]Molecular and Surface Physics, Bielefeld University — [2]Anorganic Chemistry I, Bielefeld University

Mn_6Cr is a single-molecule-magnet (SMM) consisting of two bowl-shaped compounds, each containing three Mn-atoms. These compounds are bound together by a Cr-complex. For charge neutrality, counterions have to be coupled to the SMM. Investigation of separated SMM, the molecule-substrate interaction and/or possible future applications e.g. data storage, requires preparation of monolayers or thin films. This preparation is done by solving Mn_6Cr in methanol, and dropping few μl of the solution onto a 9x9 mm sized substrate. Depending on the choice of substrate Au, SiO_2 (native Oxide, 50 nm Oxide), HOPG, Ru, Mn_6Cr concentration, the angle of the sample while being preparated and the amount of applied solution Mn_6Cr yields strongly varying kinds of assembly. On the one hand, clusters emerge in the solution just a moment before the solvent dries, depending on the concentration of Mn_6Cr in the solution. On the other hand the lateral distribution of the SMM is correlated with the droplet-size, the angle of the sample during preparation and the counterions, e.g. lactate anions cause Mn_6Cr to create membranes. The samples have been investigated by means of optical microscopy, SEM, surface profilometry and AFM.

MA 10.12 Tue 10:45 Poster A

Single molecule magnets on surfaces: recent advances and future perspectives — Sönke Voss[1], •Samuel Bouvron[1], Ulrich Rüdiger[1], Mikhail Fonin[1], Michael Burgert[2], and Ulrich Groth[2] — [1]Fachbereich Physik, Universität Konstanz, 78467 Konstanz — [2]Fachbereich Chemie, Universität Konstanz, 78467 Konstanz

In recent years, single molecule magnets (SMMs) have attracted much attention due to their unique properties such as quantum tunneling of magnetization (QTM) and hysteresis of pure molecular origin [1], making these materials potential candidates for future applications in ultra-high density data storage devices. Only very recently first experiments indicating the conservation of magnetic properties of SMM clusters upon surface deposition have been reported boosting the investigation of SMM monolayers [2].

We present an overview of the latest achievements in the investigation of Mn_{12} monolayers as well as the individual molecules by means of scanning probe techniques, synchrotron radiation based techniques, and magnetization measurements. In particular, novel approaches towards the assembly of Mn_{12} SMMs on substrates suited for advanced studies or possible applications are highlighted.

This work was supported by DFG through SFB 767 (TP C5).

[1] D. Gatteschi and R. Sessoli, Angew. Chem. Int. Ed. **42**, 268 (2003).

[2] M. Mannini et al., Nature Mater. **8**, 194 (2009).

MA 10.13 Tue 10:45 Poster A

Properties of TiO_2/Fe composites investigated by ab inito calculations — •Anna Grünebohm, Heike C. Herper, and Peter Entel — Fakultät für Physik, Universität Duisburg-Essen

Multiferroic materials offer interesting new applications through the coupling or coexistence of two order parameters - particularly ferroelectricity and ferromagnetism. While ferromagnetism is mainly mediated by highly localized *d*- and *f*- electrons, conventional ferroelectricity is mediated by cation off-centering which is based on empty *d*-shells. Therefore, multicomponent systems are promising alternatives for high performance multiferroics [1]. In such composites, the ferroelectric and ferromagnetic phases are coupled through hybridization and strain effects at the interfaces. To get an insight into the interface properties of such systems, we do calculations within the projector augmented wave method using VASP [2]. We investigate Fe/TiO_2 agglomerates as simple model systems in order to study fundamental properties of such interfaces. Although TiO_2 does not possess a ferroelectric phase, it offers a large polarizability and a magnetoelectric effect has been measured in Fe/$TiO_{2-\delta}$ films [3]. This means that TiO_2 interfaces possess similar properties as ferroelectrics. Until now little is konwn of the interface structure of TiO_2/Fe agglomerates. Hence, we present a systematic study of different layered systems as well as agglomerated nanoparticles.

[1] R. Ramesh and N. A. Spaldin, Nat. Mater. **6**, 21 (2007) [2] G. Kresse and J. Furthmüller, Phys. Rev. B **54**, 11169 (1996) [3] S. D. Yoon, *et al*, Appl. Phys. Lett. **92**, 042508 (2008)

MA 10.14 Tue 10:45 Poster A

Magnetism and ferroelectricity of Mn-doped $BaTiO_3$ thin films — •Yao Shuai, Danilo Bürger, Shengqiang Zhou, Manfred Helm, and Heidemarie Schmidt — Forschungszentrum Dresden-Rossendorf e.V., Bautzner Landstraße 400, 01328 Dresden

Strained $BaTiO_3$ (BTO) thin films grown by pulsed-laser deposition (PLD) on $SrTiO_3$ substrates can result in a nearly 500 K larger ferroelectric transition temperature. The remanent polarization of strained BTO thin films is at least 250% higher than that in BTO single crystals **[1]**. We used PLD to grow Mn-doped BTO (BTMO) thin films on MgO, and c-plane sapphire substrates. For example, we observed XRD reflexes of (00l)- and (l00)-oriented domains on BTMO deposited on MgO and sapphire, indicating the BTMO films are polycrystalline. At room temperature the saturated magnetic moment of BTMO films with a thickness of 400nm on MgO substrates amounted to 8 emu/cm^3, while that of the films deposited on c-sapphire was merely 1 emu/cm^3 even at 5 K, resulting from a weak domain orientation due to the large lattice mismatch between BTMO and c-sapphire. A capacitance-voltage hysteresis behavior of BTMO films on Pt/c-sapphire has been probed under a driving voltage of 50 mV at 100 kHz, which can be ascribed to the nonlinear ferroelectric response **[2]**. The simultaneously observed magnetic and ferroelectric ordering proves the feasibility of multiferroic BTMO for novel device applications**[3]**. **[1]** K. J. Choi et al., Science **306** (2004) 1005. **[2]** M. Dawber et al., Reviews of Modern Physics **77** (2005) 1083. **[3]** R. Ramesh et al., Nature Materials **6** (2007) 21. (2007) 21.

MA 10.15 Tue 10:45 Poster A

Angle-dependent magnetotransport in Nickel thin films — •M. Althammer, M. Wagner, A. Brandlmaier, M. Weiler, S. Geprägs, R. Gross, and S.T.B. Goennenwein — Walther-Meißner-

Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

Angle-dependent magnetoresistance (ADMR) measurements have proven to be a powerful tool to investigate magnetic anisotropy in ferromagnetic thin films [1]. We here apply the ADMR technique to polycrystalline Nickel thin films deposited via electron beam evaporation onto $LiNbO_3$, MgO and $BaTiO_3$ substrates. The 50 nm thick films were patterned into Hall-bar structures with optical lithography and etching or lift-off. In the ADMR measurements, the longitudinal and transverse resistance is recorded as a function of the orientation of the external magnetic field at constant field strength. In all samples investigated the strain in the Nickel thin film can be tuned in situ, either via temperature or an applied electric field. Due to magnetoelastic coupling the strain leads to a change in the magnetic anisotropy. We can quantitatively explain our data with basic magnetoelastic coupling theory, taking into account the thermal dependence of the lattice parameters of the respective substrate. Fitting the data by a single domain model allows to extract the magnetic anisotropy. We also discuss the external magnetic field and temperature dependence of the resistivity parameters. Financial Support by the DFG (SPP 1157 and GO 944/3) is gratefully acknowledged.

[1] W. Limmer *et al.*, PRB **74**, 205205 (2006)

MA 10.16 Tue 10:45 Poster A

Investigation of strain effects in epitaxial $CaMnO_3$ films by nonlinear optics — •Tim Günter[1], Satadeep Bhattacharjee[2], Philippe Ghosez[2], Adrian David[3], Wilfrid Prellier[3], and Manfred Fiebig[1] — [1]HISKP, University of Bonn, Germany — [2]University of Liege, Belgium — [3]CRISMAT Laboratory, ENSICAEN, CNRS, France

The family of ABO_3 perovskite oxide compounds constitutes an important class of multifunctional materials. For $CaMnO_3$, a G-type antiferromagnetic insulator (T_N = 122 K), a weak Mn-driven ferroelectric instability at its equilibrium volume was recently predicted. Furthermore this instability can be enhanced by strain engineering, driving $CaMnO_3$ towards multiferroicity.
Here optical second harmonic generation (SHG) was used for investigating $CaMnO_3$ films grown epitaxially with 2% tensile strain on (001)-$LaAlO_3$ substrates. The temperature dependence of the SHG signal indicates a phase transition at $\approx$ 20 K with an emergence of long range order that is not found in the bulk compound. SHG polarization analysis based on SHG selection rules allows to determine the origin of this novel phase. A variety of possible ferroelectric polarization directions was considered on the basis of a symmetry analysis. First results on SHG spectroscopy and domain imaging are reported.
This work is supported by the EU-STREP MaCoMuFi.

MA 10.17 Tue 10:45 Poster A

First-principles study of ferroelectric domain walls in multiferroic bismuth ferrite — Axel Lubk[1,2], •Sibylle Gemming[3], and Nicola Spaldin[2] — [1]Institute of Physics, Technical University, D-01062 Germany. — [2]Materials Department, University of California, Santa Barbara, California 93106-5050, USA. — [3]Inst. Ion Beam Physics and Materials Research, FZ Dresden-Rossendorf, D-01314 Dresden, Germany.

The structural, electronic, and magnetic properties of the ferroelectric domain walls in multiferroic $BiFeO_3$ were studied by density-functional band-structure calculations. Domain walls in which the rotations of the oxygen octahedra do not change their phase when the polarization reorients are the most favorable and of these, the 109° domain wall centered around the BiO plane has the lowest energy. The 109° and 180° walls have a significant change in the component of their polarization perpendicular to the wall; the corresponding step in the electrostatic potential is consistent with a recent report of electrical conductivity at the domain walls. Finally, we show that changes in the Fe-O-Fe bond angles at the domain walls cause changes in the canting of the Fe magnetic moments which can enhance the local magnetization at the domain walls.
[1] Seidel et al., *Nature Mater* **8** (2009) 229; [2] Lubk et al., *Phys. Rev. B* **80** (2009) 104110.

MA 10.18 Tue 10:45 Poster A

Separation and magnetic-field dependence of contributions to the magnetically induced net polarization in multiferroic $TbMn_2O_5$ — •Naëmi Leo[1], Thomas Lottermoser[1], Dennis Meier[1], Roman V. Pisarev[2], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn — [2]Ioffe Physical Technical Institute, Russian Academy of Sciences

Strong magnetoelectric coupling is expected in multiferroics in which the ferroelectric polarization is directly induced by the magnetic order. A particularly interesting magnetoelectric multiferroic is $TbMn_2O_5$, which shows a reversal of the spontaneous ferroelectric polarization P upon application of a magnetic field. Theoretical approaches predict two contributions to the net polarization directly linked to the magnetic order of the system.

The analysis of nonlinear spectra of $TbMn_2O_5$ measured by optical Second Harmonic Generation (SHG) reveals not only two but three distinct contributions P_1^{Mn}, P_2^{Mn} and P_3^{Tb}, whereas in pyroelectric measurements only the net polarization can be seen. It has been shown that the third contribution P_3^{Tb} is linked to the magnetic order of the Tb sublattice. Furthermore, spatial resolved measurements reveal additional domain structures at low temperatures.

Performing nonlinear optical measurements in an applied magnetic field reveals that the change of sign in the ferroelectric net polarization in $TbMn_2O_5$ is driven by an magnetoelectric interaction with the rare-earth order: $P(T,B) = P_1^{Mn}(T) - P_2^{Mn}(T,H) \pm P_3^{Tb}(T,H)$. This work was supported by the DFG through SFB 608.

MA 10.19 Tue 10:45 Poster A

Influence of doping on the lattice dynamics: Comparison of stoichiometric and mixed orthorhombic rare earth manganites $RMnO_3$ (R = Gd, Tb, Eu:Y) — •S. Issing[1], F. Fuchs[1], C. Ziereis[1], E. Batke[1], A. Pimenov[1], Y. Vu. Ivanov[2], A. A. Mukhin[2], and J. Geurts[1] — [1]Physikalisches Institut, Universität Würzburg, Germany — [2]General Physics Institute of the Russian Academy of Sciences, Moscow, Russia

Among the class of multiferroics, the orthorhombic manganites $RMnO_3$ are an excellent example for the intimate coupling of lattice and magnetic degrees of freedom. For a fine tuning of the magnetic properties the isovalent substitution of the R ion can be employed leading to a quasi-continuous increase of the orthorhombic crystalline distortion and thus of the magnetic frustration responsible for multiferroicity. However the question of disorder induced by isovalent substitution needs to be adressed. Thus, employing Raman and FTIR spectroscopy, we studied the lattice dynamics of stoichiometric (R = Eu, Gd, Tb) as well as mixed $RMnO_3$ compounds ($Eu_{1-x}Y_x$ $0 \leq x \leq 0.5$ - covering the R ion radius from Eu to Tb) - to gain insight into the consequences of an isovalent partial substitution on the R-site. Our spectroscopic techniques give us sensitivity not only to symmetry properties but also to the involvement of different ion types within the unit cell. Our results clearly show that the MnO_6-octahedra remain unaffected by disorder, making $Eu_{1-x}Y_xMnO_3$ an excellent model system for a quasi-continuous fine-tuning of the lattice properties relevant for the appearance of multiferroicity.

MA 10.20 Tue 10:45 Poster A

Spin-phonon coupling in multiferroic stoichiometric and mixed $RMnO_3$ compounds (R=Gd, Tb, Eu:Y) studied by Raman spectroscopy — •S. Issing[1], A. Pimenov[1], Y. Vu. Ivanov[2], A. A. Mukhin[2], and J. Geurts[1] — [1]Physikalisches Institut, Universität Würzburg, Germany — [2]General Physics Institute of the Russian Academy of Sciences, Moscow, Russia

Spin-phonon coupling, manifesting itself as phonon softening in the temperature range of the magnetically ordered phases is investigated by temperature dependent polarized Raman spectroscopy. Stoichiometric (R = Eu, Gd, Tb) and mixed (R = $Eu_{1-x}Y_x$, $0 \leq x \leq 0.5$ - covering the R ion radius range of the stoichiometric compounds) multiferroic orthorhombic $RMnO_3$ are compared in the 10 - 300 K temperature range. The strength and temperature dependence of the phonon softening depend strongly on the mody symmetry showing the correlation of this effect with the magnetic interaction of the Mn^{3+} ions within the MnO_2-plane leading to the strongest phonon renormalization for the in-plane symmetric stretching mode ($B_{2g}(1)$). Quantitative spin-phonon coupling constants for all investigated systems are derived showing the trend of weakend spin-phonon coupling for decreasing R ion radius. Strikingly, spin-phonon coupling is observed even for $RMnO_3$ compounds with an incommensurate magnetic structure of the Mn^{3+} spins, i.e. without long-scale magnetization. This underscores the role of phonons as a quasi-local probe.

MA 10.21 Tue 10:45 Poster A

Magnetic Structure of Multiferroic $DyMnO_3$ studied by Resonant Soft X-ray Scattering — •Enrico Schierle, Victor Soltwisch, Detlef Schmitz, Ralf Feyerherm, Andrey Maljuk, Fabiano Yokaichiya, Dimitri Argyriou, and Eugen Weschke —

Helmholtz-Zentrum Berlin

In multiferroic $DyMnO_3$, ferroelectricity is induced by a cycloidal magnetic structure of Mn-3d moments. However, it has been shown that ordering of Dy-4f moments strongly influences the ferroelectric properties of this compound. We examined the magnetic structure of Dy-4f moments by resonant magnetic X-ray scattering (RMXS) at the Dy-M_5 resonance in detail. As the main result, we show that over a large temperature range of the ferroelectric phase, Dy-4f moments form a magnetic cycloid of a chirality coupled to the direction of the electric polarization. This property can be exploited to map the ferroelectric domain structure at the crystal surface by RMXS.

MA 10.22 Tue 10:45 Poster A

Investigation of the triangular multiferroic order in $CuCrO_2$ by second harmonic generation — •Vera Carolus[1], Kenta Kimura[2], Tsuyoshi Kimura[2], and Manfred Fiebig[1] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, Nußallee 14-16, D-53115 Bonn — [2]Devision of Materials Physics, Graduate School of Engineering Science, Osaka University, Toyonaka, Osaka 560-8531, Japan

$CuCrO_2$ (space group $R\bar{3}m$) is a triangular lattice antiferromagnet with delafossite structure showing a modulated out-of-plane 120° spin order below $T_N = 23.6$ K. Because of the breaking of inversion symmetry by the magnetic order a magnetically induced electric polarisation with six different domains should exist.

Here we investigate the multiferroic order of $CuCrO_2$ by optical second-harmonic generation (SHG) spectroscopy. Although the value of spontaneous polarisation is about four orders of magnitude weaker than in a conventional ferroelectric, a clear SHG signal with a pronounced spectral and polarization dependence is obtained. This giant coupling to the SHG progress is not restricted to $CuCrO_2$, but is also observed in $MnWO_4$, $TbMn_2O_5$ and CuO. This points to electronic instead of ionic nature of the ferroelectric polarisation.

In SHG imaging experiments the topology of the multiferroic domains (and their manipulation) were investigated. Crystallographic and magnetic correlations between the six types of domains were revealed.

MA 10.23 Tue 10:45 Poster A

Magnetic structure in multiferroic pyroxenes: (Na, Li)$FeSi_2O_6$ — •Max Baum[1], Alexander Komarek[1], Navid Qureshi[1], Petra Becker[2], Ladislav Bohatý[2], Martin Meven[3], Astrid Schneidewind[3], Peter Link[3], Maria 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]4 Institut Laue-Langevin, BP 156, 6 rue Jules Horowitz, 38042 Grenoble Cedex 9, France

(Na/Li)$FeSi_2O_6$ both exhibit multiferroic properties. In $NaFeSi_2O_6$ magnetic ordering is incommensurate with a temperature independent modulation k=(0, 0.23, 0). The antiferromagnetic order occurs below 8K and additionally ferroelectric ordering below 6K. Polarized neutron diffraction shows that at this transition chiral magnetic components develop. Ferroelectric order in $NaFeSi_2O_6$ seems thus to arise from the inverse Dzyaloshinski-Moriya interaction. Similarly, magnetically driven ferroelectricity is detected in $LiFeSi_2O_6$ below 18K but only at applied magnetic field. In both these compounds the electric polarization can be strongly modified by magnetic fields. Our measurement on a single crystal reveals the Shubnikov group P21/c'. On the basis of the magnetic structure we calculated the totoidal moment for $LiFeSi_2O_6$: T=-0.037muB/Å^2. This is about ten times larger than in $LiCoPO_4$, the first compound where ferrotoroidicity was unambiguously observed.

MA 10.24 Tue 10:45 Poster A

Response of antiferromagnetic and ferrotoroidic domains in $LiCoPO_4$ to magnetic and electric fields — •Anne S. Zimmemann[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

Ferrotoroidicity denotes a fourth form of ferroic order with a spontaneous uniform alignment of magnetic vortices. Recently the observation of antiferromagnetic (AFM) domains coexisting with ferrotoroidic (FTO) domains in $LiCoPO_4$ was reported in second harmonic generation (SHG) experiments [1]. Controlled manipulation of these FTO domains would be the next step in demonstrating the ferroic nature of the toroidal state. This could be achieved by a toroidal field, e. g. crossed electric and magnetic fields.

Here we report on the behaviour of AFM and FTO domains in external magnetic, electric, and toroidal fields. The domain structure in zero-field cooling and field-cooling experiments was investigated by SHG. Experiments showed that a magnetic field of around 5 T along the x axis changes and pins the domains. Furthermore indications for an additional phase transition were observed. Toroidal poling is thus not possible. Therefore a setup for smaller magnetic and higher electric fields was developed. - Work supported by the SFB 608.

[1] B. B. Van Aken et. al., Nature 449, 702 (2007)

MA 10.25 Tue 10:45 Poster A

Magneto-optical investigation of strain induced magnetization switching in ferromagnetic/ferroelectric hybrid structures — •Matthias Brasse[1,2], Andreas Brandlmaier[1], Matthias Opel[1], Georg Woltersdorf[3], Rudolf Gross[1], and Sebastian T. B. Goennenwein[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching — [2]Lehrstuhl für Physik funktionaler Schichtsysteme, Physik Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching — [3]Universität Regensburg, 93040 Regensburg

We report on the investigation of multiferroic hybrid structures, which are promising for the electric field control of the magnetization orientation. The hybrid structures consist of a ferromagnetic thin film evaporated onto a commercially available piezoelectric actuator. Making use of the piezoelectric and the magnetoelastic effect allows to control the magnetization orientation by means of the voltage applied to the piezoelectric actuator.

Spatially resolved magneto-optical Kerr effect measurements were employed to study the magnetization orientation as a function of the applied strain. Using an appropriate measurement sequence, we could demonstrate the switching of the magnetization between two distinct orientations at constant external magnetic field. We also studied local magnetization switching in the hybrid structures. Our results show, that an electric field control of ferromagnetism is possible via the elastic channel both on macroscopic as well as on microscopic scales.

This work was supported by the DFG via Go 944/3.

MA 10.26 Tue 10:45 Poster A

Giant magnetic anisotropy changes in Sr_2CrReO_6 thin films on $BaTiO_3$ — •Franz D. Czeschka, Stephan Geprägs, Matthias Opel, Sebastian T.B. Goennenwein, and Rudolf Gross — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

The integration of ferromagnetic and ferroelectric materials into hybrid heterostructures leads to systems with improved or even novel functionality. We here discuss the properties of the ferromagnetic double perovskite Sr_2CrReO_6, deposited as a thin film onto ferroelectric $BaTiO_3$ single crystal substrates via pulsed laser deposition. High resolution x-ray diffraction evidences the high crystalline quality of the epitaxial Sr_2CrReO_6 layers. Temperature dependent electrical transport and SQUID measurements show abrupt changes both in resistivity and magnetization at the temperatures of the $BaTiO_3$ phase transitions. Furthermore, the coercive field abruptly changes by more than 1.2 T at the $BaTiO_3$ phase transitions. These observations reveal a giant change of the magnetic anisotropy in the Sr_2CrReO_6 thin film associated with the crystalline phase transitions of the substrate. We attribute these effects to the high sensitivity of the double perovskites to mechanical deformation.

Financial support by the DFG via SPP 1157 and 1285, GO 944/3 and the Excellence Cluster "Nanoinitiative Munich" is greatfully acknowledged.

F. Czeschka et al., Appl. Phys. Lett. **95**, 062508 (2009)

MA 10.27 Tue 10:45 Poster A

Dynamics of driven multiferroic heterostructures — •Alexander Sukhov[1], Chenglong Jia[1], Paul Horley[2], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Str. 4, 06120 Halle/Saale, Germany — [2]Centro de Fisica das Interaccoes Fundametais Instituto Superior Tecnico, Av. Rovisco Pais, 1049-001 Lisboa, Portugal

We study theoretically a ferromagnet (FM) coupled to a ferroelectric (FE) material via a multiferroic coupling. The magnetization dy-

namics in the ferromagnetic part is described in a standard way via the Landau-Lifshitz-Gilbert equation at finite temperatures with a dynamical driving term arising from the multiferroic coupling. Hence, an electric field that acts on the electric polarization triggers a magnetization dynamics. The ferroelectric dynamics is considered in the framework of the Landau theory of phase transitions and is governed by the Landau-Kholmogorov equation [1] augmented with a dynamical part that stems from the coupling to the ferromagnet, i.e. a magnetic field affects the polarization dynamics. We inspect how the nature of the multiferroic coupling, e.g. [2], is manifested in the time evolution of the order parameters.

[1] D. Ricinschi, C. Harnagea, C. Papusoi, L. Mitoseriu, V. Tura and M. Okuyama, J. Phys.: Condens. Matter 10, 477 (1998); [2] T. Cai, S. Ju, J. Lee, N. Sai, A. A. Demkov, Q. Niu, Z. Li, J. Shi and E. Wang, Phys. Rev. B 80, 140415(R) (2009).

MA 10.28 Tue 10:45 Poster A

Thermomechanical properties of mullite up to 1673 K: single crystal vs. ceramics — •Thomas Friedrich Krenzel[1], Jürgen Schreuer[1], and Hartmut Schneider[2] — [1]Ruhr University Bochum, Institute of Geology, Mineralogy and Geophysics, Bochum, Germany — [2]University of Cologne, Institute of Crystallography, Köln, Germany

This poster has been moved to MM 26.10.

MA 10.29 Tue 10:45 Poster A

Exchange Bias and Training Effect in Ni/Fe_xMn_{1-x}/Ni Trilayers — •Paul Stoll, Miriam Stampe, and Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

We have investigated ultrathin single-crystalline Ni/Fe_xMn_{1-x}/Ni/Cu(001) trilayers with out-of-plane magnetization. These trilayers show exchange bias due to the interface coupling between the ferromagnetic (FM) Ni and the antiferromagnetic (AFM) FeMn layers as well as ferromagnetic interlayer coupling between the two FM layers. Hysteresis loops for samples with different FM and AFM layer thickness and FeMn composition have been measured at different temperatures and for opposite cooling fields using polar magneto-optical Kerr effect (MOKE). The hysteresis curves show a two-step magnetization reversal with the coercivities clearly attributed to the switching fields of the two FM layers. In the minor loops unidirectional anisotropy as well as a training effect have been observed.

Financial support by the DFG (KU1115/9-1) is acknowledged.

MA 10.30 Tue 10:45 Poster A

Relative orientation of the magnetic moments in the Fe/MnPd exchange bias system — •S. Brück[1,3], S. Macke[1], X. Ji[2], Q. Zhan[2], K. M. Krishnan[2], and E. Goering[1] — [1]Max-Planck-Institut für Metallforschung, Stuttgart, Germany — [2]Department of Materials Science and Engineering, University of Washington, Seattle, USA — [3]Physikalisches Institut, Universität Würzburg, Würzburg, Germany

Recent soft X-ray resonant magnetic reflectometry (XRMR) investigations of a Fe/MnPd exchange bias system have revealed a complex magnetic configuration at the ferromagnet (F)/antiferromagnet (AF) interface in the system[1]. The existence of a considerable amount of rotatable uncompensated magnetic moments in the antiferromagnet as well as the confinement of pinned uncompensated moments to the F|AF interface was shown. Precise knowledge of the location and relative orientations of all kinds of magnetic moments at the F|AF interface is a necessary prerequisite for the development of new models for the description of exchange bias. We show how by comparing the signs and magnitudes of the absorptive part of the index of refraction, it is possible to determine the relative coupling directions in the system. It is found that rotatable Mn and the ferromagnetic Fe couple antiparallel. The pinned Mn moments are oriented antiparallel to the neighboring rotatable Mn and parallel with respect to the Fe during the field cooling process.

[1] S. Brück, G. Schütz, E. Goering, X. Ji, and K. M. Krishnan, Phys. Rev. Lett. 101, 126402-4 (2008).

MA 10.31 Tue 10:45 Poster A

Investigation of exchange bias field of NiMn pinned Co nanoparticles — •Balati Kuerbanjiang, Benjamin Riedmüller, and Ulrich Herr — Institut für Mikro- und Nanomaterialien, Universität Ulm, 89081, Ulm, Germany

Co nanoparticles deposited on a sputtered NiMn layer have been studied for the purpose of the exchange bias field. About 30 nm of NiMn layer was deposited on Si substrate by magnetron sputtering, then Co nanoparticles were deposited in situ on the NiMn layer using inert gas condensation technique. Samples were subsequently covered by about 5 nm of Cu in order to prevent oxidation of particles in air. Chemical states and compositions of the samples were examined by XPS inside the UHV system. Ex situ annealing has been carried out to achieve the antiferromagnetic NiMn phase at 350 °C for 10 min, in an applied field of 350 Oe. Annealing was performed under vacuum to avoid degradation of the magnetic properties. The phase transformation of the NiMn was investigated by X-ray diffraction. The size and the coverage of Co nanoparticles has been determined by AFM and SEM. The influence of the magnetic interaction between NiMn AFM layer and the FM Co particles of different sizes and densities was studied using vibrating sample magnetometry (VSM), magneto-optical Kerr effect (MOKE) and magnetic force microscopy (MFM).

MA 10.32 Tue 10:45 Poster A

Long and short term changes of the exchange bias field in MnIr/CoFe bilayers after ion bombardment with 10keV He ions — •Christoph Schmidt, Jörn Burbank, Niklas Stein, Tanja Weis, Dieter Engel, and Arno Ehresmann — Department of Physics, University of Kassel, Heinrich-Plett-Str.40, D-34132 Kassel

The stability and time dependence of the exchange bias (EB) field after 10 keV He^+ ion bombardment (IB) were studied. The long term measurements were done ex-situ in a time window between half an hour and several weeks after IB and the short term measurements in-situ between a few seconds and half an hour after IB. The following changes were observed: (i) the long term changes have a logarithmic behaviour of the EB field to larger values while (ii) the short term investigations show an exponential decrease of the EB field and a relaxation back to its origin direction of the unidirectional anisotropy. The two different behaviours depend on the time scale of the measurements after IB.

MA 10.33 Tue 10:45 Poster A

Remote control of superparamagnetic nanobeads on magnetically patterned thin films — •Daniel Lengemann, Tanja Weis, Alla Albrecht, Jannick Langfahl-Klabes, Dieter Engel, and Arno Ehresmann — University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

He-ion bombardment were used to get a periodic magnetic patterning with alternating anisotropy directions in exchange biased MnIr/CoFe thin layers. In remanence superparamagnetic nanobeads were located at the domain walls where the strong stray fields reach their maximum. Within an external inhomogeneous magnetic field it is possible to saturate the sample, i.e. the periodic magnetic patterning and therewith the stray fields vanish and the nanobeads can follow the gradient of the field. This mechanism allows a controlled movement of the nanobeads. First results are shown.

MA 10.34 Tue 10:45 Poster A

Coercivity mechanism in hard magnetic $SmCo_5$/$PrCo_5$ bilayers — •Felix Fleischhauer, Volker Neu, and Ludwig Schultz — IFW Dresden, Institute of Metallic Materials, 01069 Dresden, Germany

The evolution of the coercivity in hard magnetic $SmCo_5$/$PrCo_5$ bilayers shows a non-trivial dependence on the relative sublayer thickness and the stacking order.

These dependencies have been studied for bilayers with 40 nm overall thickness. They were epitaxially grown on Cr buffered MgO(110) substrates using pulsed laser deposition technique. Temperature dependent coercivity was measured in the range from 200 K to 400 K along with the magnetic relaxation at room temperature. The results are discussed within the framework of several pinning concepts.

MA 10.35 Tue 10:45 Poster A

Single or multichannel Kondo effect in graphene — •Zhen-Gang Zhu[1], Kai-He Ding[2], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther Universität Halle-Wittenberg, Heinrich-Damerow-Straße 4 06120 Halle, Germany — [2]Department of Physics and Electronic Science, Changsha University of Science and Technology, Changsha 410076, China

Dynamic screening in a Kondo system may compensate or over compensate for the localized magnetic moment signifying respectively a Fermi or a non-Fermi liquid ground state. The former (latter) case

occurs in one (two) channel Kondo effect with a magnetic impurity having spin 1/2. We investigate this issue in graphene starting from the tight-binding Anderson model. Schrieffer-Wolff transformation is performed to derive the Kondo model. To verify our findings, we also conduct direct computations by considering the two-body interaction explicitly. At last, the Kondo temperature is calculated from Anderson model in the large U limit. We find: i) for nearest neighbor hopping, a two-channel Kondo character is present when the impurity is symmetrically coupled to the A and B sublattice; otherwise a single channel Kondo is realized. ii) The exchange interaction coefficient for one channel is vanishing when the spin is symmetrically coupled to the spanned sublattice to this channel in absence of a gate voltage. However it is finite in the presence of a gate voltage. iii) The degeneracy of the two Dirac points leads only to a higher Kondo temperature which is increasing exponentially with increasing gate voltage. We point out the experimental feasibility by varying a gate voltage.

MA 10.36 Tue 10:45 Poster A

Magnetotransport measurements on Heusler compounds — •A. Krupp[1], F.D. Czeschka[1], M. Althammer[1], S.T.B. Goennenwein[1], R. Gross[1], I.-M. Imort[2], G. Reiss[2], and A. Thomas[2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Fakultät für Physik, Universität Bielefeld, Bielefeld, Germany

Magnetic anisotropy (MA) is of fundamental importance in ferromagnets, as it strongly influences their properties. Using magnetotransport measurements, we investigate the MA of the Heusler compound Co_2FeAl. A 20 nm thick Co_2FeAl film on (001)-oriented MgO substrate was patterned into Hall-bar mesa structures with optical lithography and etching. The anisotropic magnetoresistance (AMR) is then measured with the external magnetic field applied in the film plane. The measured longitudinal and transverse resistance show a clear field dependence with distinct steps at small external magnetic fields ($\mu_0 H$), indicating abrupt switching of the magnetization orientation. To quantify the MA, we record the angle dependent magnetoresistance (ADMR), i.e. the MR as a function of *H-orientation* for different magnetic field magnitudes $|H|$. From the ADMR data taken at high $|H|$, AMR coefficients are obtained. The MA is then extracted from ADMR at lower $|H|$. We obtain a cubic MA field of around $\mu_0 H_{\mathrm{cub}}$=5 mT and an uniaxial MA field of around $\mu_0 H_{\mathrm{uni}}$=1 mT. We also discuss the evolution of MA with temperature and compare our results to literature.

MA 10.37 Tue 10:45 Poster A

Anomalous Hall Effect in Heusler Compounds — •I.-M. Imort[1], G. Reiss[1], A. Thomas[1], A. Krupp[2], F.D. Czeschka[2], M. Althammer[2], R. Gross[2], and S.T.B. Goennenwein[2] — [1]Fakultät für Physik, Universität Bielefeld, Bielefeld, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

The anomalous Hall Effect (AHE) is a fundamental but still controversially discussed phenomenon in ferromagnets. Furthermore, it is a volatile characterization tool for magnetic materials. We here report on our magnetotransport experiments and the AHE in the Heusler compound Co_2FeAl. Using rf-magnetron sputtering, 20 nm thick Co_2FeAl thin films were grown on single-crystal MgO(001) substrates. Before patterning into 80μm wide Hall bars, some of the samples were annealed at different temperatures. The Hall resistivity ρ_{xy} and the magnetoresistivity ρ_{xx} were measured simultaneously over a temperature range of 3 to 300 K and a magnetic field range of $|14|$ T. For low magnetic fields $\mu_0 H$, ρ_{xx} exhibits typical anisotropic magnetoresistance features, with resistance jumps and a non-linear dependence on H. This behaviour abruptly changes at higher fields: for $\mu_0 H \geq 1.6$ T, ρ_{xx} scales strictly linearly with H. In contrast, the Hall resistivity always is proportional to $|H|$, but the slope of ρ_{xy} abruptly changes sign at $\mu_0 H \approx 1.6$ T. We will discuss the impact of temperature, surface roughness and annealing temperature on the magnetotransport properties and compare our results to the literature.

MA 10.38 Tue 10:45 Poster A

Annealing time and temperature dependence of structural, magnetic and transport properties of Co2MnSi-based MTJs — •Hendrik Wulfmeier, Markus Meinert, Daniel Ebke, Jan Schmalhorst, and Günter Reiss — Bielefeld University, Thin Films and Physics of Nanostructures, Department of Physics, Universitätsstr. 25, D-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.

Optimization of MTJ-stacks where at least one electrode is built of a Heusler-alloy has been topic of many studies in recent time.

In order to enhance the level of crystallinity post-annealing is very successful. In general this effect is limited by interdiffusion processes at the interfaces of the individual layers. Crystallization and interdiffusion are both time- and temperature-dependent processes.

In our study we investigated not only the effect of different annealing temperatures but also the influence of different annealing times on the crystal structure and on the electronic properties. We prepared half (Co2MnSi | MgO) and full (Co2MnSi | MgO | CoFe | MnIr) MTJs on MgO[001]-substrates by sputter deposition and used x-ray diffractometry, MOKE and standard transport measurements for characterization.

The comparison of the experimental results (structural, magnetic and transport properties) will be discussed.

MA 10.39 Tue 10:45 Poster A

Magnetic transport measurements of epitaxial $SmCo_5$ in pulsed magnetic fields — •Evelyn Stilp, Alexander Kauffmann, Marietta Seifert, Jens Freudenberger, Volker Neu, Nadejda Kozlova, and Ludwig Schultz — IFW Dresden, Institute for Metallic Materials, Helmholtzstr. 20, 01069 Dresden, Germany

$SmCo_5$ is a hard ferromagnetic material with a high Curie temperature around 800°C and a high coercivity of 3T. With the help of a Quantum Design PPMS vibrating sample magnetometer magnetic properties were already measured. Hence an anisotropy field of 28T was calculated [1]. The epitaxial $SmCo_5$ thin films were prepared by pulsed laser deposition on Cr buffered MgO(110) [2]. Hall measurements of $SmCo_5$ thin films will be presented.

[1] A. Singh *et al.*, Phys. Rev. B 77, 104443 (2008)
[2] A. Singh and V. Neu *et al.*, J. Appl. Phys. 99, 08E917 (2006)

MA 10.40 Tue 10:45 Poster A

Epitaxial $NdCo_5$/$SmCo_5$ bilayers — •Marietta Seifert, Ludwig Schultz, and Volker Neu — IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany

$RECo_5$ magnets are of interest due to their strong magnetocrystalline anisotropies, which in some cases change with temperature. This work presents epitaxial $NdCo_5$/$SmCo_5$ bilayers, in which $NdCo_5$ undergoes a spin reorientation transition from easy axis along the *c*-axis above 310 K to easy plane below 255 K while $SmCo_5$ keeps the uniaxial anisotropy in the whole temperature range. The films were prepared on Cr buffered MgO(110) substrates resulting in a growth of the $RECo_5$ with a single orientation of the *c*-axis parallel to the film plane. In a first step, the magnetic behavior of single $NdCo_5$ thin films have been investigated and it was found that they possess intrinsic magnetic properties and especially a spin reorientation transition in good agreement with single crystal data. To analyze the magnetic coupling of the bilayer system, a series with a fixed thickness of the $SmCo_5$ layer and a varying thickness of the $NdCo_5$ have been prepared. Phase formation and texture were controlled with XRD and texture measurements. The magnetic properties in a temperature range between 20 and 400 K have been measured with Vibrating Sample Magnetometry.

MA 10.41 Tue 10:45 Poster A

Remanence enhancement and energy density in epitaxial exchange-coupled $SmCo_5$/Fe-Multilayers — •Simon Sawatzki, Felix Fleischhauer, Marietta Seifert, Ludwig Schultz, and Volker Neu — IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01071 Dresden, Germany

Exchange-coupled $SmCo_5$/Fe-multilayers have been epitaxially grown by pulsed laser deposition on Cr covered MgO(110) substrates, such that one single in-plane easy axis of the highly anisotropic $SmCo_5$ phase is realized through the whole layer stack. The phase formation and texture was confirmed by Bragg-Brentano X-ray diffraction and pole figure measurements. The magnetic properties were characterized by vibrating sample magnetometry. In order to maximize the energy density $(BH)_{\mathrm{max}}$, as a key property for permanent magnet application, two series of samples were investigated. First, trilayers of $SmCo_5$/Fe/$SmCo_5$ with fixed $SmCo_5$ layer thickness (25 nm) and varying soft magnetic Fe film thickness have been prepared to analyze the impact of the Fe-volume fraction on remanence enhancement and coupling. In the second series $SmCo_5$/Fe alternating multilayer with constant Fe-volume fraction but reduzed single layer thickness were examined.

MA 10.42 Tue 10:45 Poster A

Epitaxial $NbFe_2$ thin films prepared by PLD — •Andreas Reisner, Silvia Haindl, Bernhard Holzapfel, and Ludwig Schultz — IFW Dresden, Institute of Metallic Materials, 01069 Dresden, Germany

The hexagonal Laves phase $NbFe_2$ shows an interesting itinerant magnetic behaviour whose ferromagnetic transition at low temperatures is strongly dependent on the stochiometry.

We report on successful preparation of epitaxial thin films grown on single crystalline Al_2O_3 (001) substrates by an UHV pulsed laser deposition process. Structural investigation show a twofold epitaxial relation of $Al_2O_3(001)[100]||NbFe_2(001)[100]$ and $Al_2O_3(001)[100]||NbFe_2(001)[210]$. Magnetic and transport properties of films with various compositions near the stochiometric point have been investigated.

MA 10.43 Tue 10:45 Poster A

In-Situ STM, LEED and MOKE Measurements of Ultrathin Epitaxially Flat Grown Fe Films on the GaAs(110) Surface — •Tim Iffländer, Martin Wenderoth, Thomas Druga, and Rainer G. Ulbrich — IV. Physikalisches Institut, Georg-August-Universität Göttingen

Fe films of up to 8 ML thickness were deposited on cleaved n-, p- and i-GaAs(110) in a two-step process combining low-temperature deposition at 130 K with a subsequent annealing to room temperature. Low-energy electron diffraction and scanning tunnelling microscopy suggest an abrupt interface without any considerable amount of compound formation and a flat continuous morphology with height variations in the monolayer range.

In-situ longitudinal magneto-optical Kerr effect measurements at RT were conducted for different in-plane orientations of the applied magnetic field with respect to the sample. In contrast to RT grown Fe films of 2-3 ML thickness, the easy and hard axes are interchanged, now parallel to the [001] and [110] directions, respectively. The hysteresis loop of films thicker than or equal to 5 ML is equivalent to magnetization curves observed in the case of RT grown films.

This work was supported by the SFB 602 TP A7.

MA 10.44 Tue 10:45 Poster A

Magnetic and structural investigations of iron based nanostructures and thin CrSb layers on GaAs(110) — •Carsten Godde, Sani Noor, Atena Rastgoo Lahrood, Gregor Nowak, Hartmut Zabel, and Ulrich Köhler — Institut für Experimentalphysik IV, Ruhr-Universität Bochum, Germany

In this contribution we present structural and magnetic measurements of the two different systems, Fe and CrSb layers on the GaAs(110) surfaces.

We investigate the growth of Fe on the GaAs(110) surface at different coverages and annealing temperatures by STM and MOKE and show that the structure remains ferromagnetic up to 500°C in combination with lateral structuring on the nanometer scale. These nanostructures consist exclusively of roof-shaped 3D-islands elongated along the $[1\bar{1}0]$-direction of the GaAs(110) substrate. An intermixing of the Fe film and the substrate material induced by the annealing step leads to a ternary alloy $Fe_3Ga_{2-x}As_x$ which is confirmed by X-ray diffraction measurements. Despite of this alloying it should be noted that the magnetic measurements of the nanostructures still show ferromagnetic characteristics.

Thin CrSb layers grow in the zinc blende structure and contrary to the Fe system they keep their ferromagnetic properties and structural stability up to very high annealing temperatures which is interesting for enabling better crystalline quality. In this context the CrSb layers were characterised by STM, LEED and SQUID magnetometry at different coverages and annealing temperatures.

MA 10.45 Tue 10:45 Poster A

Structural and magnetic investigations of Fe and Fe_3Si as CEO-grown spin aligning layers on spin LEDs — •Sani Noor[1], Carsten Godde[1], Hasmik Harutyunyan[1], Arne Ludwig[2], Mingyuan Li[3], Gregor Nowak[1], Dirk Reuter[2], Martin Hofmann[3], Hartmut Zabel[1], Andreas Wieck[2], and Ulrich Köhler[1] — [1]Experimentalphysik IV, Ruhr-Universität Bochum — [2]Angewandte Festkörperphysik, Ruhr-Universität Bochum — [3]Photonik und Terahertztechnologie, Ruhr-Universität Bochum

We focus on the the structural and magnetic properties of Fe and Fe/MgO as spin injection layers on the GaAs(110) cleaved edge of spin LEDs. Within the scope of our work, we have developed an in situ process to cleave the sample within a μm range of the designated edge and deposit the layers. We show a MOKE study of the magnetization behaviour in the case of Fe which forms a Schottky barrier on n-GaAs and Fe with an MgO interlayer as a tunnelling barrier as a function of the layer thickness. STM images of Fe grown on μm-wide terraces of the cleaved GaAs(110) surface are also presented. Finally, we discuss the results of electroluminescence measurements to determine the efficiency of spin injection across the cleaved edge.

We furthermore present an STM growth study of Fe_3Si/GaAs which as a Heusler alloy is also a possible candidate as a spin aligner. In contrast to Fe/GaAs we find layer-by-layer growth even above RT. Epitaxial and stoichiometrical quality has been confirmed by XRD and LEED. Our angular dependent in situ MOKE measurements show that the Fe_3Si/GaAs(001) system exhibits only a weak magnetic anisotropy.

MA 10.46 Tue 10:45 Poster A

Threshold photoemission magnetic circular dichroism at the spin reorientation transition of ultrathin epitaxial Pt/Co/Pt(111)/W(110) films — •Kerstin Hild, Jakob Emmel, Gerd Schönhense, and Hans-Joachim Elmers — Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

We report on the thickness dependence of threshold photoemission magnetic circular dichroism (TPMCD [1]) in one-and two-photon photoemission (1PPE and 2PPE) for a Pt-capped ultrathin Co wedge grown on Pt(111)/W(110) using femtosecond laser light. TPMCD measurements result in asymmetries continuously increasing with the sample thickness. This indicates that the TPMCD asymmetry is dominantly influenced by the Co bulk properties. At 5 monolayers (ML) asymmetry values of 0.07 % for 1PPE and 0.11 % for 2PPE are derived. The spin reorientation transition is detected at a Co thickness of 5.5 ML. For the perpendicularly saturated sample the TPMCD does not depend on the orientation of the easy axis. The comparison of the 2PPE TPMCD asymmetries with measured Kerr ellipticities in the framework of the Jones formalism reveals considerable differences between both quantities.

Funded by DFG (EL 172/15-1), the Carl-Zeiss-Stiftung and the Graduate School of Excellence MAINZ (Kerstin Hild). [1] K. Hild et al., J. Phys.: Condens. Matter 20, 235218 (2008).

MA 10.47 Tue 10:45 Poster A

Magnetization reversal and reorientation in $DyCo_5$ systems — •Radu Abrudan[1], Ilie Radu[2], Detlef Schmitz[3], Hartmut Zabel[1], and Florin Radu[3] — [1]Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Institute for Molecules and Materials, Radboud University Nijmegen, 6525 ED Nijmegen, The Netherlands — [3]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin, Germany

$DyCo_5$ is a ferrimagnet which develops a compensation point (CP) at low temperatures where the magnetic structure switches 180 degrees, a spin reorientation (SR) point at a temperature higher then room temperature, where the magnetisation axis of Dy and Co drops in plane, parallel to the substrate.

We present a systematic study of sputter deposited $DyCo_5$ thin films using XMCD technique in a transmission geometry. The spin and orbital magnetic moments of Co and Dy exhibit a monotonous temperature dependence. The ferrimagnetic alignment between the Dy and Co moments is preserved across both phase transitions, occurring at the spin reorientation (T_{SR} ∼350 K) and at the compensation (T_{CP} ∼120K) temperatures, respectively. Notably, the magnetic crystalline anisotropy changes orientation from in-plane at high temperatures to out-of-plane below T_{SR}. At T_{CP} the coercive field is strongly enhanced, diverging in size due to the reduced averaged magnetization specific to ferrimagnetic systems. Moreover, the orientation of the magnetic moments of Dy and Co reverses sign when crossing the T_{CP}.

MA 10.48 Tue 10:45 Poster A

Transition from shape anisotropy to magnetocrystalline anisotropy in ultrathin FePt films — •Karin Leistner, Juliane Wunderwald, Sebastian Fähler, and Ludwig Schultz — IFW Dresden, Dresden, Germany

FePt films have recently attracted great interest as possible media for perpendicular magnetic recording, but also for fundamental studies of magnetism in reduced dimensions. As FePt it is very corrosion resistant it is ideal for ultrathin films, however, L10 ordering and thus high magnetocrystalline anisotropy are harder to achieve at small par-

ticle size. In the present study, 2 nm thick FePt films have been deposited by pulsed laser deposition on MgO(001) with a Cr/Pt buffer. The magnetic properties have been obtained by Hall measurements and measurements of the Kerr rotation. Without post annealing, the out-of-plane (op) hysteresis is controlled by shape anisotropy with an anisotropy field of 1.4 T. The easy axis lies in-plane and in the op hysteresis curve rotation of magnetization is observed. This is as expected for smooth ultrathin disordered FePt films. When post annealing is applied, a continuous decrease of the effective in-plane anisotropy field is observed with increased annealing time. After a post annealing time of 15 min, the easy axis lies op and the op hysteresis shows switching of magnetization and a larger coercivity. The reason is that ordering in the (001)-textured films leads to an increased magnetocrystalline anisotropy in the op direction that competes with shape anisotropy. Thus, in these ultrathin FePt films anisotropy can be continuously adjusted from pure shape anisotropy to magnetocrystalline anisotropy.

MA 10.49 Tue 10:45 Poster A

Design and preparation of substrates with perpendicular magnetic anisotropy for molecular magnets — •Jonathan Fetting[1], Jan-Philipp Grote[1], Michael Stocker[2], Michael Enzelsberger[2], Veronika Höke[3], Carl-Georg Frhr. v. Richthofen[3], Paul Müller[2], Thorsten Glaser[3], and Günter Reiss[1] — [1]Bielefeld University, Department of Thin Films and Physics of Nanostructures, Universitätsstr. 25, 33615 Bielefeld — [2]University Erlangen-Nürnberg Physikalisches Institut III, Erwin-Rommel-Str. 1, 91058 Erlangen — [3]Bielefeld University, Department of Inorganic Chemistry, Universitätsstr. 25, 33615 Bielefeld

In spintronics thin films with out of plane magnetization are highly desirable for, e.g., electrodes in tunnelling cells or substrates for molecular magnets. The goal of our work is to be able to define desired film properties and to tailor the thin films correspondingly. For our approach we have chosen $[CoPd]_X$ as hard magnetic and $[CoAu]_X$ as soft magnetic multilayers. Mixing those multilayer systems gives the possibility to design the material properties. The multilayer systems have been prepared using sputter deposition techniques and the resulting thin films have been investigated with AGM, STM and MFM. The measurements give an insight into the structural and magnetic properties of the tailored samples and improve the ability to property design.

MA 10.50 Tue 10:45 Poster A

Imaging of magnetic coupling in trilayerd microstructures — •Julia Kurde[1], Jorge Miguel[1], Daniela Bayer[2], Jaime Sánchez-Barriga[3], Logane Tati Bismaths[3], Martin Aeschlimann[2], Hermann A. Dürr[3], and Wolfgang Kuch[1] — [1]Freie Universität Berlin — [2]Technische Universität Kaiserslautern — [3]Helmholtz-Zentrum Berlin für Materialien und Energie

Magnetic properties of microstructures consisting of either an FeNi single layer or an FeNi/Cu/Co trilayered system were investigated by means of photoelectron emission microscopy. We performed stroboscopic pump-probe experiments to determine the precession frequencies and the effective field of the FeNi layer. From the comparison of these measurements to micromagnetic simulations, the coupling field in the trilayered systems could be extracted. This information can then be used to explain the observed domain wall (DW) configurations in the FeNi layer. The parallel coupling of the two magnetic layers via the non-magnetic spacer layer is dominated by Néel coupling. However, the strong stray field of the DWs in the Co layer forces the magnetization to align antiparallel in the two layers, and so to turn with opposite sense of rotation from domain to domain. In 180° walls, a left turn is symmetric to a right turn, but in 90° walls of the Co layer, this will lead to a 270° turn of the magnetization in the FeNi layer. Although this case is highly unfavorable with respect to the exchange interaction within the FeNi layer, it still occurs if the Cu spacer layer reduces sufficiently the Néel coupling to the Co layer.

This work has been supported by the BMBF 05 KS7 KE2

MA 10.51 Tue 10:45 Poster A

Magnetostrictive Strain Sensors Based on FeGa Thin Films — •Ahmed Fazir Thajudin, Dirk Meyners, and Eckhard Quandt — Chair for Inorganic Functional Materials, Institute for Materials Science, Faculty of Engineering, University of Kiel, Kaiserstr. 2, 24143 Kiel, Germany

Tunneling magnetoresistance junctions generally possess a symmetrical characteristic which reflects the switching fields of the soft and hard layers, respectively. This characteristic can be changed by a stress field if the soft magnetic layer is replaced by a suitable magnetostrictive layer. Application of mechanical stress results in a stress induced rotation of the magnetostrictive layer with respect to the reference layer accompanied by a resistance change due to the magnetoresistance effect. Highly sensitive strain sensors with CoFeB electrodes based on this concept were developed recently [1]. Further increase of sensitivity is expected by the introduction of highly magnetostrictive FeGa layers. The magnetic and magnetostrictive properties of magnetron sputtered FeGa thin films are discussed. Moreover, tunneling magnetoresistance stacks with FeGa sensing layers were prepared, patterned by optical lithography and investigated with respect to microstructure, effect amplitude and magnetic switching behavior.

[1] D. Meyners, T. von Hofe, M. Vieth, M. Rührig, S. Schmitt, and E. Quandt, J. Appl. Phys. 105, 07C914, 2009

MA 10.52 Tue 10:45 Poster A

Influence of strain on magnetic and electrical properties of La0.82Sr0.18CoO3 films — •Orkidia Bilani-Zeneli, Diana Rata, Andreas Herklotz, Ludwig Schultz, and Kathrin Dörr — IFW Dresden, Institute for Metallic Materials, Helmholtzstrasse 20, 01069 Dresden, Germany

Cobaltite perovskites La(1-x)Sr(x)CoO3 have received attention mainly due to the thermally driven spin state transitions of the Co ions. For different doping, these transitions have been shown to be sensitive towards pressure in bulk and epitaxial strain in thin films. La(1-x)Sr(x)CoO3 with x=0.18 is of particular interest because it is located near the boundary of the Metal-Insulator transition. We have grown epitaxial La0.82Sr0.18CoO3 (LSCO) thin films by pulsed laser deposition on different substrates (PMN-PT, LaAlO3, SrTiO3, LSAT) providing reversible and static strain. In this work the influence of biaxial strain on the magnetic and electrical transport properties of LSCO films will be presented. Thin films reveal significant differences in magnetic behaviour with respect to bulk, e.g. the coercive fields are strongly enhanced. On the other hand tensile strain strongly suppresses the electrical conduction stabilizing thus an insulator state.

MA 10.53 Tue 10:45 Poster A

Specular and off-specular scattering of neutrons from Si-Fe multilayers — •Anke Teichert, Thomas Krist, Jan E. Hoffmann, Amitesh Paul, and Roland Steitz — Helmholtz Zentrum Berlin, Hahn-Meitner-Platz 1, 14109 Berlin, Germany

Multilayers (ML) are used as neutron optical devices. These applications require high quality MLs with low interface layer thickness, roughness and high remanence as characterized by a high reflectivity and high polarization efficiency. Here, we want to produce high quality stress-free Si-Fe MLs on Si and glass substrate. All samples (10(10nm Si+10nm Fe)+10nm Si) were produced in a triode sputter machine at p=0.065Pa and Bias voltages from 10 to 65V. Stress and reflectivity measurements were performed at a profilometer and X-ray reflectometer (XRR). Using polarized neutron reflectometry (PNR) and a positive sensitive detector (PSD) at the reflectometer V6 we measured simultaneously specular and off-specular scattering of neutrons. We find a raise in voltage leads to linear decrease of tensile stress with a slope of 5.5MPa/V. At about 60V the samples are nearly stress-free. The grain size decreased with higher Bias voltage. The off-specular data show large diffuse scattering from all samples at low applied magnetic fields (200G, 20G) as well as for samples with high compressive stress at 1030G. It appears as streaks perpendicular to specular reflectivity at Bragg peak positions. They can be interpreted as originating from vertically correlated in-plane magnetic domains. Associated longitudinal fluctuations produce additional diffuse streaks along Bragg peak positions which are independent of the stress within the samples.

MA 10.54 Tue 10:45 Poster A

Soft x-ray magnetic dichroism of undoped, hole-doped and electron-doped $LaCoO_3$: Anisotropies and valence-dependent magnetism — •Michael Merz[1], Christian Pinta[1,2], Andrei Samartsev[1,2], Markus Wissinger[1,2], Hilbert von Löhneysen[1,2], Andrea Assmann[1,2], Stephan Uebe[1,2], Dirk Fuchs[1], Peter Nagel[1], and Stefan Schuppler[1] — [1]Karlsruhe Institute of Technology, Institut für Festkörperphysik, Germany — [2]Karlsruhe Institute of Technology, Physikalisches Institut, Germany

Epitaxial thin films of undoped $LaCoO_3$, of electron-doped $(La,Ce)CoO_3$, and of hole-doped $(La,Sr)CoO_3$ exhibit ferromagnetic order with optimum transition temperatures of 80 K, 30 K, and 240 K, respectively. The spin-state structure for these compounds was stud-

ied by soft x-ray absorption and magnetic circular dichroism at the Co $L_{2,3}$ and O K edges. It turns out that for epitaxial $LaCoO_3$, strain imposed by the substrate preserves a higher spin state of the Co^{3+} ions at low temperature and prevents a non-magnetic ground state. For (La,Ce)CoO_3, the Co^{3+} ions are predominantly in a low-spin (S = 0) state and thus magnetically inactive, and the ferromagnetism is determined by the Co^{2+} species. For (La,Sr)CoO_3, on the other hand, the magnetism originates from higher spin states of Co^{3+} (S = 2) and Co^{4+} (S = 3/2) ions. The data show that ferromagnetism has a different origin in $LaCoO_3$ (superexchange), (La,Ce)CoO_3 (spin blockade), and (La,Sr)CoO_3 (double exchange). Moreover, a strong magnetic anisotropy is observed for all systems, with the spin and the orbital moments essentially lying within the substrate plane.

MA 10.55 Tue 10:45 Poster A

Soft x-ray magnetic dichroism of (Ca,Sr)RuO_3: Evidence for strain-dependent magnetism — •Andrea Assmann[1,2], Stephan Uebe[1,2], Michael Merz[1], Markus Wissinger[1,2], Hilbert von Löhneysen[1,2], Dirk Fuchs[1], Peter Nagel[1], and Stefan Schuppler[1] — [1]Karlsruhe Institute of Technology, Institut für Festkörperphysik, Germany — [2]Karlsruhe Institute of Technology, Physikalisches Institut, Germany

The 4d transition metal oxide $Ca_{1-x}Sr_xRuO_3$ exhibits ferromagnetic order in the doping range $0.4 \lesssim x \lesssim 1$ while it is a paramagnetic metal for $x \lesssim 0.4$. Since $Ca_{1-x}Sr_xRuO_3$ remains essentially isostructural and has a similar electronic configuration throughout the doping series, the differences in the magnetic properties might be caused by chemical pressure or magnetic dilution. To verify a possible dependence of the magnetic moments on pressure, (Ca,Sr)RuO_3 films were deposited on different substrates (LSAT, STO, $DyScO_3$=DSO), with the lattice mismatch imposing a specific strain on the epitaxial films that increases when going from LSAT to STO and DSO. The magnetic and electronic structure of the strained samples was studied by soft x-ray absorption and magnetic circular dichroism at the Ru $M_{2,3}$ and O K edges. It turns out that at 20 K, the magnetic moments strongly depend on the strain: while the spin moment of samples on LSAT almost vanishes, a distinct moment is found for (Ca,Sr)RuO_3 films deposited on STO and DSO. Furthermore, a significant magnetic anisotropy is observed, with the spin moments mainly oriented perpendicular to the substrate plane. Implications will be discussed.

MA 10.56 Tue 10:45 Poster A

Vector MOKE analysis on ultrathin ferromagnetic films — •Timo Kuschel[1], Hauke Bardenhagen[1], Robin Schubert[1], Henrik Wilkens[1], Daniel Bruns[1], Martin Suendorf[1], Bernd Zimmermann[1], Florian Bertram[2], and Joachim Wollschläger[1] — [1]Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49069 Osnabrück, Germany — [2]HASYLAB at DESY, Notkestr. 85, 22607 Hamburg, Germany

In order to study the magnetic reversal and the magnetic anisotropy of ultrathin ferromagnetic films, Fe layers of different thicknesses are assembled on MgO(001) substrates by Molecular Beam Epitaxy (MBE) under UHV conditions. The films are capped by amorphous silicon to avoid oxidation after leaving the UHV chamber. The structural characterization including X-Ray Reflectivity (XRR) and X-Ray Diffraction (XRD) measurements are performed at HASYLAB (DESY, Hamburg).

The vector MOKE analysis is based on measurements using parallel and perpendicular polarized light as well as external magnetic fields parallel and perpendicular to the incident plane of light to optain the components of the magnetization vector. A self-programmed tool is used for analyzing the magnetization curves and calculating the magnetization vector for the reversal process of different sample directions.

The results reveal a 180° reversal with a domain splitting involved for the external magnetic field parallel to one of the magnetic easy axis of the sample. The data for the magnetic hard axis show a rotation of the magnetization vector into the magnetic easy axis followed by a 90° reversal and subsequent rotation into the magnetic hard axis back.

MA 10.57 Tue 10:45 Poster A

Quadrupol-Magnetometer für breitbandige Magneto-Optische-Kerr-Spektroskopie — •Marc Tesch[1], Markus Gilbert[1], Hans-Christoph Mertins[1], Roman Adam[2], Herbert Feilbach[2] und Claus Michael Schneider[2] — [1]FH Münster, Stegerwaldstr. 39, 48565 Steinfurt — [2]FZ Jülich, IFF-9, 52425 Jülich

Üblicherweise nutzen Polarimetrieexperimente Laserlicht mit wenigen festen Wellenlängen. Die vorgestellte Polarimetrie-Anlage arbeitet mit einer Entladungsbogenlampe im Spektralbereich von 230nm - 1000nm. Sie ermöglicht Messungen des Faraday- und des Kerr-Effekts wobei ein neuartiges mit FeNdB Permanentmagneten arbeitendes Quadrupol-Magnetometer homogene Magnetfelder von bis zu 570mT in longitudinaler oder transversaler Geometrie erzeugt. Eine Wasserkühlung des inzwischen zum Patent angemeldeten Gerätes ist nicht erforderlich, was einen leichteren Einsatz im UHV ermöglicht. Die Funktionalität der Anlage wird anhand von Reflexions- und Polarisationsmessungen an dünnen Co Einfach- und Mehrfachschichtsystemen demonstriert und eine Verstärkung des Kerr-Effektes durch Interferenzeffekte diskutiert.

MA 10.58 Tue 10:45 Poster A

Magnetically Induced Optical Nonlinearity in the Centrosymmetric Ferromagnetic Semiconductor EuO — •Masakazu Matsubara[1], Andreas Schmehl[2], Jochen Mannhart[2], Darrell Schlom[3], and Manfred Fiebig[1] — [1]HISKP, Universität Bonn, Germany — [2]Institut für Physik, Universität Augsburg, Germany — [3]Department of Materials Science and Engineering, Pennsylvania State University, USA

EuO is a magnetic semiconductor, which undergoes a ferromagnetic transition at the Curie temperature (T_C) of 69 K. This material exhibits some extreme properties such as a huge colossal magnetoresistance (CMR) effect, the largest magneto-optical effect for any material, and nearly 100% spin polarization of the charge carriers in the ferromagnetic state. These outstanding properties make EuO a very attractive candidate for the basic and applied science of spintronics.

Here we report about the linear and nonlinear optical properties in epitaxial EuO, into which oxygen vacancies are introduced, grown on a $YAlO_3$ substrate. Even though EuO has a centrosymmetric crystal structure, second-harmonic generation (SHG) was observed below T_C at the two-photon transition energies from the 4f to the 5d states of Eu^{2+}. The results of the temperature and magnetic field dependent measurements suggest a close correlation between SHG and magnetization. The symmetry analysis provides access to the microscopic origin of this magnetically induced SHG signal.

This work was supported by the Alexander von Humboldt Foundation.

MA 10.59 Tue 10:45 Poster A

Interaction of surface acoustic waves with magnetization dynamics — •Rupert Huber[1], Mathias Weiler[2], Sebastian T.B. Goennenwein[2], Sebastian Neusser[1], and Dirk Grundler[1] — [1]Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Str. 1, 85747 Garching b. München, Germany — [2]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Walther-Meissner-Strasse 8, 85748 Garching b. München, Germany

The authors investigate the transmission of surface acoustic waves (SAWs) in the GHz regime through thin ferromagnetic films (FM) deposited on a $LiNbO_3$ substrate. We use e.g. Co and FeCoV. When applying an in-plane magnetic field $\vec{H}$ under different orientations we find characteristic angular dependencies of the SAW's amplitude and phase on $\vec{H}$. We discuss our observation in terms of the magnetic field dependent change of elastic properties of the FM/$LiNbO_3$ hybrid systems. The dependencies are investigated in detail by comparing FeCoV and Co. FeCoV is magnetically isotropic, whereas Co shows a pronounced magnetic anisotropy. We find a significant difference for the SAW transmission characteristics. The work has been supported by the German Excellence Cluster "Nanosystems Initiative Munich".

MA 10.60 Tue 10:45 Poster A

Phenomenology of the magnetic shape memory effect in modulated and non-modulated Ni-Mn-Ga and FePd alloys — •Aristide T. Onisan and Ulrich K. Rössler — IFW Dresden

Large magnetic shape memory effects in ferromagnetic martensites are observed only in modulated phases, but recently such effects are also demonstrated in the non-modulated (NM) phase of Ni-Mn-Ga with tetragonal crystal structure and $c/a > 1$. The modulated structures have been identified with adaptive, ultra-finely twinned martensite structures of the same tetragonal structure [1]. We develop a phenomenological theory of magnetic martensites based on geometric continuum theory of martensites, linear elasticity, and micromagnetism [2]. A cubic to tetragonal martensitic transition underlies the twinned microstructures, and magnetic anisotropy is modelled by easy-axis or easy-plane uniaxial anisotropy with four-fold in-plane anisotropy. Equilibrium phase diagrams for the distribution of crystallographic variants and magnetic domains are calculated in dependence on ex-

ternal magnetic fields and stresses. Applications are presented for the easy-axis system with materials parameters for 5M-type Ni_2MnGa, and for FePd and NM Ni_2MnGa as easy-plane systems. Modulated phases like 5M are constructed by second-order twinning within the concept of adaptive martensites [1]. Their magnetic properties depend on the relation between magnetic exchange length and modulation period.
[1] S. Kaufmann et al., arXiv:0906.5365. [2] A.N. Bogdanov, A. DeSimone, S. Müller, U.K. Rößler, J. Magn. Magn. Mater. 261 (2003) 204-209. Supported by DFG, SPP 1239.

MA 10.61 Tue 10:45 Poster A

Surface structure and electronic properties of epitaxial off-stoichiometric Ni-Mn-Ga films — •Aleksej Laptev[1], Philipp Leicht[1], Mikhail Fonin[1], Yuansu Luo[2], Konrad Samwer[2], Yuriy Dedkov[3], and Martin Weser[3] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen — [3]Fritz-Haber-Institut der Max-Planck-Gesellschaft, 14195 Berlin

Ni_2MnGa alloys have attracted considerable interest due to the large magnetic field-induced strain and their possible applications as microscale actuators or sensors. Upon cooling from the austenite phase a transformation to the martensite phase occurs for these materials. Here we report on the investigation of epitaxial off-stoichiometric Ni-Mn-Ga films grown on MgO substrates by dc-magnetron sputtering. To achieve appropriate surface quality the samples were treated under ultra high vacuum conditions by repeated cycles of sputtering and annealing. The crystal structure changes at the Ni-Mn-Ga (100) surface during the reversible phase transition were followed by LEED. A splitting of the main reflexes due to a longer range ordering of the surface was observed upon cooling. The twin boundary formation together with the modulation of the structure was imaged by high resolution STM in the martensite phase. Electronic properties were investigated by ultra-violet photoemission spectroscopy showing pronounced differences in the valence band spectra of two phases. Financial support by the BMBF within MSM-Sens 13N10061 and 13N10062 is gratefully acknowledged.

MA 10.62 Tue 10:45 Poster A

In vitro study of iron-palladium ferromagnetic shape-memory alloy in simulated body fluid (SBF) — •Yanhong Ma, Florian Szillat, and Stefan G. Mayr — Leibniz-Institut fuer Oberflaechenmodifizierung, Translationszentrum fuer regenerative Medizin und Fakultaet fuer Physik und Geowissenschaften der Universitaet Leipzig, Permoserstrasse 15, 04318 Leipzig

Ferromagnetic shape memory alloys are a special class of active materials. They exhibit large actuation strain in martensitic phase due to a magnetic field induced reorientation of twin variants. For their biomedical applications, the biocompatibility is very important, as e.g. indicated by simulated body fluid (SBF) test. In the present study we focus on biocompatibility of $Fe_{70}Pd_{30}$ thin films. The surface morphologies and composition of the samples were studied by scanning electron microscopy equipped with energy dispersive X-ray spectroscopy. Analysis of the thin films crystalline structure was performed by X-ray diffraction. The elemental concentrations in SBF were measured after the samples were removed, using inductively coupled plasma optical emission spectroscopy. SBF experiments show that when the samples were immersed into the solution for 48 hours, some changes on the elemental concentration in SBF occurred. The Fe concentration in the as prepared SBF was about 0.002 mg/ml and no Pd was detected. After the sample was soaked into the solution for two days, concentrations of 0.028 mg/ml(Fe) and <0.001 mg/ml (Pd), respectively, were determined. This indicates, that some Fe moved into the solution from the film while the concentration of Pd did not change during the test.

MA 10.63 Tue 10:45 Poster A

Origin of the tetragonal distortion in Fe-Pd shape memory alloys — •Ingo Opahle[1], Klaus Koepernik[2], Ulrike Nitzsche[2], and Manuel Richter[2] — [1]Institut für Theoretische Physik, Universität Frankfurt, 60438 Frankfurt/Main, Germany — [2]IFW Dresden, P.O.B. 270016, D-01171 Dresden, Germany

Magnetic shape memory alloys (MSMA) have attracted considerable attention as materials for actuator and sensor applications, due to large magnetically induced strains of up to 10%. A promising MSMA is disordered $Fe_{70}Pd_{30}$ with an induced strain of about 6% and a relatively high blocking stress.

We have calculated the electronic structure of disordered Fe-Pd alloys [1] in the framework of density functional theory using the full potential local orbital (FPLO) code. The origin of the tetragonal distortion in these completely disordered alloys is found to be a Jahn-Teller like effect, which allows the system to reduce its band energy in a narrow composition range. In this composition range, the energy landscape along the Bain path is found to be flat, in agreement with a large tunability of strain observed in epitaxial films, covering most of the Bain path from fcc to bcc [2]. On the basis of our results, we discuss the prospects for an optimization of the alloys' properties by adding third elements, including effects on the magneto-crystalline anisotropy energy.
[1] I. Opahle *et al.*, Appl. Phys. Lett. 94 (2009) 072508.
[2] J. Buschbeck *et al.*, Phys. Rev. Lett. 103 (2009) 216101.

MA 10.64 Tue 10:45 Poster A

Herstellung und magnetische Charakterisierung von Co-Nanopartikel auf ionenstrahlerodierten Siliziumsubstraten — •Matthias Buhl, Michael Körner, Monika Fritzsche, Ullrich Wiesenhütter, Oskar Liedke und Jürgen Fassbender — Forschungszentrum Dresden - Rossendorf e.V., Dresden, Deutschland

Co-Nanopartikel wurden auf den selbstorganisierten Ripplen ionenstrahlerodierter Si-Substrate mittels Molekularstrahlepitaxie deponiert. Im Rahmen der Untersuchung sind Substrattemperatur und nominelle Beschichtungsdicke gezielt variiert worden. Mit Hilfe der longitudinalen magneto-optischen Kerr-Effekt Magnetometrie wurde der Einfluss der Ripple-Oberfläche auf das magnetische Verhalten der Co-Partikel analysiert. Die Auswertung der Messergebnisse von normierter remaneter Kerr-Drehung θ_r/θ_s und Koerzitivfeldstärke H_c zeigt eine kleine uniaxiale magnetische Anisotropie. Die leichte Richtung der Magnetisierbarkeit liegt parallel zu den Ripple-Wellenfronten.

MA 10.65 Tue 10:45 Poster A

Characterization of bioinspired synthesized magnetic nanoparticles — •Annalena Wolff[1], Katrin Eckstädt[1], Dieter Akemeier[1], Inga Ennen[1], Irina Dück[1], Katrin Wollschläger[2], Norbert Sewald[2], and Andreas Hütten[1] — [1]Department of Physics, University of Bielefeld, Germany — [2]Department of Chemistry, University of Bielefeld, Germany

Size distribution, morphology and magnetization of nanoparticles are important properties in many applications. In this study Cobalt Ferrite nanocrystals were synthesized using a biomineralization protein containing 25 amino acids and oxidative coprecipitation of Co^{2+} and Fe^{2+}. An AGM was used for magnetization measurements. A FIB DualBeam System was used to examine the morphology and size distribution. Furthermore the morphology and size distribution of chemically produced CoAu nanoparticles was examined with the DualBeam System and the magnetization with an AGM. Previously GMR was succesfully measured on CoRuNanoparticles structures. Now GMR was measured of a setup consisting of two gold contacts which are connected through a structured monolayer of CoAu nanoparticles. GMR was measured at room temperature and at low temperatures. Two point measurements and four point geometry measurements on single particle are planned.

MA 10.66 Tue 10:45 Poster A

MOKE investigation of ferromagnetic nanoparticles deposited on a W(110) surface — •Christian Kleinhans[1], Wolfgang Rosellen[1], Volker Hückelkamp[1], Furkan Bulut[1,2], Joachim Bansmann[2], Armin Kleibert[3], and Mathias Getzlaff[1] — [1]Institute of Applied Physics, University of Düsseldorf, Germany — [2]Department of Surface Chemistry, Ulm University, Germany — [3]Swiss Light Source at the Paul Scherrer Institute, Villigen, Switzerland

Magnetic properties of supported 3d-metal nanoparticles, differing from the behaviour of bulk material, open the possibility of applications from a technological point of view. With a continuously working, UHV-compatible arc cluster ion source (ACIS), ferromagnetic nanoparticles have been produced and subsequently mass filtered using an electrostatic quadrupole-deflector-unit, ensuring sizes of 5 to 15 nm. The deposition of these preformed free particles onto a W(110)-substrate is performed under soft-landing conditions. Their size and shape is determined by means of STM and TEM. Applying a magnetic field in plane of the sample with variable angle, the magnetic behaviour of the nanoparticles is characterised using magneto-optical Kerr effect (MOKE). The influence of the angle and strength of the magnetic field on the magnetization is used to determine the nanoparticles' magnetic anisotropy and correlate this characteristic property

with the respective structural behaviour.

MA 10.67 Tue 10:45 Poster A

Temperaturabhängige Magnetrelaxometrie an magnetischen Nanopartikeln aus Magnetit im Temperaturbereich von 4,2 K bis 320 K — •Markus Schiffler[1], Markus Büttner[1], Peter Weber[1], Paul Seidel[1], Claus Lang[2], Dirk Schüler[2] und Michael Röder[3] — [1]Friedrich-Schiller-Universität Jena, Institut für Festkörperphysik — [2]Ludwig-Maximilians-Universität München, Bereich Mikrobiologie — [3]INNOVENT e.V. Jena

Obwohl Magnetit das älteste bekannte magnetische Material und seit vielen Jahren Gegenstand intensiver Untersuchungen ist sind die Ursachen vieler Eigenschaften noch nicht abschließend geklärt. Es wurden magnetische Nanopartikel aus einkristallinem Magnetit, die vom Bakterium Magnetospirillum gryphiswaldense erzeugt worden sind, mit Hilfe der temperaturabhängigen Magnetrelaxometrie (TMRX) untersucht. Dabei wird das Signal der magnetischen Relaxation der Probe mit einem axialen SQUID-Gradiometer zweiter Ordnung (Arbeitstemperatur 4,2 K) detektiert. Die Probentemperatur kann dabei durch einen entsprechenden Antikryostaten im Bereich von 4,2 K bis 320 K variiert werden. Bei der Untersuchung der Magnetitpartikel wurden Relaxationssignale in verschiedenen Temperaturbereichen und mit verschiedenen Ursachen gefunden. Die Néelrelaxation liefert einen Beitrag bei Temperaturen ab 300 K. Im Temperaturbereich des für Magnetit bekannten Verwey-Übergangen bei 110 K liegen ebenfalls signifikante Signale vor, deren Herkunft bei TMRX-Messungen erklärbar ist. Zusätzlich existieren Signale zwischen 4,2 K und 70 K, die auf eine Relaxation magnetischer Momente hindeuten.

MA 10.68 Tue 10:45 Poster A

Oxidation of multilayers of ligand stabilized magnetic cobalt nanoparticles — •Britta Vogel[1], Axel Dreyer[1,2], Nadine Mill[1], Katrin Eckstädt[1], Annalena Wolff[1], Dieter Akemeier[1], Alexander Weddemann[1], Alexander Auge[1], Simone Herth[1], and Andreas Hütten[1] — [1]Department of Physics, University of Bielefeld, D-33615 Bielefeld, Germany — [2]Department of Chemistry, University of Bielefeld, D-33615 Bielefeld, Germany

Cobalt nanoparticles have been prepared with TOPO, subsequently a ligand exchange was carried out. Samples have been prepared by dropping particle solution on Si-wafer, which lead to samples which consist of multilayers partially. The samples were studied with respect to the 3D order to gain information about the influence of the ligand on the 3D structure of the particle array and the oxidation process in multilayered particles.

MA 10.69 Tue 10:45 Poster A

Interplay between magnetism, structure and chemical order in small CoPt clusters: Ab initio and model calculations — •Lucila Juárez-Reyes, Jesus Dorantes-Dávila, and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Germany

The magnetic properties of small $Co_N Pt_M$ clusters ($N + M \leq 5$) are studied using a generalized gradient approximation to the density functional theory (DFT) and a self-consistent tight-binding (SCTB) model. First, we perform a systematic study of all posible different topological geometries, spin-moment configurations and chemical orders in the framework of the DFT. Second, by using the optimal ab initio structures we determine the spin moments, orbital moments and magnetic anisotropy energy within the SCTB method. The DFT calculations yield compact structures with particularly short bond lengths among the Co atoms ($d_{Co-Co} \simeq 2.2 - 2.4$Å). Pt doping induces an important enhancement of the Co spin moments μ_{Co} which are about $0.25\mu_B$ larger than μ_{Co} in Co_N. This is mainly due to important charge transfers between the Co and Pt atoms. SCTB calculations show a 15–20 % orbital contibution to the total magnetic moment. Finally, a non trivial dependence of the MAE landscape on Pt concentration is observed.

MA 10.70 Tue 10:45 Poster A

First principles study of segregation and interface effects in magnetic CoRh nanoparticles — •Luis Enrique Diaz Sanchez, Jesus Dorantes Davila, and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Heinrich Plett. Str. 40, 34132 Kassel, Germany

The magnetic properties for $Co_x Rh_{1-x}$ nanoparticles in the size range $N \simeq 50 - 250$ atoms are investigated in the framework of density functional theory for concentrations $x = 0.0, 0.25, 0.5, 0.75$, and 1.0. CoRh clusters are found to be magnetic with an average spin moment per Co atom that is larger than in macroscopic alloys with similar concentrations. Results are given for the local and average spin moments, charge distribution, and density of electronic states for different types of segregation (e.g., core-shell, wetting, and non-wetting), interface mixing, and random alloys. The theoretical findings are discussed by comparison with available experiments.

MA 10.71 Tue 10:45 Poster A

Magnetic properties of CoRh core shell nanoparticles — •Björn Münzing[1], Kai Fauth[1], Nabil Atamena[2], Diana Ciuculescu[2], and Catherine Amiens[2] — [1]Physikalisches Institut, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]LCC Toulouse, 205 rte. de Narbonne, 31077 Toulouse Cedex 04, France

We present an X-ray magnetic circular dichroism (XMCD) study of the magnetic properties of Co@Rh core-shell-nanoparticles with a mean diameter of ≈ 1.8 nm, prepared by colloidal chemistry using organometallic precursors.

The local Co atomic magnetic moments in particles of different composition increase with increasing amount of Rh. This may be attributed to a decreasing influence of tetramethylpiperidine ligands on the 3d-metal when the particle surface is enriched with Rh. The magnetic response is essentially superparamagnetic ($T \geq 12$ K) and magnetic saturation is not attained in applied fields of up to 3 T for all compositions. The measurement of the magnetic circular dichroism on Rhodium reveals the ferromagnetic coupling of Co and Rh in these particles.

Additionally we find striking differences in magnetic coupling between the particles at short inter particle distance. This could be attributed to an effective antiferromagnetic coupling once the particle surfaces are significantly enriched with Rh.

MA 10.72 Tue 10:45 Poster A

Resistive switching in nanocolumnar manganite thin films structured with e-beam lithography — •Christin Kalkert, Markus Esseling, Jon-Olaf Krisponeit, Vasily Moshnyaga, Bernd Damaschke, and Konrad Samwer — I. Phys. Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Manganites show an intriguing variety of different behavior such as the colossal magnetoresistance, the colossal electroresistance and a resisitive switching phenomenon. Changing the resistance as a function of external parameters such as a magnetic or electric field has the potential of creating non-volatile memory applications.

In this work we studied $La_{0.7}Sr_{0.3}MnO_3$ thin films prepared by metal-organic aerosol deposition technique on Al_2O_3 substrates. The films show columnar nanostructure as determined from X-ray diffraction and TEM measurements. After macroscopic electronic and magnetic characterisation we structured the films to μm-sized bridges by means of electron beam lithography. The current voltage dependances measured at 5 K indicate tunneling mechanism of conductivity and show resistive switching between low and high resistive states. The discussion is based on local structural changes at the grain boundaries.

This work is supported by DFG via SFB 602, TP A2 and the Leibniz Program.

MA 10.73 Tue 10:45 Poster A

Magnetoresistrance of thin film microstructures of the Heusler compounds Cu_2MnAl and Co_2MnSi — •Mohamed Obaida[1,2], Denise Erb[2], Kurt Westerholt[2], and Hartmut Zabel[2] — [1]Institut für Experimentalphysik 4,Ruhr-Universität Bochum,44780 Bochum — [2]National Research Center, Tahrir Street-Dokki., 12311 Cairo., Egypt.

We study the magnetoresistance of thin films of the ferromagnetic Heusler compounds Cu_2MnAl and Co_2MnSi. The Heusler thin films are prepared by UHV magnetron sputtering and shaped into rectangular bars with a width between 1 μm and 50 μm by optical lithography. The magnetoresistance is measured in magnetic fields up to 4 T and for the orientation of the field parallel and perpendicular to the in-plane current. In the as-prepared state the Heusler alloy films are non-ferromagnetic and exhibit a very small magnetoresisitance only. The magnetoresistance strongly increases when the ferromagnetism gradually develops after step by step thermal annealing at high temperatures and decreases again when the magnetic moment approaches its maximum value. The magnetoresistance is dominated by an isotropic spin

disorder contribution; only in the state with the maximum magnetic moment an additional small anisotropic magnetoresistance (AMR) can be resolved.

MA 10.74 Tue 10:45 Poster A

Large photoconductivity of $La_{0.7}Ca_{0.3}MnO_{3-\delta}/SrTiO_3$ heterostructures — •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 — [2]Institut für Metallische Werkstoffe, IFW Dresden, D-01171 Dresden

The electric resistivity of stoichiometric and oxygen-deficient epitaxial 10-nm-thick $La_{0.7}Ca_{0.3}MnO_3$ thin films on $SrTiO_3$ under photoexcitation has been investigated systematically. In contrast to the as-prepared film, the oxygen-deficient one exhibits a pronounced photoinduced decrease of the resistivity of up to five orders of magnitude at low temperatures.

A detailed analysis of the resistivity as a function of illumination intensity and wavelength (visible to ultraviolet range) is presented for the bare substrate as well as for the film/substrate heterostructure. The roles of carrier generation in the film and carrier injection from the substrate, which both contribute to the observed effects, are discussed.

MA 10.75 Tue 10:45 Poster A

X-Ray magnetic circular dichroism (XMCD) study of magnetite (Fe_3O_4) thin films on semiconducting substrates — •Dominik Kufer, Markus Paul, Andreas Müller, Christian Praetorius, Annemarie Köhl, Kai Fauth, Michael Sing, and Ralph Claessen — Lehrstuhl für Experimentelle Physik 4, Universität Würzburg, Germany

Thin films of magnetite have attracted enormous research interest in recent years because of their electronic and magnetic properties. Bulk magnetite shows ferrimagnetic ordering with a theoretically predicted magnetic moment of $4\mu_B$ per formula unit below a favorably high Curie temperature of 850 K. However, structural, electronic and magnetic properties of thin films depend on choice of substrate, deposition method, and various process parameters. We have investigated the magnetic properties of epitaxial Fe_3O_4 thin films on the technologically relevant semiconducting substrates ZnO and GaAs by means of XMCD. Thin films were deposited by oxygen-assisted MBE and characterized by LEED, XPS and XRD. XMCD measurements were performed on samples with film thicknesses ranging from 3 to 40 nm, grown both *ex situ* as well as *in situ* shortly before data acquisition in total electron yield (TEY) mode. Our XMCD results confirm rather reduced magnetic moments in comparison with Fe_3O_4 bulk values [1]. Sum rule evaluation leads to spin magnetic moments in the range of 0.7-1.0μ_B per atom and nearly vanishing orbital moments for both substrates.

[1] A.Müller *et al.*, arXiv:0911.3572

MA 10.76 Tue 10:45 Poster A

Magnetic anisotropy of Zn-substituted magnetite studied by ferromagnetic resonance — •Themistoklis Sidiropoulos, Deepak Venkateshvaran, Andreas Brandlmaier, Matthias Althammer, Matthias Opel, Rudolf Gross, and Sebastian T.B. Goennenwein — Walther-Meiner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

Ferromagnetic resonance (FMR) is a powerful technique for the investigation of the magnetic anisotropy in ferromagnetic thin films. Here, we use FMR to study the magnetic anisotropy of $Zn_xFe_{3-x}O_4$, a derivative of Fe_3O_4. We have grown coherently strained, epitaxial $Zn_xFe_{3-x}O_4$ thin films on MgO (001) substrates using pulsed laser deposition, monitored by an in situ RHEED system. Two sets of $Zn_xFe_{3-x}O_4$ films (with x = 0, 0.1, 0.33, 0.5 and 0.9) were deposited, one in pure Ar, the other in an Ar/O_2 (99:1) mixture. X-ray diffraction measurements indicate high crystallinity, as evident from a FWHM of 0.04° in the rocking curves for the $Zn_xFe_{3-x}O_4$ (004) reflection. Previously, we demonstrated that $Zn_xFe_{3-x}O_4$ shows an appreciable tunability in both its magnetic and transport properties, depending on the Zn concentration and the growth atmosphere [1]. In this study, we discuss the evolution of the magnetic anisotropy with Zn concentration, growth atmosphere and temperature.

This work is supported by the DFG within SPP 1285, GO 944/3, and by the cluster of excellence Nanosystems Initiative Munich (NIM).

[1] D. Venkateshvaran et al., Phys. Rev. B **79**, 134405 (2009).

MA 10.77 Tue 10:45 Poster A

Field and temperature dependence of spin and heat transport in dimerized spin 1/2 chains. — •Stephan Langer[1], Fabian Heidrich-Meisner[1], Rachid Darradi[2], and Wolfram Brenig[2] — [1]Physics Department, Arnold Sommerfeld Center for Theoretical Physics, and Center for NanoScience, LMU München, Germany — [2]Institute for Theoretical Physics, Technical University of Braunschweig, Germany

We study the spin and heat conductivity of dimerized spin 1/2 chains in homogeneous magnetic fields at finite temperatures. Tuning the strength of the dimerization this model connects the limit of weakly coupled dimers to the Heisenberg chain. Our goal is to understand the dependence of heat and spin transport on the magnetic field, the temperature and the strength of dimerization. At zero temperature the model undergoes a field induced quantum phase transition from a dimerized into a Luttinger liquid phase. We search for signs of this transition in the spin and heat conductivity. Using exact diagonalization we calculate the Drude weights, the frequency dependence of the conductivities and the corresponding integrated spectral weights.

A similar transition from a gapped into a Luttinger Liquid phase is observed in spin ladder materials that have a comparably small exchange coupling, allowing experimentalists to probe transport at finite temperatures and fields. This serves as an additional motivation of our study.

This work is supported by the Deutsche Forschungsgemeinschaft via FOR 912.

MA 10.78 Tue 10:45 Poster A

Magnetic and Structural Properties of $La_{1-x}Th_xCrO_3$ and $LaCr_{1-y}Ti_yO_3$ — •P. Reuvekamp[1], R. K. Kremer[1], and F. S. Razavi[2] — [1]Max Planck Institut fuer Festkoerperforschung, — [2]Department of Physics, Brock University, St. Catharines, Ontario, L2S 3A1, Canada

The magnetic properties of ceramic samples of $La_{1-x}Th_xCrO_3$ and $LaCr_{1-y}Ti_yO_3$ were investigated. In order to improve the chemical homogeneity and stoichiometry, the ceramic samples were prepared by the citrate-pyrolysis synthesis route. X-ray investigations of these samples revealed that all the phases maintained their orthorhombic structure, however with different mass densities. The substitution of Th for La does not have effect on the magnetic properties of $LaCrO_3$ with the Néel temperature remaining close to 290 K whereas, replacing Ti for Cr reduces the Néel temperature to a minimum of 237 K for y = 0.2.

MA 10.79 Tue 10:45 Poster A

Magneto-Optic Measurements of Magnetic Multilayers in Extreme Ultraviolet Range — •Roman Adam, Patrik Grychtol, Stefan Cramm, and Claus Schneider — Institute of Solid State Research IFF-9, Research Center Jülich, D-52425

We performed static and time-resolved magneto-optic measurements on Co/Si-wedge/Ni/Fe and NiFe/MgO/Co multilayers using resonant scattering of extreme ultraviolet (XUV) radiation tuned to the M absorption edges of cobalt (60.2 eV) and nickel (67.5 eV). By exploiting the linear magneto dichroic effect close to the Brewster angle a huge magnetic contrast of up to 80% from the top Co and 20 % from the buried NiFe layer upon magnetization reversal could be obtained. In order to map the magnitude of the dichroism, angular and energy dependent scans of the magnetic asymmetry were performed and compared with magneto-optical simulations. The magneto-optical response of a multilayer system to a magnetic pulse excitation results in element-specific oscillations in a frequency range of 3 to 6.5 GHz associated with magnetization dynamics of the individual Co and NiFe layers. Presented results demonstrate the feasibility of element-specific magneto-dynamic studies in magnetic multilayers in XUV spectral range.

MA 10.80 Tue 10:45 Poster A

Investigation of depletion state of high temperature protective coatings — •Iulian Teliban[1], Claas Thede[1], Steffen Chemnitz[1], Christoph Bechtold[1], Thomas Hüttel[2], Krasimir Aleksandrov[3], Willem Quadakkers[2], Michael Schütze[3], and Eckhard Quandt[1] — [1]Christian-Albrechts-Universität zu Kiel — [2]Forschungszentrum Jülich — [3]DECHEMA, Frankfurt a.M.

In many industrial applications metallic and non-metallic protective coatings are applied to protect against oxidation, corrosion or physical degradation. To date, practical non-destructive methods for the

measurement of the depletion state of the coating during the operation time do not exist. By integration of magnetic phases into the coating and measuring the magnitude of the magnetic properties important information about the coating's condition can be provided.

A new technique using frequency mixing is presented to investigate the thickness of the coatings based on their magnetic properties. The performance of the sensor was investigated using magnetic samples with defined properties and thicknesses ($Fe_{67}Co_{18}B_{14}Si_1$ multilayers), [1]. Common protective coatings consisting of a paramagnetic MCrAlY matrix in which the sensor phase (Cr, Fe) is embedded and new types of coatings based on $Al_{1-x}Cr_xN$ ($x = 0.02 \div 0.07$) are analyzed with the new technique in different stages of usage (oxidation).

Founding by the DFG via the SPP 1299 is gratefully acknowledged.

[1] I. Teliban, C. Thede, S. Chemnitz, C. Bechtold, W. J. Quadakkers, M. Schütze, and E. Quandt, Rev. Sci. Instrum. 80, 115106 (2009).

MA 11: FS: Topological Defects in Electronic Systems (with TT)

Time: Tuesday 9:30–13:45 Location: H20

Invited Talk MA 11.1 Tue 9:30 H20

Skyrmions in Chiral Magnets — •Ulrich K. Rössler, Andrei A. Leonov, Anna B. Butenko, and Alexei N. Bogdanov — IFW Dresden

In non-centrosymmetric magnets the chiral Dzyaloshinskii-Moriya (DM) exchange stabilizes tubular baby-Skyrmions. These are topologically non-trivial localized, but smooth and static textures of a spin system. Chiral Skyrmionic states may exist in various magnetic systems as the chiral DM-couplings stem from the leading spin-orbit effect, if they are allowed by crystal symmetry. Extended Skyrmionic textures are determined by the stability of the localized solitonic Skyrmion cores and their geometrical incompatibility, which frustrates a homogeneous space-filling. Two-dimensional models for these inhomogeneous magnetic states bear strong similarity with Abrikosov-lattices. Just as cylindrical vortices arrange into regular arrays in type-II superconductors, Skyrmions may form ordered arrays in chiral magnets. Basic phenomenological continuum theory suggests that a cornucopia of unexpected effects can be found in these chiral magnets. The isolated particle-like Skyrmion excitations may undergo confinement near the magnetic transition, and these molecular units may finally condense into extended mesophases. This magnetic 'Skyrmionic matter' strongly resembles chiral nematic liquid crystal textures. The underlying theoretical ideas shed new light on more fundamental question about the appearance of countable units in a continuum, and mechanisms for the formation of self-generated amorphous states.

Invited Talk MA 11.2 Tue 10:00 H20

Dirac Strings and Magnetic Monopoles in the Spin Ice, $Dy_2Ti_2O_7$ — •David Jonathan Pryce Morris[1], Alan Tennant[1,2], Santiago Grigera[3], Bastian Klemke[1,2], Claudio Castelnovo[4], Roderich Moessner[5], Clemens Czternasty[1], Michael Meissner[1], Kirrily Rule[1], Jens-Uwe Hoffmann[1], Klaus Kiefer[1], Damien Slobinsky[6], and Robin Perry[7] — [1]Helmholtz Center Berlin for Materials and Energy, Berlin, Germany — [2]Technische Universität Berlin, Germany — [3]Instituto de Fisica de Liquidos y Sistemas Biologicos, La Plata, Argentina — [4]University of Oxford, United Kingdom — [5]Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany — [6]St. Andrews University, United Kingdom — [7]University of Edinburgh, Scotland

Recent proposals in condensed matter physics that magnetic monopoles can appear as emergent quasiparticles have attracted wide levels of interest. Dirac's original picture of magnetic monopoles had them connected to strings through which magnetic flux flowed. Here we report studies into a system called Spin Ice, where spins obey "ice rules" of 2 spins into and 2 spins out of their tetrahedron. In these materials it has been predicted that strings of spins form via a 3D Kasteleyn transition [1]. The geometry of spin-ice allows for net magnetic charge (magnetic monopoles) to form where "ice rules" are broken at the tips of the strings [2]. Here we present three experimental pieces of evidence for these strings and magnetic monopoles [3].

[1] Phys Rev. Lett. 100, 067207 (2008)
[2] Nature 451, 42 (2008)
[3] Science 326, 411 (2009)

Topical Talk MA 11.3 Tue 10:30 H20

Manifestations of monopole physics in spin ice materials — •Claudio Castelnovo[1], Roderich Moessner[2], and Shivaji Sondhi[3] — [1]University of Oxford, Oxford, UK — [2]MPI-PKS, Dresden, Germany — [3]Princeton University, Princeton, USA

Spin ice materials such as $Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ provide a rare instance of fractionalisation in three dimensions: their elementary excitations carry a fraction of the magnetic moment of the microscopic spin degrees of freedom, and they can be thought of as magnetic monopoles.

The peculiar nature of these excitations leads to unique signatures in the equilibrium and response properties. These include unusual neutron scattering structure factors, dynamical arrest and long lived non-equilibrium metastable states, as well as a response to external magnetic fields that promotes spin ice as a magnetic analogue of an electrolyte. In this talk, we review several of these striking phenomena.

The formulation of the low-temperature phase in terms of an emergent gauge field permits an unusual degree of analytical progress in the modelling of these materials.

Invited Talk MA 11.4 Tue 11:00 H20

Skyrmion Lattices in Pure Metals and Strongly Doped Semiconductors — •Christian Pfleiderer — Physik Department E21, Technische Universität München, D-85748 Garching, Germany

For a long time it was anticipated theoretically, that chiral magnets may support topological defects with the characteristics of skyrmions. We used neutron scattering and measurements of the Hall effect to identify the formation of two-dimensional lattices of skyrmion lines, a new form of magnetic order, in metallic and semiconducting B20 compounds, namely MnSi [1,2], $Mn_{1-x}Co_xSi$, $Mn_{1-x}Fe_xSi$ and $Fe_{1-x}Co_xSi$ [3]. The skyrmion lattices share remarkable similarities with vortex lattices in type II superconductors. For instance, they may exhibit domain formation and complex morphologies as seen, e.g., in ultrapure Nb [4]. Moreover, the pinning of the skyrmion lattices to the crystal lattice is extremely weak. In fact, they may be viewed as a spin crystal that is essentially disconnected from the atomic lattice. Our study establishes magnetic materials lacking inversion symmetry as an arena for new forms of order composed of topologically stable spin configurations.

[1] S. Mühlbauer, et al. , Science **323**, 915 (2009).
[2] A. Neubauer, et al., Phys. Rev. Lett. **102**, 186602 (2009).
[3] W. Münzer, et al., arXiv/0902.2587.
[4] S. Mühlbauer, et al., Phys. Rev. Lett. **102**, 136409 (2009).

15 min. break

Topical Talk MA 11.5 Tue 11:45 H20

Skyrmion lattice in MnSi — •Achim Rosch — Institute of Theoretical Physics, University of Cologne, 50937 Cologne, Germany

A magnetic skyrmion is a topologically stable vortex-like spin configuration. Similarly to a vortex lattice of a superconductor, a lattice of skyrmion lines is found [1] in the metallic magnet MnSi in a small magnetic field for a small range of temperatures. This state of matter is stabilized by weak spin-orbit interactions and thermal fluctuations. The topological winding number of the skyrmions implies that moving electrons pick up a Berry phase which leads to a characteristic contribution to the Hall constant [2] and an efficient coupling of currents to the magnetic structure. We therefore also investigate how spin-torque effects can lead to modifications of the magnetic structure when electric currents are applied.

[1] S. Mühlbauer, B. Binz, F. Jonietz, C. Pfleiderer, A. Rosch, A. Neubauer, R. Georgii, P. Böni, Science **323**, 915 (2009).
[2] A. Neubauer, C. Pfleiderer, B. Binz, A. Rosch, R. Ritz, P. G. Niklowitz, P. Böni , Phys. Rev. Lett. **102**, 186602 (2009).

Invited Talk MA 11.6 Tue 12:15 H20

Topological Insulators in Applied Fields: Magnetoelectric Effects and Exciton Condensation — •Joel Moore — University of California, Berkeley CA USA

"Topological insulators" are insulating in bulk but have protected metallic surface states as a result of topological properties of the electron wavefunctions. Several examples have been discovered recently in ARPES experiments that directly probe the surface state, including its spin structure. One way to characterize the topological insulator is through its magnetoelectric response in a weak applied field: it generates an electrical polarization in response to an applied magnetic field, and a magnetization in response to an applied electrical field. This talk first reviews the origin of this response and its generalization to other insulators and topological states. A strong applied electrical field can combine with Coulomb interactions to generate an unusual "exciton condensate" involving both surfaces of a thin film of topological insulator. This exciton condensate has several topological features that distinguish it from an ordinary superfluid; the most significant is that vortices support midgap localized states ("zero modes" in the particle-hole symmetric case) with effective fractional charge $\pm e/2$.

Topical Talk MA 11.7 Tue 12:45 H20
Probing non-Abelian statistics with quasiparticle interferometry — •Kirill Shtengel — University of California, Riverside, USA

States of matter are conventionally classified according to broken symmetries. Topologically ordered phases fall outside of this paradigm: with no local order parameter, they nevertheless have many peculiar properties setting them apart from disordered phases. In 2D, such phases may support anyons - quasiparticles that are neither bosons nor fermions. Moreover, anyons with non-Abelian statistics can occur, particularly in the fractional quantum Hall regime.

In this talk, I will focus on solid state interferometers designed to detect such exotic statistics. I will discuss Recent experiments in the the quantum Hall regime at 5/2 filling where the evidence for the existence of non-Abelian anyons may have in fact been observed for the first time. I will also mention potential applications of such interferometeric schemes for topological quantum computation.

Topical Talk MA 11.8 Tue 13:15 H20
Spin Hall effects in HgTe Quantum Well Structures — •Laurens W. Molenkamp — Physikalisches Institut (EP3), Universität Würzburg, Am Hubland, 97074 Würzburg, Germany

Recently, it was pointed out that inverted HgTe structures are topologically non-trivial insulators, in which the quantum spin Hall insulator state should occur. In this novel quantum state of matter, a pair of spin polarized helical edge channels develops when the bulk of the material is insulating, leading to a quantized conductance. I will present transport data provide very direct evidence for the existence of this third quantum Hall effect: when the bulk of the material is insulating, we observe a quantized electrical conductance. Further experiments, using non-local transport measurements, show that the charge transport occurs through helical edge channels. The spin polarization of the edge channels can be demonstrated in split gate devices that are partially in the insulting and partly in the metallic regime, making use of the occurrence of the non-quantized metallic spin Hall effect to convert the magnetic spin signal into an electrical one.

MA 12: FS: Single Nanomagnets

Time: Tuesday 10:45–12:45 Location: H22

Topical Talk MA 12.1 Tue 10:45 H22
Exploring the frontiers in cluster magnetism from a theorist's perspective — •Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Germany

In past years a remarkable progress has been achieved in the experimental synthesis and characterization of magnetic clusters, which renders increasingly rigorous comparisons between realistic (experimental) and idealized (theoretical) nanostructures possible. These investigations concern in particular magnetic phenomena that are specific to single clusters. The purpose of this talk is to discuss some of the current theoretical challenges in the theory of cluster magnetism. The specific subjects to be explored are strong electron correlation effects, finite-temperature spin fluctuations and magnetic anisotropy energy (MAE). The problem of local moment formation and Kondo effect of transition-metal impurities in finite NiCuN and CoCuN metal clusters is investigated. First principles calculations show that the Ni or Co impurities preserve their magnetic degree of freedom and are therefore good candidates for developing interesting many-body phenomena. The temperature dependence of the magnetic properties of FeN clusters ($N \leq 24$) are determined in the framework of a functional-integral itinerant-electron theory. A remarkable dependence of the average magnetic moment per atom Δ N(T) on size and structure is observed. CoRh alloy nanoparticles show non-trivial correlations between chemical and magnetic order that lead to a non-monotonous dependence of the MAE as a function of composition, yielding a perspective of tailoring the MAE of nanoalloys.

Topical Talk MA 12.2 Tue 11:15 H22
Magnetic chirality in the electron microscope: Progress and Applications — •Peter Schattschneider — Inst. F. Festkörperphysik und Univ. Serviceeinrichtung für Elektronenmikroskopie, Technische Universität Wien, A-1040 Vienna, Austria

Via the electron-electron interaction it can be shown everything that can be done in a synchrotron is also feasible in an electron microscope. In practice, however, electron and photon probes behave differently. In this respect, the EMCD technique (energy loss magnetic chiral dichroism) in the electron microscope [1] - the equivalent of the synchrotron based XMCD, a standard technique for the study of atom specific magnetism - has the intrinsic advantage of high spatial resolution. The main difficulty with EMCD is the low signal intensity, asking for exposure times of the order of minutes, and very particular scattering conditions necessary to observe a chiral dichroic signal. Nevertheless, much progress was made in the last years. EMCD has evolved into several techniques, now utilising either energy filtering, spectroscopy, TEM or STEM conditions. After a synopsis of the present situation in EMCD, recent results such as nanometric resolution, the applicability of XMCD sum rules, and new image simulation software are discussed. The observation that chiral electronic transitions break certain mirror symmetries in energy spectroscopic diffraction (ESD) led to the prediction that this chirality pertains in energy filtered high resolution imaging, thus opening a road to mapping electron spins of individual atomic columns under HR-TEM conditions. [1] P. Schattschneider et al., Nature. 441 (2006), 486.

Topical Talk MA 12.3 Tue 11:45 H22
Stochastic resonance of a nanomagnet excited by spin transfer torque — •Ilya Krivorotov — Department of Physics & Astronomy, University of California, Irvine, California 92617, USA

Spin transfer torque from spin-polarized electrical current can excite large-amplitude magnetization dynamics in metallic ferromagnets of nanoscale dimensions. Since magnetic anisotropy energies of nanomagnets are comparable to the thermal energy scale, temperature can have a profound effect on the dynamics of a nanomagnet driven by spin transfer torque. We observe unusual types of microwave-frequency nonlinear magnetization dynamics co-excited by alternating spin transfer torque and thermal fluctuations in NiFe/Cu/Co spin valves of nanoscale dimensions. In these dynamics, temperature amplifies the amplitude of GHz-range precession of magnetization and enables excitation of highly nonlinear dynamical states of magnetization by weak alternating spin transfer torque. We explain these thermally activated dynamics in terms of non-adiabatic stochastic resonance of magnetization driven by spin transfer torque. We find that the non-adiabatic stochastic resonance of magnetization gives rise to strong enhancement of the rectified voltage generated by nanoscale spin valves in response to alternating spin current, and thus this type of magnetic resonance may find use in sensitive nanometer-scale microwave signal detectors.

Topical Talk MA 12.4 Tue 12:15 H22
Exploring single nanomagnets with photoelectron microscopy — •Florian Kronast — Helmholtz-Zentrum Berlin GmbH, Albert-Einstein-Str. 15, D-12489 Berlin, Germany

Nanostructures exhibit new and interesting magnetic properties that can not be derived from bulk properties. E.g. their effective magnetization and the Curie temperature may differ dramatically from bulk values due to finite size effects. Magnetic nanoparticles with core-shell structures are likely to show different magnetic order at the surface and in the core. In ensembles of nanoparticles inter-particle inter-

actions strongly influence their individual magnetic properties. To resolve those nanoscale effects on the appropriate length scale we investigate individual nanomagnets by means of microspectroscopy. Using photoelectron microscopy with synchrotron light excitation we can access their chemical composition, magnetic moment and orientation with 30nm lateral resolution. A built-in magnetic yoke and temperature control allows us to measure magnetic responses of individual nanoparticles to an external magnetic field of up to ± 50mT as a function of temperature. To correlate magnetic properties of individual nanomagnets with their size, chemical composition, structure, and local coordination we combine our microspectroscopy data with detailed structural information obtained by high resolution electron microscopy. Measurements on Fe nanoparticles with a cubic shape and a side length 18nm [1] demonstrate how strongly their magnetic properties vary with their local coordination and oxidation state. [1] A. Shavel et al, Adv. Funct. Mat. 17 (2007) 3870

MA 13: ThyssenKrupp Dissertationspreis der AG Magnetismus

Time: Tuesday 14:00–16:15 Location: H3

MA 13.1 Tue 14:00 H3

Electronic Interactions and Tailoring of the Magnetic Coupling — •Matthias Bernien — Institut für Experimentalphysik, Freie Universität Berlin

10 min. discussion

MA 13.2 Tue 14:30 H3

Spinabhängiger Transport in epitaktischen Fe-Leiterbahnen auf GaAs (001) — •Christoph Hassel — Institut für Physik, Universität Duisburg-Essen

10 min. discussion

MA 13.3 Tue 15:00 H3

Thermal and Current-Induced Magnetization Switching of Fe/W(110) Nanoislands Investigated by Spin-Polarized Scanning Tunneling Microscopy — •Stefan Krause — Institut für Angewandte Physik, Universität Hamburg

10 min. discussion

MA 13.4 Tue 15:30 H3

Ferromagnetische Korrelationen in Kondo-Gittern: YbT_2Si_2 und CeTPO (T=Übergangsmetall) — •Cornelius Krellner — MPI für Chemische Physik Fester Stoffe, Dresden

10 min. discussion

Die Verleihung des ThyssenKrupp Dissertationspreises 2010 durch das Preiskomitee erfolg sofort im Anschluss.

MA 14: Spin Dynamics / Spin Torque I

Time: Wednesday 9:30–12:45 Location: H10

Invited Talk MA 14.1 Wed 9:30 H10

Ultrafast spin-orbit excitations in ferromagnets probed by fs x-ray pulses — •Hermann A. Dürr — Helmholtz Zentrum Berlin, BESSY II, Germany — SLAC, Stanford University, USA

Polarized soft x-rays have been used over the past 20 years to obtain fascinating new insights into nanoscale magnetism. The separation of spin and orbital magnetic moments, for instance, enabled detailed insights into the interplay of exchange and spin-orbit interactions at the atomic level. The now available polarized soft x-ray pulses with only 100 fs duration allow us to observe the magnetic interactions at work in real time. The ultimate goal of such studies is to understand how spins may be manipulated by ultrashort magnetic field, spin polarized current or light pulses. In this talk I will focus on fs laser induced magnetization dynamics in 3d transition metals, 4f systems and their alloys. Using fs x-ray pulses from the BESSY II femtoslicing facility I will show how fs excitation of the electronic system modifies the spin-orbit interaction enabling ultrafast angular momentum transfer between spin, orbital and lattice degrees of freedom.

MA 14.2 Wed 10:00 H10

Element-specific Study of the Ultrafast Magnetization Switching on GdFeCo — •Ilie Radu[1,2], Kadir Vahaplar[1], Alexey Kimel[1], Christian Stamm[2], Torsten Kachel[2], Niko Pontius[2], Hermann Duerr[2], Arata Tsukamoto[3], Andrei Kirilyuk[1], and Theo Rasing[1] — [1]IMM/SSI, Radboud University Nijmegen, The Netherlands — [2]Helmholtz-Zentrum Berlin, BESSY II, Germany — [3]College of Science and Technology, Nihon University, Chiba, Japan

Recent time-resolved magneto-optical studies of GdFeCo performed in the visible spectral range have demonstrated the intriguing possibility of all-optical magnetization reversal with 40 fs laser pulses. So far, a complete understanding of the switching mechanism and of the involved elementary processes is still lacking. Here, we report on time-resolved X-ray magnetic circular dichroism (TRXMCD) studies of the fs laser-induced magnetization switching of the ferrimagnetic GdFeCo alloy. We trigger the magnetization switching by fs laser heating the material across its magnetization compensation temperature using linearly polarized laser pulses. The subsequent magnetization dynamics is probed with 10 ps X-ray pulses by TRXMCD measured at the absorption edges of Fe and Gd. TRXMCD data reveal an intricate transient magnetization dynamics: A rapid demagnetization accompanied by the onset of the magnetization switching and subsequently the full development of the magnetization reversed state on a few 100 ps.

Funding from European Union through UltraMagnetron Program is gratefully acknowledged.

MA 14.3 Wed 10:15 H10

Magnetisation dynamics of ferrimagnets close to the compensation point — •Ulrich Nowak[1], Thomas Ostler[2], Denise Hinzke[1], Stefan Gerlach[1], and Roy W. Chantrell[2] — [1]Universität Konstanz, 78457 Konstanz — [2]University of York, York YO10 5DD, U. K.

Recently it was demonstrated that a circularly polarised laser pulse in the 100 femtosecond range is able to reverse the magnetisation of the ferrimagnet GdFeCo [1,2]. It was concluded that the laser pulse leads to a combined magnetic field and heat pulse, resulting in the magnetisation switching [3]. However, so far this so-called opto-magnetic writing was only successfully demonstrated for the above class of materials. The reason for this restriction is not clear though it was speculated that the special properties of a ferrimagnet close to its compensation point could be relevant.

Therefore we investigate the dynamics of a ferrimagnet close to its angular momentum compensation point by means of computer simulations. We solve the stochastic Landau-Lifshitz-Gilbert equation for a generic, atomistic model of a ferrimagnet. The temperature dependence of the precession frequency as well as the effective damping constant is investigated. The results are compared with earlier analytical results as well as recent experiments [5].

[1] A. V. Kimel et al., Nature 435, 655 (2005) [2] C. D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007) [3] K. Vahaplar et al., Phys. Rev. Lett. 103, 117201 (2009) [4] N. Kazantseva et al., Europhys. Lett. 86, 27006 (2009) [5] C. D. Stanciu et al., Phys. Rev. B, 73, 220402 (2006).

MA 14.4 Wed 10:30 H10

Element resolved magnetisation dynamics in $Fe_{1-x}Ni_x$ thin films — •Stefan Buschhorn, Frank Brüssing, Benjamin Glaub-

itz, Radu Abrudan, and Hartmut Zabel — Experimentalphysik IV, Ruhr-Universität Bochum

X-Ray Resonant Magnetic Scattering (XRMS) in combination with pump-probe techniques is a unique tool in order to directly observe element-resolved magnetisation dynamics. We present a time resolved setup with a time resolution of less than 100ps, using a magnetic field pulse excitation. The sample is mounted on a stripline and the reflected signal is averaged over many excitations in a delay scan with respect to the synchrotron flash. The experiments were done using the ALICE diffractometer [1]. We present results on the precessional dynamics of a Py sample in a temperature range from 80...350K, showing that both Fe and Ni precess in phase within the given resolution (see also [2]). There is no discernable change in temperature over the temperature range studied. In addition, we followed the frequency dependence of the precession as a function of alloy composition for a set of $Fe_{1-x}Ni_x$ thin films in order to reveal possible variations around the invar region.

This work was supported by BMBF under contracts 05KS7PC1 and 05ES3xBA/5. St. Buschhorn is fellow of the Ruhr-University Research School.

[1] J. Grabis, *et.al.*, Rev. Sci. Inst. **74**, 4048 (2003)
[2] W. Bailey, *et.al.*, Phys. Rev. B **70**, 172403 (2004)

MA 14.5 Wed 10:45 H10

Ultrafast and Element-Selective Demagnetization Dynamics probed at the M Absorption Edges employing a tabletop High-Harmonic Soft X-ray Source — •Patrik Grychtol[1], Chan La-O-Vorakiat[4], Roman Adam[1], Stefan Mathias[2,4], Mark Siemens[4], Justin Shaw[3], Hans Nembach[3], Thomas Silva[3], Martin Aeschlimann[2], Claus M. Schneider[1], Henry Kapteyn[4], and Margaret Murnane[4] — [1]Insitut für Festkörperforschung, IFF-9, Forschungszentrum Jülich, Jülich — [2]Technische Universität Kaiserslautern und Forschungszentrum OPTIMAS, Kaiserslautern — [3]Electromagnetics Division, National Institute of Standards and Technology, Boulder, Colorado — [4]Department of Physics and JILA, University of Colorado, Boulder, Colorado

Employing tabletop soft X-ray sources based on ultrafast laser amplifier for probing magnetic materials promises to combine element-selectivity with a spatial and temporal resolution on the nanometer and femtosecond scales for studying magnetism at fundamental limits. In our T-MOKE experiment where coherent X-ray pulses were reflected off a magnetized Ni80Fe20 grating, large changes in the reflected intensity of up to 6% at the M absorption edges of Fe and Ni were observed upon magnetization reversal. We demonstrate that femtosecond soft X-ray pulses from high harmonic generation can probe the Ni80Fe20 demagnetization in the femtosecond range element-selectively. Ultrafast demagnetization induced by a femtosecond laser pump pulse can be observed at both edges pointing towards a tight exchange coupling of the respective magnetic moments.

MA 14.6 Wed 11:00 H10

Electron-phonon contribution to the ultrafast demagnetization of ferromagnetic metals — •Sven Essert, Michael Krauss, and Hans Christian Schneider — TU Kaiserslautern, 67653 Kaiserslautern, Germany

The Elliott-Yafet (EY)-mechanism is arguably the most promising candidate to explain the light-induced ultrafast demagnetization dynamics in ferromagnetic transition metals on time scales on the order of 100 fs. By numerically solving dynamical equations for spin and energy-resolved electronic distribution functions and including electron-electron interactions at the level of Boltzmann scattering integrals, we were able to show [1] that an EY-like mechanism based on electron-electron scattering has the potential to explain time-resolved magneto-optical Kerr effect measurements on thin magnetic cobalt and nickel films, without reference to a "phononic spin bath". In this contribution, we include the electron-phonon interaction as an additional scattering mechanism in our approach. We compare our numerical results for cobalt and nickel with other approaches, which assume electron-phonon scattering as the spin-diagonal scattering process underlying the demagnetization. [2]

[1] M. Krauß, T. Roth, S. Alebrand, D. Steil, M. Cinchetti, M. Aeschlimann, and H. C. Schneider, Phys. Rev. B **80**, 180407(R) (2009)
[2] D. Steiauf and M. Fähnle, Phys. Rev. B **79**, 140401(R) (2009)

MA 14.7 Wed 11:15 H10

Extension of Yafet's theory of spin relaxation to ferromagnets — •Christian Illg[1], Daniel Steiauf[2], and Manfred Fähnle[1] — [1]Max-Planck-Institut für Metallforschung, Heisenbergstraße 3, 70569 Stuttgart, Germany — [2]Materials Department, University of California, Santa Barbara, CA 93106-5050, USA

By making use of Kramer's degeneracy of the electronic states in a nonmagnetic material, Yafet [1] has derived an expression for the longitudinal spin relaxation time T_1 due to scattering of electrons at phonons in the presence of spin-orbit coupling, using rate equations near the equilibrium state and Fermi's golden rule for the scattering rates. This expression involves the properties of electronic and phononic states and the matrix elements for the scattering. In a ferromagnet, Kramer's degeneracy does not hold and then the electronic dispersion and density of states become spin-dependent. Moreover, the symmetry of the scattering matrix element changes. It is shown that an analogous (yet more complicated) expression for T_1 can be derived for ferromagnets when taking into account the conservation of the total number of electrons. This expression can be used as a starting point for the ab-initio calculation of T_1, and this quantity is required for an interpretation of the ultrafast demagnetization of ferromagnets after excitation with a femtosecond laser pulse.

[1] Y. Yafet, in *Solid State Physics* (Eds.: F. Seitz and D. Turnbull, Academic, New York, 1963), Vol. 14.

MA 14.8 Wed 11:30 H10

Theoretical investigation of ultrafast laser-induced magnetization dynamics in small quantum mechanical systems — •Daria Popova, Andreas Bringer, and Stefan Blügel — Institut für Festkörperforschung & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

Ultrafast optical control of the magnetic state of a medium is presently a subject of intense research. It is of importance for the development of novel concepts for high-speed magnetic recording and information processing. A series of experiments has revealed direct optical control on magnetization via inverse Faraday effect [1]. In these experiments femtosecond circularly polarized high-intensity laser pulses are used to excite the sample. Laser induced spin dynamics are investigated using the pump-probe technique. An open question is the evolution of the orbital momentum transferred from light to the medium, which defines the fundamental time limit on magnetic switching. In order to get insight into the magnetization dynamics we treat small quantum mechanical systems. In our work we begin from the investigation of a hydrogen atom excited by a femtosecond gauss-shaped polarized laser pulse. The connection between light and spin are introduced due to the spin-orbit coupling of the excited level. Solving the time-dependent Schroedinger equation using the Volterra iteration method we study the temporal behavior of spin and orbital momentum during and after the application of the pump and probe laser pulses. We are thankful for the financial support of the FANTOMAS project.

[1] A. V. Kimel et al., Nature **435**, 655 (2005)

MA 14.9 Wed 11:45 H10

Modelling of ultrafast laser-induced demagnetization — •Benedikt Müller, Mirko Cinchetti, Tobias Roth, Martin Aeschlimann, and Bärbel Rethfeld — University of Kaiserslautern, Germany

Experiments with ultrashort laser pulses irradiating ferromagnetic transition metals show a demagnetization on femtosecond timescale [1]. Despite the numerous experimental efforts, still no complete microscopic understanding of ultrafast magnetization dynamics have been achieved. In order to describe the microscopic processes we apply the Boltzmann equation including electrons and phonons which characterize a solid [2]. The model can be extended for a ferromagnetic material: We consider electrons with spin up and down separately and allow coupling between both reservoirs. Including this, we are able to describe changes in the magnetization by incorporating the spin dependence into the Boltzmann equation. With this model we describe the temporal evolution of a ferromagnetic material which is strongly excited by an ultrashort laser pulse.

[1] M. Cinchetti et al., PRL 97, 177201 (2006)
[2] B. Rethfeld et al., PRB 65, 214303 (2002)

MA 14.10 Wed 12:00 H10

Enhanced Spin-Orbit Interaction During Ultrafast Demagnetization of Nickel — •Christian Stamm, Niko Pontius, Torsten Kachel, Marko Wietstruk, and Hermann A. Dürr — Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, 12489 Berlin

Time-resolved x-ray absorption spectroscopy (XAS) allows for a detailed view of microscopic processes during ultrafast demagnetization following a laser pump pulse. Previously we have shown that both spin and orbital angular momentum are quenched within a few 100 fs, utilizing the x-ray magnetic circular dichroism (XMCD) sum rules [1]. In addition, XAS is able to measure the spin-orbit interaction by quantifying the absorption ratio between the spin-orbit split L3, L2 absorption edges, the so-called branching ratio [2]. We find an increase of the spin-orbit coupling just after laser excitation, which persists during the demagnetization process. This is the first experimental demonstration of laser-enhanced spin-orbit interaction.

[1] C. Stamm et al., Nature Mater. 6, 740 (2007).
[2] G. van der Laan, B. T. Thole, Phys. Rev. Lett. 60, 1977 (1988).

MA 14.11 Wed 12:15 H10

Fluence and temperature dependent studies of femtosecond magnetism — •Oliver Schmitt, Tobias Roth, Daniel Steil, Sabine Alebrand, Mirko Cinchetti, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany

We exploit the time-resolved magneto-optical Kerr effect (TRMOKE) to gain access to the physics underlying ultrafast spin-dynamics. In this contribution, external parameters like the pump pulse fluence and the ambient temperature are deliberately varied over a wide range. The won results for a thin nickel film demonstrate a strong temperature dependence on the maximum quenching q of the magnetization as well as on the demagnetization constant τ_m and the relaxation back to the initial state. The Elliott-Yafet (EY) spin-flip mechanism is the most promising candidate to explain the ultrafast loss of magnetic order. Experimental results are discussed behind the background of the two recent models for ultrafast demagnetization based on EY scattering [1,2].

[1] B. Koopmans, G. Malinowski, F. Dalla Longa, D. Steiauf, M. Fähnle, T. Roth, M. Cinchetti and M. Aeschlimann, *Nature Mater.*, accepted
[2] M. Krauß, T. Roth, S. Alebrand, D. Steil, M. Cinchetti, M. Aeschlimann and H. C. Schneider, *PRB* **80**, 180407(R) (2009)

MA 14.12 Wed 12:30 H10

Probing half-metalicity of $Co_2Fe_xMn_{1-x}Si$ Heusler films in all-optical pump-probe experiments — •Jakob Walowski[1,2], Andreas Mann[1], Markus Münzenberg[1], Shigemi Mizukami[3], Takahide Kubota[2], Mikihiko Oogane[2], Hiroshi Naganuma[2], Yasuo Ando[2], and Terunobu Miyazaki[3] — [1]I. Physikalisches Institut, Universität Göttingen, Germany — [2]Department of Applied Physics, Graduate School of Engineering, Tohoku University, Sendai, Japan — [3]WPI-AIMR, Tohoku University, Sendai, Japan

Half metals are a promising candidate as spin injectors for spintronic devices, because of a high spin polarization at Fermi level and low Gilbert damping α. All-optical TRMOKE enables us to determine the degree of spin polarization by exciting the electrons above the Fermi level and probing the demagnetization time τ_m. Because of a band gap for minority electrons at Fermi level, Elliott-Yafet scattering processes are blocked, τ_m increases to the ps regime. From the increased τ_m the degree of spin polarization and thus a half-metallic behavior can be concluded. A second time scale τ_α , which describes the decline of magnetization precession (∼1 ns) started by an anisotropy change during the excitation allows the determination of α. We studied magnetization dynamics on both timescales in epitaxial $Co_2Fe_xMn_{1-x}Si$ samples by systematically increasing the Fe content in steps of 0.2. The samples reveal a spin polarization around 80% and $\alpha < 0.01$. Both parameters are sensitive to the quality of the sample structure.

Financial support from MEXT and NEDO Spintronics Nonvolatile Devices Project and a DAAD scholarship and is greatly acknowledged.

MA 15: Magnetic Half-metals and Oxides I

Time: Wednesday 10:15–13:00 Location: H22

MA 15.1 Wed 10:15 H22

Quadratic MOKE studies on epitaxial $Co_2FeAl_{0.5}Si_{0.5}$ films — •Georg Wolf[1], Simon Trudel[2], Helmut Schultheiss[1], Jaroslav Hamrle[1], Koichiro Inomata[3], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Chemistry, University of Calgary, Canada — [3]Magnetic Materials Center, National Institute for Materials Science (NIMS), Tsukuba, Japan

Magneto-optical Kerr effect (MOKE) is often used to study the quasistatic, as well as the dynamic properties of the magnetization. While in most cases only the linear response (LMOKE) is observed, some materials show also a quadratic magneto-optical Kerr effect (QMOKE). Recently, QMOKE has been observed in the Co-based Heusler compounds [1], which are promising materials due to their predicted high spin polarization at the Fermi level.
We introduce a new MOKE setup which is designed to systematically investigate the QMOKE on Heusler thin films on a routinely basis [2]. The setup provides access to the combined LMOKE and QMOKE signal, as well as the pure QMOKE signal, each probed by an individual probing beam. We report on first results obtained on $Co_2FeAl_{0.5}Si_{0.5}$ epitaxial thin films prepared in the group of K. Inomata, Japan. The dependence of the QMOKE as a function of the annealing temperature is investigated. Financial support by the DFG Research Unit 559, New Materials with High Spin Polarization is gratefully acknowledged.
[1] O. Gaier et al. Appl. Phys. **103**, 103910 (2008).
[2] S. Trudel et al. accepted by Rev.Sci.Inst.

MA 15.2 Wed 10:30 H22

XMCD as a probe for spin-orbit interaction and spin-resolved electronic structure of Heusler compounds — •Peter Klaer[1], Michael Kallmayer[1], Elena Arbelo Jorge[1], Christian Herbort[1], Gerhard Jakob[1], Martin Jourdan[1], Christian Blum[2], Tanja Graf[2], Benjamin Balke[2], Gerhard Horst Fecher[2], Claudia Felser[2], and Hans Joachim Elmers[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, D-55128 Mainz — [2]Institut für Anorganische Chemie und Analytische Chemie, Johannes Gutenberg-Universität Mainz, D-55128 Mainz

To confirm theoretical predictions and optimize material properties of half-metallic Heusler alloys a characterization of the electronic structure is necessary. For this purpose x-ray magnetic circular dicroism (XMCD) is a powerful tool. In addition to the element-specific determination of the spin and orbital moment, XMCD allows a direct experimental observation of the spin-resolved unoccupied density of states (DOS) in Heusler alloys. It is shown that a substitution of Ge by Ga in alloys like Co2MnGe shifts the minority DOS maximum with respect to E_F, indicating half-metallic ferromagnetism for the whole series and satisfying the rigid-band like behavior. Results for polycrystalline bulk samples and single crystalline films are discussed. We report on the orbital to spin moment ratio versus composition, relating its variation to the symmetry of the unit cell. For the series Co2Ti1-xMnxGe the Fermi energy shifts opposite to the expected rigid band behavior, which can be explained by a charge transfer from the light 3d-element Ti with antiparallel moment to Co states.

MA 15.3 Wed 10:45 H22

The surface spin polarization of Co-based Heusler alloys — •Roman Fetzer[1], Jan-Peter Wüstenberg[1], Sabine Neuschwander[1], Martin Jourdan[2], Christian Herbort[2], Enrique Vilanova Vidal[2], Gerhard Jakob[2], Martin Aeschlimann[1], and Mirko Cinchetti[1] — [1]University of Kaiserslautern, Department of Physics and Research Center OPTIMAS, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern — [2]University of Mainz, Institute of Physics, Staudinger Weg 7, 55128 Mainz

Co-based Heusler alloys belong mainly to the family of half-metallic ferromagnets (HMFs). The predicted full spin polarization at the Fermi level due to the minority spin band gap makes this class of materials highly interesting for application in the field of spintronics. Thus, the characterization of the surface of Co-based Heusler compounds is extremely relevant for understanding and improving the performance of Heusler-based spintronics devices, like tunnel-magnetoresistance (TMR) junctions. Using Auger electron spectroscopy (AES) [1] and low energy spin polarized electron photoemission [2], we systematically studied the correlation between chemical composition and spin polarisation of the surface. For various Co-based Heusler alloys, e.g.

Co_2CrAl, Co_2MnAl and $Co_2FeGa_{0.5}Ge_{0.5}$, we found different degrees of spin-polarization at the very surface region. Reasons for the distinct deviation from the predicted 100% spin polarization and the dependence on the specific surface preparation procedure will be discussed.

[1] Wüstenberg et al. , J. Phys. D: Appl. Phys. 42 (2009) 084016
[2] Cinchetti et al., J. Phys. D: Appl. Phys. 40 (2007) 1544-1547

MA 15.4 Wed 11:00 H22

Anomalous transport properties of the halfmetallic ferromagnets Co_2TiSi, Co_2TiGe, and Co_2TiSn. — •B. Balke[1], T. Graf[1], J. Barth[1], G.H. Fecher[1], A. Shkabko[2], A. Weidenkaff[2], and C. Felser[1] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany — [2]EMPA, Swiss Federal Laboratories for Materials Testing and Research, Solid State Chemistry and Catalysis, CH-8600 Duebendorf, Switzerland

This work reports on the theoretical and experimental investigations of Co_2TiZ (Z = Si, Ge, or Sn) compounds. Band structure calculations predict half-metallic ferromagnetism for all three compounds with only two bands crossing the Fermi energy in the majority channel. The magnetic moments fulfill the Slater-Pauling rule and the Curie temperatures are well above room temperature. All compounds show a metallic like resistivity for low temperatures up to their Curie temperature, above the resistivity changes to semiconducting like behavior. Additionally, we observe a large negative magnetoresistance of 55 % for Co_2TiSn at room temperature. The Seebeck coefficients are negative for all three compounds and reach their maximum values at their respective Curie temperatures and stay almost constant up to 950 K. The combination of half-metallicity and the constant large Seebeck coefficient over a wide temperature range makes these compounds interesting materials for further spincaloric investigations and thermoelectric applications. *This work is financially supported by "Stiftung Innovation Rheinland-Pfalz" and by the DfG (P1 and P7, FOR 559).*

MA 15.5 Wed 11:15 H22

Analysis of $L2_1$-ordering and study of properties on Co-based Heusler thin film samples — •Enrique Vilanova Vidal[1], Tanja Graf[2], Claudia Felser[2], and Gerhard Jakob[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz

Heusler alloys have been intensively investigated because they are promising materials for use in spin-dependent devices. Their half-metallic properties are strongly related with the presence of $L2_1$, $B2$ and fully disordered $A2$ structure. However, a rigorous method to study the proportions of these different ordering states is still missing. Sputtered thin epitaxial $Co_2FeSi_{0.6}Al_{0.4}$, $Co_2FeGa_{0.5}Ge_{0.5}$ and Co_2MnAl films have been prepared. These films were grown on MgO (100) with and without MgO buffer layer under UHV conditions and at different substrates temperatures. The deposition procedure is discussed, and the degree of $L2_1$ order as well as transport and magnetic properties are analyzed.

MA 15.6 Wed 11:30 H22

A Fermi-level-tuned half-metallic Heusler compound: $Co_2FeAl_{0.5}Si_{0.5}$ — •Rong Shan[1,2], Hiroaki Sukegawa[1], Wenhong Wang[1], Koichiro Inomata[1], Benjamin Balke[2], Gerhard H. Fecher[2], and Claudia Felser[2] — [1]Magnetic Materials Center, National Institute for Materials Science (NIMS), 1-2-1 Sengen, Tsukuba, 305-0047, Japan — [2]Institute of Inorganic and Analytical Chemistry,Johannes Gutenberg - University, 55099 Mainz

Balke B. and Fecher G.H. et al. in our group made a theoretical prediction of Fermi level tuning in Heusler compounds, which suggested that the Fermi level of $Co_2Mn_{1-x}Fe_xSi$ and $Co_2FeAl_{1-x}Si_x$ could be tuned to achieve the half-metallicity by the element substituting easily. However, to realize this prediction is a difficulty in experiment because of the perplexing relationship between the spin polarization of the quaternary Heusler compound and its structure disorder, resulting from the thermal treatment. Very recently, we confirmed Fermi level tuning in Heusler alloy $Co_2FeAl_{0.5}Si_{0.5}$ (CFAS). Half-metallic band gap of CFAS was proved even at room temperature by the behavior of differential conductance of CFAS/$(MgAl_2)O_x$/CoFe magnetic tunneling junctions with an unexplored crystalline $(MgAl_2)O_x$ barrier. CFAS exhibits the highest effective spin polarization (P_{eff}) at 300 K and the weakest temperature dependence of P_{eff} among all known half-metals. Further study shows that P_{eff} of CFAS decays with increasing temperature (T) following $T^{3/2}$ law perfectly, which indicates that the depolarization of CFAS is determined by spin wave excitation only.

MA 15.7 Wed 11:45 H22

Epitaxial growth of Fe_3O_4 thin films on ZnO substrates — •Andreas Müller[1], Andreas Ruff[1], Markus Paul[1], Christian Praetorius[2], Kai Fauth[2], Uwe Bauer[3], Marek Przybylski[3], Michael Sing[1], and Ralph Claessen[1] — [1]Experimentelle Physik IV, Universität Würzburg — [2]Physikalisches Institut, Universität Würzburg — [3]MPI für Mikrostrukturphysik, Halle

Magnetite (Fe_3O_4)/ zinc oxide (ZnO) heterostructures are currently explored due to their application potential in spintronics. Semimetallic Fe_3O_4 is a ferrimagnet and was predicted to possess a fully spin-polarized Fermi surface, which makes it well suited for spin injection.

We have grown Fe_3O_4 thin films epitaxially on ZnO substrates using molecular beam epitaxy. The film quality was found to be strongly dependent on the oxygen partial pressure during growth. Structural, electronic, and magnetic properties were analyzed utilizing Low Energy Electron Diffraction (LEED), HArd X-ray PhotoElectron Spectroscopy (HAXPES), Magneto Optical Kerr Effect (MOKE), and X-ray Magnetic Circular Dichroism (XMCD). Film growth on ZnO was found to be in (111) direction. HAXPES gives clear evidence for the formation of Fe_3O_4. Non-destructive depth profiling using angle dependent HAXPES measurements showed uniform growth. However, the magnetic measurements revealed reduced magnetization for films grown on ZnO.

MA 15.8 Wed 12:00 H22

Origin of Ferrimagnetism in Ti and Cr doped α-Fe_2O_3 — •Hasan Sadat Nabi and Rossitza Pentcheva — Department of Earth and Environmental Sciences, University of Munich, Theresienstr. 41, 80333 Munich, Germany

Using density functional theory (DFT) and taking into account an on-site Coulomb repulsion term (GGA+U) we perform a comparative study of Ti and Cr substitution in α-Fe_2O_3. The charge mismatch in the $FeTiO_3$-Fe_2O_3 system is identified as a driving force towards ferrimagnetism as it leads to the formation of a mixed Fe^{2+}, Fe^{3+} layer and uncompensated spins [1-2]. While a valence discontinuity is not present in the other system (Cr_2O_3-Fe_2O_3), we show that a different magnetic order and a net magnetization can be induced by controlling the concentration and arrangement of Cr ions in the Fe_2O_3-lattice, e.g. via heterostructuring. Furthermore the magnetic interaction parameters are extracted by mapping the DFT energies of different magnetic configurations to a Heisenberg Hamiltonian.

Funding by the DFG (Pe883/4-1) and ESF as well as the computational time at the Leibniz Rechenzentrum are gratefully acknowledged.
[1] R. Pentcheva and H. Sadat Nabi, Phys. Rev. B **77**, 172405 (2008).
[2] H. Sadat Nabi and R. Pentcheva, J. Appl. Phys. **105**, 053905 (2009).

MA 15.9 Wed 12:15 H22

Orbital magnetism of strongly correlated transition-metal oxides - a LSDA+DMFT study — •Gerhard Kuhn, Jan Minár, Diemo Ködderitzsch, Sergiy Mankovskyy, and Hubert Ebert — LMU München

In this study we focus on the spin-orbit coupling induced properties of strongly correlated transition-metal oxides (MnO, FeO, CoO, NiO). We used self-consistent and fully relativistic implementations of the LSDA+U and the LSDA+DMFT within the multiple scattering KKR-method. Calculations for spin and orbital magnetic moments were performed in the atomic sphere approximation and for the full potential mode. Three different magnetic structures were treated: ferromagnetic, anti-ferromagnetic 1 and anti-ferromagnetic 2. Total energies were calculated to determine the most stable magnetic structure and subsequently used to calculate the exchange-coupling constants (J_{ij}) by mapping on a Heisenberg-Model. In addition, the J_{ij}'s were calculated by the relativistic generalisation of Lichtenstein's formula and the magnetic torque method.

MA 15.10 Wed 12:30 H22

Growth and Characterisation of Mn stabilized Zirconia — •Jan Zippel, Michael Lorenz, Anette Setzer, Jörg Lenzner, Holger Hochmuth, Pablo Esquinazi, and Marius Grundmann — Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentelle Physik II, Linnétr. 5, 04103 Leipzig, Germany

The possibility to combine both, the electron spin as a new degree of freedom and the electron charge offers opportunities for a new generation of devices. As recently predicted [1], Mn stabilized Zirconia is proposed as a ferromagnetic semiconductor with a Curie temperature Tc above room temperature. Here we present the growth of manganese doped ZrO2 with Pulsed-Laser deposition (PLD). By introducing more than 15 at% Mn, we observe only a tetragonal or cubic crystalline structure by doing X-ray diffraction (XRD). Transmission electron microscopy (TEM), energy dispersive X-ray spectroscopy, Rutherford backscattering spectroscopy (RBS) and X-ray Photoelectron Spectroscopy (XPS) were done to check the structural properties as well as the Mn content and the stoichiometry. Beside the structural also the electronic and magnetic properties were investigated. We compare the conductivity of pure ZrO2 either with Mn doped ZrO2 or with Mn stabilized Zirconia (MnSZ) co-doped with Al, Y, and Nb. Superconducting quantum interference device (SQUID) measurements revealing a superparamagnetic behavior at low temperatures (T = 5K) but, up to now, no room temperature ferromagnetism.

[1] S. Ostanin et al., Phys. Rev. Lett 98, 0161011 (2007).

MA 15.11 Wed 12:45 H22

Correlation between Curie temperature and carrier density of electron-doped EuO - is there an intrinsic limit on T_C? — •Thomas Mairoser[1], Andreas Schmehl[1], Jochen Mannhart[1], Alexander Melville[2], Tassilo Heeg[2], Darrell G. Schlom[2], Peter Böni[3], Lea Canella[3], and Jürgen Schubert[4] — [1]Universität Augsburg — [2]Cornell University, USA — [3]Technische Universität München — [4]Forschungszentrum Jülich

The ferromagnetic semiconductor europium oxide exhibits a multitude of giant properties, such as metal-to-insulator transitions, a colossal magneto-resistance, and very pronounced magneto-optic effects. The recently demonstrated spin-polarization of $> 90\,\%$ in the ferromagnetic state [A. Schmehl *et al.*, Nat. Mat. **6**, 882 (2007)] and its excellent electronic compatibility with Si make it an interesting candidate for semiconductor based spintronics. Nevertheless the low Curie temperature (T_C) of 69 K of undoped EuO is a major obstacle for the use of this outstanding material in commercial spintronic applications.

By electron doping EuO with donor impurities, T_C can substantially be increased exploiting an additional exchange interaction that is mediated via the conduction electrons.

Here we report on measurements of T_C and the carrier densities by Hall effect on La and Gd doped EuO films grown over a wide range of doping concentrations and growth conditions. The experiments show that only a small fraction of the introduced impurities actually act as donors even for optimized growth parameters. Furthermore we found a strong correlation between Curie temperatures and carrier densities.

MA 16: Micro- and Nanostructured Magnetic Materials II

Time: Wednesday 10:15–12:45 Location: H23

MA 16.1 Wed 10:15 H23

Preparation and magnetic characterization of electrodeposited Fe and FePd nanowires — •Veronika Haehnel[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, 01062 Dresden, Germany

Periodic arrays of high aspect ratio 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. Fe nanowires are of particular interest due to their high magnetization promising high shape anisotropy. FePd alloys have unique magnetic and material properties. Around the composition $Fe_{70}Pd_{30}$ they are interesting candidates with regard to the magnetic shape memory effect (MSM). Preparing MSM-active nanowires, magnetically driven nanoactuators are conceivable.

In this study we show Fe nanowires electrodeposited into nanoporous alumina membranes. The electrodeposition process was optimized in order to approach an ideal behaviour of smooth and continuous Fe nanowires. Thereon saturation polarization and an anisotropy field up to 70% compared to pure Fe were measured. By Mössbauer spectroscopy and magnetic measurements we have found that shape anisotropy aligns the preferential magnetization axis along the long axis. Furthermore, we show the first results of structural and magnetic characterization of electrodeposited FePd nanowires.

MA 16.2 Wed 10:30 H23

Magnetic Properties of Fe Wires on Vicinal Cu(111) at Finite Temperatures — •Hossein Hashemi[1], Guntram Fischer[1], Wolfram Hergert[1], Valeri S. Stepanyuk[2], Hasan Sadat Nabi[3], and Rossitza Pentcheva[3] — [1]Department of Physics, University of Halle, Von-Seckendorff-Platz 1, 06120 Halle, Germany — [2]MPI for Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [3]Departments of Earth and Environmental Sciences, University of Munich, Theresienstrasse 41, 80333 Munich, Germany

Vicinal surfaces on metals are very suitable templates to grow one-dimensional nanowires. It is known that Fe nanostripes grow on the upper terrace of a stepped Cu(111) surface. Mo, Guo et al. [1,2] have shown that, Fe adatoms form an atom chain embedded into the Cu substrate behind a row of Cu atoms at the descending step. Then a second chain of Fe atoms is formed on top of the embedded Fe chain. In this work, density functional theory (DFT) is applied to describe the structural and magnetic properties of Fe chains and wires consisting of two Fe chains embedded in the Cu(111) surface. We determine both the direct exchange interaction within the Fe wires as well as the indirect exchange interactions between parallel Fe chains as a function of the interchain distance. Furthermore, the magnetocrystalline anisotropy energy is calculated. Exchange interactions and anisotropy extracted from the ab initio calculations are used in a classical Heisenberg model. Monte Carlo simulations are done to investigate the finite temperature properties of the systems. [1] Yina Mo, et al., PRL 94, 155503 (2005). [2] J. Guo et al., Phys. Rev. B 73, 193405 (2006).

MA 16.3 Wed 10:45 H23

Switching of individual Fe_3C nanowires with transverse magnetization — •Matthias U. Lutz, Uhland Weissker, Franziska Wolny, Markus Löffler, Thomas Mühl, Albrecht Leonhardt, Rüdiger Klingeler, and Bernd Büchner — Leibniz Institute for Solid State and Materials Research (IFW) Dresden, Germany

Iron carbide nanowires contained within a multiwalled carbon nanotube feature a transverse remanent magnetization where the magnetization vectors are perpendicular to the long wire axis. TEM studies on the CVD-grown nanotubes reveal that the fillings are single crystal Fe_3C nanowires with the crystallographic b-axis along the hollow of the tube, causing the magnetic easy c-axis to be perpendicular to the long axis of the wire. Comparing the magneto-crystalline and the shape anisotropy indicates that the former dominates. The two anisotropy contributions are orthogonal, resulting in a weak effective anisotropy favouring a transverse magnetization. The remanent magnetization as well as the switching behaviour are studied with the aid of a hr-MFM with an in-situ perpendicular magnetic field. The Fe_3C wires switch at around 30 mT. The mechanism of magnetization reversal is discussed along with possible applications of the system.

MA 16.4 Wed 11:00 H23

Spin-Wave Interference in Rolled-Up Permalloy Microtubes — •Felix Balhorn, Sebastian Mansfeld, Andreas Krohn, Simon Jeni, Jesco Topp, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg

Strained semiconductor bilayers can be utilized in order to fabricate rolled-up mictrotubes [1, 2]. We have used these structures as templates to roll up permalloy films with multiple rotations to form Rolled-Up Permalloy Microtubes (RUPTs) [3]. Here, we investigate the spin-wave spectra of RUPTs in axial magnetization geometry by means of broadband microwave absorption spectroscopy. The RUPTs show up to four resonances which exist in the experimentally accessible field range. The resonances are attributed to constructively interfering Damon-Eshbach like spin waves propagating around the circumference of the tube. This interpretation is confirmed by fitting the experimental data according to an analytical model. The fit matches the exper-

imental data almost perfectly if we express the dipolar coupling between the magnetic layers by an effective layer thickness and allow for an anisotropy field. This field considers demagnetization effects caused by the curved structure of a RUPT [3] and can be measured independently in hard axis configuration. We acknowledge financial support by the SFB668, GrK 1286, and the Cluster of Excellence *Nanospintronics*.

[1] V. Y. Prinz et al., Physica E **6**, 828 (2000); [2] O. G. Schmidt, and K. Eberl, Nature **410**, 168 (2001); [3] S. Mendach et al., Appl. Phys. Lett. **93**, 262501 (2008)

MA 16.5 Wed 11:15 H23

Saturation magnetization modulated stripes embedded in a ferromagnetic matrix — •Thomas Strache[1], Sebastian Wintz[1], Mohammed Abdul Basith[2], Norbert Martin[3], Monika Fritzsche[1], Ingolf Mönch[3], Maciej Oskar Liedke[1], Michael Körner[1], Daniel Markó[1], Jörg Raabe[4], Stephen McVitie[2], Jeffrey McCord[3], and Jürgen Fassbender[1] — [1]Forschungszentrum Dresden-Rossendorf, Dresden, Germany — [2]University of Glasgow, Glasgow, U.K. — [3]Leibniz-Institut für Festkörper- und Werkstoffforschung, Dresden, Germany — [4]Swiss Light Source, Paul Scherrer Institut, Switzerland

Lateral patterning of thin magnetic films allows structuring on dimensions below certain intrinsic length scales like the domain wall width. By means of magnetic patterning using local ion irradiation periodic patterns of stripes with alternating saturation magnetization value were created in a ferromagnetic $Ni_{80}Fe_{20}$ matrix. The domain configuration during magnetization reversal was investigated using Kerr microscopy, scanning transmission x-ray microscopy, as well as Lorentz microscopy. The reversal mechanisms in the stripe panels are influenced by the domain configuration of the surrounding film. Starting from 1 μm stripe width, changes in the micromagnetic behavior with respect to decreasing width are investigated. Special emphasis is put on the formation of 180° walls between adjacent stripes with different saturation magnetization, on the orientation of the magnetization inside the stripes with respect to the stripe axis orientation, as well as on the transition of the patterned material to an effective medium.

MA 16.6 Wed 11:30 H23

Two distinct magnetic switching events in core-shell nanowires with fully controlled geometric parameters — Yuen Tung Chong, Detlef Görlitz, Stefan Martens, Kornelius Nielsch, and •Julien Bachmann — Institut für Angewandte Physik, Universität Hamburg

A preparative strategy that combines atomic layer deposition (ALD) with electrodeposition in a porous template (anodic alumina) enables one to arrange a nickel core with an iron oxide shell coaxially in biphasic magnetic nanowires. The wires have large aspect ratios (>100), they are ordered in parallel arrays, and in each of them, a non-magnetic silica spacer layer physically separates core from shell. The thickness of each layer is adjustable between 3 and 30 nm or so, thus, given a fixed outer diameter of 150 nm, the core diameter may be varied between approximately 50 and 100 nm.

In the presence of a sufficiently thick non-magnetic spacer, core and shell revert their magnetization separately from each other, and the switching fields are determined mostly by the respective geometric parameters. The two distinct reversal events are characterized by magnetometric measurements on the ensembles: the hysteresis loops strongly depend on systematic changes in geometry and temperature.

MA 16.7 Wed 11:45 H23

Semiconductor-ferromagnet core-shell nanowires grown by molecular beam epitaxy — •Maria Hilse, Yukihiko Takagaki, Jens Herfort, Claudia Herrmann, Manfred Ramsteiner, Steffen Breuer, Lutz Geelhaar, and Henning Riechert — Paul-Drude-Institut für Festkörperelektronik, Berlin

The special geometry of nanowires (NWs) offers the possibility to elastically absorb lattice mismatch strain. Thus, axial and radial NW heterostructures consisting of dissimilar materials can be grown with high quality. In addition, spin dependent functionalities are introduced to NW devices when a ferromagnet is incorporated into these heterostructures. MnAs is one of the attractive materials as it is ferromagnetic at room temperature (the Curie temperature is about 40 °C). In this work, we combine GaAs and MnAs in a NW core-shell geometry by means of molecular beam epitaxy (MBE). The GaAs NWs were grown using the Au-assisted vapor-liquid-solid mechanism on GaAs(111)B substrates. The MnAs growth took place under the typical conditions for planar growth on GaAs. A curving of the NWs is observed if the sample stage is not rotated during MnAs overgrowth, evidencing the diffusion length of Mn being less than the perimeter of the NWs. By analyzing the planar film and NW shell thicknesses, we demonstrate the MnAs growth to take place by direct deposition on the NW sidewalls. NWs exhibit a hexagonal cross section indicating the c-axis, i.e., the magnetic hard axis of MnAs to be parallel to the NW axis. This orientation is confirmed by magnetization measurements and magnetic-force microscopy.

MA 16.8 Wed 12:00 H23

Domain walls in bent nanowires — •André Kobs, Sebastian Hankemeier, Robert Frömter, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

We have investigated the magnetic fine structure in remanence and the appearance of domain walls in bent nanowires depending on their geometrical properties by means of scanning electron microscopy with polarization analysis (SEMPA). The wires were carved from 18 nm thick soft-magnetic $Co_{39}Fe_{54}Si_7$ film via Focused Ion Beam (FIB) milling. By gradually decreasing the angle of the bend we find the transition from vortex wall to transverse wall via the so called asymmetric transverse wall. For the vortex walls, the vortex core is not exactly aligned with the mirror axis of the wire, but is slightly shifted into one of the two arms of the wire. The direction of the magnetic field that is used to seed the domain wall determines which of the energetically degenerated vortex wall states occur. More important, the chirality is linked to the location of the vortex wall and is therefore also experimentally accessible. Micromagnetic simulations verify these results and show in addition that the polarity can be tuned on purpose by applying a moderate out of plane field during vortex core nucleation. The ability to control the chirality and the polarity is a necessary prerequisite for new storage concepts based on vortex walls in combination with current induced domain wall movement, like in the racetrack memory device.

MA 16.9 Wed 12:15 H23

Hall micromagnetometry of current-assisted domain-wall motion in permalloy nanowires — •Stephan Marauska, Peter Lendecke, Guido Meier, and Ulrich Merkt — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

We use ballistic Hall micromagnetometry to analyze the effect of current-injection on domain-wall (DW) depinning in permalloy nanowires. DW motion controlled by current is a key function for the magnetic racetrack memory proposed by Stuart Parkin. The domain walls are pinned in constrictions defined by a triangularly shaped notch in one edge of the wires. The high sensitivity of the Hall sensors to local stray fields allows non-invasive detection of individual DWs pinned at spezific locations in a nanowire [1, 2]. We determined the dependence of the depinning fields on parameters such as current-pulse length and current density by injecting nanosecond current pulses at temperatures below 2 K. The reduction of the depinning fields is commonly explained due to spin-torque interaction. Hall micromagnetometry allows to investigate DW depinning with a high capability to acquire enough statistics.

[1] P. Lendecke, R. Eiselt, G. Meier and U. Merkt, J. Appl. Phys. 103, 073909 (2008)
[2] P. Lendecke et al., JMMM, in press (2009)

MA 16.10 Wed 12:30 H23

Preparation and characterisation of regularly arranged MnAs nanoclusters and chains on (111)B-GaAs substrates — •Matthias T. Elm[1], Shingo Ito[2], Hans-Albrecht Krug von Nidda[3], Shinjiroh Hara[2], and Peter J. Klar[1] — [1]1. Physikalisches Institut, Justus-Liebig University, Heinrich-Buff-Ring 16, 35392 Giessen — [2]Research Center for Integrated Quantum Electronics, Hokkaido University, Sapporo, Japan — [3]Experimentalphysik V, University of Augsburg

Ordered arrangements of ferromagnetic MnAs nanoclusters and cluster chains were obtained by selective-area MOVPE on pre-patterned (111)B-GaAs substrates. Using this new method it is possible to control the position, the size and the shape of the nanoclusters on the surface in the growth process, which offers interesting opportunities to tune the properties of individual nanoclusters and the interaction

of the clusters with the carriers of the surrounding semiconducting matrix. Several cluster arrangements and cluster chains were grown consisting of nanoclusters with a length of 690 nm and a width of 290 nm. The quality of the cluster growth was investigated by SEM and AFM. The magnetic properties were probed by MFM and FMR in order determine the magnetic anisotropy and the domain formation of the clusters. The samples were also investigated by angle-dependent magneto-transport measurements in the temperature range from 20 to 280 K in external magnetic fields up to 10 T. The transport properties were correlated with the cluster arrangement of the samples and the magnetization orientation.

MA 17: Spin Dynamics / Spin Torque II

Time: Wednesday 14:00–18:30 Location: H10

Invited Talk MA 17.1 Wed 14:00 H10

Current-induced magnetization dynamics — •Mathias Kläui — Fachbereich Physik, Universität Konstanz, 78457 Konstanz

When combining transport with magnetic materials on the nanoscale, a range of exciting and novel phenomena emerge. While magnetoresistance effects have been widely studied, the reciprocal spin transfer torque effect that leads to current-induced domain wall motion, has become the focus of intense research in the last few years [1]. In current-induced domain wall motion (CIDM), due to a spin torque effect, electrons transfer angular momentum and thereby push a domain wall with velocities > 100m/s. We have comprehensively investigated this effect using magnetotransport and dynamic imaging techniques based on synchrotron light sources and we have observed that this interaction is strongly dependent on the wall spin structure [2-4]. To understand the underlying mechanisms, we have separated the effects of the adiabatic and non-adiabatic spin torque terms from parasitic Oersted field effects and we have developed a robust measure of the non-adiabaticity parameter. Dynamic imaging shows that AC currents can excite non-linear domain wall oscillations and we determine the oscillatory eigenmodes and quantitatively map the asymmetric and even non-linear potential, which can be engineered by applying external fields [5]. [1] M. Kläui, Topical Review in J. Phys: Condens. Matter 20, 313001 (2008);[2] M. Kläui et al., PRL 94, 106601 (2005), PRL 95, 26601 (2005);[3] O. Boulle et al., PRL 101, 216601 (2008);[4] L. Heyne et al., PRL 100, 66603 (2008);[5] D. Bedau et al., PRL 99, 146601 (2007); PRL 101, 256602 (2008)

Invited Talk MA 17.2 Wed 14:30 H10

Ultrafast switching of magnetic vortex cores – The role of the internal energy — •Riccardo Hertel — Institut für Festkörperforschung IFF-9, Forschungszentrum Jülich GmbH, Leo-Brandt-Str., D-52425 Jülich

The recently discovered dynamic switching of magnetic vortex cores can be regarded as the most complex fundamental micromagnetic switching process. It is mediated by the rapid formation and annihilation of vortex-antivortex pairs. The first observation of this core switching was obtained by varying the amplitude of an external field tuned at the gyrotropic resonance frequency [1]. This switching route is rather slow, since it requires several nanoseconds to resonantly excite a vortex from the equilibrium state up to the switching threshold. Alternatively, an ultrafast route has been proposed based on single, short field [2] or electric current [3,4] pulses which can switch the core within a few tens of picoseconds. In spite of these differences in switching times, simulations show that the micromagnetic process of the core reversal is the same for both routes. With our finite-element code we studied the role of the internal energy in these processes. We find that the vortex core always switches at well-defined energy thresholds. Careful analysis of the mesh-size dependence of the computed values shows that the critical switching energy is in agreement with the analytic value for the formation energy of a vortex-antivortex pair. [1] B. Van Waeyenberge et al., Nature 444, 461 (2006) [2] R. Hertel et al., Phys. Rev. Lett. 98, 117201 (2007) [3] K. Yamada et al., Nature Mater. 6, 270-273 (2007) [4] Y. Liu et al., Appl. Phys. Lett. 91, 112501 (2007)

MA 17.3 Wed 15:00 H10

Dynamics of massless magnetic domain walls in cylindrical Permalloy nanowires — •Ming Yan, Attila Kákay, Sebastian Gliga, and Riccardo Hertel — Institut für Festkörperforschung, IFF-9, Forschungszentrum Jülich, D-52425 Jülich

It is well known that there exists an upper limit to the velocity of magnetic domain walls (DWs) driven by an external force. This is related to the accumulation of energy or, in other words, the increase of effective mass of the DW during its motion. We have found that DWs formed in cylindrical nanowires can be effectively massless, such that their velocity is not limited by these effects [1]. Driven by a magnetic field or a spin polarized electric current, this DW-type propagates along a characteristic spiraling path. Owing to the cylindrical symmetry of the wire, the DW maintains its configuration during its motion, thereby avoiding the accumulation of energy. This type of DW may have important implications in fundamental studies and for applications, especially in the case of current-driven DW motion. We show that the spin polarization rate of the current can be directly determined by measuring the DW velocity. Moreover, the rotational motion of the DW can be used to measure the non-adiabatic spin transfer torque parameter. The smooth linear motion of the DW provides a possibility to achieve precisely controlled DW motion, which is essential for race-track memories [2].

References:
[1] M. Yan, A. Kákay, S. Gliga, and R. Hertel, submitted.
[2] S. S. Parkin, M. Hayashi, and L. Thomas, Science 320, 190 (2008).

MA 17.4 Wed 15:15 H10

Dynamics of domain walls in thin films with out-of-plane magnetization — •Benjamin Krüger[1], Imam Makhfudz[2], Oleg Tchernyshyov[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg — [2]Department of Physics and Astronomy, Johns Hopkins University

The possibility that domain walls can be shifted by a spin-polarized current flowing through the wall or by magnetic fields is important for memory and spintronic devices. While for small wires the dynamics of the wall is well described by a model in which the wall moves as a quasi particle[1,2,3] this model has to fail for broader wires and magnetic films where the current or field may be inhomogeneous.

We investigate the dynamics of domain walls in a thin magnetic film with a strong easy-axis anisotropy that favors the out-of-plane direction. It is found that the dominance of the gyrotropic force over the viscous one makes the dynamics of Bloch walls rather unusual. By distorting the wall it is possible to excite waves that propagate with different speed in the two directions along the wall. From these results one finds that the star-shaped gyrational trajectory of a magnetic bubble in a magnetic disc[4] is a result of superposition of two waves with the same wavenumber and different frequencies running in opposite directions along the wall that surrounds the bubble.

[1] W. Döring Z. Naturforsch. 3a, 373 (1948)
[2] L. Thomas et al. Nature 443, 197 (2006)
[3] L. Bocklage et al. Phys. Rev. Lett. 103, 197204 (2009)
[4] C. Moutafis et al. Phys. Rev. B 79, 224429 (2009)

MA 17.5 Wed 15:30 H10

Field and current driven depinning of domain walls in V-shaped nanowires — •Sebastian Hankemeier, Björn Beyersdorff, Robert Frömter, and Hans Peter Oepen — Universität Hamburg, Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg, Germany

We have studied the depinning behaviour of domain walls in V-shaped nanowires. In our geometry, the angle between the two arms of the Permalloy wire is 170°, width and thickness are 350 nm and 18 nm, respectively. At the intersection of the two arms, domain walls can be easily nucleated by an external field, which is aligned parallel to the mirror axis of the V-shaped wire. The electrical resistivity is measured to reveal the existence of a domain wall within the wire via the anisotropic magnetoresistance (AMR). The depinning behaviour of the domain wall has been investigated by measuring the AMR in dependence of strength and orientation of the external magnetic field. When cooling the nanowire, the DC current density can be increased up to $4 \cdot 10^{12} \frac{\mathrm{A}}{\mathrm{m}^2}$ without destroying the wire [1]. Beyond a DC current den-

sity of $1 \cdot 10^{11} \frac{\mathrm{A}}{\mathrm{m}^2}$, the current affects the depinning field of a domain wall via Joule heating, Oersted field and the spin torque effect. We demonstrate a procedure that allows a separation of these effects to study their individual influences on the depinning field of the domain wall. This work is supported by DFG, SFB 668.

[1] S. Hankemeier, K. Sachse, Y. Stark, R. Frömter, and H. P. Oepen, Appl. Phys. Lett. **92**, 242503 (2008).

MA 17.6 Wed 15:45 H10

Tailoring laser-induced domain wall pinning — •Philipp Möhrke[1], Jeroen Franken[2,1], Jan Rhensius[1,3], Jan-Ulrich Thiele[4], Ursula J. Gibson[5], Laura J. Heyderman[3], Ulrich Rüdiger[1], and Mathias Kläui[1] — [1]Universität Konstanz, Fachbereich Physik, Universitätsstraße 10, 78457 Konstanz, Germany — [2]Department of Applied Physics, University of Technology, Einhoven, Netherlands — [3]Paul Scherrer Institut, 5232 Villingen PSI, Switzerland — [4]Hitachi Global Storage, San Jose, CA, USA — [5]Thayer School of Engineering, Dartmouth Colege, Hanover, NH, USA

The generation of spin-currents due to temperature gradients was predicted from theoretical calculations and measured in experiment (spin Seebeck effect). This topic has attracted interest lately, but so far no influence of such spin-currents on domain wall (DW) motion has been reported.

We first probe the effect of the current-induced heating on the magnetic and magneto-optical properties of Permalloy nanowires with increasing current density using a dynamic Kerr-microscope. Furthermore the creation of tunable pinning sites by local laser-induced heating, which could be explained by spin-currents, is shown for higher laser powers. We find that the laser spot focused onto the wire can act as a flexible pinning site for a DW. As part of the power is absorbed by the sample, it is heated locally and a strong thermal gradient is created. The field or current required to depin the DW from the spot increases with laser power so that the pinning strength can be tuned by adjusting the laser.

MA 17.7 Wed 16:00 H10

Ultrafast all-optical switching of magnetic domains using circular polarized laser light — •Alexander Hassdenteufel, Daniel Steil, Sabine Alebrand, Mirko Cinchetti, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany

Magnetic switching is typically a continuous process that can be described as a damped precession of the magnetization in an external magnetic field. This process takes typically up to 1 ns. Recently it has been shown that it is possible to achieve magnetic switching within 100 fs [1,2]. This process is induced by circularly polarized ultrashort laser pulses, where the direction of this opto-magnetic switching is determined only by the helicity of light. In this contribution, the femtosecond laser-induced reversal mechanism of GdFeCo thin films is investigated by static and time-resolved magneto-optical Faraday measurements. In particular, we studied the dependence of the writing threshold on the laser duration and bandwidth by using chirped laser pulses with different durations from 0,1 ps to 1,5 ps as well as by modifying the pulses with a slit. This work was supported by the European project ULTRAMAGNETRON.

[1] Kimel, A. V. et. al. Nature **435**, 2005, 655-657
[2] Stanciu, *PRL* **99**, 047601 (2007)

MA 17.8 Wed 16:15 H10

Dependence of Magnetic Domain-Wall Motion on a Fast Changing Current — •Lars Bocklage[1], Benjamin Krüger[2], Hauke Langner[1], Toru Matsuyama[1], Markus Bolte[1], Ulrich Merkt[1], Daniela Pfannkuche[2], and Guido Meier[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany — [2]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstrasse 9, 20355 Hamburg, Germany

Domain walls in magnetic nanowires can be moved by an electrical current. Using resonant excitations the temporal shape of the current strongly influences the dynamics of the wall [1]. Theoretically it was predicted that the time derivative of the current density also affects the wall motion [2,3]. We observe a dependence of the depinning probability of a vortex wall on the rise time of current pulses in permalloy nanowires [4]. The characteristic time scale in which the rise time affects the depinning probability is in the order of some nanoseconds. An analytical description shows that a strong force acts on the domain wall for short rise times which arises from the time derivative of the current. The damping time of the domain wall, that is independent of the pinning potential, is the scaling time on which the force of the time derivative of the current gets significant. [1] L. Thomas et al., Nature 443, 197 (2006)
[2] B. Krueger et al., Phys. Rev. B 75, 054421 (2007)
[3] T. Suzuki et al., J. Appl. Phys. 103, 113913 (2008)
[4] L. Bocklage et al., Phys. Rev. Lett. 103, 197204 (2009)

MA 17.9 Wed 16:30 H10

Different Walker fields in the same nanostripe: The influence of slanted edges on the domain wall dynamics — •Sascha Glathe, Matthias Zeisberger, and Roland Mattheis — IPHT Jena, Albert-Einstein-Str. 9, 07745 Jena

The Walker field is the key parameter describing field driven domain wall (DW) dynamics. We analyzed the Walker field in giant magnetoresistance (GMR) nanostripes by means of time resolved resistance measurements. With this technique we are able to determine the Walker field strength directly by evaluating the obtained single shot measurements. The 160*45*45000 nm^3 (sense layer thickness was 20 nm) GMR nanostripe was deposited by dc magnetron sputtering and structured via photolithography and Ar ion etching under tilt. Therefore the nanostripes have slanted edges in the cross section. This geometrical feature breaks the symmetry between a moving head-to-head and a tail-to-tail DW, respectively, giving rise to different Walker field strengths in the same sample. This difference is explained by means of the different stray field contribution appearing for both configurations and is confirmed by micromagnetic simulations.

MA 17.10 Wed 16:45 H10

Ion-milled permalloy nanowires sputtered on heated substrates for current-induced domain-wall depinning — •Gesche Nahrwold[1], Sedat Dogan[1], Lars Bocklage[1], Toru Matsuyama[1], Guido Meier[1], Ulrich Merkt[1], Kouta Kondou[2], Gen Yamada[2], and Teruo Ono[2] — [1]Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg — [2]Institute for Chemical Research, Kyoto University, Kyoto 611-0011, Japan

Current-induced domain-wall motion is a subject of wide interest, most prominently represented by the race-track memory invented by S. Parkin [1]. In order to investigate reliable devices it is crucial to optimize the material properties of permalloy [2], which is commonly used for the fabrication of nanowires for domain-wall depinning. By sputtering permalloy on heated substrates the specific resistance is significantly decreased while keeping other relevant characteristics, such as crystal structure, magnetic properties, crystallite size, and material composition at desired levels. For sample preparation with this material a subtractive process is needed as due to the high temperatures during deposition lift-off is impossible. We have fabricated curved wires by subtractive ion-milling of permalloy films sputtered on substrates heated to 300 °C. Current-induced domain-wall experiments yield low depinning fields and a reliable depinning process. [1] S. S. P. Parkin et al., Science **320**, 190 (2008), [2] G. Nahrwold et al., J. Appl. Phys. **105**, 07D511 (2009)

15 min. break

MA 17.11 Wed 17:15 H10

Vortex dynamics in arrays of dipolar coupled ferromagnetic disks — •Andreas Vogel[1], André Drews[1,2], Markus Bolte[1,2], and Guido Meier[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany — [2]AB Technische Informatik Systeme, Department Informatik, Universität Hamburg, Vogt-Kölln-Strasse 30, 22527 Hamburg, Germany

Vortices trapped in small ferromagnetic structures are of intense scientific interest because of their sub-nanosecond dynamics and potential technological applications as ultra-fast and high density digital storage elements [1-2]. We study the influence of the magnetostatic interaction on the vortex dynamics in arrays of ferromagnetic disks by means of a broadband ferromagnetic-resonance setup using a vector-network analyzer. Transmission spectra reveal a strong dependence of the frequency of resonant circular vortex-core motion on the inter-element distance within the array. For decreasing distance, a considerable broadening of the absorption peak is observed following a sixth-order power law, known from the Van der Waals type interaction. The experimental data are in accordance with analytical and numerical calculations using the rigid vortex model [3-4]. Additionally, micromagnetic

simulations give a deeper insight into the observed phenomena.

[1] T. Shinjo et al., Science 289, 930 (2000);
[2] R. P. Cowburn et al., Phys. Rev. Lett. 83, 1042 (1999);
[3] J. Shibata et al., Phys. Rev. B 67, 224404 (2003);
[4] J. Shibata and Y. Otani, Phys. Rev. B 70, 012404 (2004).

MA 17.12 Wed 17:30 H10

Experimental Proof for the Vortex-Antivortex Mediated Vortex Core Reversal — •Hermann Stoll[1], Arne Vansteenkiste[2], Bartel Van Waeyenberge[2], Markus Weigand[1], Michael Curcic[1], Matthias Kammerer[1], Matthias Noske[1], Georg Woltersdorf[3], Kang Wei Chou[4], Tolek Tyliszczak[4], Christian H. Back[3], and Gisela Schütz[1] — [1]MPI für Metallforschung, Stuttgart — [2]Ghent University, Belgium — [3]Universität Regensburg — [4]Advanced Light Source, LBNL, Berkeley, CA, USA

The reversal of the vortex core polarization via excitation of vortex gyration was discovered experimentally by time-resolved X-ray microscopy [1]. A model was suggested based on dynamic vortex-antivortex (VA) creation and annihilation [1]. Meanwhile this model is generally accepted for vortex core switching. However, in all experiments so far the vortex core polarization was only determined 'before' and 'after' the vortex core reversal and the evidence for the VA model is only indirect, by comparing the experimental parameters with micromagnetic simulations. No direct support for the VA model has been given so far. We present experimental data supporting the VA model directly. Time-resolved imaging of the out-of-plane vortex core magnetization has given a direct proof for the initial step, the deformation of the vortex core [2]. A region with opposite magnetization becomes visible at sufficiently high excitation power when the vortex is gyrating fast and its velocity is approaching the critical velocity.

[1] Van Waeyenberge et al., Nature 444 (2006) 461-464
[2] Vansteenkiste et al., Nature Physics 5 (2009) 332-334

MA 17.13 Wed 17:45 H10

Direct imaging of current induced vortex gyration in an asymmetric potential well — •Andre Bisig[1,2], Jan Rhensius[1,3], Matthias Kammerer[2], Michael Curcic[2], Bartel Van Waeyenberge[4], Kang Wei Chou[5], Tolek Tyliszczak[5], Stephen Krzyk[1], Arndt von Bieren[1], Hermann Stoll[2], Gisela Schütz[2], Laura Jane Heyderman[3], and Mathias Kläui[1] — [1]Universität Konstanz, 78457 Konstanz, Germany — [2]Max-Planck-Institut für Metallforschung, 70569 Stuttgart, Germany — [3]Labor für Mikro- und Nanotechnologie, 5232 Villigen PSI, Switzerland — [4]Ghent Univerity, 9000 Ghent, Belgium — [5]Advanced Light Source, 94720 Berkeley LBNL, USA

Employing time-resolved scanning transmission x-ray microscopy (STXM), we investigate the dynamics of a pinned magnetic vortex domain wall in a magnetic nanowire. The gyrotropic motion of the vortex core is imaged in response to an exciting ac current. Using the analytical model of a two-dimensional harmonic oscillator, we determine the resonance frequency of the vortex core gyration by measuring the phase at various excitation frequencies. The elliptical vortex core trajectory at resonance reveals asymmetries in the local potential well that are correlated with the pinning geometry. Furthermore, we can measure the stiffness of the local potential well by determining the eccentricity of the vortex core trajectory at resonance. In the nanowire geometry, where the electrical contacts are placed far away from the area under investigation, Oersted field contributions are minimized.

MA 17.14 Wed 18:00 H10

The Barnett effect in magnetic nanostructures — •Stefan Bretzel[1], Gerrit E. W. Bauer[1], Arne Brataas[2], and Yaroslav Tserkovnyak[3] — [1]Kavli Institute of NanoScience, TU Delft, Lorentzweg 1, 2628CJ Delft, The Netherlands — [2]Department of Physics, Norwegian University for Science and Technology, 7491 Trondheim, Norway — [3]Department of Physics and Astronomy, University of California, Los Angeles, California 90095, USA

The Barnett effect – magnetization induced by mechanical rotation – was discovered at the dawn of quantum mechanics and provided first evidence of the anomalous electron g-factor. We discuss the Barnett effect in the framework of the Landau-Lifshitz-Gilbert equation for magnetic nanostructures, providing theoretical estimates for its observation in different structures and materials. Furthermore, we propose a magnetomechanical device consisting of a sliding domain wall in a rotatable magnetic wire, which relates the Barnett effect with its close relative, the Einstein-de Haas effect via Onsager's reciprocity relations.

MA 17.15 Wed 18:15 H10

Calculation of damping parameter in bulk-Gd — •Jonas Seib and Manfred Fähnle — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

We calculate a damping matrix for the 5d6s-valence magnetic moment in bulk-Gd within the Breathing Fermi Surface model. This model describes the damping in magnetization dynamics caused by the creation of intraband electron-hole pairs in the low temperature limit. It has been shown that the creation of electron-hole pairs is the dominant contribution to damping in 3d transition metals [1]. In an approach similar to the sd-model, we get from the valence moment damping parameter to a damping parameter for the 4f magnetic moment which contributes the main part to the total magnetic moment.

[1] K. Gilmore, Y.U. Idzerda, and M.D. Stiles, Phys. Rev. Lett. **99**, 027204 (2007).

MA 18: Magnetic Thin Films II

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

MA 18.1 Wed 15:15 H3

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

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

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

MA 18.2 Wed 15:30 H3

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

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

MA 18.3 Wed 15:45 H3

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

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

MA 18.4 Wed 16:00 H3

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

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

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

MA 18.5 Wed 16:15 H3

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

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

MA 18.6 Wed 16:30 H3

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

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

MA 18.7 Wed 16:45 H3

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

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

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

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

This work is supported by DFG via SFB 668.

MA 18.8 Wed 17:00 H3

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

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

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

MA 18.9 Wed 17:15 H3

Induced Magnetic Anisotropy in Amorphous $Fe_{24}Co_{68}Zr_8$ Thin Films — •Yu Fu[1], Igor Barsukov[1], Marina Spasova[1],

Hossein Raanaei[2], Björgvin Hjövarsson[2], and Michael Farle[1] — [1]Fakultät für Physik and CeNIDE, Universität Duisburg-Essen, Duisburg, Germany — [2]Department of Physics and Materials Science, Uppsala University, Uppsala, Sweden

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

15 min. break

MA 18.10 Wed 17:45 H3

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

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

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

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

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

MA 18.11 Wed 18:00 H3

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

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

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

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

[1] S. Pütter et al., Phys. Rev. B 64, 092409, (2001)

[2] P. Bruno, J. Phys. F 18, 1291, (1988)

MA 18.12 Wed 18:15 H3

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

Magnetic materials with a large saturation magnetic moment are used in many applications like e.g. write heads for computer hard disk drives. Since the rare earth metals are known for their large magnetic moments but low Curie temperatures, one may think of a rare earth/3d transition metal system to achieve a high saturation magnetic moment in combination with an enhanced Curie temperature caused by the coupling to the 3d transition element. As a prototype system, 13ML Gd on 15ML Fe was chosen. Since Fe and Gd spins tend to be aligned antiparallel, a ferromagnetic coupling between these compounds was forced by a Cr interlayer. The spin alignment was measured by means of x-ray magnetic circular dichroism (XMCD) at the Fe $L_{3,2}$ and Gd $M_{5,4}$ absorption edges. While for a Cr interlayer thickness of 4ML an antiparallel alignment was obtained, 5ML Cr yield a parallel alignment of Fe and Gd spins as predicted by theory. Temperature dependent measurements of the XMCD at the Gd $M_{5,4}$ absorption edges indicate an enhanced Curie temperature due to the strong coupling to the Fe thin film. – Funded by BMBF(05ES3XBA/5) and DFG(SFB491).

MA 18.13 Wed 18:30 H3

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

We studied the influence of Fe overlayers on the anisotropy constants K_1 and K_2 of a Co/Pt multilayer. Fe is deposited on a stack that consists of a 2 nm Pt covered $(Co_{0.7nm}/Pt_{2nm})_8$ multilayer, grown on a Pt seed layer (5 nm). From investigations of the magnetic microstructure via x-ray holography it is known that the iron causes a domain size reduction indicating changes of the anisotropy constants [1].

We used the magneto-optical Kerr effect to study the magnetization behavior. From the magnetization curves the anisotropy constants are determined. The uncoated multilayer has an out-of plane easy axis. Increasing the Fe thickness up to 4 nm reduces K_1 while K_2 remains nearly constant. Between 2 and 3 nm Fe thickness the magnetization changes from out-of-plane to a canted magnetization orientation. Additional Fe up to a thickness of 9 nm leads to a decrease of K_2 while K_1 exhibits only marginal changes and the magnetization remains canted. The influence of the Pt cap layer thickness which separates Fe from the Co/Pt multilayer is discussed.

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

MA 18.14 Wed 18:45 H3

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

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

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

MA 18.15 Wed 19:00 H3

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

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

MA 19: Magnetic Half-metals and Oxides II

Time: Wednesday 15:15–16:45 Location: H22

MA 19.1 Wed 15:15 H22

Phase diagram of $(La_{1-y}Pr_y)_{0.67}Ca_{0.33}MnO_3$ thin films: structural, magnetic and transport data — •Sebastian Hühn, Camillo Ballani, Markus Jungbauer, Kai Gehrke, Vasily Moshnyaga, and Konrad Samwer — 1. Physikalisches Institut, Universität Göttingen

Colossal magnetoresistance (CMR) has been extensively studied in prototypic $(La_{1-y}Pr_y)_{0.67}Ca_{0.33}MnO_3$ (LPCMO) bulk material [1], in which Pr substitution (y) provides a way to control the electron-lattice coupling. CMR was discussed within disorder induces phase separation scenario and percolative metal insulator transition [2]. Here we try to get more reliable information on the CMR physics on epitaxial strain-free LPCMO films (single crystals are not available). We prepared LPCMO films on MgO(100) substrates by metalorganic aerosol deposition technique. The structure was studied by X-ray diffraction. Magnetization and resistivity were measured as a function of temperature, $T = 10 - 300K$, and magnetic field, $B = 0 - 7T$. With these data, we were able to create a phase diagram for LPCMO films and to observe hysteretic temperature and magnetic field behavior as well as the influence of cation ordering. Support by Deutsche Forschungsgemeinschaft via SFB 602, TP A2 is acknowledged.

[1] M. Uehara, S. Mori, C.H. Chen, S.-W. Cheong "Percolative phase separation underlies colossal magnetoresistance in mixed-valent manganites" Nature, 399:560, 1999

[2] Elbio Dagotto. "Nanoscale Phase Separation and Colossal Magnetoresistance" Spinger-Verlag, 2002

MA 19.2 Wed 15:30 H22

Optically induced electron conduction in Ce-doped lanthanum manganite 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 — [2]Institut für Metallische Werkstoffe, IFW Dresden, D-01171 Dresden

The question whether electron-doped mixed-valence manganites, such as $La_{0.7}Ce_{0.3}MnO_3$, can be synthesized as single-phase compounds has been under debate for more than a decade. By now there is some agreement that it is possible to prepare high-quality single-phase material through epitaxial thin-film growth [1], but as-prepared films often suffer from overoxygenation and concomitant hole doping instead of the nominal and desired electron doping. Deoxygenation through post-deposition annealing in vacuum seems to solve this problem [2]. However, oxygen-reduced samples are insulating and do not exhibit a phase transition from a paramagnetic insulating to a ferromagnetic metallic phase any longer [3].

In the present work, we show that photoexcitation renders such thin films conductive and recovers the phase transition [3]. Possible mechanisms behind the pronounced photoconductivity effect are presented, especially the role of the $SrTiO_3$ substrate. Several indications that strongly point towards an electron-doped nature of the illuminated films are discussed. [1] Mitra et al., *J. Appl. Phys.* **89**, 524 (2001). [2] Beyreuther et al., *Phys. Rev. B* **73**, 155425 (2006). [3] Beyreuther et al., *Phys. Rev. B* **80**, 075106 (2009).

MA 19.3 Wed 15:45 H22

Switching on the Nanoscale on $La_{0.7}Ca_{0.3}MnO_3$Thin Films — •Jon-Olaf Krisponeit, Christin Kalkert, Bernd Damaschke, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Perowskite manganites are known to show a variety of resistance effects, including not only temperature-driven metal to insulator transitions but also the colossal magneto resistive effect (CMR).

Here, we have examined a $La_{0.7}Ca_{0.3}MnO_3$ thin film prepared by the metalorganic aerosol deposition technique. The resistance behavior was studied not only macroscopically but also on the nanoscale. Topography and current images have been recorded with an atomic force microscope (AFM) using a tip with conductive coating. Local I-V-characteristics have been taken.

We observed repeatable switching of individual nano-scaled regions that is reversible by applying a voltage of the opposite polarity. Our results clearly show a threshold voltage as well as a dependance on pulse duration. The results are discussed in terms of oxygen drift versus local structural changes.

Acknowledgement: The work is supported by DFG via SFB 602, TP A2 and the Leibniz program.

MA 19.4 Wed 16:00 H22

Ultrafast optical and X-ray studies of multifunctional oxide multilayers — •Marc Herzog[1], Wolfram Leitenberger[1], Roman Shayduk[2], and Matias Bargheer[1] — [1]Universität Potsdam, Institut für Physik und Astronomie — [2]Helmholtz-Zentrum Berlin für Materialien und Energie

We compare ultrafast optical and x-ray measurements on epitaxial multifunctional oxide multilayers possessing a perovskite crystal structure arranged in alternating layers of ferromagnetic (FM) metals and paraelectric/ferroelectric insulators. The FM oxides include $(La_{2/3}Sr_{1/3})MnO_3$ and $SrRuO_3$ while the non-metallic layers are built from $Pb(Zr_{0.2}Ti_{0.8})O_3$ and $SrTiO_3$. All-optical pump-probe experiments across the FM transition temperature are presented and optical pump - x-ray probe measurements at room temperature evidence the excitation of coherent acoustic phonon modes leading to drastic modulations of the X-ray diffraction patterns on a 1-ps time scale. These measurements allow for an accurate calibration of all-optical experiments regarding the amplitude of lattice motion.

MA 19.5 Wed 16:15 H22

Optical CMR in Manganites — •Markus Jungbauer, Sebastian Hühn, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen

Colossal magnetoresistance (CMR) and metal insulator transition in the perovskite manganites are still puzzling phenomena. We focussed on epitaxial films of $(La_{1-y}Pr_y)_{0.7}Ca_{0.3}MnO_3$ with $y = 0{-}0.7$, where a phase separation scenario with coexisting ferromagnetic metallic and charge-ordered insulating phases is believed to be the origin of the CMR.

Using reflectivity measurements, we observed changes in the optical conductivity with external magnetic field in the visible range. This optical CMR peaks at the metal insulator transition temperature T_{MI} as does the CMR. Furthermore the magnetic field behaviour resembles the field dependence of the resistance. Moreover optical CMR shows a pronounced spectral dependence for photon energies $E = 1.2 - 4\,eV$. This indicates that with optical CMR we probe the short range order of the Mn-Spins. Since this optical technique generates information on the volume of our samples, we get further insight to the CMR-effect,

proving the percolative nature of phase transition by modelling the results within random resistor networks.

Support of the DFG via SFB 602 TP A2 is acknowledged.

MA 19.6 Wed 16:30 H22

Ultrasound velocity of CMR manganites at the phase transition — •Markus Michelmann, Walter Arnold, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37707 Göttingen

Perovskite (La, Pr, Ca)MnO_3 manganites attract great attention due to colossal magnetoresistance (CMR), strong electron-phonon-coupling and electronic phase-separation. Here we studied elastic properties of polycrystalline $(La_{1-y}Pr_y)_{0.7}Ca_{0.3}MnO_3$ bulk samples by means of ultrasound velocity measurement (at ∼5MHz) as a function of temperature ($T = 20-300$K) and magnetic field ($B = 0-5$T). The sound velocity drops near the M-I-transition by ∼3% in a single step but changes its shape with applied magnetic field ($B > 2$T). The results of the elastic properties look first like a CMR-behaviour indicating a significant structural modification. However, in higher fields the nature of the transition seems to vary. The results will be compared with specific heat and magnetization measurements for the same CMR compounds.

Support by Deutsche Forschungsgemeinschaft via SFB 602, TP A2 is acknowledged.

MA 20: Micromagnetism / Computational Magnetics

Time: Wednesday 17:00–18:15 Location: H22

MA 20.1 Wed 17:00 H22

Transmission and reflection of spin waves in the presence of Néel walls. — •Sebastian Macke and Dagmar Goll — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

Within the framework of the continuum theory of micromagnetism the interaction of spin waves with domain walls is presented.

For a thin stripe a coupled differential equation system based on the linearization of the Landau-Lifshitz-Gilbert equation is derived including exchange interaction, crystal anisotropy and demagnetization field. The ground state of the stripe is a homogeneous magnetization state on both sides of the stripe separated by a Néel-type domain wall. On one side of the stripe monochromatic spin waves with well-defined frequency and orientation are excited. Then the reflected and transmitted fractions of the spin wave are analyzed. For wavelengths larger than the wall width we observe a reflection of the waves while for smaller wavelengths the spin waves transmit by 100%. The phase of the spin wave can shift on a wide range. A resonance effect inside the domain wall can occur for special wave vectors. It will be shown that especially the demagnetizing field plays a fundamental role. The accuracy of the method is tested for special cases using micromagnetic finite element simulations. Different materials are analyzed dependent on the thickness of the stripe and the direction of the spin wave.

MA 20.2 Wed 17:15 H22

Domain wall motion damped by the emission of spin waves — •Robert Wieser, Elena Y. Vedmedenko, and Roland Wiesendanger — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany

The domain wall motion of field driven transverse domain walls in biaxial ferromagnets is investigated by solving the Landau-Lifshitz-Gilbert equation. It is demonstrated that with increasing easy plane or hard axis anisotropy D_h different types of domain wall motion occur: The different scenarios correspond to different velocity equations. In the limit of absent hard axis anisotropy ($D_h/J = 0$) a precessional domain wall motion can be found, while for $D_h/J \neq 0$ a steady domain wall motion interrupted by a Walker breakdown at high fields prevails. In the limit of huge anisotropies ($D_h/J \gg 0$) a domain wall motion damped by emission of spin waves occurs. The emitted spin waves have been analyzed with aid of a spatial and a temporal Fourier transformation to give the corresponding energy dispersion. Furthermore, the connection between magnetic systems and the theory of solitons is discussed.

This work has been supported by the Deutsche Forschungsgemeinschaft in the framework of subproject B3 of the SFB 668 and by the Cluster of Excellence "Nanospintronics".

MA 20.3 Wed 17:30 H22

Magnetic friction - from thin films to slabs — •Martin P. Magiera[1], Dietrich E. Wolf[1], and Ulrich Nowak[2] — [1]Faculty of Physics and CeNIDE, University of Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Physics, University of Konstanz, 78457 Konstanz, Germany

Energy dissipation in magnetically interacting systems attract increasing interest recently (e.g. [1]). We study the magnetic contribution to friction force by atomistic computer simulations [2]: A substrate is modeled in the framework of the anisotropic Heisenberg model. Parallel to the substrate a dipole is moved with constant velocity, affecting the substrate spins by dipolar interaction. We integrate the stochastic Landau-Lifshitz-Gilbert equation for each substrate spin. Friction force can be calculated from the energy dissipation rate.

For T=0, friction can be understood by virtue of a macrospin model; it is "viscous" and proportional to the damping constant α [2]. Depending on substrate thickness, tip strength and scanning velocity, we observe a transition between two states, which directly changes the strength of magnetic friction by one order of magnitude. At T>0, the strict α-proportionality breaks down, and inverts above T_0. For this regime we present an intriguing consistence of an algebraic temperature-decay of friction with the critical decay of the susceptibility above T_c.

[1] D. Kadau, A. Hucht and D.E. Wolf, PRL **101**, 137205 (2008)

[2] M.P.Magiera, L. Brendel, D.E. Wolf and U. Nowak, EPL **87**, 26002 (2009)

MA 20.4 Wed 17:45 H22

Effect of the Anisotropy Distribution on the Coercive Field and Switching Field Distribution of Bit Patterned Media — •Philipp Krone[1], Denys Makarov[1], Thomas Schrefl[2], and Manfred Albrecht[1] — [1]Chemnitz University of Technology, Institute of Physics, D-09107 Chemnitz, Germany — [2]St. Pölten University of Applied Sciences, A-3100 St. Pölten, Austria

Bit patterned media (BPM) is a promising concept for future magnetic storage devices providing ultra-high recording densities beyond 1 Tbit/inch^2. The concept of BPM implies the formation of an ordered two dimensional array of magnetic nanostructures with an out-of-plane magnetic anisotropy, where an individual nanostructure will store a single bit of information. A systematic study on the magnetization reversal in square arrays of magnetic nanostructures will be presented. To account for the unavoidable inhomogeneities of the magnetic properties, a distribution of magnetic anisotropy values was taken into account. We show that the variation in magnetic anisotropy and the influence of magnetic dipole-dipole interaction between the individual bits with separation distance is crucial for the performance of bit patterned media concerning in particular the switching field distribution [1]. Interestingly, a narrowing of the switching field distribution was found with the angle between the direction of the external magnetic field and easy axis of magnetization, which is an important aspect for the usability of bit patterned media with tilted anisotropy at ultra-high storage densities beyond 1 Tbit/inch^2.

[1] Krone et al., J. Appl. Phys. 106 (10), 103913 (2009)

MA 20.5 Wed 18:00 H22

Micromagnetic study of field-driven domain wall dynamics in Permalloy nanotubes — •Christian Andreas, Ming Yan, Attila Kákay, and Riccardo Hertel — Institut für Festkörperforschung, Elektronische Eigenschaften, Forschungszentrum Jülich GmbH

At sufficiently large propagation velocity, magnetic domain walls (DWs) in thin strips reach the Walker limit[1], a dynamic micromagnetic instability characterized by complex domain wall transformations and a drastic reduction of the DW speed. Using our hybrid FEM/BEM micromagnetic code, we found that DWs in nanotubes are much more stable against such transformations than DWs in thin strips. We studied in detail the field-driven motion of vortex DWs[2] in Permalloy nan-

otubes with outer diameter of 60 nm and various inner diameters. In the case of nanotubes, the breakdown process involves the nucleation of a vortex-antivortex pair, while in thin strips a single (anti-)vortex is nucleated at the lateral boundary. These differences are due to topological reasons and also lead to different values of the critical field, since the threshold for pair creation is higher than for the nucleation of a single (anti-)vortex. In conclusion we find that DWs in nanotubes can propagate much faster than in thin strips. The possibility to fabricate such magnetic nanotubes[3] should allow for the experimental verification of the predicted fast DW motion.

[1] N. L. Schryer and L. R. Walker, J. Appl. Phys. **45**, 5406 (1974)
[2] R. Hertel et al., J. Magn. Magn. Mater. **278** 291 (2004)
[3] K. Nielsch et al., J. Appl. Phys. **98** 034318 (2005)

MA 21: Magnetic Materials

Time: Wednesday 15:15–18:00 Location: H23

MA 21.1 Wed 15:15 H23

Phase Stability in Magnetocaloric La(Fe,Si)$_{13}$ Ribbons — •Maria Krautz, Jian Liu, Julia Lyubina, Konstantin Skokov, Ludwig Schultz, and Oliver Gutfleisch — IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden

In the last decade several materials, exhibiting a giant magnetocaloric effect (MCE), have been studied. Magnetic refrigeration appears now as a viable alternative to conventional gas compression/expansion techniques. Some alloys with the $NaZn_{13}$-structure are of high interest, as they show a first-order phase transition in the vicinity of the Curie temperature, leading to a giant MCE. As the binary $LaFe_{13}$-phase does not exist, it has to be stabilised by adding a third element such as Al or Si. In order to remove the primary α-Fe and obtain nearly pure 1:13-phase from the as-cast alloy, a prolonged heat treatment taking up to several weeks is usually performed. The melt-spinning technique is proven to be very useful to synthesize various functional magnetic materials with a homogenous chemical composition and a refined microstructure. Here we applied this technique to the La-Fe-Si system. After a short time annealing of only a few hours, the 1:13-phase is established in the melt-spun ribbons. However, little knowledge about the pseudobinary phase diagram of La(Fe,Si)$_{13}$ is available so far. Therefore, melt-spun alloys with different Si contents were annealed at different temperatures. The structure was studied by XRD (Rietveld-refinement) and SEM and correlated with magnetic data. In view of application, the significant volume change of the 1:13-phase during the magnetic phase transition is analysed.

MA 21.2 Wed 15:30 H23

Investigations of highly ordered, half-metallic Co_2FeSi single crystals — •C. G. F. Blum[1,2], S. Wurmehl[1], G. Behr[1], C. Hess[1], B. Büchner[1], J. Barth[2], C. A. Jenkins[2], C. Felser[2], S. Riegg[3], A. Reller[3], and J. T. Kohlhepp[4] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Helmholtzstraße 20, D-01069 Dresden — [2]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg-University, Mainz — [3]Universität Augsburg, D-86159 Augsburg — [4]Eindhoven University of Technology, 5600 MB Eindhoven, The Netherlands

In this presentation the properties of highly ordered, halfmetallic Co_2FeSi single crystals will be shown. A wide variety of properties, such as half-metallicity and semiconductivity, is found among the Heusler compounds. In order to separate intrinsic and extrinsic properties, high quality single crystals are required. Here we report on crystals of the half-metallic ferromagnet Co_2FeSi [1], grown with different techniques. All crystals show excellent ordering, probed by XRD and NMR, resulting in outstanding electrical behavior. Low residual resistivity and high residual-resistivity-ratio is found. All Co_2FeSi crystals show a plateau in resistivity below 50 K, which might point to half-metallic ferromagnetism. The cross-over from this unusual to more conventional transport (T^2 dependence) around 50 K indicates the onset of spin flip scattering and thus is indispensable for understanding the strong temperature dependence of Co_2FeSi tunneling magnetoresistance-devices. The authors gratefully acknowledge financial support by the DFG (Research Unit 559). [1] Blum et al. Appl. Phys. Lett. 95 161903 (2009).

MA 21.3 Wed 15:45 H23

Disorder Effects on the Magneto-Crystalline Anisotropy Energy of Strained Fe-Co Alloys — •Carsten Neise, Stephan Schönecker, 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 applicability as new media for high density recording, combining a large uniaxial **M**agneto-**C**rystalline **A**nisotropy with a large saturation magnetisation for certain chemical compositions x and certain tetragonal distortions. Previous calculations by Burkert *et. al.* [Phys. Rev. Lett. 93, 027203 (2004)] disregarded volume relaxation, which is present in epitaxially grown layers and may alter the magnetic properties of these alloys. We investigated this and the influence of disorder on the MCA and on the magnetic moment of $Fe_{1-x}Co_x$ alloys along the epitaxial Bain path. Two different methods were used to describe disorder, (i) the virtual crystal approximation, and (ii) a stochastic average of supercells with randomly distributed atoms. Comparison with the ordered structures of the $L1_0$ and the $L1_2$ phases reveals the impact of disorder on the magnetic properties. We employed the **f**ull **p**otential **l**ocal **o**rbital program package FPLO [*http://www.fplo.de*] for our density functional calculations.

MA 21.4 Wed 16:00 H23

Interplay between chemical and magnetic orders in alloys — •Josef Kudrnovsky[1], Vaclav Drchal[1], and Ilja Turek[2] — [1]Institute of Physics AS CR, Prague — [2]Institute of Physics of Materials AS CR, Brno

Based on the first-principles modeling we will investigate the interplay between the chemical and magnetic orders in the magnetic transition metal alloys. As a case study we will investigate the change of magnetic order due to the chemical order-disorder transformation in fcc-Ni(75)Fe(25), fcc-Ni(75)Mn(25), and bcc-Fe(50)Al(50). The theoretical modeling is done in two steps: in the first-step we will determine the electronic structure of studied magnetic alloys in both disordered and ordered state (Cu3Au-structure for fcc NiFe and NiMn alloys, CsCl-structure for bcc FeAl alloys) by using the tight-binding linear muffin-tin orbital method suitable for description of transition-metal alloys. The chemical disorder is treated in the framework of the coherent-potential approximation. In the second step, the calculated electronic structure is used to estimate the pair exchange interactions by using the method of infinitesimal rotations (the construction of the classical Heisenberg model) for ordered and disordered phases. We will demonstrate that chemical ordering strongly influences the magnetic order in fcc-NiMn and bcc-FeAl alloys. This can be understood on the basis of calculated exchange Heisenberg parameters of alloys in both ordered and disordered phases.

MA 21.5 Wed 16:15 H23

Magneto-impedance measurements on iron whiskers — •Matthäus Langosch, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, D-66123 Saarbruecken, Germany

After the discovery of the giant magneto-impedance (GMI) effect in 1994, the research on GMI mainly focuses on the enhancement of the effect by developing new materials and on potential applications. But a better understanding of the effect itself is as well needed. GMI measurements on iron single crystals (iron whiskers) with <100> growth direction were carried out at room temperature. The GMI effect of the whiskers has been observed as a function of driving current and frequency. A maximum MI value of 63% was found for the chosen samples having a particularly simple domain structure. MOKE imaging was employed to investigate more clearly the relationship between GMI effect and the respective domain structures. It was found that the magnetic-field-dependent skin effect provides major contributions.

MA 21.6 Wed 16:30 H23

Magnetic detector based on giant magnetoimpedance and its application to vehicle detection — Qing Zhang[1], •Haibin Gao[2], Zhenjie Zhao[1], and Uwe Hartmann[2] — [1]Department of Physics,

East China Normal University, 3663 Zhongshan North Road, 200062 Shanghai, P.R. China — [2]Institute of Experimental Physics, Saarland University, D-66123 Saarbruecken, Germany

A field detector based on the giant magnetoimpedance (GMI) effect is developed. The GMI sensor is made of a $Co_{68.15}Fe_{4.35}Si_{12.5}B_{15}$ microwire with a diameter of $25\mu m$ and a length of $5mm$. A pick-up coil is around the microwire. The driving ac current through the wire induces an axial magnetization variation and thus a voltage in the pick-up coil. The field dependence of the second harmonics of this voltage is measured. The characteristics of the complete detector in terms of sensitivity, resolution, linearity, and temperature behavior were obtained under laboratory conditions. A $10pT$ magnetic field at a frequency of 40 Hz was detected. The output signal change is lower than 4 x $10^{-4}/K$ in the working range of -40^0C to 85^0C. A first field test result on vehicle detection will be presented.

15 min. break

MA 21.7 Wed 17:00 H23

Effect of non-magnetic impurities on the ferromagnetism of Mn_5Ge_3 — •Ivetta Slipukhina[1,2], Emmanuel Arras[1], Phivos Mavropoulos[2], and Pascal Pochet[1] — [1]Laboratoire de simulation atomistique, SP2M, INAC, CEA, 38054 Grenoble cedex 9, France — [2]Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

Mn_5Ge_3 is a ferromagnet with a magnetisation of 2.6 μ_B/Mn, spin polarisation $P_0 = 42\%$ and T_C=304 K. Experimentally, interstitial C in this material enhances its ferromagnetic properties and results in essentially increased T_C. To understand the nature of exchange interactions in doped Mn_5Ge_3 and their dependence on the chemistry and concentration of interstitials, we performed first principles electronic structure calculations, utilizing the Korringa-Kohn-Rostoker Green function method within the Coherent-Potential Approximation [1]. The transition temperatures are calculated by means of Monte Carlo method, using a classical Heisenberg Hamiltonian and calculated exchange constants. A non-monotonous variation of the T_C with x is found in $Mn_5Ge_3C_x$, reflecting the non-monotonous change of the impurity mediated exchange interactions [2]. Strong enhancement of T_C is predicted for B- and N-doped Mn_5Ge_3 [3], making them, along with the $Mn_5Ge_3C_x$, promising candidates for spintronics applications.

[1] H. Ebert and R. Zeller, The SPR-TB-KKR package, http://olymp.cup.uni-muenchen.de/ak/ebert/SPR-TB-KKR.
[2] I. Slipukhina *et al.*, Appl. Phys. Lett. **94**, 192505 (2009).
[3] I. Slipukhina, E. Arras, and P. Pochet, in preparation.

MA 21.8 Wed 17:15 H23

Magnetic measurements on Tb_5Ge_3 — •Ariane Haase[1,2], Mathias Doerr[2], Marek Bartkowiak[1], Ramzy Daou[1,3], Yurii Skourski[1], Martin Rotter[4], and Marc Uhlarz[1] — [1]Hochfeld-Magnetlabor Dresden, Forschungszentrum Dresden-Rossendorf, 01314 Dresden — [2]Institut für Festkörperphysik, TU Dresden, 01069 Dresden — [3]Max-Planck-Institut für Chemische Physik fester Stoffe, 01187 Dresden — [4]University of Oxford, Department of Physics, Oxford OX1 3PU

Tb_5Ge_3 is a weak antiferromagnet, which orders at 83 K. It crystallizes in Mn_5Si_3-type hexagonal structure with two different positions for the Tb^{3+} ions. The hexagonal ab-plane is the easy plane of magnetization.

Magnetization and magnetostriction measurements have been done on a single crystal in static fields up to 30 T and in pulsed fields up to 50 T. In addition to the antiferromagnetic phase, three more phases were found in fields in the ab-plane at low temperatures. Surprisingly, the measurements along the b-axis do not resemble the a-axis properties which indicates an anisotropy in the hexagonal plane. Initial model calculations reveal the anisotropy of the magnetic exchange, which is dominant over the crystal electric field effect, as cause. The hard c-axis shows only one phase transition at 5 T followed by a nearly linear magnetization and magnetostriction slope which is attributed to a steady-going rotation of the moment.

MA 21.9 Wed 17:30 H23

Grain refinement in HDDR $Nd_2Fe_{14}B$ powders by high pressure reactive milling — •Konrad Güth, Julia Lyubina, Ludwig Schultz, and Oliver Gutfleisch — IFW Dresden, Institut für Metallische Werkstoffe, Postfach 270016, D-01171 Dresden, Germany

The HDDR process (Hydrogenation Disproportionation, Desorption, Recombination) is a unique method to produce highly coercive powders for resin bonded permanent magnets. The process is carried out under carefully controlled hydrogen atmosphere resulting in $Nd_2Fe_{14}B$ crystallites with a size of about 300 nm well-oriented within micrometer-sized particles. A further increase of the energy product in these HDDR powders may be achieved via inter-grain exchange coupling that requires the decrease of the grain size by one order of magnitude. A novel approach is the high pressure reactive milling (HPRM) technique prior to the hydrogen desorption and recombination process. The NdFeBGaNb starting alloy is milled in dedicated ball vial under 50 bar hydrogen pressure for 5 hours. After recombination at elevated temperatures under reduced hydrogen atmosphere the final powder shows a much smaller grain size than that in the HDDR processed powder. Phase analysis and grain size determination were performed using Rietveld refinement of x-ray data. High resolution scanning electron microscopy (HR SEM LEO 1530 GEMINI) was used to study the microstructure. In order to investigate the texture of the final magnet, the powder is aligned applying a transverse magnetic field of 2 T during pressing. The influence of the HPRM on the structure and magnetic properties of the HDDR Nd-Fe-B alloys will be discussed.

MA 21.10 Wed 17:45 H23

Magnetic properties of the main group diradical ion 5,5'-Bis(1,2,3,4-trithiazolium) in a solid state matrix — •Manuel Presnitz[1], Ernst-Wilhelm Scheidt[1], Wolfgang Scherer[1], and Jack Passmore[2] — [1]Lehrstuhl für Chemische Physik und Materialwissenschaften, Institut für Physik, Universität Augsburg, 86135 Augsburg, Germany — [2]Department of Chemistry, University of New Brunswick, Fredericton NB E3B 6E2, Canada

The diradical nature of the main group molecule $(CNSSS)_2$, systematic name 5,5'-Bis(1,2,3,4-trithiazolium), is remarkable because it is – like the prominent diradical O_2 – a non sterically hindered main group compound, which retains its paramagnetic characteristics also in the solid state. Here the $(CNSSS)_2$ diradical ions are embedded in a PnF_6 (Pn = As, Sb) matrix.

The specific heat $C(T)$ and magnetic susceptibility $\chi(T)$ data (for SbF_6 matrix) show some irreversible behavior during the first cooling stage down to 2 K. By subsequent heating/cooling cycles different states seem to be accessible until a final reversible behavior (χ_{rev}) is observed.

The magnetic susceptibility of different model systems was fitted to χ_{rev} but the distinction between an alternating spin chain (Johnston *et al.*) and spin ladder (Barnes/Riera) is not possible based on experimental results for $\chi(T)$ only. Hence, to gain deeper insight into the magnetic coupling mechanism, our $\chi(T)$ measurements are complemented by *ab initio* calculations to obtain *inter-* and *intra*-molecular coupling constants and disqualify one of the models.

MA 22: Spin Dynamics / Spin Torque III

Time: Thursday 9:30–12:45 Location: H10

Invited Talk MA 22.1 Thu 9:30 H10

Tailoring the spin functionality of a hybrid metal-organic interface by means of alkali metal doping — •Mirko Cinchetti, Sabine Neuschwander, Jan-Peter Wüstenberg, Alexander Fischer, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany

Doping of organic semiconductors (OSCs) has proven to be an efficient strategy to adjust their electronic properties for implementation in organic-based electronic devices. The recent success in the application of OSCs for spintronics raises the fundamental question if doping can be used as well to tailor the functionality of hybrid metal-organic interfaces, and thus to control the high spin injection efficiency achievable in OSC. We employ a recently developed purpose-made technique based on spin resolved two-photon photoemission spectroscopy [1] to study the influence of alkali doping (Cs and Na) on the spin function-

ality of the interface between a thin cobalt film and the organic semiconductor copper phthalocyanine (CuPc). We find two alkali-induced effects. First, alkali atoms act as impurities and increase the spin-flip probability for the electrons crossing the interface (detrimental effect). Second, they allow to enhance the efficiency of spin-injection at an arbitrary energy above the Fermi level of the cobalt (intrinsic effect). We show that the intrinsic effect dominates over the detrimental one, giving rise to the possibility to actively tailor the spin functionality of the considered hybrid interface by changing the doping concentration.

[1] M. Cinchetti et al., Nature Materials 8, 115-119 (2009)

MA 22.2 Thu 10:00 H10

Critical Current for Switching the Magnetization of Quasistable Nano-Islands Using SP-STM — •Stefan Krause, Gabriela Herzog, Anika Emmenegger, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

Spin-polarized scanning tunneling microscopy (SP-STM) has been demonstrated to be capable for manipulating the superparamagnetic switching behavior of nano-islands, using the spin torque and Joule heating of elevated spin-polarized tunnel currents [1]. The question arises whether SP-STM can also be used to manipulate static magnetic nanostructures, thereby opening perspectives for future data storage technologies based on SP-STM.

In our experiment, an individual thermally quasistable nano-island consisting of about 40 iron atoms on a W(110) surface has been addressed using a magnetic probe tip. Sweeping the spin-polarized tunnel current between tip and sample from the nA to the μA regime allows for switching the island's magnetization back and forth, depending on the bias polarity. The critical current for switching the magnetization back and forth is discussed in terms of the current sweep rate, and numerical simulations supporting the experimental findings are presented. The local current density necessary for switching the magnetization is found to be comparable to that used in experiments on nanopillar devices [2].

[1] S. Krause *et al.*, Science **317**, 1537 (2007).
[2] G. D. Fuchs *et al.*, Appl. Phys. Lett. **85**, 1205 (2004).

MA 22.3 Thu 10:15 H10

Optimum tunnel barrier thickness for spin torque memory devices — •Santiago Serrano-Guisan[1], W. Skowronski[2], N. Liebling[1], J. Wrona[2], M. Czapkiewicz[2], T. Stobiecki[2], J. Langer[3], B. Ocker[3], G. Reiss[4], and H.W. Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, D-38116, Braunschweig, Germany — [2]AGH University of Science and Technology, Department of Electronics, Al. Mickiewicza 30, 30059 Krakow, Poland — [3]Singulus, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany — [4]Bielefeld University, Department of Physics, P.O. Box 100131, 33501 Bielefeld, Germany

We study the influence of the exchange coupling strength J_{FP} between the free and the reference layer magnetization on the precessional magnetization dynamics in CoFeB/MgO/CoFeB based magnetic tunnelling junction stacks with different MgO barrier thickness (tMgO) by pulse inductive microwave magnetometry (PIMM). From PIMM data the field dependent precession frequency f and the effective Gilbert damping α as well as their respective dependence on tMgO are derived. For tMgO $<$ 0.76 nm the strong J_{FP} inhibits reversal of the free layer. However, for a thickness range 0.85 nm $>$ tMgO $>$ 0.76 nm free layer reversal is possible and a relative low damping $\alpha \approx 0.017 \pm 0.003$ is found with no significant barrier thickness dependence. For such relatively low α, a low current density spin torque reversal is expected as it scales linearly with α. Additionally, the large TMR ratios (larger than 150%) and small RA products (2-4 $\Omega\mu m^2$) occurring in this thickness range make it optimum for ST memory applications

MA 22.4 Thu 10:30 H10

Spin-transfer torque experiments on magnetic disks near the vortex regime — •Volker Sluka, Daniel Bürgler, and Claus Schneider — Institute of Solid State Research, Research Center Jülich, Jülich, Germany

In thin magnetic disks vortex states appear as ground states of magnetization as a result of the interplay between exchange interaction and dipolar energy. The vortex structure can be divided into two regions. The magnetization basically lies in the disk plane while possessing a circular shape, thereby closing the flux and minimizing the stray field. In the center of this pattern referred to as the vortex core region however, this would lead to a strong build-up of exchange energy. Therefore in this part the magnetization points out of plane, defining the vortex polarity. In this work nano-pillars containing two single crystalline Fe disks close to the vortex regime have been prepared. The structures are processed from MBE grown layers and have diameters of roughly 150 nm. The 30 and 15 nm thick disks are seperated by a non-magnetic spacer (Ag, 6 nm). DC and HF measurements are performed to investigate the nano-pillar's response to external fields and pulsed / constant currents.

MA 22.5 Thu 10:45 H10

Spin shot noise and spin torque dynamics — •Jacek Swiebodzinski[1], Alex Kamenev[2], Thomas Dunn[2], Daniela Pfannkuche[3], and Alexander Chudnovskiy[3] — [1]Theoretische Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Physics, University of Minnesota, Minneapolis, Minnesota 55455, USA — [3]I. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany

Investigations of noise in nano-scale devices are indispensable in any use-oriented consideration and - at the same time - a broad and fascinating field from the basic-researcher's point of view. In this theoretical contribution we investigate the role of spin shot noise in spin torque dynamics of mono-domain ferromagnets. Spin shot noise is a consequence of the discreteness of angular momentum transfer and present in any spin torque experiment. At low temperatures it gives the dominant contribution to magnetization noise. Unlike its thermal counterpart the nonequilibrium noise displays a dependence on the relative orientation of the ferromagnets forming the magnetic junction. We address the question of spin torque switching by applying a generalized Fokker-Planck approach that models switching rates with the help of an effective temperature in the Arrhenius factor. We show that the spin shot noise leads to a renormalization of the effective temperature. The details of the renormalization depend on the geometry of the system. In particular, the nonequilibrium noise may lead to the occurrence of "cold" and "hot" trajectories of the magnetization vector with respect to the noise intensity.

MA 22.6 Thu 11:00 H10

Local spin-transfer torque within narrow domain walls — •Stellan Bohlens and Daniela Pfannkuche — I. Institut für Theoretische Physik

In mesoscopic ferromagnets, a domain structure that consists of regions in which the magnetization points in different spatial directions is energetically more favorable than a monodomain. The individual domains are separated by domain walls, where the magnetization changes continuously. A current traversing such a non-collinear magnetization texture exerts a spin-transfer torque on the local magnetization. A consistent theory of spin-transfer torque and spin transport that is also applicable for narrow domain walls is still missing and its impacts are not assessable to date.

We present a theoretical formulation of electron and spin transport that allows for the derivation of the local spin-transfer torque in general magnetization textures. The framework provides the microscopic derivation of transport coefficients that were treated so far as phenomenological parameters in the theory of the spin-transfer torque. [1] We apply our formalism to a Bloch wall and calculate the spatially resolved spin-transfer torque. In the case of narrow domain walls it turns out that the treatment of coupled charge and spin transport offers startling insight into fascinating physics in an intermediate transport regime that comprises diffusive charge transport and ballistic spin transport at the same time.

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

MA 22.7 Thu 11:15 H10

Non-adiabatic spin transfer torque investigated using thermally activated magnetic domain walls in permalloy wires — •Matthias Eltschka[1], Mathias Wötzel[1,2], Takeshi Kasama[2], Jan Rhensius[1,3], Stephen Krzyk[1], Laura Heyderman[3], Rafal Dunin-Borkowski[2], Ulrich Nowak[1], and Mathias Kläui[1] — [1]Fachbereich Physik, Universität Konstanz, Universitätsstraße 10, 78457 Konstanz, Germany — [2]Center for Electron Nanoscopy, Technical University of Denmark, 2800 Kgs. Lyngby, Denmark — [3]Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

The understanding of the interplay between spin-polarized currents and magnetization as well as the determination of the spin torque terms are of scientific interest and essential for many proposed applications.

Using transmission electron microscopy we investigate thermally ac-

tivated domain walls (DWs) jumping back and forth between two pinning sites in permalloy wires at room temperature. The motion is of pure thermal origin without the influence of external magnetic fields or electron currents. Considering the DW as a quasi particle in a local potential with two metastable states we show that this DW movement can be described by an Arrhenius law. Subsequently, we investigate the change of the local potential by constant currents which are far below the threshold values needed for DW propagation and do not induce significant heating. Based on a 1D description of the spin transfer torque effect and the Arrhenius law we derive the non-adiabatic coefficient β for a transverse and a vortex DW.

MA 22.8 Thu 11:30 H10

Heat assisted Spin Torque Switching of Nanomagnets by SP-STM — •Gabriela Herzog, Stefan Krause, Anika Emmenegger, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

Recently it has been shown that spin-polarized scanning tunneling microscopy (SP-STM) can be applied to manipulate magnetization switching of individual thermal agitaded nano-islands by the injection of elevated spin-polarized tunnel currents [1].

The open question remained whether it is possible to manipulate the static magnetization of nanostructures with a SP-STM. We demonstrate the capability of current-induced magnetization switching of quasistable nanostructures. Therefore in-plane magnetized uniaxial Fe monolayer nano-islands on W(110) were prepared. Using spin-polarized tunnel current pulses originating from the microscope tip the magnetization of individual nano-islands is switched reliably and reversibly. We find the current pulse length to be of crucial importance for magnetization reversal, and by changing pulse polarity we ascertain the roles of both Joule heating and spin torque.

[1] S. Krause *et al.*, Science **317**, 1537 (2007).

MA 22.9 Thu 11:45 H10

Spin torque and waviness in magnetic multilayers: a bridge between Valet-Fert theory and quantum approaches — •Valentin Rychkov[1,3], Simone Borlenghi[1], Henry Jaffres[2], Albert Fert[2], and Xavier Waintal[1] — [1]Nanoelectronics group, Service de Physique de l'Etat Condensé, CEA Saclay F-91191 Gif-sur-Yvette Cedex, France — [2]Unité Mixte de Physique CNRS-Thales, Route départementale 128, 91767 Palaiseau Cedex and Université Paris-Sud 91405, Orsay, France — [3]Institut fuer Theoretische Physik und Astrophysik Universitaet Wuerzburg Am Hubland D-97074 Wuerzburg Germany

We develop a simple theoretical framework for transport in magnetic multilayers, based on Landauer-Buttiker scattering formalism and Random Matrix Theory. A simple transformation allows one to go from the scattering point of view to theories expressed in terms of local currents and electrochemical potential. In particular, our theory can be mapped onto the well established classical Valet Fert theory for collinear systems. For non collinear systems, in the absence of spin-flip scattering, our theory can be mapped onto the generalized circuit theory. We apply our theory to the angular dependance of spin accumulation and spin torque in non-collinear spin valves.

MA 22.10 Thu 12:00 H10

Ab initio **calculation of the spin torque in all metallic spin valves and magnetic tunnel junctions** — •Frank Freimuth, Daniel Wortmann, and Stefan Blügel — Institut für Festkörperforschung, & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

We present calculations of the current perpendicular to the plane (CPP) spin torque for the all metallic spin valves Co/Cu/Co, Fe/Ag/Fe and Fe/Au/Fe and for MgO-based magnetic tunnel junctions. Compared to the Co/Cu/Co spin valve the Fe/Ag/Fe and Fe/Au/Fe spin valves are characterized by a much larger asymmetry of the angular dependence of the torque. In the case of Fe/Au/Fe we investigate the influence of spin-orbit coupling on the spin torque. Special attention is given to the dependence of the torque on the thicknesses of the free magnetic layer and the interlayer. For MgO-based magnetic tunnel junctions we discuss the dependence of the spin torque on the magnetic lead material and the bias-dependence of the torque. Our calculations are based on an order-N implementation of the full-potential linearized augmented-plane-wave method `FLEUR` (www.flapw.de) within the Green function embedding formalism.

MA 22.11 Thu 12:15 H10

Multi-macro spin simulations of opto-magnetic switching — •Stefan Gerlach[1], Denise Hinzke[1], Thomas Ostler[2], Roy W. Chantrell[2], and Ulrich Nowak[1] — [1]University of Konstanz, 78457 Konstanz, Germany — [2]University of York, York YO10 5DD, U. K.

The ultrafast manipulation of the magnetization with the aid of femtosecond laser pulses promises to become a real alternative to writing techniques where magnetic field pulses are used in addition to laser heating. It was recently demonstrated [1] that a 40 fs, circularly polarized laser pulse is able to reverse the magnetization on a picosecond time scale as if the laser pulse acts as an equally short magnetic field pulse with a polarization dependent direction caused by the so-called inverse Faraday effect.

To investigate the opto-magnetic magnetization reversal, we use Landau-Lifshitz-Bloch (LLB)-based multi-macro spin simulations [2] for extended systems with up to 4×10^6 macro-spins ($10\ \mu m \times 10\ \mu m$) where the exchange coupling as well as the dipolar interaction is taken into account. Furthermore, we assume a Gaussian temperature profile in order to model a realistic laser spot and to explore the size of a stable opto-magnetically reversed area after excitation. We will show and discuss results of the magnetization evolution of thin films and compare with recent experiments [3].

[1] C. D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007) [2] N. Kazantseva et al., Phys. Rev. B 77, 184428 (2008) [3] K. Vahaplar et al., Phys. Rev. Lett. 103, 117201 (2009)

MA 22.12 Thu 12:30 H10

Numerical investigation of opto-magnetic switching — •Denise Hinzke[1], Stefan Gerlach[1], Thomas Ostler[2], Roy W. Chantrell[2], and Ulrich Nowak[1] — [1]Universität Konstanz, 78457 Konstanz — [2]University of York, York YO10 5DD, U. K.

Ultrafast magnetisation dynamics has been extensively studied recently as a possibility to improve the storage density as well as the writing speed in magnetic data storage. It was demonstrated [1] that a 40 fs, circularly polarised laser pulse is able to reverse the magnetisation. One possible explanation is that the laser pulse acts as an equally short magnetic field pulse pointing along the direction of light caused by the so-called inverse Faraday effect [2].

We perform single macro-spin simulations [3] within the framework of the Landau-Lifshitz-Bloch equation recently derived by Garanin [4]. One of our findings consistent with experimental results is that field pulse durations as short as 250 fs can be sufficient to reverse the magnetisation [5]. Furthermore, we found that the magnetisation switching is via a linear pathway [6] without any precession.

[1] C. D. Stanciu et al., Phys. Rev. Lett. 99, 047601 (2007) [2] A. V. Kimel et al, Nature (London) 435, 655 (2005) [3] N. Kazantseva et al, Phys. Rev. B 77, 184428 (2009), [4] D. A. Garanin, Phys. Rev. B 55, 3050 (1997), [5] K. Vahaplar et al, Phys. Rev. Lett. 103, 117201 (2009) [6] N. Kazantseva et al, Europhys. Lett. 81, 27004 (2008)

MA 23: Micro- and Nanostructured Magnetic Materials III

Time: Thursday 10:15–12:45 Location: H3

MA 23.1 Thu 10:15 H3

Magnetic properties of closely packed NiFe nanodots — •Norbert Martin[1], Jeffrey McCord[1], Ingolf Mönch[1], Rudolf Schäfer[1], Roland Mattheis[2], Oliver G. Schmidt[1], and Ludwig Schultz[1] — [1]Leibniz Institut für Festkörper- und Werkstoffforschung IFW Dresden, Postfach 270116 — [2]Institut für Photonische Technologien IPHT Jena, Postfach 100239

Permalloy nanodots have been fabricated by means of nanosphere lithography, where a monolayer of nanospheres self assembles to a hexagonal array on top of the ferromagnetic film. To etch closely packed structures of NiFe dots with a small tilt at the dot's edge more robust Silica nanospheres in comparison to Polystyrene nanospheres are used. Therefore it is possible to decrease the dipolar interaction and favor vortex nucleation, which is necessary to achieve highly dense

magnetic vortex structures. Magneto-optic hysteresis measurements and micromagnetic simulations of hexagonal dot arrays with tilted edges confirm that vortex nucleation takes place, which is mainly attributed to the shape of the dots.

MA 23.2 Thu 10:30 H3

Determining the magnetic properties of small assemblies of nanodots — •Simon Hesse[1], Matthias Jacobi[1], André Kobs[1], Daniel Stickler[1], Holger Stillrich[1], Alexander Neumann[1], Andreas Meyer[2] und 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 successfully developed a technique to fabricate nanodots of variable size and varying magnetic properties based on self-organized assembling of diblock-copolymer micelles on magnetic multilayers [1]. The micelles are filled with silica cores, which are used as shadow mask for subsequent Ar^+ ion milling. The method allows for creating superparamagnetic as well as ferromagnetic Co/Pt nanodots. The magnetic properties are investigated via magneto-optical Kerr Effect (MOKE) and anomalous Hall Effect (AHE). Due to the free scalability of the AHE it is possible to measure very small ensembles of dots. To achieve these small ensembles Hall cross geometries have been created via ion beam lithography (IBL). Varying the size of the crossing area and the filling factor of silica cores enables us to adjust the number of dots to measure. It has been found that the AHE has an extremely high sensitivity that makes it possible to identify magnetization curves of the dots down to filling factors of about 5 %. Hence, we report on AHE measurements of the magnetic behaviour of less than 10 dots.

[1] H. Stillrich et al., Adv. Funct. Mat. **18**, 76 (2008)

MA 23.3 Thu 10:45 H3

Anisotropic stray field effect on magneto-dynamic properties of square element arrays — •Claudia Patschureck[1], Manfred Wolf[1], Jeffrey McCord[1], Rudolf Schäfer[1], Ludwig Schultz[1], Ingolf Mönch[1], Oliver Schmidt[1], Konstantin Kirsch[2], and Roland Mattheis[2] — [1]Leibniz Institute for Solid State and Materials Research Dresden, Helmholtzstraße 20, 01069 Dresden — [2]Institute of Photonic Technology e.V., POB 100239, 07702 Jena

The role of stray-field interaction on the magneto-dynamic properties of *quasi-saturated* arrays of square Permalloy thin film elements is presented. The lateral element size ranges from 20 to 100 μm with a constant inter-element spacing of 10 μm and film thicknesses of 50 and 100 nm. The frequency of the uniform resonance mode was found to be enhanced compared to an extended reference film. Although square elements can be, in first approximation, considered to be isotropic and to have equal demagnetizing factors N_x and N_y along the element main axes, an additional positive contribution to the effective field was measured. This is in contrast to Kittel's equation which predicts a change of the resonance frequency in case of N_x unequal N_y. It is found that the resonance frequency shift decreases with increasing element size and decreasing film thickness. The additional effective field contribution is attributed to anisotropic stray field coupling of neighbouring elements. A model of interacting dipoles is presented that qualitatively describes the experimental results.

MA 23.4 Thu 11:00 H3

Temperature dependence of the magnetic properties of $L1_0$-FePt nanostructures — •Thomas Bublat, Achim Breitling, and Dagmar Goll — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart, Germany

$L1_0$-FePt/Fe composite media are one of the most promising candidates for solving the writeability/thermal stability/signal-to-noise ratio trilemma of next generation high-density magnetic storage media. The hard magnetic component guarantees thermal stability for smallest dot sizes whereas the soft magnetic component reduces the coercivity and thus enables writeability with conventional write heads. To get a deeper understanding of the hard magnetic $L1_0$-FePt part the magnetic properties of $L1_0$-FePt nanoislands obtained by cosputtering Fe and Pt at elevated temperatures for thicknesses less than 20 nm have been measured as a function of the temperature from 40 K up to the Curie temperature. The smallest dot sizes of the $L1_0$-FePt nanostructures studied were found to be 15 nm. Furthermore by nanoimprint lithography (NIL) large area (2 x 2 mm^2) nanopatterns with a regular arrangement of nanodots (dot sizes 40 - 100 nm) have been produced and characterized.

MA 23.5 Thu 11:15 H3

Ground state and magnetization reversal of spin ice patterns — •Alexandra Schumann[1], Björn Sothmann[2], Philipp Szary[1], and Hartmut Zabel[1] — [1]Experimentalphyik IV, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Theoretische Physik, Universität Duisburg-Essen, 47048 Duisburg, Germany

We present experimental realizations of magnetic dipole arrays on honeycomb lattices and discuss the remanent state as well as the magnetization reversal in an external field parallel to the main symmetry directions. Because of the large shape anisotropy, the ground state can only be reached by driving the system through minor loops. The nanostructures were prepared by means of e-beam lithography and the dipole configurations were imaged by magnetic force microscopy (MFM) at room temperature. They consist of Fe-bars with dimensions length, width and thickness of 3000 nm, 300 nm, and 20 nm, respectively. Here we discuss three honeycomb patterns with inter island distances of 400 nm, 800 nm and 1700 nm. For large dipolar separation we observe a nearly uncorrelated ground state with the frequency of type I (three in or three out) and type II (two in - one out, or two out - one in) vertices as expected for random distribution. For short separations between the dipoles the system is highly correlated with a predominance of type II states, but due to defects in the lattice also type I states are present. Further investigations, including the application of magnetic fields in different directions with respect to the main symmetry axes are currently being performed. This work is supported by DFG-SFB 491, which is gratefully acknowledged.

MA 23.6 Thu 11:30 H3

Magnetic properties of bimetallic nanoislands deposited on Pt(111) — •Sven Bornemann[1], Jan Minár[1], Sergey Mankovsky[1], Safia Ouazi[2], Stefano Rusponi[2], Harald Brune[2], Julie B. Staunton[3], and Hubert Ebert[1] — [1]Department Chemie und Biochemie, LMU München, 81377 München, Germany — [2]Institute of Condensed Matter Physics, EPF Lausanne, Switzerland — [3]Department of Physics, University of Warwick, United Kingdom

In recent years, magnetic nanostructures on surfaces have been the subject of intense research activities which are driven by fundamental as well as practical interests. One of the central questions for future applications is how the magnetic properties like the magnetic anisotropy evolve in-between single magnetic adatoms and submonolayer magnetic particle arrays. Experimentalists have succeeded in assembling surface supported single domain particles where the magnetic moments of all atoms form a so-called macrospin and it is commonly believed that the special magnetic characteristics of such structures are mainly due to their exposed low-coordinated edge atoms. For some of these novel systems, however, unexpected low anisotropies or reduced magnetic moments are observed which makes it difficult to find promising candidates for real life technical applications. To support these experimental efforts the fully relativistic spin-polarized KKR method has been applied to investigate the influence of spin-orbit coupling on the magnetic properties of various FeCo nanostructures deposited on Pt(111). The discussion will focus on interface and alloy contributions to the magnetic anisotropy in these systems.

MA 23.7 Thu 11:45 H3

Time-resolved magnetization dynamics of antidot square lattices in nickel — •Benjamin Lenk, Fabian Garbs, Henning Ulrichs, Andreas Mann, and Markus Münzenberg — I. Physikalisches Institut, Universität Göttingen

Femtosecond laser pulses can be used to optically excite (pump) and subsequently measure (probe) magnetization dynamics on timescales as long as nanoseconds. We use pulses from a Ti:Sa mode-coupled laser system to investigate nickel films with thicknesses of several tens of nanometers and find (on continuous films) uniform precession as well as propagating dipole-dominated spin waves.

The creation of a periodic magnetic "potential", namely arrays of micron-sized antidots, induces – in analogy to photonic crystals – drastic changes in the magnetization dynamics: Not only do some previously observed modes disappear, but moreover, additional modes can be excited whose frequency shows only minimal dependence on the applied field. We focus on the behaviour of these new modes and especially resolve the influence of the in-plane angle between external field and antidot lattice orientation. In particular, we verify the collective nature of the non-dispersive modes by experiments on single antidots.

Additionally, first results on magnonic wave guides – represented by a missing line of antidots – are shown. These provide an outlook to

future applications in terms of spin wave logic devices.

MA 23.8 Thu 12:00 H3

Anisotropies of permalloy elements in multidomain states — •Sabine Pütter, Mahmoud Reza Rahbar Azad, Nikolai Mikuszeit, Moritz Bubek, Germar Hoffmann, and Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

The artificial fabrication of nano– and microstructures, e. g. by mask techniques, comes along with the problem that edge faces are not perfectly perpendicular to the substrate plane; a tapered shape is produced, which results in a reduced shape anisotropy [1].

To study this effect experimentally, we fabricated arrays of isolated thin permalloy cuboids of about 15 nm thickness and investigated them by means of the magneto-optical Kerr effect and atomic force microscopy. As the lateral dimensions of the elements are in the low micron range multi-domain states must be considered when deriving the anisotropy from hysteresis loops. In addition to the shape anisotropy we extract an anisotropy from hard axis minor loops and relate it to zero remanent states. Our results confirm the theoretical predictions for single as well as for arrays of coupled elements.

[1] S. Pütter et al., J. Appl. Phys. **106**, 043916 (2009)

MA 23.9 Thu 12:15 H3

Kondo effect in magnetic nanocontacts — •David Jacob — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

We present LDA+DMFT calculations of the electronic structure and coherent transport properties of nanocontacts containing magnetic atoms (Fe,Co or Ni) in the contact region [1]. The strong electron correlations of the 3*d*-electrons are fully taken into account by combining Density Functional Theory (DFT) calculations of the nanocontact with a dynamical treatment of the 3*d*-shells of the magnetic atoms by the Dynamical Mean-Field Theory (DMFT) within the so-called One-Crossing-Approximation (OCA). We find that the strong electron correlations can give rise to Kondo resonances at the Fermi level which in turn lead to Fano lineshapes in the coherent transport characteristics of the nanocontact. The exact shape of the Kondo-Fano lineshapes depends on the type of magnetic atoms and the geometry of the contact in agreement with recent experiments with magnetic nanocontacts [2].

References: [1] D. Jacob *et al.*, Phys. Rev. Lett. **103**, 016803 (2009). [2] M. R. Calvo *et al.*, Nature **458**, 1150 (2009).

MA 23.10 Thu 12:30 H3

Switching monolayer Fe islands on NiAl by spin polarized current. — •Frank Dietermann[1] and Ruqian Wu[2] — [1]Max-Planck Institute for Metals Research, Heisenbergstr. 3, D-70569 Stuttgart, Germany — [2]University of Irvine, Irvine, CA, United States of America

A preliminary investigation into spin-torque induced switching processes of very small (2-3nm) monolayer Fe islands on NiAl is reported. A rough estimate for the minimum spin-polarized current where switching occurs is obtained through dynamic simulations of the atomic moments. The simulation takes the Heisenberg interaction, dipole fields and the adiabatic spin torque into account, and numerically solves the Landau-Lifshitz-Gilbert equation through Runge-Kutta-Fehlberg methods. A rather large discrepancy to the experimental observations is discussed and a very simple explanation proposed.

MA 24: Spinelectronics / Spin Injection in Heterostructures

Time: Thursday 10:15–12:45 Location: H22

MA 24.1 Thu 10:15 H22

Spin-orbit coupling fields in Fe/GaAs junctions — •Martin Gmitra[1], Alex Matos-Abiague[1], Claudia Ambrosch-Draxl[2], and Jaroslav Fabian[1] — [1]Univesity of Regensburg, 93040 Regensburg, Germany — [2]University of Leoben, 8700 Leoben, Austria

The existence of the spin-orbit fields induced by the interface structure in Fe/GaAs junctions is proven from first-principles calculations. While the underlying symmetry of the fields follows that of the interface, the specific realization of the symmetry depends on the electron momentum and energy. The calculated atomic-layer-resolved expectation values of the Bloch states' spins show that the spin-orbit fields peak at the GaAs side of the interface. The employed technique is applicable to ferromagnetic junctions in general. This work has been supported by SFB 689.

MA 24.2 Thu 10:30 H22

Spin Injection and Extraction in Fe/GaAs — •Bernhard Endres, Frank Hoffmann, Dieter Schuh, Georg Woltersdorf, Christian Back, and Günther Bayreuther — Universität Regensburg, Institut für Experimentelle und Angewandte Physik

Majority spin injection into GaAs(001) has recently been observed from Fe [1] and FeCo [2] epitaxial contacts. Consequently, minority polarization is expected in the semiconductor when the tunneling current is reversed from electron injection to extraction. This was clearly observed for FeCo contacts [2], but a complex bias dependence of the spin polarization was found in the case of Fe contacts changing from sample to sample [1]. In order to find out whether this discrepancy originates from a different band filling in the two materials or from specific interface properties, the GaAs structure [2] and an epitaxial Fe contact layer were grown in two connected MBE chambers without breaking the vacuum. After lithographic patterning the spin polarization in the GaAs, P_n, was measured by MOKE across a cleaved edge as described in ref. 2. P_n as a function of magnetic field reproduces the switching behavior of the Fe contact. The bias dependence of P_n showed the same sign reversal as previously seen for FeCo [2] in contrast to the behavior found in ref. 1. This rules out the material-specific band structure to be the origin of previous contrasting results, and it indicates that spin injection is crucially affected by interface properties like Schottky barrier profile or interfacial bands which in turn depend on the specific growth conditions. [1] X. Lou et al., Nature Phys. 3, 197 (2007); [2] P. Kotissek et al., Nature Phys. 3, 872 (2007)

MA 24.3 Thu 10:45 H22

In situ fabrication of lateral Cu/Co spin-valves to create pure spin currents — •Julius Mennig, Frank Matthes, Daniel E. Bürgler, and Claus M. Schneider — Institut für Festkörperforschung (IFF-9) and JARA-FIT, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

Pure spin currents attain more and more attention in the field of spintronics. Common structures to investigate this phenomenon are lateral spin-valves. Previous experiments showed that the quality of the interfaces between the magnetic and non-magnetic elements is of outmost importance. In order to obtain optimized interface conditions, we fabricate and investigate lateral spin-valves by in-situ ultra-high vacuum (UHV) methods (MBE, Auger, FIB, SEMPA) instead of the commonly used lithography and the ex situ transport measurements. Electrical 4-point measurements with external magnetic field can also be done in situ.

We prepared Cu/Co spin valves with clean, non-oxidized interfaces and a Cu track widths of 250 - 300 nm. The nanomagnets have a length up to 4 micrometer and a width of 200 - 300 nm. We measured the AMR dependence on magnetic field to investigate the switching fields and coupling behavior of the two nanomagnets and confirm our conclusions with SEMPA. The results leads to spin valves with a modified design, in which we detect pure spin currents with Lock-In technique with constant current amplitude in order to avoid AMR influences.

MA 24.4 Thu 11:00 H22

Optical detection of spin-pumped magnetization in a $Ni_{81}Fe_{19}$/Cu multilayer — •Frederik Fohr[1], Jaroslav Hamrle[1], Helmut Schultheiss[1], Alexander A. Serga[1], Burkard Hillebrands[1], Yasuhiro Fukuma[2], Le Wang[2], and YoshiChika Otani[2] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]ASI RIKEN, and ISSP, University of Tokyo, Japan.

We report on Brillouin light scattering (BLS) investigations of induced magnetization from a $Ni_{81}Fe_{19}$-layer to an adjacent copper-wedge via the spin-pumping effect.

The intensity of the detected BLS signal contains information about the precessing magnetization in the $Ni_{81}Fe_{19}$-layer, which is decay-

ing exponentially with the optical penetration depth, and about the spin pumped magnetization in the copper-wedge, which is decaying with the much longer spin diffusion length. The detected signal in the copper-wedge is a sum of contributions from different depths of the wedge, weighted by the decaying intensity of the probing laser light as well as by the decaying spin-pumped magnetization.

To separate both contributions of the signal experimentally, additional BLS scans were performed on a reference sample, prepared with an interlayer between $Ni_{81}Fe_{19}$ and copper to block the spin pumping. The measurements on both samples are discussed and compared to their respective calculated BLS intensities.

Support by the DFG within the project JST-DFG Hi380/21-1 is acknowledged.

MA 24.5 Thu 11:15 H22

Control of magnetic domain formation and domain wall movement in Permalloy nanowires — •Saleh Getlawi, Markus König, Michael R Koblischka, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany

Nanoscale magnetic systems have been attracting much attention from both fundamental and technical reasons. For magnetoelectronic applications it is essential to have a variety of structures, where sizes and shapes are precisely controlled with high accuracy. Permalloy nanowires were fabricated using electron beam lithography and the lift-off technique. We have studied the control of magnetic domain formation, domain wall movement and magnetization reversal in magnetic nanowires. The switching field of the nanowires was observed using magnetic force microscopy. The experimental results were compared to those obtained by micromagnetic simulations.

MA 24.6 Thu 11:30 H22

Growth and characterization of ferromagnetic MnGa on GaN — •Christian Zube, Amilcar Bedoya-Pinto, Daniel Broxtermann, Till Benter, Jörg Malindretos, and Angela Rizzi — IV. Physikalisches Institut Universität Göttingen,D-37077 Göttingen

In the last years, the δ- phase of MnGa, which has a Curie temperature well above 300 K, gained great interest as a spin-injector for GaAs [1], achieving spin injection efficiencies of 5% at 2 K.

Recent results of MnGa growth on GaN [2] showed a nearly perfect epitaxial match between MnGa(111) and GaN(0001) layers exhibiting magnetic anisotropy along out-of-plane and in-plane directions.

We studied the MBE-growth of Mn_xGa_{1-x} on GaN(0001) templates with the aim of achieving spin injection through the MnGa/GaN interface, varying the Mn content x from 0.3 to 0.6. In order to obtain a smooth interface, different substrate temperatures and annealing methods have been investigated. The growth has been monitored in situ by *RHEED*. Magnetic and electrical transport properties have been measured in a temperature range from 2 to 400 K and magnetic fields up to 50 kOe. *XRD* and *EDX* measurements showed a strong dependence of these properties on stoichiometry and structure. Samples prepared in the van-der-Pauw and Hall-Bar geometry showed an anomalous hall effect, confirming spin polarized carrier transport in the MnGa layer. As a first step to characterize the electrical properties of the MnGa/GaN interface, Schottky diodes have been fabricated.

[1] Adelmann et al, APL 89 (2006),Nr. 11

[2] Lu et al, PRL 97 (2006)

MA 24.7 Thu 11:45 H22

In-situ fabrication of lateral organic spin-valve structures with sub-100nm channel-length — •Matthias Grünewald[1,3], Frank Würthner[2], Georg Schmidt[1,3], and Laurens W. Molenkamp[1] — [1]Experimentelle Physik 3, Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Organische Chemie 2, Universität Würzburg, Am Hubland, 97074 Würzburg — [3]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle

Many spin-valves (SVs) based on an organic semiconductor (OSC) layer sandwiched between two ferromagnetic electrodes have been demonstrated recently. It is, however, still unclear whether the observed effect is based on GMR or TMR because intermixing during the metal deposition on top of the OSC layer can reduce the effective layer thickness. Lateral transport structures using an OSC layer deposited in the gap between two electrodes avoid this possible side effect, but may suffer from interface contamination or oxidation during the lithography process.

Here we report the fabrication of lateral SV structures using a combination of optical lithography and shadow evaporation. The process allows for the in-situ deposition of two ferromagnetic contacts with different coercive fields, separated by a gap of about 80 nm, and covered by a layer of the n-type OSC perylene-diimide. Magnetic and electrical properties are investigated, and gate dependent measurements are performed showing clear gate action. Magnetotransport studies at room temperature show SV action with a magnetoresistance ratio of up to 50% and I/V characteristics indicate lateral tunneling.

MA 24.8 Thu 12:00 H22

Structural and transport properties of Permalloy nanowires — •Saleh Getlawi, Michael R Koblischka, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany

The study of the relationships between geometry and structure of magnetic nanowires on the one hand and their electron transport properties on the other hand is a growing research area of current importance. Permalloy nanostructres with contact pads of various designs (diamonds, ellipses, rectangles, squares) were prepared by electron-beam lithography and the lift-off process in order to find the optimally suited structure for measurements of the magnetoresisance and magnetoimpedance and simultaneous domain observation by means of magnetic force microscopy (MFM). Fur this purpose, all samples were equipped with four current/voltage electrodes made of Pt by employing a dual-beam focused-ion beam system. The obtained MFM images were compared to micromagnetic simulations.

MA 24.9 Thu 12:15 H22

Preparation of Permalloy nanostructures using focused ion beam methods — •Saleh Getlawi, Michael R Koblischka, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, Campus C 6 3, D-66123 Saarbrücken, Germany

Focused ion beam (FIB) milling is a powerful and versatile tool for the maskless fabrication of structures and devices at micro- and nanometer scales. The approach is based on the milling and deposition capabilities of a focused ion beam, where the latter is achieved by ion-beam-assisted decomposition of a metalorganic gas precursor of the specific material that has to be deposited. The combination of FIB and scanning electron microscopy in the same unit (so-called dual-beam unit) further expands the capabilities of the approach by the possibility of performing electron-beam-assisted deposition and inspection. Permalloy nanowires with electrical contacts patterned by FIB-Pt deposition were prepared in the dual-beam unit. Various types of notches to pin magnetic domain walls were additionally fabricated by means of FIB. The fabrication parameters for a structural modification of the Permalloy structures without too strongly affecting the material properties were determined previously [1]. Magnetic force microscopy was employed for an observation of the resulting magnetic domain structures.

[1] S.Getlawi et al., Superlatt. and Microstruct. 44 (2008) 699.

MA 24.10 Thu 12:30 H22

HAXPES studies of FeCoB-MgO-FeCoB tunnel junctions. — •X. Kozina[1], G. Stryganyuk[1], B. Balke[1], G.H. Fecher[1], C. Felser[1], S. Ikeda[2], H. Ohno[2], and E. Ikenaga[3] — [1]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany — [2]Research Institute of Electrical Communication, Tohoku University, Sendai, Japan — [3]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan

This work reports on hard X-ray photoelectron spectroscopy of FeCoB-MgO-FeCoB magnetic tunnel junctions. The studies were performed on both the lower part of a tunnel junction only as well as on the full junction. The multilayer structures were deposited on SiO wafers with the sequence Ta/Ru/Ta/FeCoB/MgO/AlO_x or Ta/Ru/Ta/FeCoB/MgO/FeCoB/Ta/AlO_x. The final samples were annealed at temperatures of 520 K to 920 K. Core level spectroscopy reveals clearly the thermally stimulated interlayer diffusion of boron. The efficiency of the boron transfer between FeCoB and the contiguous Ta layer increases at higher annealing temperatures. Valence band spectroscopy shows strong changes of the electronic structure with increasing annealing temperature and shows a good agreement with the calculated density of states. The dependence of the tunnel magnetoresistance on the annealing temperature is explained for by the combined effects of an improved crystalline structure together with a change in the spin polarization at the Fermi energy caused by the removal of boron from the FeCoB layer.

This work is financially supported by the DfG (P7, FOR 559).

MA 25: Surface Magnetism / Magnetic Imaging I

Time: Thursday 10:15–12:45 Location: H23

MA 25.1 Thu 10:15 H23

Measuring the distance dependence of the magnetic exchange interaction across a vacuum gap: First experimental results obtained with magnetic exchange force spectroscopy — Rene Schmidt, Uwe Kaiser, •Alexander Schwarz, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

Magnetic exchange force microscopy (MExFM) has been established as an atomic force microscopy (AFM) based imaging technique to map the spin structures of insulating [1] as well as metallic surfaces [2]. Here we employ the spectroscopic mode, i.e., magnetic exchange force spectroscopy (MExFS), to probe the distance dependence of the magnetic exchange interaction between an atomically sharp magnetic tip and the antiferromagnetically ordered Fe monolayer on W(001). The site specific distance dependence of the total tip-sample interaction is recorded above Fe atoms which exhibit parallel as well as antiparallel atomic magnetic moments with respect to the tip. The contribution of the magnetic exchange interaction can be extracted by subtracting the two curves from each other, because all other interactions are identical on both sites. The experimental results are compared with theoretical calculations [3] and thereby allow us to determine the distance dependence of the effective coupling constant J between the tip apex atoms and the surface atoms underneath.

[1] U. Kaiser et al., Nature 446, 522 (2007).
[2] R. Schmidt et al., Nano Lett. 9, 200 (2009).
[3] C. Lazo et al., Phys. Rev. B 78, 214416 (2008).

MA 25.2 Thu 10:30 H23

Ferromagnetic versus antiferromagnetic tips for magnetic exchange force microscopy — •Cesar Lazo and Stefan Heinze — Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, 24098 Kiel, Germany.

Magnetic exchange force microscopy (MExFM) is a promising new technique to perform magnetic imaging with atomic resolution by measuring the magnetic exchange force between a magnetically coated tip and a magnetic sample [1]. Here, we apply density functional theory using the full-potential linearized augmented plane wave (FP-LAPW) method to simulate MExFM on the antiferromagnetic monolayer Fe on W(001) [2]. We use single atom tips of Cr, Mn and Fe, and multi-atom tips of Cr and Fe as models. For single atom tips, we find a magnetic exchange interaction which resembles the Bethe-Slater curve. Using multi-atoms tips, we observe that relaxations of the cluster and the surface are significant and larger for Cr tips than for Fe tips. In conclusion, Cr tips exhibit a higher magnetic exchange force than Fe tips and are well suited for MExFM experiments.

[1] U. Kaiser *et al.*, Nature 446, 522 (2007)
[2] R. Schmidt, C. Lazo. *et al.*, Nano Lett. 9, 200 (2009)

MA 25.3 Thu 10:45 H23

Resolving the interface magnetism of a molecule-based spin filter — Jens Brede[1], •Nicolae Atodiresei[2], Stefan Kuck[1], Predrag Lasic[2], Stefan Blügel[2], Roland Wiesendanger[1], and Germar Hoffmann[1] — [1]Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany — [2]Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

The use of magnetic molecules opens a gateway to a flexible design of spintronic devices to store, manipulate, and read spin information at nanoscale level. Crucial is the precise knowledge of molecular properties at the interface towards an electrode. Progress in this field relies on resolving and understanding the physics at the relevant interface, the role of individual molecular constituents, and the impact of the atomic environment on molecular properties.

In this work, we apply spin-polarized scanning tunneling microscopy to resolve the physics of such an interface formed of a single magnetic metal-organic molecule adsorbed on a magnetic substrate to observe on an atomic scale the operation of single-molecule spin filter. The experimental data reveal a significant and strongly site dependent localization of spin split states at the interface. To understand the resulting spin-polarization, state of the art first principles calculations are performed. The density functional theory code is extended to describe non-local correlation effects present when a molecule and a metallic substrate are in close proximity. The physical processes at the molecule-electrode interface will be discussed.

MA 25.4 Thu 11:00 H23

SP-STM of Co nano-islands on Cu(111) with bulk Cr tips — •Marco Corbetta[2], Fabio Donati[1,2], Andrea Li Bassi[1], Matteo Passoni[1], Carlo Casari[1], Safia Ouazi[2], Yasmine Nahas[2], Dirk Sander[2], and Jürgen Kirschner[2] — [1]CNISM, NEMAS and Dipartimento di Energia - Politecnico di Milano, Milano, Italy — [2]Max Planck Institut für Mikrostrukturphysik, Halle, Germany

From its first application, SP-STM has been performed using tunneling tips fabricated with a great variety of ferromagnetic (Fe, Ni, Co or Fe-coated W tips) or antiferromagnetic materials (MnNi, MnPt, Cr-coated or Mn-coated W tips). In order to avoid perturbing stray fields induced by strong magnetic polarization of the tip, antiferromagnetic materials are usually preferred [1]. The main drawback of coated tips is that an in-situ preparation is required. Recently an easy, reliable and reproducible procedure for the production of bulk Cr tips has been developed using only a standard electrochemical etching [2]. We produced and used such tips for in-field spin-polarized STM measurements at 7 K on Co nano-islands on Cu(111). The obtained images show a spin resolved high spatial resolution on the Co islands. Changing the magnetic field we measured the variation of the dI/dV signal. We obtained butterfly hysteresis loops which show that the magnetization direction of the tip apex is not pinned but follows the external magnetic field direction, similar to our previous results obtained with Cr-coated W tips [3]. [1] A. Kubetzka et al., Phys. Rev. Lett. 88, 057201 (2002). [2] A. Li Bassi et al., Appl. Phys. Lett. 91, 173120 (2007). [3] G. Rodary et al., Jpn. J. Appl. Phys. 47, 9013 (2008).

MA 25.5 Thu 11:15 H23

Cr Bulk Tips for Spin Polarized Scanning Tunneling Microscopy with both In-plane and Out-of-plane Sensitivity — •Anika Emmenegger, Gabriela Herzog, Stefan Krause, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg

Spin-polarized scanning tunneling microscopy (SP-STM) is a powerful technique to investigate magnetic surface properties on the local scale. The advantage of antiferromagnetic probe tips, e.g. Cr- or Mn-coated W-tips, is their negligible stray field, that otherwise may interact with the sample magnetization. Chromium has a bulk Néel temperature of 311 K which makes it a promising bulk tip material for SP-STM measurements over a wide temperature range.

While first indications exist that Cr bulk tips are sensitive to the in-plane-component of sample magnetization [1], we show that these tips are also sensitive to the out-of-plane component. After introducing our *ex situ* and *in situ* tip preparation method we present SP-STM measurements on 1.8 monolayers of Fe/W(110) which is known to have the easy magnetization direction in the surface plane for the monolayer [2] and perpendicular to the surface in the second layer [3]. Imaging with a Chromium bulk tip reveals a magnetic contrast in the monolayer as well as in the double layer, thereby proving not only the in-plane but also the out-of-plane sensitivity of the tip.

[1] A. L. Bassi *et al.*, APL **91**, 173120 (2007).
[2] M. Pratzer *et al.*, PRL **87**, 127201 (2001).
[3] O. Pietzsch *et al.*, PRL **84**, 5212 (2000).

MA 25.6 Thu 11:30 H23

Non-collinear magnetism in monatomic transition-metal chains — •Franziska Schubert[1], Paolo Ferriani[1,2], Yuriy Mokrousov[3], and Stefan Heinze[1,2] — [1]Institute of Applied Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstr. 15, 24098 Kiel, Germany — [3]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich, Germany

Recent advances in experimental techniques allow the creation of one-dimensional transition-metal nanostructures on surfaces by self-assembly [1] or by atom manipulation with an STM tip [2]. Here, we used density functional theory calculations based on the full-potential linearized augmented plane wave (FLAPW) method to study the possibility of non-collinear magnetism in monatomic 3*d* transition-metal chains. We first focus on freestanding Mn and Fe chains as a function

of the interatomic spacing. While Fe chains remain ferromagnetic independent of interatomic distance, Mn chains possess spin-spiral ground states in a broad regime of lattice constants. Therefore, we investigated Mn chains on the (110)-surfaces of Cu, Pd, Ag, and NiAl. We demonstrate that the chain-surface hybridization is sufficient to dramatically change the magnetic coupling in the chain. Nevertheless, a non-collinear magnetic ground state is found for Mn chains on Cu(110) and Ag(110).

[1] P. Gambardella *et al.*, Nature **416**, 301 (2002)
[2] C. Hirjibehedin *et al.*, Science **312**, 1021 (2006)

MA 25.7 Thu 11:45 H23

Nonequilibrium effects in spin inelastic tunneling spectroscopy — •Björn Sothmann and Jürgen König — Universität Duisburg-Essen and CeNIDE, 47048 Duisburg, Germany

In a recent experiment, Hirjibehedin et al. [1] measured the differential conductance of a single iron atom absorbed on a substrate using an STM tip. While the observed steps could be explained [2] in terms of inelastic tunneling processes exciting the atom out of its ground state, an explanation for the nonmonotonic conductance behaviour as a function of bias voltage is missing.

Here we develop a generalized theory which takes into account nonequilibrium spin occupations using a master equation approach. We find that the conductance overshoots at the inelastic steps and drops to its equilibrium values afterwards. This behaviour can be explained by bias-dependent spin occupations. Furthermore, we show that the experimentally observed absence of these overshoots at certain spin excitations can be ascribed to a spin-dependent relaxation mechanism. Finally, we discuss that the nonequilibrium effects also give rise to a super-Poissonian current noise.

[1] C. Hirjibehedin et al., Science **317**, 1199 (2007).
[2] J. Fernández-Rossier, Phys. Rev. Lett. **102**, 256802 (2009).

MA 25.8 Thu 12:00 H23

Determining the Magnetism of Single Atoms on a Semiconductor Surface — •Bruno Chilian, Alexander Khajetoorians, Jens Wiebe, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Hamburg, Germany

We demonstrate a method in which we combine spin-resolved Landau level spectroscopy and inelastic tunneling spectroscopy (IETS) to determine the magnetization and anisotropy of single Fe atoms coupled to a 2D electron gas on a III-V (110) semiconductor surface. We show here, using ultra-low temperature (300mK) scanning tunneling spectroscopy in high magnetic fields (12T) that the states of the Fe atom couple to the spin-split Landau levels thereby producing an overall asymmetry in the local density of states (LDOS) for a given Landau level. By probing the LDOS with changing magnetic field, we determine the magnetization of the atom. Furthermore, we observe spin excitations of the Fe atom by IETS. From these excitations, we observe a zero-field splitting of the Fe spin which we attribute to magnetic anisotropy. We relate these two measurements using a simple quantum magnetic Hamiltonian which suitably describes both experimental observations.

MA 25.9 Thu 12:15 H23

Lifetime information of excited states in magnetic single atoms and clusters studied by STM — •Toshio Miyamachi[1,2], Tobias Schuh[1], Timofey Balashov[1], Albert. F. Takács[1], Shigemasa Suga[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, Karlsruhe, Germany — [2]Graduate School of Engineering Science, Osaka University, Toyonaka, Japan

The magnetic stability of bits in a hard disk relies on the energetic barrier to reverse the magnetization, which is governed by magnetic anisotropy energy (MAE). Recent x-ray magnetic circular dichroism study has revealed a giant MAE of Co atoms on Pt(111) of 9.3 meV [1], raising hope for realizing ultimate miniaturization of bits. This technique, however, cannot extract information about the magnetization dynamics, which also plays an important role for the stability of bits. Here we demonstrate that inelastic tunneling spectroscopy using scanning tunneling microscopy (STM) can investigate the lifetimes of magnetically excited states in addition to MAE [2]. By virtue of atomic manipulation capabilities of the STM, these properties are determined with the highest precision for single atoms, dimers and trimers of Fe and Co on Pt(111). The estimated short lifetimes of the order of femtoseconds are explained from efficient electron-electron scattering processes induced by the strong hybridization of the impurity state and the substrate.

[1] P. Gambardella et al., Science 300, 1130 (2003)
[2] T. Balashov et al., PRL 102, 257203 (2009)

MA 25.10 Thu 12:30 H23

Inversion of Spin Polarization above Magnetic Adatoms — •Lihui Zhou, Focko Meier, Jens Wiebe, and Roland Wiesendanger — Hamburg University, Germany

The spin-resolved electronic structure of magnetic adatoms on surfaces is essential to the understanding of magnetism and the realization of magnetic devices at the atomic level. Here we present an investigation of the electronic density of states of Co adatoms on platinum(111) using spin-polarized scanning tunneling spectroscopy at cryogenic temperature. It revealed a pronounced spin-polarized resonance of majority character just below the Fermi energy in the vacuum above the adatoms, giving rise to a positive spin polarization at the Fermi energy. This is in contrast to atomically flat surfaces where minority states are dominating. The comparison to other Co nanostructures suggests that the inversion of the spin polarization is a unique property for single adatoms on surfaces.

MA 26: Spin Dynamics / Spin Torque IV

Time: Thursday 14:00–17:00 Location: H10

Invited Talk MA 26.1 Thu 14:00 H10

Magnonics - Exploring spin waves on the nanoscale — •Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Str. 1, 85747 Garching b. München, Germany

Collective spin excitations in ferromagnets have regained great interest in magnetism research. Recent observations such as spin-wave quantization, localizaton and interference in nanopatterned ferromagnets have stimulated further the field of magnonics where spin waves (magnons) are explored in order to carry and process information.[1] Here, magnonic waveguides and magnonic crystals, i.e. the magnetic counterpart of photonic crystals, are expected to offer intriguing perspectives for the transmission and manipulation of spin waves, respectively. However, the experimental realization is still in its infancy and challenging. We will discuss recent developments and all-electrical spin-wave spectroscopy on magnonic nanodevices based on nanowires as well as antidot lattices. We gratefully acknowledge collaborations and discussions with M. Becherer, B. Botters, G. Dürr, F. Giesen, G. Gubbiotti, D. Heitmann, M. Kostylev, V. Kruglyak, S. Neusser, J. Podbielski, D. Schmidt-Landsiedel, S. Tacchi, and J. Topp. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n°228673, from SFB 668 and the German Excellence Cluster 'Nanosystems Initiative Munich'. [1] S. Neusser and D. Grundler, Advanced Materials 21, 2927 (2009); and references therein.

Invited Talk MA 26.2 Thu 14:30 H10

Spin dynamics of complex metallic magnets — •Paweł Buczek, Arthur Ernst, and Leonid Sandratskii — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Magnons, often termed as spin-waves, are elementary collective excitations of magnets. Every magnon lowers the magnetization of the system by $2\mu_B$, carries energy and crystal momentum. Their signature is found in the inelastic neutron scattering, spin polarized electron energy loss spectroscopy, inelastic scanning tunneling microscopy and spin-resolved two-photon photoemission experiments. Magnons and other magnetic excitation can be one of the coupling mechanisms in high temperature superconductivity. They control the thermodynamics of magnets. Spintronics approaches limits where the magnetic excitations start to interfere with operation of the devices.

In this theoretical talk we will outline an *ab-initio* method of study-

ing magnetic excitations based on time dependent density functional theory. The method allows to access both the energies and life times of magnons. We will discuss the applications of the method to half-metallic Heusler compounds. In these materials certain decay channels become inoperative for low-energy spin-waves. Next, we will focus on magnons in thin metallic films, where their properties are strongly influenced by the structure of the films and the presence of substrate. Finally, some attention will be paid to the theoretical interpretation of certain novel experiments capable of probing magnons in nanostructures.

MA 26.3 Thu 15:00 H10

Time-resolved and wave-vector sensitive observation of a pump-free BEC — •Christian W. Sandweg[1], Alexander A. Serga[1], Vitaliy I. Vasyuchka[1], Andrii V. Chumak[1], Timo Neumann[1], Björn Obry[1], Helmut Schultheiss[1], Gennadii A. Melkov[2], Andrei N. Slavin[3], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Radiophysics, National Taras Shevchenko University of Kiev, Ukraine — [3]Department of Physics, Oakland University, Rochester, MI, USA

We report on the temporal and wave-vector sensitive investigation of a pump-free Bose-Einstein-Condensate (BEC) of magnons at room temperature. To create the condensate the technique of parametric microwave pumping is used. A microwave photon splits into two magnons with half of the pumping frequency and opposite k-vector. In a competing process only the group of magnons at half of the pumping frequency having the lowest damping survives. The magnons of this dominant group (DG) thermalize to the lowest energy state and a BEC of magnons is formed. The DG not only plays the role of an energy source for the BEC but is in the same time the most important disruptive factor for it. When the pumping is switched off the BEC of magnons can freely evolve which result in a strong increase of intensity of the condensate on the same time scale as the dominant group decays. To separate the BEC dynamics from the evolution of the other components of the magnon gas near the lowest energy state, time-resolved measurements were performed in combination with wave-vector sensitivity.

MA 26.4 Thu 15:15 H10

Parametric resonance and the kinetics of magnons in Yttrium Iron Garnet — •Thomas Kloss, Andreas Kreisel, and Peter Kopietz — Goethe-Universität, Frankfurt, Deutschland

The time evolution of magnon gases subject to an external time-dependent microwave field is usually described within the so-called "S-theory", which amounts to deriving self-consistent kinetic equations for the distribution function within the time-dependent Hartree-Fock approximation. For the theoretical description of the recently observed "Bose-Einstein condensation of magnons" under external microwave pumping the "S-theory" should be generalized to include the Gross-Pitaevskii equation for the time-dependent expectation value of the magnon creation and annihilation operator. We explicitly solve the resulting coupled equations within a simple approximation where only the condensed mode and its fluctuations are retained. We also re-examine the usual derivation of time-dependent effective boson models from a realistic spin model for Yttrium-Iron-Garnet films and argue that for strictly parallel pumping (where the time-dependent part of the magnetic field is parallel to its static component) the magnons should condense.

MA 26.5 Thu 15:30 H10

Reversible folding of acoustic spin waves in an one-dimensional magnonic crystal — •Jesco Topp[1], Mikhail Kostylev[3], Detlef Heitmann[1], and Dirk Grundler[2] — [1]Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg, Germany — [2]Physik-Department E10, Technische Universität München, 85747 Garching, Germany — [3]School of Physics, M013, University of Western Australia, 35 Stirling Hwy, 6009 Crawley, WA, Australia

Spin waves can be tailored by geometric confinement, through inhomogenuous internal fields or bandstructure engineering in magnonic crystals, i.e. periodic arrays of magnetic structures that support spin-wave propagation from structure to structure. We have investigated spin waves in a one-dimensional magnonic crystal fabricated out of from 300 nm wide and 20 nm thick nanowires and investigated the magnetic-field dispersion near the Brillouin-zone center by means of broadband microwave spectroscopy. The spin-wave spectrum of this crystal can be controlled by (reversibly) modifying the bandstructure of the crystal during the experiment. We find that two different kinds of spectra can be chosen, depending on the unit cell of the crystal. A simple cell (a single wire) or a complex one (two wires with antiparallel magnetization) can be selected using a careful magnetic-field history. Modes of the complex unit cell can be understood by a folding of the (simple cell's) wavevector dispersion into the new Brillouin zone. The lowest-order acoustic spin wave and its folded counterpart exhibit a peculiar magnetic-field dispersion. Funding via "SFB 668" and the "Nanosystems Initiative Munich" (NIM) is acknowledged.

MA 26.6 Thu 15:45 H10

Sub-wavelength non-diffractive spin-wave beams — Thomas Schneider[1], •Alexander A. Serga[1], Andrii V. Chumak[1], Christian W. Sandweg[1], Simon Trudel[1], Sandra Wolff[2], Mikhail P. Kostylev[3], Vasil S. Tiberkevich[4], Andrei N. Slavin[4], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Nano + Bio Center, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [3]School of Physics, M013, University of Western Australia, Crawley, WA 6009, Australia — [4]Department of Physics, Oakland University, Rochester, Michigan 48309, USA

We report on the investigation of linear sub-wavelength non-diffractive spin-wave beams in a 2D magnetic medium. These beams, are formed due to the anisotropy which is induced in the magnetic media by the bias magnetic field. Due to this anisotropy, it is possible, that spin waves have different oriented wave vectors but an identical direction of group velocity. A newly developed waveguide antenna allows the excitation of spin waves with the necessary wide angular wavevector spectrum. We investigated the dependence of the behaviour of the non-diffractive beams on the magnetic field and the antenna spectrum using space-, time- and phase-resolved Brillouin light scattering spectroscopy. It is shown that the sub-wavelength spin-wave beams propagate without noticeable broadening for more than 10 mm. The measurements demonstrate that the beam width is of the same order of magnitude as the wavelength. Results on the reflection and scattering of the beams are reported.

MA 26.7 Thu 16:00 H10

Splitting of the homogeneous mode in high power ferromagnetic resonance experiment — •Peter Majchrak[1], Georg Woltersdorf[1], Thorsten Kachel[2], Christian Stamm[2], Hermann Dürr[2], and Christian Back[1] — [1]Institut für Exp. und Angewandte Physik, Uni Regensburg, 93040 Regensburg — [2]BESSY II, Albert-Einstein-Straße 15, 12489 Berlin, Germany

Utilizing X-ray magnetic circular dichroism (XMCD) we measured the transversal components of the precessing magnetization in a thin film under cw microwave excitation (phase locked to the X-ray pulses) in a coplanar waveguide structure. From the signal calibrated by XMCD hysteresis loops we directly evaluated the absolute values of precessing magnetization. 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). The measured amplitude of the excursion saturates above the critical field and at the same time the resonance line of the uniform mode is splitting. The split of the line increases with growth of the pumping field and that results in an effective linewidth broadening. The measurement of both components of the complex susceptibility allows for evaluation of the phase of the two modes with respect to the exciting field and then to reconstruct their lineshapes. This way we distinguished two separate uniform precession modes, which appeared in nonlinear regime and characterized their phase and the resonance field for various microwave excitation amplitudes. Support by the BMBF (05 ES3XBA/5) is gratefully acknowledged.

MA 26.8 Thu 16:15 H10

All-optical detection of phase fronts of propagating spin waves in a $Ni_{81}Fe_{19}$ microstripe — •Katrin Vogt, Helmut Schultheiss, Sebastian J. Hermsdoerfer, Philipp Pirro, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We present the determination of the wavelength and phase of propagating spin waves in magnetic microstructures made of $Ni_{81}Fe_{19}$ using the shorted end of a coplanar waveguide for local excitation. The spin wave characteristics have been measured by phase resolved Brillouin light scattering microscopy. This recently developed technique allows for the experimental visualization of the phase structure of propagat-

ing spin waves and is employed here to magnetic microstructures. The results show an excellent agreement with the calculated dispersion relations for the spin-wave waveguide modes.

Financial support by the DFG Priority Program SPP 1133 is gratefully acknowledged as well as the Nano+Bio Center of the Technische Universität Kaiserslautern for their assistance in sample preparation.

MA 26.9 Thu 16:30 H10

ESR in CuCrO2 — •Mamoun Hemmida[1], Hans-Albrecht Krug von Nidda[1], Nikola Pascher[1], Alois Loidl[1], and Christine Martin[2] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany — [2]Laboratoire CRISMAT, UMR 6508 CNRS-ENSICAEN, and IRMA FR3095, 6 Boulevard Maréchal Juin, Caen Cedex 4, France

Electron Spin Resonance (ESR) measurements were performed at X band (9.4 GHz) frequency on a delafossite compound CuCrO2, both on single crystal and polycrystalline samples, which represents a model system of the two-dimensional triangular lattice Heisenberg antiferromag- net. The spin-spin relaxation behavior, which appears in the temperature dependence of the linewidth is similar to that previously observed in some iso-structural rock salt Cr- compounds like HCrO2, LiCrO2, and NaCrO2. In those oxides, the linewidth is well described in terms of a Berezinskii-Kosterlitz-Thouless (BKT) like scenario [1, 2, 3]. The deviation from the ideal BKT scenario was attributed to the effect of geometrical frustration [4]. References [1] V. L. Berezinskii, Sov. Phys. JETP 32, 493 (1971). [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] Hemmida, M., Krug von Nidda, H.-A., Buettgen, N., Loidl, A. , Alexander, L. K., Nath, R., Mahajan, A. V., Berger, R. F., Cava, R. J., Singh, Yogesh, and Johnston, D. C., Phys. Rev. B 80, 054406 (2009). 1

MA 26.10 Thu 16:45 H10

Spin dynamics in a ferromagnetic spin-orbital chain beyond mean-field decoupling — •Alexander Herzog[1], Andrzej Oleś[1,2], Peter Horsch[1], and Jesko Sirker[1,3] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]Marian Smoluchowski Institute of Physics, Jagellonian University, Kraków, Poland — [3]Technische Universität Kaiserslautern, Fachbereich Physik, Kaiserslautern, Germany

We study the spin dynamics and thermodynamics of a one-dimensional spin-orbital model relevant for transition metal oxides. In mean-field decoupling this model shows a dimerized phase at intermediate temperatures while the spins order ferromagnetically in the ground state. Using a modified spin-wave theory we calculate the dynamical spin structure factor in the uniform and dimerized phase. We then address the question how the spin dynamics is affected if the spin-orbital coupling is taken into account beyond mean-field. Finally we also study corrections to thermodynamic quantities beyond the mean-field decoupling and compare with a numerical solution of the model obtained by the density-matrix renormalization group.

MA 27: Spin Structures and Magnetic Phase Transitions

Time: Thursday 17:15–18:45 Location: H10

MA 27.1 Thu 17:15 H10

A scheme to calculate the Curie temperature for systems with induced magnetic moments with application to Co-Pt and Fe-Pd alloys — •Svitlana Polesya[1], Sergiy Mankovsky[1], Ondrej Sipr[2], Christoph Strunk[3], and Hubert Ebert[1] — [1]LMU Munchen, Dept. Physikalische Chemie, Butenandtstraße 11, D-81377 München — [2]Institute of Physics Acad. of Science, Prague, Czech Republic — [3]Institute for Exper. and Appl. Physics, University of Regensburg, Germany

The importance of including induced magnetic moments when calculating the Curie temperature of transition metal systems is shown for Pd-rich Fe-Pd alloys and Co-Pt alloys. For this binary alloys the components exhibit a different type of magnetism, i.e. spontaneous and induced. The finite temperature magnetic properties of these alloys are described using a generalised Heisenberg Hamiltonian that allows to account for the longitudinal fluctuation of induced moments of the Pd and Pt atoms. In Fe-Pd alloys with small Fe concentration the role of effective Fe-Fe interaction mediated by the induced Pd moments is crucial for the creation of ferromagnetic (FM) order. The Curie temperature T_c obtained for these alloys are in good agreement with experiment for the Fe concentration up to 15%. For the Co-Pt alloys the improvement of the T_c values with inclusion of the induced moments on Pt atoms is shown for the whole considered concentration range. The FM order in the ordered $CoPt_3$ alloy that is observed experimentally is only possible due to the FM coupling to induced Pt moments while Co-Co coupling is primarily anti-ferromagnetic.

MA 27.2 Thu 17:30 H10

Nature of the Magnetic Order and Magnetic Interactions in $BaMn_2As_2$ — •Yogesh Singh[1], Philipp Gegenwart[1], David Johnston[2], Rob McQueeney[2], Alan Goldman[2], and Bella Lake[3] — [1]1. Physikalisches Institut, Georg August Universitaet, Goettingen, Friedrich Hund Platz 1, 37077, Goettingen, Germany. — [2]Ames Laboratory and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA. — [3]Helmholtz-Zentrum Berlin für Materialien und Energie (HZB), Glienicker Straße 100, 14109 Berlin, Germany.

The recent discovery of high temperature superconductivity in several structure classes containing FeAs-layers has led to a flurry of activity not seen since the discovery of CuO-based high temperature superconductors more than 20 years ago. In an attempt to discover new materials related to these FeAs-based systems we have studied in detail the properties of $BaMn_2As_2$ which is iso-structural to tetragonal $BaFe_2As_2$. In this talk I will present our magnetic, thermal, transport, and neutron diffraction and scattering studies on polycrystalline and single crystalline samples of $BaMn_2As_2$. We find that $BaMn_2As_2$ undergoes a transition into a G-type antiferromagnetic state below $T_N = 620$ K with the ordering direction being the c axis. Our estimates of the magnetic interactions indicate that $BaMn_2As_2$ is a quasi-two-dimensional magnetic system with frustrating antiferromagnetic nearest-neighbor (J_1) and next-nearest-neighbor (J_2) in-plane interactions.

MA 27.3 Thu 17:45 H10

Weak random anisotropy in the two-dimensional limit - FeZr-based thin films and multilayers — •Andreas Liebig[1], Panagiotis Korelis[2], Gabriella Andersson[2], Manfred Albrecht[1], and Björgvin Hjörvarsson[2] — [1]Chemnitz University of Technology, Institute of Physics, Chemnitz, Germany — [2]Dept. of Physics and Material Sciences, Uppsala University, Uppsala, Sweden

We present a study on the magnetic properties of $Fe_{90}Zr_{10}/Al_{70}Zr_{30}$ amorphous multilayers, based on MOKE and SQUID magnetometry. $Fe_{90}Zr_{10}$ is an archetypical example for a reentrant ferromagnet, exhibiting spin glass phase at low temperatures and a ferromagnetic phase at intermediate temperatures.

From structural and magnetic measurements we could ensure the absence of a crystalline phase, and interlayer thicknesses of 4.5 nm yielded negligible interlayer exchange coupling. The amorphous layers can therefore be treated as magnetically decoupled, besides dipolar interactions. Consequently, the ordering temperature scales with the thickness of the magnetic layers. Furthermore, the finite thickness influences the character of the phase transition itself. For the low-temperature limit the spin-glass phase is suppressed. Above the apparent ferromagnetic ordering temperature a phase with exceedingly high magnetic susceptibility is found. Similarities with the random anisotropy two-dimensional X-Y model are discussed.

MA 27.4 Thu 18:00 H10

Low-energy excitations in the three-dimensional random-field Ising model — Martin Zumsande[1,2] and •Alexander K. Hartmann[3] — [1]Institute of Theoretical Physics, University of Göttingen — [2]Max-Planck Institut fof Physics of Complex Systems, Dresden — [3]Institute of Physics, University of Oldenburg

The random-field Ising model (RFIM), one of the basic models for magnetic alloys exhibiting quenched disorder, can be studied numerically [1] with the help of efficient ground-state algorithms [2]. In this study [3], we extend these algorithm by various methods in order to analyze

low-energy excitations for the three-dimensional RFIM with Gaussian distributed disorder as a function of the disordered strength, i.e. in the ferromagnetic phase, in the paramagnetic phase and right at the phase transition. These excitations appear in the form of clusters of connected spins. We analyze several properties of these clusters. Also we show that the stiffness exponent θ, describing the scaling of the energy of the excitations, is related to the distribution of cluster radii via $P(R) \sim R^{-\theta}$. Our results support the validity of the droplet-model description for the RFIM.

[1] A.K. Hartmann, *Practical Guide to Computer Simulations*, (World Scientific, 2009)
[2] A.K. Hartmann and Heiko Rieger, *Optimization Algorithms in Physics*, (Wiley-VCH, 2001)
[3] M. Zumsande and A.K. Hartmann, to appear in Eur. Phys. J. B

MA 27.5 Thu 18:15 H10

Magnetic Spin Configuration in $Fe_{50}Pt_{50-x}Rh_x$ alloys — •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]Juelich Research Centre — [4]Institute for Magnetism, National Ukrainian 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. 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 $Fe_{50}Pt_{50-x}Rh_x$ studied by magnetization measurements refer to three different phase transitions with increasing temperature: (I) An antiferromagnetic (AF) - paramagnetic (PM) transition for 30< x <14.25, (II), an AF - ferromagnetic (FM) transition for 14.25< x <9.5 and, (III), a FM - PM transition 9.5< x <0 [1]. Here we present results on a series of 200nm $Fe_{50}Pt_{50-x}Rh_x$ films with different Rh concentrations. These films were examined by neutron diffraction in dependence of temperature and magnetic field. By the use of polarized and unpolarized neutron diffraction we could develop a detailed model of the magnetic spin structure in these thin films. [1] S. Yuasa, H. Miyajima and Y. Otani, J. Phys. Soc. Jpn. 63 (8), 1994

MA 27.6 Thu 18:30 H10

Skyrmion textures in noncentrosymmetric cubic helimagnets — •Andrey A. Leonov, Alexei N. Bogdanov, and Ulrich K. Rössler — IFW Dresden, P.O.B. 270116, D-01171 Dresden

In noncentrosymmetric magnetic systems, chiral Dzyaloshinskii-Moriya (DM) interactions give rise to one-dimensional (cycloids and conical helices), two-dimensional (baby-Skyrmions), and three-dimensional (Hopfions) modulated and localized structures with a fixed sense of rotation. Within the standard phenomenological (Dzyaloshinskii) theory [1], which includes only basic isotropic interactions the conical phase is a global minimum. Other modulated textures exist only as metastable states. Detailed numerical analysis on two dimensional models shows that bound Skyrmion states arise as hexagonal lattices of $\pm\pi$-Skyrmions or square staggered lattices of $\pi/2$-Skyrmions. In real materials additional magnetic couplings (for example, uniaxial or exchange anisotropy) can render Skyrmionic states into thermodynamically stable phases. The transitions between different Skyrmionic and other modulated phases is generally first order, which should be discernible as hysteresis of magnetization processes. The model results show that diverse Skyrmionic textures may underlie the exotic magnetic phenomena of "partial order" or the field-driven "A-phase" observed in MnSi and other cubic helimagnets.

[1] U.K.Rößler, A.N.Bogdanov, C.Pfleiderer, Nature (London) **442**, 797 (2006); U. K. Rößler, A. A. Leonov, A. N. Bogdanov, J. Phys., in press; arXiv: 0907.3651v2 (2009).

MA 28: Spin-dependent Transport Phenomena

Time: Thursday 15:15–19:00 Location: H3

MA 28.1 Thu 15:15 H3

Magnetic properties and high room temperature TMR ratios of Co_2FeAl in magnetic tunnel junctions — •Daniel Ebke, Zoë Kugler, Patrick Thomas, Oliver Schebaum, Markus Schäfers, Dennis Nissen, Jan Schmalhorst, Andreas Hütten, and Andy Thomas — Thin Films and Physics of Nanostructures, Physics Department, Bielefeld University, Germany

Spintronic devices have found a lot of attention in the recent years due to the possible new applications, e.g. a magnetic random access memory (MRAM). Therefore, materials with a high spin polarization such as half metallic Heusler compounds are eligible.

In this work, we present low temperature tunnel magnetoresistance (TMR) values of up to 270% for MgO based magnetic tunnel junctions (MTJs) with Co_2FeAl and Co-Fe electrodes. A low temperature dependence leads to high room temperature TMR values of about 150%. The bulk magnetic moment and the element specific magnetic moment at the barrier interface were examined as a function of annealing temperature by alternating gradient magnetometer (AGM) and X-ray absorption spectroscopy (XAS) / X-ray magnetic circular dichroism (XMCD), respectively.

MA 28.2 Thu 15:30 H3

Direct measurement of the spin polarization of Co_2FeAl — •Oliver Schebaum[1], Daniel Ebke[1], Andrea Niemeyer[1], Günter Reiss[1], Jagadeesh S. Moodera[2], and Andy Thomas[1] — [1]Thin Films and Physics of Nanostructures, Bielefeld University, Germany — [2]Francis Bitter Magnet Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Heusler compounds are of great interest in materials science due to the predicted 100% spin polarization. A high spin polarization of the tunneling current is necessary for a large tunnel magnetoresistance (TMR) ratio. A large TMR ratio is a key requirement for spintronic applications. Thus, Heusler compounds are considered promising candidates as ferromagnetic electrodes in future spintronic devices based on magnetic tunnel junctions (MTJs). Although the room temperature TMR ratio of Heusler based MTJs could be increased in the recent years the enormous effect expected for highly spin polarized electrodes has not been observed.

We directly measured the spin polarization of Co_2FeAl in contact with a MgO tunnel barrier by spin polarized tunneling into a superconducting Al-Si electrode. The BCS density of states of the superconductor is spin split in an in-plane magnetic field. Due to this Zeeman splitting a spin polarized tunneling current results in an asymmetry of the conductance vs. voltage measurements.

We found a spin polarization of the tunneling current of $P = 55\%$. This value is in good agreement with the spin polarization obtained from our TMR measurements and results published by other groups.

MA 28.3 Thu 15:45 H3

Ab-initio transport calculations of Fe/MgO/Fe tunnel junctions modified by Co and Cr interlayers — •Peter Bose[1,3], Jürgen Henk[2], Peter Zahn[1], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]International Max Planck Research School for Science and Technology of Nanostructures

For spintronic device applications, large and tuneable tunnel magnetoresistance ratios (TMR) are inevitable. However, experimental TMR ratios of epitaxial Fe/MgO/Fe junctions can be strongly reduced by imperfect Fe/MgO interfaces. A way to increase the TMR ratio is the insertion of thin metallic layers at the Fe/MgO interfaces. With respect to their magnetic and electronic properties as well as their small lattice mismatch to Fe(001), Co and Cr interlayers have been preferably studied [1,2].

We report on systematic ab-initio investigations of Co and Cr interlayers focussing on the changes of the electronic structure and the transport properties. The results of spin-dependent ballistic transport calculations reveal options to specifically manipulate the TMR ratio. The observed effects are directly addressed and interpreted by means of electronic states with complex wave vectors.

[1] S. Yuasa et al., APL**87** 222508 (2005), [2] R. Matsumoto et al., PRB**79** 174436 (2009)

MA 28.4 Thu 16:00 H3

Inelastic Electron Tunneling Spectroscopy of CoFeB/ MgO/ CoFeB based magnetic tunnel junctions in high magnetic fields — •Marvin Walter[1], Vladyslav Zbarskyy[1], Markus Münzenberg[1], Michael Seibt[2], Volker Drewello[3], Markus Schäfers[3], Günter Reiss[3], and Andy Thomas[3] — [1]I. Phys. Inst., Georg-August-Universität Göttingen, 37077 Göttingen — [2]IV. Phys. Inst., Georg-August-Universität Göttingen, 37077 Göttingen — [3]Bielefeld University, Physics Department, 33501 Bielefeld

Magnetic tunnel junctions (MTJs) showing a high tunnel magnetoresistance (TMR) are important for the fabrication of MRAM devices when combined with current induced switching.

We discuss inelastic electron tunneling spectroscopy (IETS) measurements on CoFeB/MgO/CoFeB magnetic tunnel junctions. The junctions are prepared by means of magnetron sputtering of CoFeB and e-beam evaporation of stoichiometric MgO. Structuring of the multilayer is done using a photolithography process and Argon ion-milling.

The IETS measurements are carried out at low temperatures down to 4.2 K, high magnetic fields up to 9 T and in parallel as well as antiparallel electrode configuration in order to distinguish between different kind of excitations such as e.g. magnons and phonons. Furthermore, oxygen vacancies in the MgO barrier are controlled through variation of the sample temperature during e-beam growth to investigate the influences of these vacancies on the tunneling spectra of MTJs. Research is supported by DFG SFB 602.

MA 28.5 Thu 16:15 H3

Tunneling spectroscopy and magnon excitation in Co_2FeAl/MgO/Co-Fe magnetic tunnel junctions — •Volker Drewello, Daniel Ebke, Markus Schäfers, Günter Reiss, and Andy Thomas — Bielefeld University, 33615 Bielefeld, Germany

Magnetic tunnel junctions with the Heusler compound Co_2FeAl as the soft electrode are prepared. Pinned Co-Fe is used as the hard reference electrode. The electronic transport is investigated by tunneling spectroscopy (dI/dV and d^2I/dV^2). In the parallel magnetic state the tunneling spectra are asymmetric with respect to the bias voltage, with a pronounced bias-independent region. In the antiparallel state the dependence on bias voltage is much stronger and the curves are symmetric. The findings can be explained with a gap in the minority density of states of Co_2FeAl.

MA 28.6 Thu 16:30 H3

X-ray microscopy and transport measurements in lateral spin valves including tunneling barriers — •Jeannette Wulfhorst[1], Andreas Vogel[1], Lars Bocklage[1], Peter Fischer[2], Ulrich Merkt[1], and Guido Meier[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany — [2]Center for X-ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Various approaches to generate, manipulate, and detect spin currents are presently investigated. In lateral all-metal spin valves, generation and nonlocal detection of spin-polarized currents are realized with ferromagnetic materials, e.g., permalloy. The generated spin current is injected into a normal metal and can be manipulated by a perpendicular external magnetic field [1,2]. Transport measurements at temperatures of liquid helium are performed and the Hanle effect is observed. From the comparison of the experimental data amd theory, the spin-relaxation time and -length in copper are determined. High resolution transmission soft X-ray microscopy with magnetic contrast is used to image spin accumulation in copper [3]. The images show indications of spin accumulation at 933 eV after optimization of the magnetic contrast via energy scans. This work has been supported by DFG and by DOE.

[1] A. van Staa et al., Phys. Rev. B **77**, 214416 (2008)
[2] A. Vogel et al., Appl. Phys. Lett. **94**, 1225210 (2009)
[3] O. Mosendz et al., Phys. Rev. B **80**, 104439 (2009)

MA 28.7 Thu 16:45 H3

Magnetism and spin transport in spin filter/silicon heterostructures — •Martina Müller[1], Marc J. van Veenhuizen[2], Jagadeesh S. Moodera[2], and Claus M. Schneider[1] — [1]Institut für Festkörperforschung, Forschungszentrum Jülich — [2]Francis Bitter Magnet Laboratory, MIT, USA

Controlling spin transport in ferromagnet(FM)/semiconductors(SC) systems is a key objective in the development of semiconductor spintronics. Recently, spin injection and -detection into silicon (Si) has been realized using FM/oxide tunnel contacts. Here, we present an alternative route to engineer functional spin tunnel contacts, which are based on magnetic insulator/Si heterostructures.

We fabricated EuS/Si and Co/EuS/Si embedded tunnel contacts on n-doped Si substrates. Ferromagnetic EuS tunnel barriers were grown by means of MBE, with thicknesses between d=2 to 6 nm. The transport experiments showed a characteristic metal-to-insulator transition of EuS at T<20 K, which clearly confirms a spin filter effect being in effect. I(V) measurements revealed a highly non-linear behavior indicative for tunnel transport. However, no totally symmetric I(V) curves were found under forward/reverse bias, which is due to an additional Schottky barrier present at the EuS/n-Si interface. MR measurements of Co/EuS/Si contacts yielded MR values up to 10% combined with a pronounced bias voltage dependence. This unique feature is due to superimposing spin tunneling pathes [1] and principally should allow the electrical injection of spins into silicon at elevated bias voltages.

[1] G.-X. Miao, M. Müller, J. S. Moodera, PRL 102, 076601 (2009)

15 min. break

MA 28.8 Thu 17:15 H3

Macroscopic theory for time-dependent noncollinear spin transport — •Steffen Kaltenborn, Yao-Hui Zhu, and Hans Christian Schneider — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern

We employ a macroscopic theory based on the semiclassical Boltzmann equation for the spin-density matrix to analyze the propagation of signals encoded in a spin current, which flows through a multilayer structure with *noncollinear* magnetization and spin directions. [1] We find that, due to the wave-like character of spin currents, modifications of pure spin-diffusion dynamics may result, depending on the signal time-scale (or frequency). In particular, we determine the finite spin-signal propagation velocity, which is not possible in the framework of the spin-diffusion equation, and numerically study the dynamics of a pure spin current pumped into a nonmagnetic Cu layer by a precessing magnetization in an adjacent ferromagnetic permalloy layer for precession frequencies ranging from GHz to THz. Extensions of the theory to nanostructures will be discussed.

[1] Y.-H. Zhu, B. Hillebrands, and H. C. Schneider, Phys. Rev. B **79**, 214412 (2009)

MA 28.9 Thu 17:30 H3

Ab initio **study of the spin-Hall effect in nonmagnetic 4*d* and 5*d* transition metals** — •Frank Freimuth, Yuriy Mokrousov, and Stefan Blügel — Institut für Festkörperforschung, & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

Due to the spin-orbit interaction an electrical current induces a transverse spin current leading to the appearance of spin accumulation on the lateral surfaces of current-carrying samples. This phenomenon is known as the spin-Hall effect and offers new perspectives for the design of spintronics devices. A quantitatively reliable theoretical description of the spin-Hall effect is desirable for computer-aided material design. However, in the presence of spin-orbit coupling the standard formulation of the spin current is unsatisfactory, because it does not meet the requirement of conservedness. Moreover, the relationship between spin current and spin accumulation is still an open question. We present DFT-based *ab initio* calculations of the spin-Hall conductivity in nonmagnetic bulk 4*d* and 5*d* transition metals. We compare various formulations of the spin current and discuss their relevance for the spin accumulation. Additionally, we describe our computational method, which is based on the Kubo formalism within a Green-function based implementation of the full-potential linearized augmented-plane-wave (FLAPW) method `FLEUR` (www.flapw.de). Our method is not restricted to bulk calculations, but we are able to tackle a huge spectrum of geometries (bulk, film, semi-infinite slab) and to calculate the spin current beyond linear response.

MA 28.10 Thu 17:45 H3

Ab initio description of the extrinsic spin Hall effect — •Martin Gradhand[1], Dimitry V. Fedorov[2], Peter Zahn[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany

The gigantic Spin Hall effect for Au, measured by Seki et. al. [1],

could not be explained by the intrinsic contribution described by the Berry curvature. The extrinsic mechanisms for the spin separation, namely the side jump and the skew scattering, must be responsible for the observed effect.

Here we present our relativistic ab initio approach to analyze the skew scattering at substitutional impurities. The iterative solution of a linearized Boltzmann equation leads to the extrinsic contribution to the spin Hall effect. Using that, a new explanation for the gigantic spin Hall effect in Au is proposed [2]. In addition, we show that a sign change of the spin Hall effect is generated by varying the type of the impurity atom and can be understood from the microscopic transition probabilities.

[1] T. Seki et al., Nature Materials 7, 125 (2008)
[2] M. Gradhand et al., submitted to PRL (2009)

MA 28.11 Thu 18:00 H3

Anisotropy of anomalous Hall conductivity in $L1_0$ 3d-Pt alloys from first principles — •Hongbin Zhang, Stefan Blügel, and Yuriy Mokrousov — Institut für Festkörperforschung & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

Using first-principles calculations, we investigate the anisotropy of the intrinsic anomalous Hall conductivity (AHC) in ordered and disordered ferromagnetic bimetallic $L1_0$ 3d-Pt (3d = Cr, Mn, Fe, Co and Ni) alloys. The AHC is calculated via the Wannier interpolation procedure with consequent Brillouin zone integration of the Berry curvature [1]. We find very large anisotropies of the AHC both upon rotating the magnetization away from the easy [001]-axis (axis along the stacking direction of the ordered alloys) to in-plane, as well as for some alloys upon rotating the magnetization in the plane normal to the stacking direction. To elucidate the origin of this anisotropy, we study in detail the contributions from different atoms and the role of spin-scattering transitions in the vicinity of the Fermi surface. At last, we provide a simple interpretation of obtained chemical trends of the AHC and its anisotropy based on a toy tight-binding model.

[1] X. Wang, J. R. Yates, I. Souza, D. Vanderbilt *Phys. Rev. B* 74, 195118 2006.

MA 28.12 Thu 18:15 H3

Spin dependent transport of hot electrons in bcc Fe(100) and bcc $Fe_{34}Co_{66}$(100) — •Emanuel Heindl, Johann Vancea, and Christian H. Back — Department of Physics, University of Regensburg, 93040 Regensburg, Germany

We investigate hot electron spin filtering in thin bcc Fe(100) and bcc $Fe_{34}Co_{66}$(100) layers using Ballistic Electron Emission Microscopy. An STM tip is used as a tunable constant current source of hot electrons being injected into single crystalline metallic spin valve structures. The subsequent ballistic hot electron transport is recorded and separated from thermalized electron transport by means of a metal semiconductor junction whose Schottky barrier acts as a spectrometer. Electron transport is carried out with the main transport axis along the [100]-axis of the ferromagnetic layers at electron energies between 1 eV and 2.5 eV above the Fermi level. Parallel and antiparallel magnetization configurations of the spin valve are readily adjustable with an external magnetic field as revealed by Kerr effect and magnetocurrent measurements.

When the $Fe_{34}Co_{66}$ electrode is replaced by Fe the spin contrast drops by more than a factor of 5 in the studied energy interval. We interpret this observation to the spin asymmetry of unoccupied states and to the electron velocity being distinct for majority and minority spins. By cooling down from room temperature to 130 K ballistic currents become significantly enhanced for both materials in the parallel and the antiparallel magnetization configuration, while hot electron spin polarization is enhanced for $Fe_{34}Co_{66}$, only.

MA 28.13 Thu 18:30 H3

Angular dependence of the tunneling anisotropic magnetoresistance — •Alex Matos-Abiague, Martin Gmitra, and Jaroslav Fabian — Univesrity of Regensburg, Regensburg, Germany

A phenomenological model in which the tunneling anisotropic magnetoresistance (TAMR) effect originates from the presence of spin-orbit interaction is developed. The model is based on general symmetry considerations and reveals the dependence of the TAMR in tunnel junctions with a single magnetic lead on the magnetization orientation. Some relevant cases of spin-orbit interaction induced by structure and/or bulk inversion asymmetries are investigated.

Acknowdlegments: This work was supported by the DFG via SFB 689.

MA 28.14 Thu 18:45 H3

Magnetic anisotropy and tunneling anisotropic magnetoresistance in 3d-5d bimetallic antiferromagnets Mn_2Au and MnIr. — •Alexander Shick[1], Sergii Khmelevskiy[2], Joerg Wunderlich[3], and Tomas Jungwirth[1,4] — [1]Institute of Physics ASCR, Praha, Czech Republic — [2]Wien Univ. of Technology, Wien, Austria — [3]Hitachi Cambridge Laboratory, Cambridge, UK — [4]Univ. of Nottingham, Nottingham, UK

Full-potential relativistic density functional theory is employed to study the magnetic anisotropy energies (MAE) and tunneling anisotropic magnetoresistance (TAMR) in the 3d-5d bimetallic antiferromagnets Mn_2Au and MnIr. The electronic and magnetic structure are calculated making use of the full-potential linearized augmented plane wave FP-LAPW method. The torque approach is employed to evaluate the element-specific MAE. We find strong uniaxial MAE and attribute these anisotropies to combined effects of large moment on the Mn 3*d* shell and large spin-orbit coupling of the 5*d* shell. The sizable TAMR ratio (up to 50 %) associated with the strong uniaxial MAE is evaluated assuming its proportionality to the anisotropy in the density of states. Furthermore, we apply the in-plane strain in Mn_2Au and find sizable changes in the MAE and TAMR. Based on these results we propose a concept for building spintronics in compensated antiferromagnets in which the staggered moment orientation is controlled via the response of the MAE to induced lattice strains and sensed by antiferromagnetic TAMR in nanoscale devices.

MA 29: Magnetic Semiconductors I

Time: Thursday 15:15–16:45 Location: H22

MA 29.1 Thu 15:15 H22

Defect pairing and magnetism in C or N-doped MgO and ZnO: a density-functional study — •Peter Kratzer[1], Hua Wu[2], Sung Sakong[1], Xin-Gao Gong[3], and Matthias Scheffler[4] — [1]Fakulät für Physik, Universität Duisburg-Essen, D-47048 Duisburg, Germany — [2]II. Physikalisches Institut, Universität zu Köln, D-50937 Köln, Germany — [3]Fudan University, Shanghai, China — [4]Fritz-Haber-Institut der MPG, D-14195 Berlin, Germany

It is demonstrated that C or N doping recently proposed as a way to create magnetism in otherwise nonmagnetic oxide insulators is curtailed by formation of defect pairs. Our density-functional calculations show that N-N pairing in MgO lowers the energy by 0.4 eV, leading to a nonmagnetic state. C-C pairing is even exothermic by more than 3 eV, and the resultant $(C\text{-}C)^{4-}$ molecules with spin=1 couple antiferromagnetically in MgO. However, calculations for C-doped ZnO, when properly treated using the PBE0 hybrid functional, show that the spin-polarized $pp\pi^*$ levels resonate with the host conduction band, which could possibly mediate a long-range ferromagnetic order. Magnetism of open-shell *impurity molecules* is proposed as a possible route to d^0-ferromagnetism in oxide spintronic materials.

MA 29.2 Thu 15:30 H22

Magnetic Effects of Defect Pairs in Zinc Oxide — •Waheed Adeagbo[1], Guntram Fischer[1], Arthur Ernst[2], and Wolfram Hergert[1] — [1]Institute of Physics, MLU Halle-Wittenberg, Von-Seckendorff-Platz 1, 06120 Halle, Germany — [2]Max Planck Institute for Microstructure Physics, Weinberg 2, 06120 Halle, Germany

In order to gain insight into intrinsic and extrinsic d^0-magnetic properties of defectious ZnO we have carried out *ab initio* calculations on various types of defects formed by substitutionally doped atoms, Zn vacancies, and doped atom and vacancy defect pairs. The doped atoms include N and H which substitute either O or Zn lattice sites. The largest magnetic moment is induced when a Zn vacancy pair is created. Our results also show that some defects that are magnetic when isolated can become non-magnetic when being near other de-

fects. We also investigate the magnetic interaction of different defect pairs. The results of total energy calculations show in all cases the stability of ferromagnetic configurations when compared to the antiferromagnetic counterparts. This characteristic is the strongest for the Zn-Zn vacancy.

MA 29.3 Thu 15:45 H22

Ab-initio **study of zinc oxide surfaces and interfaces in presence of cobalt clusters** — •Sanjeev K. Nayak, Heike C. Herper, and Peter Entel — University of Duisburg-Essen, 47057 Duisburg, Germany

The magnetic properties of Co doped ZnO are controversially discussed in both theory and experiment. Cationic substitution of Co in ZnO bulk shows ferromagnetic properties only if the concentration of Co exceeds the percolation threshold. The Curie temperature is always below room temperature (RT). In order to enhance the Curie temperature above RT, which is necessary for spintronics applications, lattice defects and the ZnO surfaces play an important role. In addition, not only doped bulk ZnO is of interest but also ZnO nanoclusters with embedded Co clusters.

In this contribution we present results of migration of single doped Co atom and of small Co clusters from the center of ZnO to the surface. This self-purification is of primary interest and hindering successful doping of ZnO nanomaterials [1,2]. We investigate various ZnO surfaces and their structural and magnetic properties in presence of Co impurities. In particular clustering effects over the ZnO surfaces will be discussed.

[1] M. Opel et al., Eur. Phys. J. B, **63**, 437 (2008), [2] G. M. Dalpian et al., Phys. Rev. Lett. **96**, 226802 (2006)

MA 29.4 Thu 16:00 H22

Thermodynamical limits of diluted magnetic semiconductors — •Danilo Bürger, Michael Seeger, Shengqiang Zhou, Manfred Helm, and Heidemarie Schmidt — Forschungszentrum Dresden-Rossendorf e.V., Bautzner Landstraße 400, 01328 Dresden

The incorporation of transition metals dopants in semiconductors over their solubility limit is the main challenge for the fabrication of diluted ferromagnetic semiconductors. Dietl et al. [1] calculated the Curie temperatures for various semiconductors doped with 5 at% Mn. A lot of experimental effort was focused on the fabrication of diluted magnetic semiconductors. Unfortunately, such metastable alloys try to reach their thermodynamical equilibrium by the diffusion of the incorporated dopants. The equilibrium state at room temperature for semiconductors with a low solubility of magnetic dopant atoms is characterized by unwanted secondary phases. We present the results from combined random walk simulations and heatflow calculations and explain the successful fabrication of GaAs:Mn and the impossibility to produce diluted Si:Mn. The clustering process is simulated under the assumption that neighbouring magnetic atoms stick together. This is a general approach for the growth of clusters in supersaturated materials [2]. With the knowledge of the diffusion coefficient our modelling can be used to predict the thermodynamical limit at room temperature and the producibility by pulsed laser annealing of diluted magnetic semiconductors. [1] T. Dietl, H. Ohno, F. Matsukura, J. Cibert, and D. Ferrand, Science **287**, 1019 (2000) [2] P. Meakin, Fractals, scaling and growth far from equilibrium (Cambridge University Press, 1998)

MA 29.5 Thu 16:15 H22

Secondary phase formation in (Zn,Mn)O and its influence on the magnetic properties — •Gillian Kiliani[1], Mikhail Fonin[1], Ulrich Rüdiger[1], Reinhard Schneider[2], Dimitri Litvinov[2], and Dagmar Gerthsen[2] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [2]Laboratorium für Elektronenmikroskopie, Karlsruher Institut für Technologie, 76128 Karlsruhe, Germany

ZnO is a wide gap semiconductor which attracted a renewed attention as a material for possible spintronic applications after Dietl *et al.* calculated Curie temperatures above room temperature for transition metal doped ZnO [1].

(Zn,Mn)O thin films were prepared by radio frequency magnetron sputtering on $Al_2O_3(0001)$ and $SiO_2/Si(100)$ substrates from a composite, partially oxidized ZnMn target. Sputtering was performed in Ar or N_2, since nitrogen is considered to enhance ferromagnetism in the (Zn,Mn)O system [2]. Structural properties were investigated by different techniques of transmission electron microscopy and X-ray diffraction. The formation of at least one secondary phase in samples with high Mn content could be observed, which had significant influence on the magnetic properties as shown by magnetization measurements. Ferromagnetism and exchange bias were observed in samples with high Mn concentration, suggesting the presence not only of a ferromagnetic, but also of an antiferromagnetic phase.

[1] T. Dietl *et al.*, Science **287**, 1019 (2000).
[2] K. R. Kittilstved *et al.*, Nat. Mater. **5**, 291 (2006).

MA 29.6 Thu 16:30 H22

Analysis of electric dipolar and quadrupolar transitions in X-ray absorption spectroscopy for Co doped ZnO — •Mehmet Kaya, Andreas Ney, Carolin Antoniak, and Heiko Wende — Fakultät für Physik and CeNIDE, Universität Duisburg-Essen, Duisburg, Germany

Co doped ZnO (Co:ZnO) is a promising candidate for dilute magnetic semiconductor devices. To realize a practical device, it is essential that a magnetic order is present above room temperature. Co:ZnO has been intensively investigated and there exist controversial results regarding its magnetic behavior. The authors in [1] report an absence of intrinsic ferromagnetic interactions of isolated and paired Co dopant atoms in Co:ZnO.

For optimum magnetic properties the analysis of the local structure is vital. The local structure can be studied by the linear dichroism in the X-ray absorption spectroscopy. We present an ab-initio study of XANES spectra of Co:ZnO using self-consistent potentials and full multiple scattering calculations. The calculations were made using the FEFF 8.4 code [2]. The results show a good agreement to experimental data. We present also an analysis of electric dipolar and quadrupolar transitions in the calculated spectra by comparison with the angular momentum resolved density of states. Furthermore our calculations will be compared to simulations obtained with the FDMNES code [3].

[1] Ney, A., et al. Phys. Rev. Lett. 100, 157201, (2008).
[2] Ankudinov, A. L., et al. Phys. Rev. B. 58, 7565, (1998).
[3] Joly, Y. Phys. Rev. B. 63, 125120, (2001).

MA 30: Electron Theory of Magnetism

Time: Thursday 17:00–18:15 Location: H22

MA 30.1 Thu 17:00 H22

Electronic structure, localization and spin-state transition in Cu-substituted FeSe — •Stanislav Chadov[1], Daniel Schärf[1], Gerhard H. Fecher[1], Claudia Felser[1], Lijun Zhang[2], and David J. Singh[2] — [1]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg Universität, 55099 Mainz — [2]Material Science and Technology Division, Oak Ridge National Laboratory, TN 37831-6114, USA

We report the density functional studies of the $Fe_{1-x}Cu_xSe$ alloy using the coherent potential approximation (CPA) method. Magnetic behaviour was investigated using the disordered local moment (DLM) approach. We find that Cu occurs in a nominal d^{10} configuration and is highly disruptive to the electronic structure of the Fe sheets. This would be consistent with a metal-insulator transition due to Anderson localization. We further find a strong crossover from a weak moment itinerant system to a local moment magnet at $x \approx 0.12$. We associate this with the experimentally observed jump near this concentration. Our results are consistent with the characterization of this concentration-dependent jump as a transition to a spin-glass.

The financial support by the SFB/TRR49 is gratefully acknowledged.

MA 30.2 Thu 17:15 H22

Theoretical description of spin-spirals using the KKR Green's function method — •Sergiy Mankovsky[1], Gerhard H. Fecher[2], and Hubert Ebert[1] — [1]Dept. Chemie und Biochemie/Phys. Chemie, Universität München, Butenandtstr. 11, D-81377 München, Germany — [2]Universität Mainz, Inst. of Anorg. und Analyt. Chemie, 55099 Mainz , Germany

We present a formalism for the theoretical description of spin-spirals within the KKR (Korringa-Kohn-Rostoker) Green's function formalism. The present technique is applicable to any system, e.g., elemental solids, ordered compounds, as well as it allows also to deal with random alloys using the CPA (Coherent Potential Approximation) alloy theory. As examples, we present results of calculations for pure Fe (bcc and fcc), Ni (fcc), Fe-Pd alloys and Fe-Ni alloys in ordered and disordered phases and compare to available experimental data as well as theoretical results obtained by other authors.

MA 30.3 Thu 17:30 H22

Theoretical study of the stability of AFM order in iron pnictides — •Alexander Yaresko — Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany

The wave-vector ($\mathbf{q}$) and doping (δ) dependences of the total energy, $E(\mathbf{q})$, in electron ($\delta > 0$) doped $LaFeAsO_{1-x}F_x$ and $M(Fe_{1-x}Co_x)_2As_2$ and hole ($\delta < 0$) doped $M_{1-x}K_xFe_2As_2$ (M=Ba, Sr) are studied by performing self-consistent LSDA calculations for coplanar spin spirals using the LMTO method. For the undoped compounds the minimum of $E(\mathbf{q})$ is found at $\mathbf{q} = (\pi, 0)$ corresponding to stripe AFM order with the Fe magnetic moment of about $1.5\mu_B$. In $LaFeAsO_{1-x}F_x$ the minimum shifts to an incommensurate $\mathbf{q}$ already at δ=0.1 (x=0.1). Similar behavior is also found when FeAs layers in $M(Fe_{1-x}Co_x)_2As_2$ are doped with electrons. In contrast, stripe AFM order in $M_{1-x}K_xFe_2As_2$ remains stable in a wide range of hole doping up to δ=−0.3, which corresponds to the K content x=0.6, although the stabilization energy of the AFM solution rapidly decreases with doping. Spin-spiral calculations for LiFeAs predict a magnetic ground state with $\mathbf{q} = (\pi, 0)$ but with the Fe moment ($0.6\mu_B$) and the stabilization energy which are significantly smaller than in the other two families of Fe pnictides.

According to the calculated q_z dependence of the total energy, the magnetic interactions in LaFeAsO are 2D-like, whereas in MFe_2As_2 compounds FeAs layers are coupled antiferromagnetically, with the coupling in $SrFe_2As_2$ being stronger than in $BaFe_2As_2$.

MA 30.4 Thu 17:45 H22

An ab-initio description of the magnetic shape anisotropy — •Sven Bornemann, Jan Minár, Jürgen Braun, and Hubert Ebert — Department Chemie und Biochemie, LMU München, 81377 München, Germany

For magnetic transition metal systems with reduced dimensionality and low symmetry the shape anisotropy becomes a significant contribution to the magnetic anisotropy. In fact, it can reach the same order of magnitude as the spin-orbit induced anisotropy. So far, the shape anisotropy has always been treated as a classical interaction between magnetic dipoles while the spin-orbit anisotropy has been determined by relativistic band structure calculations. It is uncertain, however, whether such an inconsistent treatment of the two anisotropy contributions is still valid for low-dimensional nano structures such as magnetic thin films, wires or clusters where the magnetic easy axis can depend strongly on the interplay between these two contributions. As an alternative to the classical approach an ab-initio description of the shape anisotropy has been developed. This is achieved by including the Breit interaction, being the natural cause of the shape anisotropy, in the Dirac-equation set up within the framework of spin density functional theory. We have implemented this approach using the fully relativistic KKR band structure scheme. We will present the details of our implementation and show results for the shape anisotropy of thin Fe films on Au(001) as well as for free-standing Fe and Co wires in comparison with the classical treatment.

MA 30.5 Thu 18:00 H22

Ab initio **spin-wave spectra of the bulk magnets Fe, Co, and Ni from many-body perturbation theory** — •Ersoy Sasioglu[1], Christoph Friedrich[1], Arno Schindlmayr[2], and Stefan Blügel[1] — [1]Institut für Festkörperforschung & Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Department Physik, Universität Paderborn, 33095 Paderborn, Germany

Spin excitations are of fundamental importance in many areas of condensed matter physics. First-principles calculations of spin-wave spectra have so far mostly been carried out within the frozen-magnon approach where the excitation energy is calculated by assuming a static spin-spiral configuration. We study the magnetic excitations of bulk magnets within the framework of many-body perturbation theory (MBPT) as implemented in the full-potential linearized augmented plane-wave (FLAPW) method. Starting from the *GW* approximation we obtain a Bethe-Salpeter equation for the magnetic susceptibility treating single-particle Stoner excitations and magnons on the same footing. We found that the spin-wave dispersion of Fe and Co exhibit gaps close to the middle of the Brillouin zone along the high symmetry directions. For Ni, the theoretical spin-wave dispersion exhibits two branches while those for Fe and Co show only one branch. Furthermore, at high energies the spin waves are heavily damped due to the coupling to single-particle Stoner excitations. In Fe the damping suppresses the spin waves in a large part of the Brillouin zone along the $\Gamma - H - N$ direction. The obtained results are in good agreement with available experimental data as well as previous calculations.

MA 31: Surface Magnetism / Magnetic Imaging II

Time: Thursday 15:15–19:15 Location: H23

MA 31.1 Thu 15:15 H23

Theory of chirality selection in magnetic nanostructures: vortex states in magnetic nanodots — •Anna B. Butenko, Ulrich K. Rössler, and Alexei N. Bogdanov — IFW Dresden

Broken inversion symmetry at surfaces or interfaces of magnetic nanostructures induces Dzyaloshinskii-Moriya (DM) couplings. These chiral exchange couplings can essentially change the magnetic properties of nanostructures by stabilizing twisted magnetic states. In particular these DM couplings favour one sense of rotation in non-collinear magnetic configurations. Vortex states in magnetic thin film elements are chiral themselves, but they arise solely due to the demagnetization. In such magnetization structures, the effect of the chiral DM couplings is less obvious, but the degeneracy of the left- and right-handed vortices is lifted. Within a basic micromagnetic approach we analyse this chirality selection for the vortex ground states of circular thin-film elements. We calculate the differences between the core shapes and sizes of vortices with opposite handedness in the presence of DM couplings. These differences of the core structure may be observable in experiments, e.g., as differences in core diameter or net polarity of vortices, when switching their chirality. We suggest that such experiments can be used to determine the magnitude of surface-induced DM couplings in ultrathin magnetic films/film elements.

MA 31.2 Thu 15:30 H23

Non-collinear groundstate in the Fe monolayer on Ir(111) — •Matthias Menzel[1], Stefan Heinze[2], Kirsten von Bergmann[1], Gustav Bihlmayer[3], André Kubetzka[1], Stefan Blügel[3], and Roland Wiesendanger[1] — [1]Institut für Angewandte Physik, Universität Hamburg, 20355 Hamburg — [2]Institut für Theoretische Physik und Astrophysik, Universität Kiel, 24098 Kiel — [3]Institut für Festkörperforschung, Forschungszentrum Jülich, 52425 Jülich

Various complex magnetic groundstates have been observed recently [1,2,3], which depend crucially on the interplay of different magnetic interactions like exchange interaction, magnetocrystalline anisotropy or Dzyaloshinskii-Moriya (DM) interaction. Some uniaxial spin-spirals have been found [1,2] but a two dimensional non-collinear lattice has not been observed yet.

Using spin-polarized scanning tunneling microscopy we revisited the Fe monolayer on Ir(111). With an out-of-plane magnetized tip this system exhibits a quadratic magnetic unit cell on the hexagonal atomic lattice [3]. Recent measurements with an in-plane magnetized tip reveal that this magnetic configuration is indeed a two dimensional non-collinear groundstate. The driving force for the formation of this complex groundstate has been identified by density functional theory calculations as the 4-spin interaction, a higher order magnetic interaction.

[1] M. Bode *et al.*, Nature **447**, 190 (2007)
[2] P. Ferriani *et al.*, Phys. Rev. Lett. **101**, 027201 (2008)
[3] K. von Bergmann *et al.*, Phys. Rev. Lett. **96**, 167203 (2006)

MA 31.3 Thu 15:45 H23

Magnetic order in the ultrathin iron film on the Ir(001) surface — •Frantisek Maca[1], Josef Kudrnovsky[1], Vaclav Drchal[1], Ilja Turek[2], and Josef Redinger[3] — [1]Institute of Physics ASCR, Praha — [2]Institute of Physics of Materials ASCR, Brno — [3]Vienna University of Technology, Vienna

We present detailed ab initio study of structural and magnetic stability of a Fe monolayer on the fcc(001) surface of iridium extending our last investigation [1]. The Fe monolayer has a strong tendency to order antiferromagnetically for the true relaxed geometry. We compare the influence of two adsorbate species on the magnetic ground state - H and O. We found that the adsorption of oxygen (contrary to the H) lowers the stability of antiferromagnetic order and prefers ferromagnetic ground state. The ferromagnetism is stabilized by the increased Fe-Ir layer spacing. The present study centers around the evaluation of pair exchange interactions between Fe atoms in the Fe overlayer as a function of adsorbate coverage which allows for a detailed understanding of the antiferromagnetism of a Fe/Ir(001) overlayer. Our calculations indicate that the nature of the true ground state could be more complex and display a spin spiral like rather than a c(2x2)-antiferromagnetic order. A comparison with recent experimental data [2] will be also given.

[1] J. Kudrnovsky, F. Maca, I. Turek, and J. Redinger, Phys. Rev. B 80, 064405 (2009).

[2] V. Martin at al., Phys. Rev. B 76, 205418 (2007).

MA 31.4 Thu 16:00 H23

Non-collinear magnetism in the Mn double layer on W(110) — •Silke Schröder, Paolo Ferriani, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstr. 15, 24098 Kiel, Germany

The discovery of a homochiral spin-spiral state for a monolayer (ML) Mn on W(110) [1] has dramatically demonstrated that magnetism in ultrathin films can be extremely complex. Heisenberg exchange, magnetic anisotropy and Dzyaloshinskii-Moriya interaction compete and span a vast magnetic phase space that is still largely unexplored. Recently the double layer (DL) of Mn on W(110) has been studied by spin-polarized scanning tunneling microscopy [2] and a spin-spiral propagating along the [001] direction has been found. Surprisingly, the finding of a short period hints at a ferromagnetic exchange interaction in the Mn DL, on the contrary to what was found in the Mn ML.

To shed light onto this issue, we studied the magnetic properties of the Mn DL on W(110) by means of density functional theory calculation, using the full-potential linearized augmented plane wave (FLAPW) method. We considered several possible magnetic configurations that revealed an antiferromagnetic nearest neighbour exchange and performed spin-spiral calculations to explore the magnetic phase space. We found a non-collinear magnetic ground state. By including spin-orbit coupling we investigated the influence of the magnetic anisotropy and the Dzyaloshinskii-Moriya interaction.

[1] M. Bode *et al.*, Nature **447**, 190 (2007)

[2] Y. Yoshida *et al.*, in preparation

MA 31.5 Thu 16:15 H23

Unoccupied quantum-well states in Co/Cu(001): Spin-orbit coupling and magnetic linear dichroism — Cheng-Tien Chiang, Aimo Winkelmann, Ping Yu, Jürgen Kirschner, and •Jürgen Henk — Max Planck Institute of Microstructure Physics, Halle, Germany

A prerequisite for magnetic linear dichroism (MLD) is the hybridization of electronic states due to spin-orbit coupling (SOC). The sp_z quantum well states in thin Co films on Cu(001) are marginally affected by SOC but nevertheless exhibit a sizable MLD in two-photon photoemission (2PPE) [1], thereby questioning the established origin of MLD.

To resolve this conflict, we performed extensive 2PPE experiments which are completed by electronic-structure, photoemission, and analytical calculations. Having obtained this way a detailed characterization of the quantum well states, the MLD is fully explained; it turns out that a key issue is the proper choice of light polarization. Other sources of the MLD, e. g., the occupied Co states, are ruled out.

Our joint investigation establishes that MLD in 2PPE is a valuable tool for probing SOC in unoccupied electronic states.

[1] C.-T. Chiang, A. Winkelmann, P. Yu, and J. Kirschner, Phys. Rev. Lett. **103**, 077601 (2009).

MA 31.6 Thu 16:30 H23

Spin-polarized two-photon photoemission from Co/Cu(001) via unoccupied quantum well states — •Cheng-Tien Chiang, Aimo Winkelmann, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, Halle(Saale), Germany

We measured spin-resolved two-photon photoemission (2PPE) from ultrathin cobalt films grown on Cu(001). By using p-polarized light with 3.1 eV photon energy, we observed a dominant majority spin-polarization in 2PPE, extending from the initial states at 1.4 eV below the Fermi level up to the Fermi level. Moreover, we resolved an enhancement of spin-polarization by about 10% in 2PPE through the majority quantum well state in a 6 ML cobalt film. This is confirmed by a cobalt thickness dependent measurement. Comparison between spin-resolved one- and two-photon photoemission conveys the important role of the intermediate states in spin-dependent nonlinear photoemission.

MA 31.7 Thu 16:45 H23

Influence of Co-Cu alloying on spin-dependent surface states — •Tobias Allmers[1], Markus Donath[1], Jürgen Braun[2], Jan Minár[2], and Hubert Ebert[2] — [1]Physikalisches Institut, University of Münster, Germany — [2]Dep. Chemie und Biochemie, LMU Universität München, Germany

In literature it is reported that Co films grown on Cu(001) held at 300 K can be annealed to $\approx$ 500 K without Co diffusion towards the surface [1]. As will be shown in this contribution, Cu diffusion takes place even at 295 K. This can be avoided when the film is grown at 115 K. In this case the surface can be annealed to 555 K without Cu diffusion. For annealing temperatures above 555 K an alloying between Co and Cu takes place. Due to the low miscibility of Co and Cu the alloy consists of different phases, mainly Co- and Cu-rich areas. The alloying has a significant influence on the surface states. It results in a suppression of the occupied minority surface state around $\bar{\Gamma}$ [2]. This indicates that the symmetry cap closes for the Co-Cu alloy due to the non-magnetic Cu. In contrast, the projected bulk band structures for Co(001) and Cu(001) are very similar to each other including the gap position. Consequently, the unoccupied surface state $\bar{X}$ persists for the Co-Cu alloy. The spin splitting is reduced with increasing Cu content. The same is true for the exchange splitting of the image potential state. Our results show impressively how important a careful thin film preparation is for the study of pure Co films. [1] Schneider *et al.*, in Magnetism and Structure in Systems of Reduced Dimension, p. 453 (Plenum Press, 1993). [2] Schmidt *et al.*, J. Phys. D **41** (2008) 164003.

MA 31.8 Thu 17:00 H23

On the magnetic anisotropy of free-standing and deposited Fe_xCo_{1-x} monolayers — •Sven Bornemann[1], Ondřej Šipr[2], Jan Minár[1], Sergey Mankovsky[1], Julie B. Staunton[3], and Hubert Ebert[1] — [1]Department Chemie und Biochemie, LMU München, Germany — [2]Institute of Physics of the ASCR v. v. i., Prague, Czech Republic — [3]Department of Physics, University of Warwick, United Kingdom

An accurate theoretical determination of the magnetic anisotropy energy (MAE) is still today a very challenging task for current ab-initio theories. The results can be highly dependend on the applied computational scheme as well as on various approximations and calculational parameters. As the magnetic anisotropies are so sensitive to these factors special care has to be taken when comparing new numerical results with values from the literature. Here, we present MAE results for free-standing and deposited Fe_xCo_{1-x} monolayers and analyse in detail the occuring trends with corresponding changes in the electronic band structure. Our findings are compared with results of Moulas et al. and the various conjectures of Wang et al., Daalderop et al. as well as Kondorskii and Straube. Furthermore, a decomposition of the spin-orbit coupling (SOC) operator into spin-diagonal and spin-off-diagonal contributions allows for a distinct comparison with the models of Bruno and van der Laan. In line with all these considerations we discuss the most important features that are necessary for obtaining a very large MAE.

MA 31.9 Thu 17:15 H23

Magnetic properties of Fe films on flat and vicinal Au(111): Consequences of the different growth behavior — •Tobias Allmers and Markus Donath — Physikalisches Institut, University of Münster, Germany

The epitaxial growth of Fe on flat Au(111) differs from Fe on vicinal Au(111). One consequence is a higher critical Fe overlayer thickness at which a phase transition from fcc(111) to bcc(110) takes place for Fe on

vicinal Au(111) in comparison to flat Au(111) [1]. Accompanied with the structural phase transition is a spin-reorientation transition (SRT) of the easy magnetization direction from out-of-plane to in-plane. In agreement with the impeded phase transition an impeded SRT on vicinal Au(111) was observed. The SRT, however, proceeds in a narrow coverage range while the structural phase transition occurs gradually over a larger thickness range. A further consequence of the different growth behavior is a different topography for thicknesses beyond the phase transition. Fe on flat Au(111) exhibits a six-fold symmetry, Fe on vicinal Au(111) only a two-fold symmetry. The different symmetries influence the magnetic properties: While for bcc Fe(110) on flat Au(111) no easy magnetization direction could be determined, a preferred direction for Fe on vicinal Au(111) was identified which is perpendicular to the step edges. The two-fold symmetry causes an uniaxial magnetic behavior. This knowledge of the magnetization behavior is essential for correctly analyzing spin-resolved measurements of the electronic structure as demonstrated by photoemission measurements. [1] T. Allmers and M. Donath, New J. of Physics **11** (2009) 103049.

15 min. break

MA 31.10 Thu 17:45 H23

Spin-dependent quantum interference within a single Co nanoisland — •Hirofumi Oka, Sebastian Wedekind, Guillemin Rodary, Dirk Sander, Pavel Ignatiev, Larissa Niebergall, Valeri Stepanyuk, and Jürgen Kirschner — Max-Planck-Institute of Microstructure Physics, Weinberg 2, D-06120, Halle, Germany

We present a combined experimental and theoretical study of spin-polarized electron confinement on individual Co nanoislands on Cu(111). Low-temperature SP-STM in magnetic fields is used to identify parallel (P) and anti-parallel (AP) states of the magnetization orientation between a Co island and a magnetic tip.[1,2] We find a pronounced spatial modulation of the differential conductance (dI/dV) within one island, which is ascribed to electron confinement, in both states. Maps of the asymmetry of the dI/dV, $(dI/dV_{AP} - dI/dV_P)/(dI/dV_{AP} + dI/dV_P)$, which is related to the spin-polarization within the Co islands, show strong spatial variations and bias-voltage dependence of the contrast. Comparing the results with theory, we conclude that the modulated spin-polarization and its variation with energy can be described by the relative magnitudes between majority and minority spin states, where the spatial modulation is mainly due to electron confinement of the majority state.

[1] G. Rodary *et al.*, JJAP 47, 9013 (2008). [2] G. Rodary *et al.*, APL 95, 152513 (2009).

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MA 31.11 Thu 18:00 H23

Imaging the in-plane magnetisation of Co microstructures by soft x-ray holography — •Carsten Tieg[1], Robert Frömter[2], Daniel Stickler[2], Sebastian Hankemeier[2], André Kobs[2], Hans Peter Oepen[2], Simone Streit-Nierobisch[3], Christian Gutt[3], and Gerhard Grübel[3] — [1]Helmholtz-Zentrum für Materialien und Energie GmbH, Berlin, Germany — [2]Institut für Angewandte Physik, Universität Hamburg, Hamburg, Germany — [3]Deutsches Elektronen-Synchrotron, Hamburg, Germany

We report how Fourier transform holography (FTH) experiments can be used to image the magnetic state of isolated Co microstructures. Up to now, FTH imaging has been applied solely to magnetic systems with out-of-plane magnetisation, owing to the large magnetic sensitivity in transmission geometry at normal incidence. The angular dependence of the x-ray magnetic circular dichroism (XMCD) does not allow to sense the in-plane magnetization with the standard holography sample design, containing reference holes fabricated perpendicularly to the membrane surface by focussed ion beam milling. Samples with an in-plane magnetisation have to be imaged at off-normal incidence to obtain XMCD, so the transmission of the high-aspect-ratio reference holes is lost. The solution is to mill the reference holes at the same tilt angle that is used for imaging. We have used this scheme to image a $2 \times 2\,\mu m^2$ Co element with 20 nm thickness. We found a multi domain state that differs from the expected Landau state for this element size. We attribute the observed higher-energy domain state to the presence of pinning centers and to imperfections of the shape of the Co element.

MA 31.12 Thu 18:15 H23

Magnetism of Rh nano-structures on inert Xe buffer layers and in contact with Ag(100) surfaces — •J. Honolka[1], V. Sessi[1,2], K. Kuhnke[1], C. Tieg[2], O. Sipr[3], J. Minar[4], H. Ebert[4], and K. Kern[1] — [1]MPI für Festkörperforschung, Stuttgart, Germany — [2]ESRF, Grenoble, France — [3]Academy of Sciences of the Czech Republik, Prague, Czech Republik — [4]LMU München, Germany

Previous x-ray magnetic circular dichroism measurements have shown that submonolayer coverages of Rh directly deposited on Ag(100) at T=5K are not magnetic [1], in contrast to theoretical predictions (see [2] and references therein). We further investigated this discrepancy and studied the magnetism of nano-structures of Rh prepared on inert Xe buffer layers on Ag(100). For Rh nano-structures (monomers, dimers, trimers etc.) situated on the Xe buffer layer we find a cluster size dependet magnetic moment similar to the one measured on free clusters in the Stern-Gerlach experiment [3]. During desorption of the Xe layer the Rh nano-structures grow in size and make contact with the substrate, which leads to a full quenching of the magnetic moment. The results are discussed modelling the Rh cluster size distribution on Xe and Ag(100) and comparing the spectroscopy results with ab initio theory.

[1] J. Honolka et al., Phys. Rev. B 76, 144412 (2007) [2] V. Bellini, N. Papanikolaou, R. Zeller, and P. H. Dederichs, Phys. Rev. B 64, 094403 (2001) [3] A.J. Cox, J. G. Louderback, and L.A. Bloomfield, Phys. Rev. Lett. 71, 923 (1993)

MA 31.13 Thu 18:30 H23

Wurtzite-type CoO nanocrystals in ultrathin ZnCoO films observed by surface x-ray diffraction — •Meyerheim H. L.[1], Tusche C.[1], Ernst A.[1], Ostanin S.[1], Maznichenko I.[2], Mohseni K.[1], Jedrecy N.[3], Zegenhagen J.[4], Roy J.[4], Mertig I.[2], and Kirschner J.[1] — [1]MPI f. Mikrostrukturphysik, Halle, Germany — [2]Institut f. Physik, Martin-Luther-Univ. Halle-Wittenberg, Halle, Germany — [3]INSP, Université P. et M. Curie-Paris 6 and CNRS-UMR7588, Paris, France — [4]ESRF, B.P. 220, Grenoble, France

We present a surface x-ray diffraction study on 2-5 monolayer thick Co-doped (25 at. %) ZnO-films deposited on Ag(111) by pulsed laser deposition to study the arrangement of the Co-atoms within the ZnO host in the ultrathin film limit [1]. The film structure is dramatically different from a random alloy commonly assumed: Wurtzite (WZ) type CoO nanocrystals are coherently embedded within the ZnO host. In contrast to the WZ-CoO nanoislands, ZnO adopts the hexagonal Boron-Nitride (h-BN) type structure within the first layers next to the Ag(111) surface. In the h-BN structure the metal atoms are surrounded by O-atoms in a planar trigonal coordination, whereas in the WZ-structure the metal atoms are tetrahedrally coordinated. Our study supports the proposed phase separation model to explain the weak ferromagnetic signatures of doped ZnO films and other systems [2]. [1] H. L. Meyerheim, C. Tusche, A. Ernst, S. Ostanin, I.V. Maznichenko, K. Mohseni, N. Jedrecy, J. Zegenhagen, J. Roy, I. Mertig, and J. Kirschner, Phys. Rev. Lett. 102, 156102 (2009); [2] T. Dietl, T. Andrearczyk, A. Lipinska, M. Kiecana, M. Tay, and Y. Wu, Phys. Rev. B 76, 155312 (2007);

MA 31.14 Thu 18:45 H23

Iron filled carbon nanotubes - Novel high resolution high stability probes for quantitative magnetic force microscopy — •Wolny Franziska, Weissker Uhland, Mühl Thomas, Lipert Kamil, Vock Sylvia, Schumann Joachim, Leonhardt Albrecht, and Büchner Bernd — IFW Dresden, Helmholtzstraße 20, 01069 Dresden

Iron filled carbon nanotubes (FeCNT) exhibit various outstanding properties that make them ideal candidates for the application as magnetic force microscopy (MFM) probes [1]. An Fe-CNT contains a single domain single crystalline iron nanowire of 20-30 nm diameter and several microns length. The carbon shell around the ferromagnetic core inhibits its oxidation and makes the Fe-CNT mechanically very stable. This ensures a much longer probe lifetime compared to coated MFM probes. The high aspect ratio leads to MFM images with a high resolution. Furthermore, due to the large shape anisotropy the magnetization direction of the nanowire remains aligned with the nanotube axis and thus perpendicular to the sample surface even in parallel external magnetic fields exceeding 250 mT. For the calibration of these MFM probes, the point probe model can be applied with very good agreement [2]. The long iron nanowire can be regarded as an extended dipole of which only the monopole closest to the sample surface interacts with the sample stray field. Thus, the determination of the probe's monopole moment enables quantitative MFM.

[1] Wolny et al., JAP 104, 064908 (2008)

[2] Lohau et al., JAP 86(6), 3410 (1999)

MA 31.15 Thu 19:00 H23

Measuring GMR of single phthalocyanine molecules — •Detlef Kramczynski[1], Stefan Schmaus[1,2], Annika Bork[1], Yasmine Nahas[1], Toyokazu Yamada[1], and Wulf Wulfhekel[1,2] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, Germany — [2]Center for Functional Nanostructures, Karlsruher Institut für Technologie, Germany

The ongoing downsizing process in electronics and data storage has set the focus of the last years on studying the properties of nanoscale objects, like single molecules and single atoms.
We present the results of our measurements of the spin-dependent conductance of single hydrogen phthalocyanine molecules, obtained with low temperature scanning tunneling microscopy. The molecules were evaporated on different magnetic metal surfaces, that serve as one of the spin-polarized electrodes. The second electrode was a W-tip coated with magnetic material (Co, Fe). Direct contact was established by a controlled approach of the tip towards the surface, until a sidegroup of the molecule flipped up, touching the tip and bridging the tunneling gap. By changing the relative magnetization of tip or substrate, we were able to measure the GMR of a single molecule.

MA 32: Magnetic Semiconductors II

Time: Friday 10:15–10:45 Location: H10

Invited Talk MA 32.1 Fri 10:15 H10

Light-Induced Magnetization in Colloidal Semiconductor Nanocrystals — •Gerd Bacher[1], Lars Schneider[1], Remi Beaulac[2], Paul I. Archer[2], and Daniel R. Gamelin[2] — [1]Werkstoffe der Elektrotechnik and CeNIDE, Universität Duisburg-Essen, 47057 Duisburg, Germany — [2]Department of Chemistry, University of Washington, Seattle, USA

Future spintronics and spin-photonics technologies will require a portfolio of techniques for manipulating spins in semiconductor nanostructures. One key ingredient is the magnetic exchange interaction between charge carriers and magnetic impurity ions embedded in the semiconductor. Pulsed laser excitation can thus lead to light-induced spontaneous magnetization. Despite its long history and its actual renaissance due to implications on semiconductor spintronics, weak exchange fields observed in experiment up to now suppose that this kind of light-induced magnetization is a low temperature phenomenon, not suitable for any room temperature application.

Here we demonstrate spontaneous photoinduced polarization of Mn2+ spins in colloidal CdSe nanocrystals [1]. Very large effective internal magnetic fields are observed that lead to complete magnetization of the nanocrystals in the absence of an external magnetic field, with signatures of photomagnetization observable even at or near room temperature. These large spin effects could lead the way to a new generation of room temperature spin-based semiconductor devices.

[1]R. Beaulac, L. Schneider, P.I. Archer, G. Bacher, D.R. Gamelin, Science 325, 973 (2009)

MA 33: Poster II

Time: Friday 11:00–14:00 Location: Poster B1

MA 33.1 Fri 11:00 Poster B1

Exact-exchange spin density functional study of quantum rings: Successive spin Wigner transitions and spin magnetization of the ground state. — •Thorsten Arnold, Marc Siegmund, and Oleg Pankratov — Lehrstuhl für Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7/B2, 91058 Erlangen, Germany

We employ exact-exchange spin density functional theory to study correlated electrons on one-dimensional (1D) and two-dimensional (i.e. with finite width) quantum rings. The rings are threaded by a magnetic flux confined to the ring center, which induces a persistent current. A weak impurity potential is introduced to break the rotational symmetry. The strength of electron-electron interaction relative to kinetic energy described by parameter r_s is varied. The Fermi liquid state and the Wigner crystal state can be distinguished by resorting to the spin-resolved densities, currents and electron localization functions. Fixing the spin magnetization to admissible non-vanishing values, we found the amplitude of the spin density wave, the magnitude of the persistent current drop and the degree of electron localization to be different for spin-up and spin-down electrons. The transition point of Wigner crystallization is found at $r_s < 1$. It crucially depends on the (effective) width of the ring. Relaxing the constraint of the spin magnetization, (for the case of the 1D ring), three ground state regimes are identified: an unpolarized Fermi liquid, an antiferromagnetic Wigner crystal and a fully polarized Fermi liquid. The transitions between these states occur in the range of rather small r_s values ($r_s < 1$).

MA 33.2 Fri 11:00 Poster B1

Electronic and Magnetic Properties of Transition Metal Fluorides from first principles — •Guntram Fischer[1], Waheed Adeagbo[1], Hossein Hashemi[1], Arthur Ernst[2], Martin Lüders[3], Zdzislawa Szotek[3], Walter Temmerman[3], and Wolfram Hergert[1] — [1]Institute of Physics, MLU Halle-Wittenberg, Von-Seckendorff-Platz 1, 06120 Halle, Germany — [2]Max Planck Institute for Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [3]Daresbury Laboratory, Daresbury, Warrington, WA4 4AD, UK

We performed a multi-code *ab initio* investigation of the electronic and magnetic properties of the insulating and antiferromagnetic transition metal fluorides MnF_2, FeF_2, CoF_2, and NiF_2. To treat the strong correlations adequately we used self-interaction corrections within a KKR multiple scattering approach[1] and the LDA+U method with the plane-wave pseudopotential code VASP[2]. Heisenberg interaction parameters were calculated via a magnetic force theorem[3] and also via total energy differences. Resulting critical temperatures were obtained using Mean Field Approximation, Random Phase Approximation and Monte Carlo simulations and compared to experiment and other theoretical results. Spinwave dispersions were calculated as well and discussed.

[1] M. Lüders et al., Phys. Rev. B **71**, 205109 (2005)
[2] G. Kresse and J. Furthmüller, Phys. Rev. B **47**, 558 (1993)
[3] A.A. Liechtenstein et al., JMMM **67**, 65 (1987)

MA 33.3 Fri 11:00 Poster B1

Low-voltage gating of ferromagnetic GaMnAs structure — Sam Owen[1,2], Joerg Wunderlich[1,3], Andrew Irvine[2], Zbynek Soban[3], Kamil Olejnik[1,3], Tomas Jungwirth[3], and •Vit Novak[3] — [1]Hitachi Cambridge Laboratory, Cambridge, UK — [2]Microelectronic Research Centre, Cavendish Laboratory, University of Cambridge, UK — [3]Institute of Physics ASCR, Praha, Czech Republic

We report on low-voltage control of magnetic properties of a p-n junction field effect transistor via depletion effect in the ferromagnetic semiconductor channel. We show variable Curie temperature and anisotropic magnetoresistance, and demonstrate magnetization switchings induced by short electrical pulses of a few volts. The gatable ferromagnetic device is realized in an all-semiconductor epitaxial structure and offers a pricipally faster operation than the metal-oxide-semiconductor structures reported so far.

MA 33.4 Fri 11:00 Poster B1

Ferromagnetic resonance study on highly doped $(Ga_{1-x}Mn_x)As$ films — •Matthias Kiessling[1], Georg Woltersdorf[1], Vít Novák[2], and Christian Back[1] — [1]University of Regensburg, Universitätsstrasse, 31, 93053 Regensburg, Germany — [2]Institute of Physics ASCR, Cukrovarnická 10, Prague, 16253, Czech Republic

We studied highly doped (Ga_{1-x},Mn_x)As films grown by low temperature molecular beam epitaxy (LT-MBE) having a Mn concentration of $x = 12.5\%$ and a nominal thickness of 20 nm. All samples were annealed in air for 6 hours at 160°C. SQUID measurements reveal Curie temperatures of about 184 K. Ferromagnetic Resonance measurements performed from 8 to 18 GHz show that the magnetic anisotropy is dominated in the temperature range (10 - 180 K) by a large uniaxial anisotropy (K_u) pointing along the [1-10] crystallographic direction. $K_u = 1.64 * 10^4$ erg/cm^3 at 35 K is an order of magnitude larger than the fourfold magnetocrytalline anisotropy. The frequency dependence of the FMR line width $\Delta H(\omega)$ is used to study the magnetic relaxation. The Gilbert damping parameter α is found to be very small ($\alpha = 0.003$ - 0.0044 at 60 K) compared to previous studies [1,2]. Inhomogeneous broadening of the line width $\Delta H(0)$ due to variation of the magnetic properties in the sample or due to two magnon scatter observed at 10 K decrease with increasing temperature. In order to distinguish between magnetic inhomogeneities and two magnon scattering measurements are performed in the perpendicular configuration. [1] J. Sinova, PRB 69, 085209 (2004); [2] Y.H. Matsuda, Physica B 376-377, 668-671 (2006)

MA 33.5 Fri 11:00 Poster B1

Cross-sectional STM investigations of manganese diffusion in GaAs based heterostructures — •Gerhard Münnich, Martin Utz, Dieter Schuh, and Jascha Repp — Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

GaMnAs is a ferromagnetic semiconductor that has recently attracted a lot of scientific interest [1]. One possible application of GaMnAs may be using it for spin-injection into GaAs-based functional heterostructures. Recent studies addressed the influence of a non-equilibrium ($T \approx 250°C$) grown GaMnAs layer on the performance of such heterostructures below.

These investigations showed that photoluminescence was quenched as a result of the GaMnAs layer, even though the GaMnAs layer was 10nm away from the optically active layer. This was attributed to possible back-diffusion of manganese into adjacent layers [2].

We addressed this issue in real space by using cross-sectional STM. As a first result of our work, we can give an upper boundary of the Mn content to diffuse into the GaAs.

[1] Sanghoon Lee et. al., Mater. Today **12**, 14 (2009)
[2] R. Schulz et. al., Physica E **40**, 2163 (2008)

MA 33.6 Fri 11:00 Poster B1

Magnetic aftereffect in compressively strained GaMnAs resolved by Kerr microscopy — •Liza Herrera Diez[1], Jan Honolka[1], Klaus Kern[1], Helmut Kronmüller[2], Ernesto Placidi[3], Fabrizio Arciprete[3], Andrew Rushforth[4], Richard Campion[4], and Bryan Gallagher[4] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [2]Max-Planck-Institut für Metallforschung, Stuttgart — [3]Dipartimento di Fisica, Università di Roma "Tor Vergata" — [4]School of Physics and Astronomy, University of Nottingham

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]. However, a full control over magnetic reversal dynamics mediated via nucleation and propagation of domain walls (DWs) is required. While magneto-transport measurements like e.g. the planar Hall effect only give spatially averaged information about DW dynamics we use Kerr microscopy to track individual in-plane domains in space and time[4]. In this work we specifically address the influence of the magnetic aftereffect on the dynamics.

References

[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 33.7 Fri 11:00 Poster B1

Electronic localization and variable-range-hopping transport in GaMnN and GaGdN epitaxial layers — •Amilcar Bedoya-Pinto, Martin Roever, Dong-Du Mai, Joerg Malindretos, and Angela Rizzi — IV. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

The interplay between magnetic and transport phenomena has been found to be a key issue to understand the origin of ferromagnetic coupling in dilute magnetic semiconductors (DMSs), as in the case of GaMnAs. Regarding III-V nitride DMSs, while there is a considerable number of reports based on magnetometry, only a few studies are devoted to the electrical transport behavior. In this sense, GaMnN and GaGdN epitaxial layers have been grown by molecular-beam epitaxy on both 6H-SiC and GaN:C highly-resistive substrates. Magnetic characterization was performed by SQUID-magnetometry. Temperature-dependent resistivity measurements of GaMnN layers show a transition from n-type activated transport to variable-range-hopping (VRH) as the Mn-concentration is increased. Regarding GaGdN layers, on the other hand, the observation of VRH-transport at low Gd-concentrations ($\sim 10^{16}$cm^{-3}) and the evaluation of the inferred hopping parameters suggest that not Gd itself, but Gd-induced defect states are the effective source for electronic localization. In both cases, the relation between magnetic and electrical transport properties is discussed taking into account the well-established models of ferromagnetic coupling in DMSs, as well as recent models proposing defect-induced magnetism in wide band-gap III-Nitrides.

MA 33.8 Fri 11:00 Poster B1

Hydrogen mediated ferromagnetism in ZnO single crystals — •Khalid Muhammad[1], Esquinazi Pablo[1], Spemann Daniel[2], Anwand Wolfgang[3], and Brauer Gerhard[3] — [1]Division of Superconductivity and Magnetism, University of Leipzig, 04103 Leipzig, Germany — [2]Division of Nuclear Solid State Physics, University of Leipzig, 04103 Leipzig, Germany — [3]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Dresden-Rossendorf, 01314 Dresden, Germany

We have investigated the magnetic properties of hydrogen (H) plasma treated ZnO single crystals. The H-concentration before and after H-plasma treatment has been determined by using nuclear reaction analysis. The H-concentration after treatment was found $\simeq 0.6$ at%. The magnetic properties of H-plasma treated ZnO single crystals have been investigated by SQUID magnetometry. Hysteresis loops applying magnetic fields parallel and perpendicular to the plane of the sample were measured at 5 and 300 K for each sample revealing magnetic anisotropy. We have observed a giant enhancement of magnetization in H-plasma treated ZnO samples. The ferromagnetic Curie temperature was found to be above 400 K. The saturation magnetization at 300 K was ~ 10 emu/g, several orders of magnitude higher than that reported in literature. In order to investigate the penetration of H-ions in the ZnO single crystals we have etched the surface of the samples. We found that most of the sample ferromagnetic moment vanishes after etching the first 20 nm layer in agreement with the expected H-penetration depth.

MA 33.9 Fri 11:00 Poster B1

Magnetic field induced changes of the magnetic phase transition in metastable zincblende MnS layers grown by MBE — •Manuel Demper[1], Limei Chen[1], Christine Bradford[2], Hans-Albrecht Krug von Nidda[3], Kevin A. Prior[2], Alois Loidl[3], and Wolfram Heimbrodt[1] — [1]1Department of Physics and Material Science Center, Philipps-University Marburg — [2]School of Engineering and Physical Sciences, Heriot-Watt University, Edinburgh — [3]Center for Electronic Correlation and Magnetism, University Augsburg

The continuous decrease of magnetic structures meets fundamental limits. Hence, it is essential to understand the magnetic interactions in low dimensions. Therefore, we investigated the 3D-2D transition on a series of MBE grown antiferromagnetic zincblende MnS-layers with various thicknesses by using magnetic photoluminescence techniques. The MnS photoluminescence spectra exhibit a strong yellow emission band which belongs to the internal $^4T_1 \rightarrow {}^6A_1$ transition of the manganese ions in a tetrahedral crystal field. The temperature evolution of this emission reveals a characteristic red-shift towards the Néel-Temperature due to the energy relaxation of the Mn d-states in the antiferromagntic phase. This optical access has been used to study the influence of the 3D-2D transition and the effect of an external magnetic field on the magnetic properties of the MnS layers. Surprisingly, no clear effect was found on the phase transition temperature with decreasing MnS-layer thickness but on increasing external magnetic fields for the thinnest layers. This unique behavior will be discussed in detail.

MA 33.10 Fri 11:00 Poster B1

Influence of exchange and correlation on the magnetic ground state of MnO — •Andreas Schrön, Claudia Rödl, and Friedhelm Bechstedt — Institut für Festkörpertheorie und -

optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany

Transition-metal oxides (TMOs) are of great interest for applications in e.g. dilute magnetic semiconductors (DMSs) which are supposed to allow for transparent ferromagnets with critical temperatures around room temperature. Although TMOs have been investigated a long time experimentally, their theoretical description is still unsatisfying. (Semi-)local approximations like local spin-density approximation (LSDA) or generalized-gradient approximation (GGA) to density functional theory (DFT) work well for many materials, but fail for TMOs, since they do not account sufficiently for the electron correlation effects.

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

MA 33.11 Fri 11:00 Poster B1

Origin of Resonance Structures in Magneto-optical Spectra of InMnSb and InSb — •Christoph Thurn and Vollrath Martin Axt — Theoretische Physik III, Universität Bayreuth, D-95440 Bayreuth, Germany

We have calculated the magneto-optical Kerr and the magnetic circular dichroism spectra of ferromagnetic $In_{0.985}Mn_{0.015}Sb$ and intrinsic InSb using an eight band $\vec{k}\cdot\vec{p}$ model accounting for the coupling to external magnetic fields $B = 0.4\ldots8$ T as well as for the mean-field exchange coupling between holes and Mn spins.

The numerical results show that for InSb the spectra exhibit narrow and distinct resonances which can be associated with dipole-allowed transitions between the Landau levels in conduction and valence bands. With increasing B the Landau and the Zeeman splitting increase, and the observed peaks change their position and amplitude accordingly.

Contrarily, the calculated spectra of the diluted magnetic semiconductor InMnSb show only one strong and broad resonance. The shape and position of this resonance does not change with B. It is found, however, that the amplitude depends linearly on the magnetization M of the samples. Nota bene: B can easily exceed $\mu_0 M$. An involved analysis of the band structure and the dipole transitions explains these features. In particular, the spectra of InMnSb are dominated by intravalence band transitions. Our results are in excellent agreement with measurements performed by A. Winter and H. Pascher.[1]

[1]C. Thurn, V. M. Axt, A. Winter, H. Pascher, H. Krenn, X. Liu, J. K. Furdyna, and T. Wojtowicz, Phys. Rev. B **80**, 195210 (2009)

MA 33.12 Fri 11:00 Poster B1

Electrodeposited $Fe_{(100-x)}Ga_x$ thin films with high magnetostriction — •Diana Iselt[1,2], Heike Schlörb[1], Sebastian Fähler[1], and Ludwig Schultz[1,2] — [1]IFW Dresden, Institute for Metallic Materials, Helmholtzstr. 20, 01069 Dresden — [2]TU Dresden, Faculty of Mechanical Engineering, 01062 Dresden

Magnetostrictive materials can be used to build up electromagnetic sensing and actuating devices. A promising candidate to overcome the mechanical limitations of Terfenol-D is $Fe_{(100-x)}Ga_x$ with 15 to 25 at.% Ga, which shows a high mechanical strength and low saturation fields. For the application as sensors thin films, ribbons and nanowires need to be produced in a cheap way over large areas. In this study a suitable deposition process for Fe-Ga alloy thin films has been developed using electrochemical pulse plating. By optimising the deposition parameters such as electrolyte composition, deposition potential, deposition time and pulse sequences, homogeneous (110)-oriented thin films with low oxygen content have been prepared. Preliminary investigations of magnetic properties correlated to magnetostriction will be presented and discussed in sense of shape anisotropy.

MA 33.13 Fri 11:00 Poster B1

Ni_2MnIn Heusler electrodes for spin valves — •Hauke Lehmann[1], Jeannette Wulfhorst[1], Andreas Vogel[1], Jan M. Scholtyssek[1,2], Guido Meier[1], and Ulrich Merkt[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik, Technische Universität Braunschweig, Hans-Sommer-Str. 66, 38106 Braunschweig

Injection, manipulation, and detection of spin-polarized currents are fundamental issues in spintronics. We study the spin-dependent transport in lateral spin-valves [1, 2]. Nanopatterned, halfmetallic Ni_2MnIn Heusler electrodes are prepared by electron-beam lithography and lift-off processing. Post-growth annealing is utilized to achieve the ordered $L2_1$ crystal structure. Thin films grown on Si_3N_4 membranes are investigated in situ in a transmission-electron microscope using electron diffraction [3]. The local spin-valve effect is measured with a copper channel between the two Heusler electrodes. Transport measurements are performed at low temperatures around 2 K in external magnetic fields of up to $\pm$ 5 T. In further experiments we aim at the detection of the extrinsic spin-Hall effect which has attracted significant interest. All-electrically detection in spin valves is possible by two additional leads on the sides of the copper channel [4].

[1] A. Vogel et al., Appl. Phys. Lett. **94**, 122510 (2009)
[2] A. van Staa et al., Phys. Rev. B **77**, 214416 (2008)
[3] J. M. Scholtyssek et al., J. Crystal Growth **311**, 79 (2008)
[4] S. O. Valenzuela and M. Tinkham, Nature **442**, 176 (2006)

MA 33.14 Fri 11:00 Poster B1

Distortion of the magnetization dynamics by domain walls — •Philipp Pirro, Sebastian Hermsdörfer, Björn Obry, Helmut Schultheiss, Katrin Vogt, Peter Andreas Beck, Peter Clausen, Thomas Brächer, Britta Leven, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Magnetic domain walls in soft magnetic thin film structures have attracted increasing attention during the last years due to their interaction with spin-polarized currents. The idea of new magnetic storage devices, the racetrack memories [1], was developed. An alternative solution to implement lateral spin transport are spin-waves which avoid a dissipative charge flow. New devices like spin-wave logic elements [2] can be constructed. In these devices, domain walls are supposed to play an important role [3]. The investigation presented is focused on the influence of magnetic domain walls on spin-waves. To analyze these interactions we use Brillouin Light Scattering Microscopy and Magnetic Force Microscopy. In the investigated $Ni_{81}Fe_{19}$-microstructures, domain walls can be nucleated and annihilated to study their influence on spin waves which are excited by the Oersted field of a microwave current flowing in a stripe antenna. Large effects of a domain wall on the spin-wave intensity are observed.

[1] S. S. P. Parkin, et al., Science 320,190 (2008)
[2] T. Schneider et al., Appl. Phys. Lett. 92, 022505 (2008)
[3] C. Bayer et al., IEEE Trans. Magn. 41, 3094 (2005)

MA 33.15 Fri 11:00 Poster B1

Noise characterization of a linearized submicron MTJ sensor array with CoFeB and Heusler alloy free-layers — •Peter Hedwig, Camelia Albon, Alexander Weddemann, and Andreas Hütten — Universität Bielefeld, Fakultät für Physik, Universitätsstr. 25, 33615 Bielefeld

Recently a lot of effort is put into the detection of magnetic particles and beads based on magnetoresistive elements, employing Spin-Valves, GMR and TMR elements. Most of these have a large size of several micrometers and are therefore of limited spatial resolution.

In our work, we present a submicron sensor-array based on linearized CoFeB/MgO/CoFeB-MTJs with a very high spatial resolution of below xy μm for the dynamic detection of magnetic markers, further extending the scope of possible applications as a "magnetic microscope".

The sensor-array is characterized by static bead measurements and also by measuring its noise performance. According theoretical calculations regarding the sensor-bead-interaction and the limits of detection under consideration of the signal-to-noise-ratio were carried out. Additionally first results for Heusler-Alloys as the free-layer material will be presented, indicating an improved noise performance over the standard CoFeB free-layer.

MA 33.16 Fri 11:00 Poster B1

Evolution of magnetoresistance in electromigrated ferromagnetic break junctions — •Arndt von Bieren[1], Ajit Kumar Patra[1], Stephen Krzyk[1], Jakoba Heidler[1], Jan Rhensius[1,2], Laura Heyderman[2], Regina Hoffmann[3], and Mathias Kläui[1] — [1]Fachbereich Physik, Universität Konstanz, Germany — [2]Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut, Villingen, Switzerland — [3]Physikalisches Institut, Universität Karlsruhe, Ger-

many

Recently, magnetotransport measurements of magnetic nanocontacts have led to a better understanding of the interactions between spin-polarized charge carriers and magnetization taking place at extremely small length scales. Here, we present the evolution of magnetoresistance (MR) in clean electrical break junctions. Ferromagnetic nanocontacts with variable constriction width are fabricated by performing in-situ controlled electromigration of notched magnetic half ring structures in UHV. Low temperature MR measurements, in agreement with micromagnetic simulations, indicate that the dominant contribution in Py ($Ni_{80}Fe_{20}$) contacts down to the size of a few nm is anisotropic magnetoresistance (AMR). Moreover, Ni shows enhanced AMR in constrictions approaching the atomic limit and high tunnelling anisotropic magnetoresistance (TAMR) after carefully opening the contact, suggesting that material-specific parameters such as the electron mean free path play a crucial role. By analyzing the angle-dependent MR we can furthermore extract the domain wall pinning strength of the constriction as a function of its size down to the atomic scale.

MA 33.17 Fri 11:00 Poster B1

Magnetic properties of ion beam induced ripple patterned Fe layers — •Felix Büttner, Hans Hofsäss, and Kun Zhang — II. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany

There is a rapidly growing interest in nanopattered ferromagnetic films. Apart from fundamental investigations, one motivation is the search for materials which are ferromagnetic even at nanometer scale. It has been found that ion beam induced ripples of epitaxially grown Co induce a strong uniaxial magnetic anisotropy [1]. Comparable experiments with epitaxial Fe films on MgO [2] and polycrystalline Fe films on Si [3], both textured by ion beam erosion, showed similar magnetic properties. This study is about nanopattered thin epitaxial Fe layers grown on MgO by PLD. Pattering was done by grazing incidence sputter erosion using 5 keV Xe ions with a fluence of $1.8 \cdot 10^{17}$ ions cm^{-2}. We investigate the magnetic and structual properties of the nanopattered Fe layers as a function of the residual film thickness using MOKE, RBS and AFM. Both side polished MgO substrates were used to perform MOKE measurements of the Fe / MgO interface to determine the influence of the ion beam induced surface ripple patterns on the magnetic properties of the unirradiated underlying layer.

[1] D. Sekiba, R. Moroni, G. Gonella, F. Buatier de Mongeot, C. Boragno, L. Mattera and U. Valbusa, Appl. Phys. Lett. **84**, 762 (2004)
[2] Q. Zhan and K. Temst, Appl. Phys. Lett. **91**, 122510 (2007)
[3] K. Zhang, M. Uhrmacher, H. Hofsäss and J. Krauser, J. Appl. Phys. **103**, 083507 (2008)

MA 33.18 Fri 11:00 Poster B1

Mangnetic domain patterns in Co2MnGe Heusler thin film microstructures — Katherine Gross, •Philipp Szary, Melanie Ewerlin, Frank Brüssing, Alexandra Schumann, Oleg Petracic, Kurt Westerholt, and Hartmut Zabel — Institut für Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum, Germany

Cubic Heusler alloys like Co2MnGe are soft feromagnetic materials with a weak cubic crystalline magnetic anisotropy. Thin films of Co2MnGe can be grown on sapphire a-plane with a dominating growth-induced uniaxial magnetic anisotropy, which originate from the miscut of the single crystalline substrate. This feature makes this Heusler alloy ideally suited for the study of magnetic domain structures resulting from the competition between an uniaxial growth-induced magnetic anisotropy and the shape anisotropy in magnetic microstructures. Using electron beam lithography we have prepared rectangular stripes of Co2MnGe with the length to width aspect ratios m = l/b from m=1 to m=20. The magnetic domains are observed by magnetic force microscopy in the remanent state as well as with an applied magnetic field up to 600 Oe. We find regular, highly symmetric domain patterns in the stripes, changing systematically with the aspect ratio and the applied magnetic field. When the uniaxial anisotropy is oriented perpendicular to the shape anisotropy, the domain width along the long axis of the stripes scales as 1/m. The essential features of the domain patterns we have observed could well be reproduced by OOMMF micromagnetic simulations.

MA 33.19 Fri 11:00 Poster B1

Anisotropy studies of individual micro structured elements using the magneto-optical Kerr effect (MOKE) — •Thomas Sebastian, Georg Wolf, Andrés Conca, Britta Leven, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

MOKE is a well established technique for the investigation of crystal- or induced anisotropies in homogenous magnetic films of layer stacks [1]. By the use of a micro focused probing laser-beam in combination with a positioning system in horizontal and vertical direction as well as a rotator with high resolution it is possible to expand this anisotropy studies to individual micron sized elements. The new rotating Kerr-microscope setup is the experimental realization of this concept.

On the micrometer-scale the influence of the demagnetizing fields - caused by the geometrical shape of the sample - is not negligible any longer and becomes even more important with decreasing size. With our new setup it is possible to observe the magnetization reversal for different orientations of the sample taking into account the contribution of the shape anisotropy. The poster presents first results obtained with this setup for CoFe- and NiFe-ellipses.

We acknowledge financial support by the BMBF VDI-TZ 13N9913: 'MultiMag-project'.

[1] J. Hamrle et al., Magnetic anisotropies and magnetization reversal of the $Co_2Cr_{0.6}Fe_{0.4}Al$ Heusler compound, J. Appl. Phys. 100, 103904 (2006)

MA 33.20 Fri 11:00 Poster B1

Antiferromagnetically coupled Fe/Cr/Fe micropatterns in a ferromagnetically coupled environment — •Roland Neb[1], Peter Andreas Beck[1], Thomas Sebastian[1], Philipp Pirro[1], Burkard Hillebrands[1], Stefan Pofahl[2], Rudolf Schäfer[2], Bernhard Reuscher[3], and Michael Kopnarski[3] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]IFW Dresden, 01069 Dresden, Germany — [3]IFOS, 67663 Kaiserslautern, Germany

The exchange-coupled Fe/Cr/Fe-trilayer system is known to exhibit different kinds of coupling, depending on the thickness of the interlayer. We examine antiferromagnetically coupled trilayers which are magnetically patterned by focused ion beam irradiation with 30 keV Ga-ions. The irradiated regions become ferromagnetic, which allows us to create well defined areas with very low topographic inhomogenities where the two Fe layers couple ferromagnetically. We study antiferromagnetically coupled elements in a ferromagnetic environment using Kerr microscopy and MFM, showing that the coupling turns ferromagnetic when the elements are smaller than a few microns. The influence of the environment on the elements is analyzed by using different sizes and shapes of elements and environment, showing that the magnetic behavior of such elements is mainly driven by the surrounding ferromagnetic area.

Support from the Deutsche Forschungsgemeinschaft and Graduiertenkolleg 792 is gratefully acknowledged.

MA 33.21 Fri 11:00 Poster B1

Ensemble and single-object measurements of magnetic nanowires with modulated diameter — Kristina Pitzschel[1], Josep M. Montero Moreno[1,2], Stephan Martens[1], •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 a porous alumina membrane as template with modulated diameter [1,2]. Filling the pores with Ni by electrodeposition delivers wires replicating the changes in diameter from 70 to 150 nm. These structures are ferromagnetic. Ensemble magnetic measurements by SQUID (Superconducting QUantum Interference Devic) and single-objetc measurements by Magneto-optical Kerr effect evidence a strong correlation between geometric parameters and magnetic properties. On the contrary to single-object measurements ensemble measuremets also show their dipolar interactions. Magneto-optical Kerr effect measurements on single wires reveal that motion of domain boundaries are blocked at certain changes in diameter. This demonstrates for the first time that domain wall motion can be controlled in nano-object prepared by a mass production method.[1] W. Lee et al., Nature Nanotech. 3, 234 - 239 (2008).[2] K. Pitzschel et al., ACS Nano 2009 3 (11), 3463-3468

MA 33.22 Fri 11:00 Poster B1

Magnetic and thermoelectrical measurement of multi-segmented Co/Cu nanowires — •Bastian Lie, Tim Böhnert, Johannes Kimling, and Kornelius Nielsch — Institut für Ange-

wandte Physik, Universität Hamburg, Hamburg, Germany

Nanostructures, e.g. modulated nanowires, reveal quantum effects due to their size which are advantageous for thermoelectrical applications. The thermoelectric properties depend on phonon- and electron-scattering in a material. We prepared high aspect-ratio multisegmented cobalt/copper nanowires and measured the thermal conductivity and the giant magnetoresistance (GMR). The desired approach for the preparation is the bottom-up method. In our case the single-bath-electrodepostion of cobalt and copper in eloxated alumina templates is applied by means of galvanostatic and potentiostatic deposition to fabricate alternating segments with a thickness of several nm's. The thickness of the copper layer is varied to validate the oscillation of the GMR-ratio dependant on the spin diffusion length. We will present details of the sample processing, magnetoresistance measurements and 3ω-measurements.

MA 33.23 Fri 11:00 Poster B1

Structural, electrical and magnetic properties of single Au-Ni/NiO-Au nanowires — •Corinna Steinweg[1], René Sewcz[1], Sabrina Baldus[1], Saskia F. Fischer[1], Mihaela Daub[2], and Kornelius Nielsch[3] — [1]Werkstoffe und Nanoelektronik, Ruhr-Universität Bochum, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]Multifunctional Nanostructures, Universität Hamburg, Germany

Ferromagnetic metallic nanowires are of high interest for magnetic sensing and storage applications. However, due to surface oxidation of the nanowires electrical contacts easily lead to high-contact resistances of a few kΩ. Here, we present multisegmented Au-Ni(NiO)-Au nanowires with a direct Au-Ni interface. Individual nanowires were laterally contacted in a four-terminal geometry via optical lithography, electron-beam lithography, thermal evaporation and lift-off patterning. The nanowires exhibit low-ohmic contacts of about 20 Ω. The resistivity decreases with the temperature (300 K to 4.2 K) and is in the order of that of high-purity bulk nickel [1]. The longitudinal anisotropic magnetoresistance (AMR) is about 1.5 % at 80 K and decreases with higher temperatures, 0.5 % at 300 K. The coercive field and the AMR are investigated for different angles between the current and magnetic field.

[1] T. FARRELL et al. J. PHYS. c (PROC. PHYS. SOC), ser. 2, 1359 (1968)

MA 33.24 Fri 11:00 Poster B1

Synthesis and characterization of boron-doped magnetic thin films and nanowires — •Martin Waleczek, Robert Zierold, Julien Bachmann, and Kornelius Nielsch — Institut für Angewandte Physik, Jungiusstr. 11, D-20355 Hamburg

Boron-doped magnetic thin films and nanowires can be fabricated by means of iron-boron electrodeposition from an alcaline electrolyte [1], using electropolished copper as substrate for the films and self-ordered porous alumina as template for the wires.

Due to the high pH of the electroplating bath, the alumina template has to be protected by a thin silica layer via atomic layer deposition (ALD) [2]. The Fe/B ratio can be optimized by changing the electrolyte composition, as well as the electrodeposition parameters. Diameter (40-300 nm) and length (micrometer-range) of the wires can easily be adjusted by controlling the template synthesis and the deposition time, respectively.

Investigation of the magnetic behaviour of the FeB thin films and of the nanowire arrays is done by SQUID and MOKE measurements.

The magnetic properties as well as the high boron content enclosed in a biocompatible and functionizable silica shell show this system's potential as a new approach to applications in boron neutron capture therapy (BNCT), where ^{10}B near or in tumor cells converts to ^{7}Li upon catching a thermal neutron and emits high energy particles, which have a very local, highly destructive effect on nearby tissue.

[1] Rakovich, E. V. et. al. : Russ. J. of Appl. Chem. **73** 7 (2000)
[2] Bachmann, J. et. al. : Angew. Chem. Int. Ed. **47** 33 (2008)

MA 33.25 Fri 11:00 Poster B1

Controlled reduction of the nucleation field in Co/Pt multilayer wires — •Judith Moser[1], André Kobs[1], Andreas Vogel[1], Theo Gerhardt[1], Markus Bolte[1], Mi-Young Im[2], Peter Fischer[2], Sebastian Wintz[3], Ulrich Merkt[1], Hans Peter Oepen[1], and Guido Meier[1] — [1]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Germany — [2]Center for X-ray Optics, Lawrence Berkeley National Laboratory, Berkeley, CA, USA — [3]Institut für Ionenstrahlphysik und Materialforschung, Forschungszentrum Dresden-Rossendorf, Dresden, Germany

Due to their narrow domain walls, nanowires with high uniaxial out-of plane anisotropy are interesting candidates for spin-momentum transfer studies. Since high current densities can change or destroy the wires investigated, weak pinning potentials allowing the controlled and reliable depinning of domain walls at low current densities are desirable. A prerequisite for the preparation of a domain wall at such pinning sites are nucleation fields smaller than the fields required to depin the domain wall from the respective pinning site. We suggest two methods to tune the nucleation field of lithographically designed Co/Pt multilayer wires. The magnetization reversal of the wires is investigated by means of transmission X-ray microscopy. An up to fourfold reduction of the nucleation field could be achieved through altering the lateral shape of the wires or by depositing Fe stripes on top.

The authors gratefully acknowledge financial support by the DFG and the DOE.

MA 33.26 Fri 11:00 Poster B1

Superparamagnetism of Co/Pt nanodots with perpendicular anisotropy — •Alexander Neumann[1], Simon Hesse[1], André Kobs[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

In this paper we present measurements of the magnetic behavior of Co/Pt nanodots with a mean diameter and a mean distance of 19 nm/90 nm, respectively. The dots were fabricated from Co/Pt multilayers using SiO_2 particles as a shadow mask for Ar^+ sputtering at 500 eV. The nanodots exhibit an easy axis of magnetization that is perpendicular to the substrate surface [1].

We studied the temperature dependence of the hysteresis loops of nanodots made from single and double Co/Pt bilayer with Co thickness of 7 Å within the range of 80 K to 325 K. The magnetization curves are determined by means of the extraordinary Hall effect (EHE). To determine the blocking temperature T_B we used the temperature dependence of the coercive field. In case of the single Co/Pt bilayer nanodot a maximum of the ac-susceptibility is found that shifts to higher temperatures on frequency increase. From the results we calculated the nanodots switching time τ_0.

[1] H. Stillrich *et al.*, Adv. Funct. Mat. **18**, p76-81, (2008).

MA 33.27 Fri 11:00 Poster B1

Ultrafast magnetization dynamics of single antidot structures on nickel — •Darius G. Vahdat-Pajouh, Jakob Walowski, Andreas Mann, Henning Ulrichs, Gerrit Eilers, Benjamin Lenk, and Markus Münzenberg — I. Physikalisches Institut, Universität Göttingen

The time-resolved magnetization dynamics in a thin magnetic film can be investigated with femtosecond laser pulses. After optical excitation (pump pulse) the magnetic relaxation is recorded via the magneto-optical Kerr effect using a second laser pulse of lower intensity (probe pulse) which allows a depiction of $M(t)$.

The aim of this contribution is to find the influence of one single antidot on the magnetization dynamics depending on its diameter and the applied external field. Another point of interest concerns the magnetic mode spectrum and its resemblance to spectra of arrays structures consisting of many periodically arranged antidots. Time resolved magnetization dynamics measurements were performed for various distances from the single circular antidots of different diameters ranging from 5 to 20 micrometers.

The experimental findings indicate that the lower frequency modes generated in the dot vicinity can be accounted to field inhomogeneities arising from dipole surface modes around the structure. These can be predicted by analytical calculations and numerical simulations of the magnetic field in the nickel film.

MA 33.28 Fri 11:00 Poster B1

Spin wave propagation in $Ni_{80}Fe_{20}$ antidot lattices — •Hans Bauer[1], Georg Woltersdorf[1], Sebastian Neusser[2], Dirk Grundler[2], and Christian Back[1] — [1]Universität Regensburg, 93043 Regensburg, Germany — [2]Technische Universität München, 85747 Garching, Germany

Magnetic materials can be structured to form a two dimensional periodic antidot lattice. These artificial materials have properties different from the ones found in unpatterned thin films and open the door to the

new field of magnonics, the magnetic analogon of photonics. We investigated a $Ni_{80}Fe_{20}$ antidot square lattice with a unit cell of 800 nm × 800 nm by time resolved Kerr microscopy. In our experiments the sample is excited by a coplanar wave guide at GHz frequencies and the spatial structure of the dynamic modes is observed at various bias field amplitudes and angles. Localized modes as well as extended modes are imaged with a spatial resolution of about 250 nm and are in good agreement with simulations performed on similar samples [1]. Finally, the spatio-temporal evolution of spinwave packets excited by nanosecond microwave bursts is imaged. The aim is to achieve field controlled propagation of spinwave pulses across the antidot lattice [2]. Part of the work was financially supported through the German Excellence Cluster "Nanosystems Initiative Munich".
[1] S. Neusser et al., Appl. Phys. Lett. 93, 122501 (2008)
[2] S. Neusser et al., Phys. Rev. B 78, 054406 (2008)

MA 33.29 Fri 11:00 Poster B1

Magnetic coupling in manganese doped silicon nanocrystals — •Christian Panse[1], Roman Leitsmann[2], and Friedhelm Bechstedt[1] — [1]Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena, Germany — [2]GWT-TUD GmbH, Abteilung Material Calculations, Annabergstr. 240, 09125 Chemnitz, Germany

To understand the magnetic properties on a nanoscale we examine transition metal doped semiconductors. In particular silicon nanocrystals doped with manganese are under investigation. We consider two different doping positions: substitutional and interstitial sites. Single doped systems tend to create high spin phases ($3\,\mu_B$) while the magnetic density is strongly localized at the Mn doping site.

Our fully unconstrained density-functional studies on pairwise-doped NCs show a clear dependency of the strength and type of the magnetic coupling on the Mn-Mn distance d. Due to the localized magnetic moments of the Mn atoms the system favors strong antiferromagnetic ordering for $d < 2.9$ Å. Larger distances yield weaker ferromagnetic coupling. Strong noncollinear spin effects could be found if the Mn atoms are separated by more than 5 Å. Unless the angle between both magnetic moments is less than 6° no significant energy gain due to noncollinearity occur.

A comparison of different doping sites show that the inclusion of at least one substitutional Mn atom will raise stability of the pairs significantly.

MA 33.30 Fri 11:00 Poster B1

Cell-size independent micromagnetic simulations including thermal effects — •Claas Abert[1], Benjamin Krüger[2], Jacek Swiebodzinski[2,3], Massoud Najafi[4], Gunnar Selke[4], André Drews[1], Guido Meier[1], and Markus Bolte[1,4] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Institut für Theoretische Physik, Universität Hamburg, Germany — [3]Theoretische Physik, Universität Duisburg-Essen, Germany — [4]Arbeitsbereich Technische Informatik Systeme, Department Informatik, Universität Hamburg, Germany

Micromagnetic simulations are a well established and powerful tool for zero temperature problems. Since experiments show that temperature strongly influences the magnetization dynamics, it is important to include thermal effects into the micromagnetic approach. This can be done by introducing an effective fluctuating field. The variance of this field is determined by solving the micromagnetic Fokker-Planck equation and demanding a Boltzmann distribution in thermal equilibrium [1]. A remaining challenge is the dependence of the simulation results on the simulation cell-size. This dependence can be eliminated by renormalizing simulation constants. Here a renormalization of the saturation magnetization and exchange constant is investigated using a finite difference micromagnetic simulation tool with a second-order Runge-Kutta stochastical integrator. A correction factor is found that solely depends on well-known simulation constants and which reduces the error by up to an order of magnitude as compared with previous approaches. [1] J. García-Palacios et al., Phys. Rev. B **58** 14937 (1998)

MA 33.31 Fri 11:00 Poster B1

Massively parallel micromagnetic FEM calculations with Graphical Processing Units — •Attila Kákay[1], Elmar Westphal[2], and Riccardo Hertel[1] — [1]Forschungszentrum Jülich GmbH, Institut für Festkörperforschung, Elektronische Eigenschaften — [2]Forschungszentrum Jülich GmbH, IFF-Netzwerke und Numerik

We have adapted our Finite Element Micromagnetic simulation software to the massively parallel architecture of Graphical Processing Units (GPUs) by employing NVIDIA's "Compute Unified Device Architecture" (CUDA)[1] software platform for high-performance computing. The performance of the code is demonstrated on the example of μMAG standard problem #4, where the computation time of a single GPU is compared with an OpenMP-parallelized version of our code using eight CPUs. In this comparison, the adaption of both the magnetostatic field calculation and the time integration of the Landau-Lifshitz-Gilbert equation to the GPU architecture can lead to a speedup factor of up to ten. The performance of the GPU code increases with increasing number of discretization points. The computation time required for high-resolution micromagnetic simulations of the magnetization dynamics in large magnetic samples can thus effectively be reduced by employing GPUs.

[1] CUDA Programming Guide, http://www.nvidia.com/

MA 33.32 Fri 11:00 Poster B1

The influence of size and aspect ratio on the switching properties of elliptical elements: an OOMMF Approach — •Andres Conca Parra, Ana Ruiz Calaforra, Britta Leven, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

The understanding and control of the switching properties in TMR elements is a critical point for certain applications such as MRAM memories. The magnetization dynamics depends on the size and shape of the element, the interlayer coupling in the TMR stack as well as the duration and amplitude of the magnetic field pulses used for switching. The elliptical shape is widely used due to the fact that the demagnetizing field induces a homogeneously magnetized state in remanence. However, depending on the thickness and the aspect ratio of the ellipse, the magnetic elements may show a domain structure in remanence or after excitation with magnetic field pulses.

We performed micromagnetic simulations for elliptical elements with different dimensions using the open code OOMMF. The simulations were performed for application relevant materials such as NiFe, CoFe and CoFeB. The magnetization state in remanence as well as the reaction of the elements to excitation with pulses with different amplitudes and duration were simulated. A comparison between elements and the most suitable strategy for a fast and reliable operation is discussed.

Support by the BMBF project MultiMag (VDI-TZ 13N9913) is acknowledged.

MA 33.33 Fri 11:00 Poster B1

Influence of the magnetostatic coupling on the depinning field of geometrically pinned domain walls in adjacent magnetic nanostrips — •Felipe Garcia-Sanchez, Attila Kakay, and Riccardo Hertel — Institut für Festkörperforschung, Elektronische Eigenschaften, Forschungszentrum Jülich GmbH

Magnetic domain walls in thin strips (DW) have attracted much attention due to potential applications in logic and magnetic storage devices [1]. Such applications require dense arrays of ferromagnetic nanowires and artificial pinning sites to control the DW position. Recently, it has been reported that transverse DWs with different configurations (head-to-head and tail-to-tail) in adjacent wires attract each other, resulting in a non-zero DW depinning field [2]. However, it is still unclear to which extent this interaction influences the depinning from artificially defined sites. In this work we study by means of micromagnetic simulations the separation-dependent interaction between DWs in two permalloy rectangular nanowires containing a double notch. We show that the DW configuration and the relative chirality affect the field required for depinning from the notch. In the case of repulsive interaction, we found that the DWs are unstable at small separation distances since they can depin even without applying external fields. We have also quantified the effect of this interaction on the stability by calculating the energy barrier connected with the depinning mechanism. [1] S. S. P. Parkin, M. Hayashi, and L. Thomas, Science 320, 190 (2008). [2] L. O'Brien et al., Phys. Rev. Lett. 103, 077206 (2009).

MA 33.34 Fri 11:00 Poster B1

Domain-wall types and switching fields in magnetic nanowires with perpendicular magnetic anisotropy determined by micromagnetic simulations — •Theo Gerhardt[1], Judith Moser[1], Andreas Vogel[1], André Kobs[1], Guido Meier[1], and Markus Bolte[1,2] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Arbeitsbereich Technische Informatik Systeme, Department Informatik, Universität Hamburg, Germany

Magnetic multilayers with perpendicular magnetic anisotropy are a

well known material system with potential application e.g. in storage concepts based on current-driven domain-wall motion [1]. We present a systematic investigation of the influence of the material parameters of a thin nanowire, i.e., saturation magnetization M_S, anisotropy constant K_1, and exchange constant A, on the domain-wall type and the switching field via micromagnetic simulations. For low K_1 and high M_S, the multilayers have in-plane magnetization, while for high K_1 and low M_S, the magnetization of the wire points out-of plane with Bloch walls separating the domains. At the phase boundary, Néel walls predominate. The switching fields are found to decrease with increasing M_S and decreasing K_1, but are much larger than in comparable experiments, even when edge roughness is considered in the simulations. By introducing a local variation of the material parameters, as was recently done in Ref. [2], good agreement with experimental data is achieved. [1] S. S. P. Parkin et al., Science **320**, 190 (2008), [2] C. Burrowes et al., Nature Physics, Adv. Online Publication Nov. (2009), DOI:10.1038/NPHYS1436

MA 33.35 Fri 11:00 Poster B1

Micromagnetic simulations of depinning process of a head-to-head transverse domain wall by propagating spin waves on a magnetic nanowire — •June-Seo Kim[1], Luis Lopez-Diaz[2], Eduardo Martinez[2], and Mathias Kläui[1] — [1]Fachbereich Physik, Universität Konstanz, Universitätsstr. 10, D-78457 Konstanz, Germany — [2]Universidad de Salamanca, Plaza de la Merced s/n, E-37008, Salamanca, Spain

The recent discovery that a propagating spin-wave moves a domain wall has created a new possibility to manipulate magnetization [1]. This is now the subject of extensive research motivated not only by its fundamental interest but also by promising applications for novel spintronic devices. In this work, we investigate the domain wall motion induced by propagating spin waves (SWs) on a magnetic nanowire by using the objected oriented micromagnetic framework (OOMMF) code [2]. We observe that domain wall velocity gradually decreases due to the SW attenuation as it moves further from the spin wave source. We also study the depinning of the wall due to the combined effect of longitudinal applied field and propagating SWs. The depinning field depends on the frequency and amplitude of SWs. A correlation between SW frequency and the resonance frequency of local mode inside the domain wall is found. This work is supported by the EU-RTNs SPINSWITCH (MRTN-CT-2006-035327). [1] Dong-Soo Han et al., Appl. Phys. Lett. 94, 112502 (2009). [2] See http://math.nist.gov/oommf

MA 33.36 Fri 11:00 Poster B1

Modeling of intergrain exchange coupling for quantitative predictions of δm plots — •Volker Neu[1,2], Robert Biele[1,2], and Ludwig Schultz[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]Dresden University of Technology, Institute for Solid State Physics, D-01062 Dresden, Germany

Exchange coupling of nanocrystalline materials or interface coupling of multilayers can be studied by means of δm-plots, which compare the irreversible magnetization processes in the magnetizing branch (starting from the thermally demagnetized state) and the demagnetizing branch (starting from the fully saturated state) of a hysteresis. Assuming nanocrystalline grains with sizes well below the single domain particle size, deviations from δm=0 are attributed to either short-range intergrain exchange interactions or long-range magnetostatic interactions. While numerous experimental studies lead to qualitatively sound results, quantitative analysis on δm-plots is missing. This paper studies the effect of intergrain exchange coupling (IGEC) by looking into the fundamental magnetization process of two coupled grains by a combined numerical and analytical model. It reconstructs hysteresis and δm-plots for such coupled pairs as a function of grain size, easy axis orientation and field direction. That way, it allows predictions of the influence of grain size distributions and texture spread on the shape and absolute values of δm-curves for realistic, nanocrystalline samples. Among other findings these calculations reveal, that IGEC can lead to negative δm-results without the effect of magnetostatic interactions.

MA 33.37 Fri 11:00 Poster B1

Micromagnetic simulation of three magnon scattering processes in spin-valve nanocontacts — •Florin Ciubotaru[1], Alexander A. Serga[1], Britta Leven[1], Elzbieta Jaromirska[2], Luis Lopez Diaz[2], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Departamento de Fisica Aplicada, University of Salamanca, I-37008 Salamanca, Spain

The spin-wave emission from point contact spin-valve structures subjected to microwave and direct electrical currents through the contact is a topic of intensive research due to the large potential for on-chip data transfer. We report on micromagnetic simulations of the spin-wave distribution and on the analysis of the three magnon scattering processes (confluence and splitting of magnons) which were observed experimentally in such devices [1]. The obtained results evidence the localization of the splitting process within the contact area. The thresholds for the generation of the nonlinear spin-wave modes behave similarly with the experiment. Spectral position of linear and nonlinear modes is determined in phase and frequency domains. The simulations were performed using the OOMMF open code [2]. Support from EC-MRTN SPINSWITCH (MRTN-CT-2006-035327) is gratefully acknowledged.

[1] H. Schultheiss et al. Phys. Rev. Lett. 103, 157202 (2009)

[2] M. J. Donahue, and D. G. Porter, Report NISTIR 6376, National Institute of Standards and Technology, Gaithersburg, MD (1999).

MA 33.38 Fri 11:00 Poster B1

Simulation of long range Kondo signatures in the local density of states for buried magnetic impurities — •Piet Eric Dargel[1], Robert Peters[1], Thomas Pruschke[1], Henning Prüser[2], Martin Wenderoth[2], Alexander Weismann[2], and Rainer G. Ulbrich[2] — [1]Institut für Theoretische Physik, Georg-August Universität Göttingen, Germany — [2]IV. Physikalisches Institut, Georg-August Universität Göttingen, Germany

Recent scanning tunneling spectroscopy (STS) studies of buried magnetic impurities in copper have shown strong signatures in the local density of states (LDOS) at the surface of the system above the impurities. We identify these signatures as long range fingerprints of the Kondo effect and choose the Single Impurity Anderson Model (SIAM) to model the system. Using an equation of motion (EOM) technique for the evaluation of the Green's function (GF) at the surface, we need to calculate the GF on the impurity with hybridization functions that depend on the free GF of the copper crystal at the impurity position. A linear combination of atomic orbitals (LCAO) approach is used for the free GF of the copper crystal and for the evaluation of the GF of the impurity we apply the Numerical Renormalization Group (NRG). The resulting LDOS at the surface shows a qualitatively very good agreement with the experimental data.

MA 33.39 Fri 11:00 Poster B1

Probing the long range signatures of single Kondo impurities — •Henning Prüser[1], Martin Wenderoth[1], Alexander Weismann[1], Rainer G. Ulbrich[1], Piet Dargel[2], Robert Peters[2], and Thomas Pruschke[2] — [1]IV. Physikalisches Institut, Georg-August Universität Göttingen — [2]Institut für Theoretische Physik, Georg-August Universität Göttingen

Scanning tunnelling spectroscopy (STS) has provided an approach to study the Kondo effect - one of the oldest many particle phenomena known in condensed matter physics - in real space. In spite of the high spatial resolution of scanning tunnelling spectroscopy recent studies have shown that the hallmark of the Kondo effect is only visible if the tip is placed directly above the impurity [1]. We follow a new way and investigated single isolated Co and Fe atoms buried below a Cu(100) surface using low temperature STS [2]. For both impurity atoms we observe, in contrast to previous works a long range Kondo signature which is periodic with the distance to the impurity. The periodicity of the oscillations is given by the Friedel wave length of the surrounding copper crystal. Comparing the experimental results with many body calculations combined with a realistic band structure of copper we show that the observed long range signature can be attributed to the Kondo effect. This work was supported by DFG SFB 602 TPA3.

[1] M. Ternes et al., Journal of Physics: Cond. Mat. 053001 (2009)

[2] A. Weismann et al., Science 323, 1190 (2009)

MA 33.40 Fri 11:00 Poster B1

Polarized Neutron scattering on the triple-axis spectrometer PANDA: first results — •Enrico Faulhaber[1], Astrid Schneidewind[1], Fei Tang[2], Peter Link[3], Dirk Etzdorf[3], and Michael Loewenhaupt[2,1] — [1]Gemeinsame Forschergruppe Helmholtz-Zentrum Berlin - Technische Universität Dresden, Helmholtz-Zentrum Berlin für Materialien und Energie, D-14109 Berlin, Germany — [2]Institut für Festkörperphysik, Technische Universität Dresden, D-01062 Dresden, Germany — [3]Forschungsneutronenquelle Heinz-Maier-Leibnitz (FRM II), D-85747 Garching, Germany

Typical applications of cold neutron triple-axis spectrometers comprise studies of spin and lattice dynamics, magnetic excitations and magnetic structures. In the past years, the PANDA spectrometer, located at the German research reactor FRM II, operated these fields in the conventional, unpolarized mode. To complement this normal mode of operation, a full polarization analysis of the neutrons was highly desired and, therefore, was recently implemented at PANDA.

First tests were made with neutron spins perpendicular to the scattering plane, utilizing static vertical guide fields between Heusler monochromator, spin flipper, sample and Heusler analyzer. Finally, an automated setup of split coils around the sample space was implemented, allowing for longitudinal polarization analysis in arbitrary configurations.

We will present recent results obtained by the completed set-up and discuss the status of the polarization analysis on PANDA in detail.

MA 33.41 Fri 11:00 Poster B1

Commissioning results of MAXYMUS at BESSY II — •Markus Weigand[1], Brigitte Baretzky[1], Michael Bechtel[1], Eberhard Goering[1], Corinne Grevent[1], Marcel Mayer[1], Gisela Schütz[1], Hermann Stoll[1], Christian Wolter[1], Rolf Follath[2], and Christian Jung[2] — [1]MPI für Metallforschung, Stuttgart, Germany — [2]HZB Bessy II, Berlin, Germany

MAXYMUS (MAgnetic X-raY Micro- and UHV Spectroscope), a next generation cutting-edge UHV scanning magnetic X-ray microspectroscope has been developed for high-resolution magnetic and nonmagnetic contrast imaging, local XMCD/XAS spectroscopy (less than 20nm lateral spectro-microscopy resolution). It has been installed in an especially build noise-reducing and temperature stabilizing cabin at the newly constructed PGM undulator beamline (UE 46-2) at BESSY II, Berlin which supplies soft X-rays of elliptical or rotatable linear polarization. First measurements already showed very promising results concerning reduced noise and high-resolution, due to its exceptional high scanning stability together with the unique ability of zoneplate scanning. The instrument is equipped with worldwide unique features. New insight into dynamic behavior of magnetic systems has been gained by applying pump-and-probe measurements with time resolution of less than 50 ps. Due to UHV conditions, TEY-measurements have been performed successfully. Thus, opaque targets can also be studied. First results concerning Fresnel Zone Plate development based on Atomic Layer Deposition will be presented. The microscope will be available for external users in the second half of 2010.

MA 33.42 Fri 11:00 Poster B1

High resolution magnetic imaging using scanning electron microscopy with polarization analysis — •Jakoba Heidler[1], Daniel Rüffer[1], Gregory Malinowski[1], Jan Rhensius[1,2], Laura Heyderman[2], Stephen Krzyk[1], and Mathias Kläui[1] — [1]Fachbereich Physik, Universität Konstanz, Germany — [2]Laboratory for Micro- and Nanotechnology, Paul Scherrer Institut, Villingen, Switzerland

Scanning electron microscopy with polarization analysis is a powerful tool to investigate the spin structure in magnetic nanostructure by measuring the spin polarization of secondary electrons. In this poster, we will describe the SEMPA technique and present examples of measurements of the domains and domain wall spin structure in different magnetic nanostructures. For instance, we used SEMPA to image a domain wall displacement along a ferromagnetic nanowire, the domain configuration in NiFe disks and the change of spin polarization of a thin Co layer when changing the capping layer from Pt to Al_2O_3. All these measurements provide essential informations to understand the relationship between the domain wall configuration, the material spin polarization and the domain wall displacement in current induced domain wall motion experiements.

MA 33.43 Fri 11:00 Poster B1

Improved spin-SEM for high quality imaging of magnetic structures — •Fabian Lofink, Sebastian Hankemeier, Robert Frömter, and Hans Peter Oepen — Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

The unique feature of spin-SEM is the fact that it gives direct access to the magnetization orientation at the surface of a ferromagnetic sample. The high surface sensitivity allows for the investigation of ultrathin samples down to the monolayer regime. The latter property is often advantageously used when contaminated samples are to be investigated. In this case dusting with ultrathin ferromagnetic material is utilized to mirror the magnetic structure in the clean ferromagnetic film to make the magnetic structure accessible for spin-SEM. In this poster we present a new design of a spin-SEM where the LEED-detector performance is optimized with respect to the properties of underlying physics, the secondary electron emission process. The secondary electron emission process determines the energy and polarization distribution of electrons that are used for the imaging. With the improvement it is possible to take overview images in less than a minute and high quality images within 5-10 minutes. The simulated properties are compared to the results of experimental investigations. A very good agreement is found proving the optimized working condition in our set up.

MA 33.44 Fri 11:00 Poster B1

Advanced imaging and characterization of ferroic domains by optical second harmonic generation — Christian Wehrenfennig, •Dennis Meier, and Manfred Fiebig — Helmholtz-Institut für Strahlen- und Kernphysik, Nußallee 14-16, 53115 Bonn

In the investigation of magnetic and electric order in solid state systems, understanding the domain topologies is of prime significance, especially because it directly influences the performance in technical applications. The behavior of domains and domain walls reveals valuable information about the microscopic interactions and interaction paths leading to magnetic and electric ordering and, in particular, magnetoelectric couplings in multiferroics. With optical second harmonic generation (SHG), a powerful technique exists for probing all types of ferroic order using the same experimental setup. Most notably, it enables straightforward imaging even of antiferroic domains.

Here we present two advanced possibilities of domain characterization by SHG: **(1)** In antiferromagnetic compounds with incommensurate periodical modulation of the magnetic moment, conventional techniques fail to distinguish between adjacent translation domains, since they do not differ in the orientation of the order parameter. In contrast, SHG allows us to image those domains by phase sensitive detection. **(2)** Optical visualization of very small domains is naturally restricted by the resolution limit. Here we present a statistical model, which allows us to exploit the information in the remaining signal to estimate the average size of domains, even if it is orders of magnitude below the resolution limit.

MA 33.45 Fri 11:00 Poster B1

Quantitative Magnetic Force Microscopy with iron filled carbon nanotubes (Fe-CNT) — •Silvia Vock[1], Franziska Wolny[1], Ulrike Wolff[1], Christoph Hassel[2], Jürgen Lindner[2], Thomas Mühl[1], Volker Neu[1], and Ludwig Schultz[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]Fachbereich Physik, Experimentalphysik, AG Farle, Universität Duisburg-Essen, 47048 Duisburg, Germany

The quantitative measurement of magnetic stray fields with Magnetic Force Microscopy (MFM) requires calibrated MFM tips. Conventional MFM probes are usually Si cantilevers with a sharp pyramidal tip, hard magnetically coated. The lateral extension of the magnetically active volume of the tip coating reduces the resolution and makes the overall quantitative description difficult. Using the simple point probe approximation, the tip parameters such as the size of the magnetic moment and its fictive position within the tip depend strongly on the measured stray field geometry. In contrast to that a Fe filled carbon nanotube (Fe-CNT), which is attached to a conventional force microscopy cantilever, constitutes an MFM tip with well defined geometry, a high aspect ratio and a homogenous magnetization. We will show that for such a tip the point probe parameters are independent of the measured magnetic structure. Calibration of both tip types was performed on perpendicularly magnetized CoPt stripes with varying width from 300 to 2200 nm. Quantitative MFM measurements were successfully performed on a [Co/Pt]/Ru multilayer sample by using the calibrated Fe-CNT tip revealing the correct sample magnetization.

MA 33.46 Fri 11:00 Poster B1

Quantitative characterisation of magnetic force microscopy (MFM) tips in high homogeneous external magnetic fields — •Denny Köhler, Peter Milde, Ulrich Zerweck-Trogisch, and Lukas M. Eng — Institut für Angewandte Photophysik, Technische Universität Dresden

Measuring quantitative magnetic moments becomes one of the major tasks in nanomagnetic research. We present here a novel way to characterise Magnetic Force Microscopy (MFM) tips in high homogeneous external magnetic fields. The applied measurement technique bases on the deflection of the cantilever caused by the mechanical torque [1]

which is induced by the external magnetic field.

Low temperature measurements of the frequency-shift, damping and static deflection of the cantilever in a variable external magnetic field are used to access the horizontal and vertical components of the magnetic moment of the tip. Amplitude and orientation of the magnetic moment is calculated quantitatively based on the analytic model of a harmonic oscillator.

The new characterisation technique is applied on hard- and soft-magnetic cantilevers, i.e. a whisker- type and a Co-coated MFM tip.

[1] T. Mizoguchi, Jpn. J. Appl.Phys. 43 (2004) 4610.

MA 33.47 Fri 11:00 Poster B1

Conical magnetic structure in the kagome-related Swedenborgite CaBaFe4O7 — •Navid Qureshi, Martin Valldor, and Markus Braden — II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, 50937 Köln

Recently, a new type of metal oxides with magnetic kagome substructure was discovered, being closely related to the Swedenborgite mineral. Valldor et al. were able to synthesise the structural homologue YBaCo4O7 [1] and the spin-spin correlation proved to be strong and antiferromagnetic, which immediately raised the question about geometrical frustration in the magnetic Co substructure. Late last year, a new Swedenborgite homologue only containing Fe has been discovered: CaBaFe4O7 [2]. Macroscopic measurements showed that this compound undergoes a magnetic transition at 270 K into a ferrimagnetic state and a spin reorientation at 200 K into a multi-k structure, which could be confirmed by our neutron single crystal diffraction experiment. The temperature dependent investigation of the magnetic reflections (h k 0), (0 0 l) and (h+d k l) yielded first conclusions concerning the magnetic structures. At Tc the Fe magnetic moments order along the c axis with a small component within the a-b plane which does not break translation symmetry. Rietveld analysis shows that the c-component of the moments alternate between the Fe layers. Below 200 K the a-b component becomes modulated by k=(1/3 0 0) resulting in an interesting conical magnetic structure.

[1] Valldor et al., Solid State Sci. 2002, 4, 923 [2] Raveau et al., Chem. Mater. 2008, 20, 6295

MA 33.48 Fri 11:00 Poster B1

Structural and magnetic chirality of the transition metal silicides $Fe_{1-x}Co_xSi$ and $Mn_{1-x}Fe_xSi$ — •Dirk Menzel[1], Vadim Dyadkin[2], Sergey Grigoriev[2], Dmitry Chernishov[3], Vladimir Dmitriev[3], Evgeny Moskvin[2], Daniel Lamago[4], Thomas Wolf[5], Joachim Schoenes[1], Sergey Maleyev[2], and Helmut Eckerlebe[6] — [1]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany — [2]Petersburg Nuclear Physics Institute, Gatchina, Russia — [3]Swiss-Norwegian Beamline, ESRF Grenoble, France — [4]Laboratoire Léon Brillouin, Saclay, France — [5]Institut für Festkörperphysik, KIT Karlsruhe, Germany — [6]GKSS Forschungszentrum, Geesthacht, Germany

The crystallographic structure and the spin helix chirality of $Fe_{1-x}Co_xSi$ ($0.1 \leq x \leq 0.5$) and $Mn_{1-x}Fe_xSi$ ($0.06 \leq x \leq 0.29$) single crystals were determined by X-ray diffraction using synchrotron radiation and polarized neutron small angle diffraction, respectively. A close relationship between the crystalline and the magnetic structures is observed: A left-handed structural configuration found in $Fe_{1-x}Co_xSi$ corresponds to a right-handed magnetic helix and, vice versa, a right-handed structural helix reveals a left-handed spin helix. On the contrary, in $Mn_{1-x}Fe_xSi$ a left (right) handedness of the atomic structure coexists with a left (right) handedness of the spin helix. The origin of the complementary behavior is the sign of the Dzyaloshinsky-Moriya interaction which for a left-handed crystallographic configuration is positive in the $Fe_{1-x}Co_xSi$ system and negative in the $Mn_{1-x}Fe_xSi$ compound.

MA 33.49 Fri 11:00 Poster B1

Spin-waves decay in a helicoidal magnetic. — •Dmitri Efremov and Giniyat Khaliullin — MPIFKF, Stuttgart

We investigate Heisenberg magnetic with ferromagnetic nearest J_1, and antiferromagnetic next-nearest J_2 and next-next-next nearest J_4 spin interactions. We show that the phase diagram consists on several phases: ferromagnetic, Neel antiferromagnetic, A-, helicoidal phases. We argue that spin waves in the helicoidal phase near to a transition point are highly damped. We compare the obtained results with the experiments on inelastic neutron scattering study of iron perovskite oxides such as $CaFeO_3$.

MA 33.50 Fri 11:00 Poster B1

The S=1/2 Heisenberg model on the 2D orthorhombic lattice: A numerical study — •Mohammad Siahatgar, Burkhard Schmidt, and Peter Thalmeier — Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Germany

The ground state properties and finite temperature behavior of the $S = 1/2$ frustrated Heisenberg model on the 2D orthorhombic lattice are studied using exact diagonalization. This model, named as the $J_{1a,b} - J_2$ model, can be used to describe the low energy spin excitation of the parent compounds of newly discovered iron based superconductors, as well as two classes of layered vanadium phosphate, based on the data obtained from inelastic neutron scattering. Using the finite temperature Lanczos method, the ground state energy and the temperature dependence of the specific heat, magnetic susceptibility and staggered magnetization are calculated. For the latter different lattice sizes and geometries are used to investigate the finite size effect.

MA 33.51 Fri 11:00 Poster B1

Magnetic Properties of the quasi-2D S=1/2 Heisenberg antiferromagnet $[Cu(pyz)_2(HF_2)]PF_6$ — •Mykhaylo Ozerov — Hochfeld-Magnetlabor Dresden (HLD), Forschungszentrum Dresden - Rossendorf, Dresden, Germany

We report on electron spin resonance, high-field magnetization, and specific-heat studies of $[Cu(pyz)_2(HF_2)]PF_6$ single crystals, identified as a quasi-two-dimensional spin-1/2 Heisenberg antiferromagnet. Our measurements revealed $J_{inter}/J_{intra} \leq 0.063$ and $A/J \sim 0.003$, where J_{inter}, J_{intra}, J are the interplane, intraplane and mean exchange interactions, respectively, and A is the anisotropy constant. It is argued that the magnetic properties of this material (including high-magnetic-field magnetization and the temperature-field phase diagram) are strongly affected by two-dimensional spin fluctuations, despite of onset of 3D long-range magnetic ordering at $T_N \approx 4.4$ K. The ESR magnetic excitation spectrum in the 3D ordered phase is studied in detail.

The work was made in collaboration with E. Čižmár, R. Beyer, M. Uhlarz, Y. Skourski, S.A. Zvyagin J. Wosnitza, J.L. Manson, J.A. Schluter.

MA 33.52 Fri 11:00 Poster B1

Stability of ferromagnetic order in monoatomic transition-metal nanowires : A first-principles study of the effective exchange interactions between local moments — •Muhammad Tanveer, Pedro Ruiz Diaz, and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Heinrich Plett Straße 40, 34132 Kassel, Germany

A first principles study of the stability of the magnetism in transition-metal (TM) nanowires (NW) is presented. Constrained spin moment calculations of the effective exchange interactions between local moments in V, Fe and Co nanowires are performed in the framework of a generalized gradient approximation (GGA) to density-functional theory (DFT). In the case of V wires, ferromagnetic (FM) order is stable at the equillibrium nearest neighbor (NN) distance of the free standing wire. However, very small changes in the NN distance render FM order unstable. A transition from FM to spiral spin-density wave (SDW) order is found upon a contraction of about 1%. This remarkable result is interpreted in terms of the distance dependance of the effective exchange intractions J_{ij} between first, second, and third NN moments. Results are also given for the electronic density of states as a function of wave vector q of the spiral SDW state, which could be observed in STM experiments. Finally, the V results are contrasted with ongoing studies on Fe and Co wires.

MA 33.53 Fri 11:00 Poster B1

Magnetic fluctuations in FeRh. — •Leonid Sandratskii — Max Planck Institute of Microstructure Physics, Halle, Germany

FeRh experiences a first-order phase transition antiferromagnet-ferromagnet at about 350 K and can be treated as a natural magnetic multilayer system where large magnetoresistance can be easily realized. Recent time-resolved pump and probe experiments have shown an ultra-fast transition to the ferromagnetic state within femtosecond time scale. Despite much efforts devoted to the study of FeRh the nature of the phase transition remains the matter of debates. Although it is now clear that the Rh moments play crucial role in the stabilization of the ferromagnetic phase there is no consensus with respect to the selection of the magnetic degrees of freedom to describe the thermodynamical equilibruium. Some researches assume that the Rh moments

are uniquely determined by the Fe environment and therefore should not be considered as separate degrees of freedom. Other groups consider the Rh moment as a separate Heisenberg or Ising variable. We use density-functional theory to study the spectrum of magnetic excitations in FeRh. Both transversal and longitudinal atomic fluctuations are considered. The study provides deeper insight into the nature of the Rh moment and the connection between the fluctuations of the Fe and Rh magnetization.

MA 33.54 Fri 11:00 Poster B1

Electrophysical and magnetoresistivity properties of granular multilayers based on Co, Ag, Au and Cu — •Dmytro Kutnyakhov[1], Sergej Nepijko[1], Iryna Cheshko[2], Larysa Odnodvorets[2], Nataliya Shumakova[2], Gerd Schönhense[1], and Ivan Protsenko[2] — [1]Institute of Physics, University Mainz, 55099, Mainz, Germany — [2]Sumy State University, 40007, Sumy, Ukraine

Aiming at a possible use as functional spintronics elements, we study the structural and electrical properties of thin films with spin-depending scattering of electrons based on Co nanoparticles embedded in a matrix of Ag, Au and Cu. Correlations of structure with electrophysical and magnetoresistive properties of these systems are shown, in particular for two- and multilayer films of metastable solid solutions (s.s.) of Ag/Co, Au/Co and Cu/Co. For the systems based on Cu/Co s.s. formed during condensation and partially disintegrated after annealing up to 700 K. For the systems based on Ag/Co or Au/Co s.s. formed during annealing near 700 K, whereas in non-annealed films no s.s. forms. In all systems grains of hcp-Co with 10 nm average size are observed. Formation of s.s. gives rise to change of resistivity, thermal coefficient of resistivity, gauge factor, and magnetoresistance. In the as-grown films no magnetoresistance was observed. After annealing up to 700 K a magnetoresistance of about 0.7% for Ag/Co and 0.4% for Au/Co systems was observed. This change was related with stabilization of granular state of hcp-Co in the matrix. Project funded by BMBF (UKR 08/022) and by Graduate School of Excellence MAINZ (D.K.)

MA 33.55 Fri 11:00 Poster B1

Magnetic and structure studies on thin films of co-evaporated Heusler compounds — •Jan Rogge, Fabian Schmid-Michels, and Andreas Hütten — Thin Films and Physics of Nanostructures, Department of Physics, Bielefeld University, Universitätsstr. 25, 33615 Bielefeld, Germany

Heusler compounds are promising candidates for spinelectronic devices like magnetic sensors or MRAM because of their unique magnetic properties. High Curie temperatures and low coercive fields, an indispensable pair for most applications, attract more and more attention to these materials. Above all the theoretically predicted 100% spin polarization [1] of many Heusler compounds shows great promise for reaching high MR ratios with magnetic tunnel junctions containing ferromagnetic Heusler electrodes.

We grow Heusler thin films by molecular beam epitaxy (MBE) co-evaporation, which enables us to produce alloyed Heusler layers with various compositions. We will present magnetic and structure studies on co-evaporated thin films of different Heusler compounds. The impact of stoichiometric variations on the examined properties will further be discussed.

[1] R.A. de Groot, F.M. Mueller, P.G. van Engen and K.H.J. Buschow, Phys. Rev. Lett. 50 (1983) 2024

MA 33.56 Fri 11:00 Poster B1

Magnetic anisotropy of (Ga,Mn)As epitaxial layers on GaAs — •Sergiy Mankovsky, Svitlana Polesya, and Hubert Ebert — Dept. Chemie und Biochemie/Phys. Chemie, Universität München, Butenandtstr. 11, D-81377 München, Germany

A study of the magnetic anisotropy of (Ga,Mn)As film deposited on GaAs substrate have been performed using the fully-relativistic spin-polarised KKR Green's function method. Experimentally observed in-plane magnetic anisotropy exhibiting two-fold and four-fold symmetry at different temperatures is attributed particularly to the effects of lattice relaxation caused by the mismatch of GaAs and (Ga,Mn)As lattice parameters. In present work we have investigated the effect of tetragonal distortion in (Ga,Mn)As and the role of the (Ga,Mn)As/GaAs interface for the magnetic anisotropy as a function of the Mn concentration. Preliminary results suggest that the anisotropic exchange interaction contribute to the magnetic anisotropy as well in an appreciable way.

MA 33.57 Fri 11:00 Poster B1

Fabrication of CNT-based devices for spin transport measurements — •Caitlin Morgan, Karin Goss, Carola Meyer, and Claus Michael Schneider — Institute of Solid State Research, Electronic Properties, Forschungszentrum Jülich, 52425 Jülich, Germany

Due to their excellent electronic properties, carbon nanotubes (CNTs) are a material of interest in future computing applications. CNTs have been shown to exhibit ballistic transport, which is interesting for quantum transport studies. Furthermore, small spin-orbit interactions and relatively few spin nuclei (13C) allow for slow spin relaxation through carbon nanotubes when electron spins are injected through ferromagnetic contacts, making CNTs interesting for the field of spintronics.

Contacting CNTs for spin-injection purposes has presented a challenge because of poor interfaces and high contact resistivity between carbon and most ferromagnetic materials. In this work, cobalt-palladium alloys were studied to determine an optimal material for ferromagnetic contacts to CNTs. The alloys were tested via atomic force microscopy (AFM), x-ray diffraction (XRD), x-ray reflectivity (XRR), and magneto-optic Kerr effect (MOKE) experiments. Samples of contacted CNTs have been fabricated for quantum transport and spin injection measurements, performed in a cryostat. Initial results are discussed. As a long-term goal, we hope to be able to do transport measurements, Raman spectroscopy, and transmission electron microscopy (TEM) all on one CNT in order to determine the effects of chirality or number of walls on a CNTs electronic properties.

MA 33.58 Fri 11:00 Poster B1

Current-induced domain wall motion: Separating spin torque and Oersted-field effects in Co/Pt nanowires — •Jan Heinen[1], Olivier Boulle[1], Kevin Rousseau[1], Gregory Malinowski[1], Mathias Kläui[1], Henk J. Swagton[2], Bert Koopmans[2], Christian Ulysse[3], and Giancarlo Faini[3] — [1]Universität Konstanz, Fachbereich Physik, D-78457 Konstanz, Germany — [2]Eindhoven University of Technology, Department of Applied Physics, MB 5600, Netherlands — [3]CNRS, Phynano team, Laboratoire de Photonique et de Nanostructures, 91460 Marcoussis, France

We report on magnetotransport studies on perpendicularly magnetized nanowires with narrow domain wall (DW) structures. Using Co/Pt multilayer nanowires, we have previously shown that Joule heating is concealing most of the current induced domain wall effects, but using a constant sample temperature a large non-adiabacity factor β has been deduced[1]. Here, we carry out experiments for both applied field directions and current polarities, starting from different DW configurations within a Hall cross. We clearly show, using the different symmetries of spin torque and Oersted-field, that the much debated Oersted-field does not contribute to the DW depinning significantly. This allows us to extract the spin torque contribution and the non-adiabacity factor β, which turns out to be in line with previous measurements.

References: [1] O. Boulle et al., Phys. Rev. Lett. 101, 216601 (2008).

MA 33.59 Fri 11:00 Poster B1

Resistance tuning of GMR devices via domain wall motion — •Jana Münchenberger, Patryk Krzysteczko, Günter Reiss, and Andy Thomas — Bielefeld University, Department of Thin Films and Physics of Nanostructures, Universitätsstr. 25 33615 Bielefeld

We have investigated the possibilities of adjusting the resistance of a stuctured GMR system by controlling domain wall motion. The bottom pinned GMR systems are prepared by dc sputtering through a magnetic mask and are structured via e-beam lithography after the deposition. We obtain stripes with a length of 1μm and a width of 200nm. Depending on the used GMR stack we get GMR ratios up to 6% as prepared.

In such a long spin valve structure we expect domain wall movement in the free layer and the resistance of the device depends on the domain-wall position. In a first approach we want to control the domain-wall position with an applied magnetic field while on long terms we aim to control the resistance only with current induced domain wall motion.

MA 33.60 Fri 11:00 Poster B1

Imaging of field induced domain wall excitation in permalloy nanowires — Jan Rhensius[1,2], •Daniel Rüffer[2], Lutz Heyne[2], Stephen Krzyk[2], Laura Jane Heyderman[1], Frithjof Nolting[1], and Mathias Kläui[2] — [1]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [2]Fachbereich Physik, Universität Konstanz, Universitätsstr. 10, D-78457 Konstanz, Germany

We present time resolved imaging of the spin structure of a magnetic head-to-head DW induced by an applied magnetic field pulse, using a pump-probe X-ray photoemission electron microscopy technique to determine the origin of the inertia. We find a clear inertia for the DW leading to a time lag between the field pulse and the reaction of the wall of 200 ps. By direct time-resolved magnetic imaging, we find that this is due to a change in the wall spin structure that stores exchange energy. This is caused by a transfer of Zeeman energy to exchange energy, for which the wall acts as a reservoir and this leads to an effective inertia of the wall (effective wall mass). We also see an oscillation of the DW around its equilibrium position after the excitation is switched off. Assuming a harmonic oscillator, an effective DW mass of $1.3 \cdot 10^{-24}\,kg \pm 1 \cdot 10^{-25}\,kg$ can be determined for the wall. This effective mass of our quasi particle is in line with results of micromagnetic simulations and with measurements that use transport techniques to determine the oscillation frequency.

MA 33.61 Fri 11:00 Poster B1

Depinning behaviours of domain walls at artificial notches in GMR nanostrips — •Björn Burkhardt[1], Sascha Glathe[1], Roland Mattheis[1], and Jeffrey McCord[2] — [1]IPHT Jena, Albert-Einstein-Str. 9, 07745 Jena — [2]IFW Dresden, Helmholtzstr. 20, 01069 Dresden

Domain wall (dw) motion can be described by the Landau-Lifshitz-Gilbert equation. During the motion, the dw can be trapped in local energy minima. Such a local energy minimum can be created by an artificial notch. The pinning behaviour of a dw at the notch (30% in depth of the stripe width) was measured in long narrow nanostrips (width=500nm, length=30um) using the giant magneto resistance between a sense layer (NiFe - 10nm thick) and a reference layer (CoFe - part of an AAF/AF-combination). We examine the pinning process in dependence of a longitudinal and a transverse magnetic field. The depinning of the dw occurred under a specified longitudinal field. Below this critical field we found a reversible change of the resistance as a result of a dw, elongated in the longitudinal direction, which is still partly pinned at the pinning site. Decreasing the field to zero, the elongated dw relaxes to the starting configuration. This behaviour is analyzed by magneto-optical Kerr-measurements and confirmed by means of micro magnetic simulations.

MA 33.62 Fri 11:00 Poster B1

Current-induced domain-wall depinning in substractive argon-sputtered permalloy nanowires — •Sedat Dogan, Gesche Nahrwold, Lars Bocklage, Toru Matsuyama, Ulrich Merkt, and Guido Meier — Institut für Angewandte Physik, Jungiusstr. 11, 20355 Hamburg

The realization of magnetic race-track memory [1] requires a good understanding of domain-wall dynamics. Domain-wall motion in permalloy nanowires can be achieved by current induced spin-transfer torque [2]. We detect depinning of a domain wall in a curved permalloy by the anisotropic magnetoresistance. One important aim is to lower the depinning fields and to get reliable depinning behavior of the domain walls. This can be achieved by an improved quality of the ferromagnet by sputtering permalloy onto heated substrates [3]. Another important aspect is the reduction of the edge roughness of the permalloy nanowires, which play an important role in the depinning process. Different fabrication techniques like lift-off processing, substractive argon plasma-sputtering and wet-etching are used to prepare wires. They are contacted by coplanar waveguides and measured in a high-frequency setup. Results of the differently prepared samples are compared in terms of depinning fields and depinning efficiency. [1] S. S. P. Parkin et al., Science **320**, 190 (2008), [2] J. C. Slonczewski et al., J. Magn. Magn. Mat. **159** (1996), [3] G. Nahrwold et al., J. Appl. Phys. **105** , 07D511 (2009)

MA 33.63 Fri 11:00 Poster B1

Field-pulse exited precessional motion — •Stefan Buschhorn[1], Jie Li[2], Min-Sang Lee[2], Björn Redeker[2], and Thomas Eimüller[2,3] — [1]Institut für Experimentalphysik IV, Ruhr-Universität Bochum, 44780 Bochum — [2]Junior Research Group Magnetic Microscopy, Ruhr-Universität Bochum, Universitätsstr. 150, D-44780 Bochum, Germany — [3]Hochschule Kempten, University of Applied Sciences, Bahnhofstr. 61, D-87435 Kempten, Germany

Recently we presented a high spatial and temporal resolution fs laser system using an all-optical approach to study magnetisation dynamics [1]. This setup has now been extended to enable magnetic field pulse excitation as well. These two methods give similar information, however as we are using one laser system, we may be able to separate the effect of heating from the effect resulting in a change of the instantaneous magnetic field direction. We will present the new part of our setup and our first results measured with a series of FeNi alloy samples, including Py.

[1] J. Li, M. Lee, *et. al.*, Rev. Sci. Instr. **80**, 073703 (2009)

MA 33.64 Fri 11:00 Poster B1

Inductive Detection of Magnetic Vortex Gyration in Permalloy Squares — •Hauke Hendrik Langner, Lars Bocklage, Toru Matsuyama, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany

In micrometer-sized thin permalloy squares with a Landau-domain pattern a vortex core points out of the plane with two possible polarizations. High frequency fields or currents applied to the permalloy square excite the vortex to gyrate around the center. We propose a procedure to detect the gyration frequency and phase in such permalloy squares. A rectangular induction loop is deposited above the permalloy square so that the changes of the stray field of the gyrating vortex induce a periodic voltage. We expect an alternating voltage close to the resonance frequency of the vortex.

The method provides the possibility to detect magnetization dynamics of single microstructures.

MA 33.65 Fri 11:00 Poster B1

A sensor layer to magnify the magnetic vortex core — •Edward Prabu Amaladass[1], Vitalij Sackmann[1], Manfred Fähnle[1], Markus Weigand[1], Michael Curcic[1], Hermann Stoll[1], Joachim Albrecht[2], Bartel Van Waeyenberge[3], Tolek Tyliszcak[4], Georg Woltersdorf[5], and Gisela Schütz[1] — [1]MPI für Metallforschung, Stuttgart, Germany — [2]Hochschule Aalen, Germany — [3]Ghent University, Belgium — [4]ALS, LBNL Berkeley, CA, USA — [5]Universität Regensburg, Germany

Vortex core switching could be achieved by dynamic in-plane Oersted fields or spin torque excitations. Since the dimension of the vortex core is only about 10 - 20 nm in diameter, reading out the magnetization direction of the vortex core has been a hurdle for technological applications. We have found that a GdFe layer can act as a sensor for vortex core switching by magnifying significantly the lateral size of the out-of-plane magnetization. A GdFe layer, showing perpendicular anisotropy and coercivity fields of the order of mT, was used in a Permalloy (PY) - Al - GdFe multilayer system. By magnetic X-ray microscopy and by taking advantage of the element specificity of XMCD, the switching of the out-of-plane magnetization is observed at the Ni L3 and Gd M5 absorption edges. It could be demonstrated that by application of a magnetic RF burst of adequate amplitude and length the vortex core polarization in the PY layer is reversed. Consequently, the magnetization of the whole GdFe cover layer is also switched by the stray field of the tiny PY vortex core. This enabled us to detect the vortex core polarization by magneto-optical Kerr microscopy for the first time.

MA 33.66 Fri 11:00 Poster B1

Spin-wave eigenmodes in small magnetic disks in the vortex state — •Björn Obry, Katrin Vogt, Helmut Schultheiss, Philipp Pirro, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern

We study the eigenmode spectrum of small magnetic permalloy disks with their magnetization in the vortex state. Brillouin light scattering microscopy experiments yield different spin-wave eigenmode spectra, depending on the excitation geometry and the disk size. By means of an oscillating out-of-plane magnetic field only radial standing spin-wave modes can be excited directly. Furthermore it is observed that mode coupling induces an indirect excitation of some azimuthal eigenmodes, the latter being expected for an in-plane excitation only.

Sample preparation by the Nano+Bio Center of the Technische Universität Kaiserslautern and financial support by the Graduiertenkolleg 792 is gratefully acknowledged.

MA 33.67 Fri 11:00 Poster B1

Proposal of a robust measurement scheme for the non-adiabatic spin torque using the displacement of magnetic vortices — •Benjamin Krüger[1], Massoud Najafi[2,3], Stellan Bohlens[1], Robert Frömter[3], Dietmar Möller[2], and Daniela Pfannkuche[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg — [2]Arbeitsbereich Technische Informatik Systeme, Univer-

sität Hamburg — [3]Institut für Angewandte Physik, Universität Hamburg

A spin-polarized current flowing through a ferromagnetic sample exerts a spin-torque on the local magnetic moments. This interaction can be described by adding two current-dependent torque terms to the Landau-Lifshitz-Gilbert equation.[1] The strength of the non-adiabatic spin torque is under debate since measurements differ by one order of magnitude.

A vortex in a micro- or nanostructured magnetic thin-film element is a promising system for the investigation of the spin-torque effect. It is known that vortices are displaced from their equilibrium position when excited by spin-polarized electric currents. The spatial confinement of the vortex core within the film element yields an especially accessible system for measurements. Based on analytical calculations[2] it is possible to derive a robust scheme which allows to measure the contributions due to the adiabatic spin torque, the non-adiabatic spin torque, and the Oersted field separately.

[1] S. Zhang and Z. Li, Phys. Rev. Lett. 93, 127204 (2004)
[2] B. Krüger et al., Phys. Rev. B 76, 224426 (2007)

MA 33.68 Fri 11:00 Poster B1

Spin-transfer torque in MgO based tunnel junctions for different magnetic materials — •Christian Franz and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany

We use the non-equilibrium Keldysh formalism implemented in the Korringa-Kohn-Rostoker Green's function method [1] to calculate the spin-transfer torque in MgO based tunnel junctions. In particular, we discuss the bias voltage dependence of the torque for different magnetic materials. We investigate Fe, Co, and FeCo leads. For pure Fe leads our calculations of the spin-transfer torque [2] show excellent quantitative agreement with experimental observation. Furthermore, our results show the importance of the Δ_1 band gap in the ferromagnetic materials. There is a drastic change in the bias dependence of the spin-transfer torque if the applied bias voltage is larger than the Δ_1 band gap.

[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 33.69 Fri 11:00 Poster B1

Influence of band parameters on spin-transfer torque in tunnel junctions: model calculations — •Asma Heena Khalil and Christian Heiliger — . Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany

Investigations of the spin-transfer torque in magnetic tunnel junctions have come into focus of current research because these devices are a basis of magnetic random access memories (MRAM). In particular, one is interested in the bias voltage dependence of this torque. For a Fe/MgO/Fe system our ab initio calculations [1] are supported by experimental data [2] where the bias dependence seems to be linear. On the other hand results of simple-band model calculations show deviations from this behavior [3]. In this contribution we study the in-plane spin-transfer torque in magnetic tunnel junctions for different band fillings and exchange splittings. For parameters that reproduce the important features of the Fe band structure, the results are in agreement with experimental data as well as with ab initio calculations.

[1] C. Heiliger and M.D. Stiles, Phys. Rev. Lett. 100, 186805 (2008).
[2] J. C. Sankey, Y.-T. Cui, J. Z. Sun, J. C. Slonczewski, R. A. Buhrman, D. C. Ralph, Nature Phys. 4, 67, 2008
[3] I. Theodonis, N. Kioussis, A. Kalitsov, M. Chshiev, and W. H. Butler, Phys. Rev. Lett. 97, 237205 (2008).

MA 33.70 Fri 11:00 Poster B1

Temperature-Induced Magnetic Switching in Finite Chains — •David Bauer, Samir Lounis, Phivos Mavropoulos, and Stefan Blügel — Institut für Festkörperforschung and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

Understanding spin dynamics in magnetic nanostructures is important for applications in data storage. In particular the bistability of the magnetic state can lead to spontaneous switching and data loss at finite temperatures. For its investigation we adopt an approach on the basis of a classical spin model coupled to a heat bath. This requires the solution of the stochastic Landau-Lifschitz equations.

We apply this model to study the temperature-induced magnetic switching behavior of finite chains on surfaces. Different switching types are found, depending on the chain length, the exchange coupling constants and the magnetocrystalline anisotropy. A switch can occur either by coherent magnetization rotation, which is well described by an Arrhenius-Néel-law, or by a domain wall propagating through the chain after nucleation. We show that the domain-wall type of switching can be described by a combination of a random walk model and a modified Arrhenius-Néel-law. Furthermore, a possible strong increase of the anisotropy at the chain edges influences the switching time under certain contitions, related to the creation of an additional energy barrier acting against nucleation.

MA 33.71 Fri 11:00 Poster B1

Interaction of two magnon condensates — •Vitaliy I. Vasyuchka[1], Alexander A. Serga[1], Christian W. Sandweg[1], Andrii V. Chumak[1], Timo Neumann[1], Björn Obry[1], Helmut Schultheiss[1], Gennadiy A. Melkov[2], Andrei N. Slavin[3], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Radiophysics, National Taras Shevchenko University of Kiev, Ukraine — [3]Department of Physics, Oakland University, Rochester, MI, USA

The interaction of two magnon condensates was studied by means of time-resolved Brillouin light scattering spectroscopy in a tangentially magnetized yttrium-iron-garnet film at room temperature. Both condensates were created using parametric microwave pumping. Firstly, the pump action results in the injection of phase correlated magnon pairs at half of the pumping frequency. Thus a condensate of photon coupled magnons arises. Secondly, a Bose-Einstein condensate (BEC) of magnons is formed at the lowest energy state [1]. We show that the interaction of these two condensates leads to distortion of the BEC of magnons due to scattering on the condensate of magnon pairs. Shortly after the pumping is switched off this distortion vanishes and the BEC signal increases drastically. Applying a second probing pump pulse during the pump-free evolution of the BEC of magnons results in the restoration of the condensate of magnon pairs and consequently in a sharp slump of the BEC signal. Financial support by the DFG (SFB/TRR 49). [1] S.O. Demokritov et al., Nature **443**, 430 (2006).

MA 33.72 Fri 11:00 Poster B1

Broadband spin-wave spectroscopy on permalloy plain films at low temperature — •Florian Brandl, Sebastian Neusser, Georg Dürr, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Straße 1, D-85747 Garching b. München, Germany

We investigate spin wave propagation in $Ni_{80}Fe_{20}$ (permalloy) thin films. Using, both, the vector network analyzer ferromagnetic resonance (VNA-FMR) and propagating spin wave spectroscopy (PSWS) techniques we perform temperature dependent measurements on permalloy thin films. An external magnetic field of up to 2.5 T is applied along the growth direction of the thin films. We study resonance frequencies and damping of standing and propagating spin waves from helium to room temperature. We report data obtained in the time and frequency domain using PSWS and VNA-FMR, respectively. We acknowledge financial support through the German excellence cluster "Nanosystems Initiative Munich".

MA 33.73 Fri 11:00 Poster B1

Micro-stripline mediated emission and detection of spin wave propagation in permalloy thin films — •Klaus Thurner, Georg Dürr, Sebastian Neusser, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Straße 1, D-85747 Garching b. München, Germany

We report spin-wave propagation experiments performed on ferromagnetic $Ni_{80}Fe_{20}$ (permalloy) thin films in the frequency domain. Spin waves are induced and detected by a pair of collinear coplanar waveguides (CPWs) connected to a broadband vector network analyzer. Tailored designs of both emitter and receiver CPWs for efficient and predefined spin-wave excitation are investigated. Electromagnetic impedance matching and wave vector matching to the spin-wave dispersion relation of permalloy are taken into account. The measurements are performed at room temperature with an in plane magnetic field applied in different directions. We acknowledge financial support through the German excellence cluster "Nanosystems Initiative

Munich".

MA 33.74 Fri 11:00 Poster B1

Spin-wave quantization in a thermal well — •Sebastian Schäfer, Helmut Schultheiss, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We report on micromagnetic simulations of two-dimensional spin-wave quantization caused by a local reduction of the saturation magnetization M_S, using the OOMMF code [1]. This reduction models the effect of a heat gradient in a 10 nm thin Permalloy film as could be caused by nanometer-sized point contacts with high current densities as well as a focused laser beam of high intensity. It is therefore called *thermal well*. We found high-intensity spin-wave excitations confined to the area of the *thermal well*. Those modes exhibit frequencies distinctively different from the spin-wave band of the thin Permalloy film. The quantization effects apparently are not – as in previous investigations [2] – governed by the geometrical confinement or demagnetization fields but only by the modified saturation magnetization. The nature of these modes as well as the dependence on the depth and width of the *thermal well* will be discussed.

[1] M. J. Donahue, and D. G. Porter, Report NISTIR 6376, National Institute of Standards and Technology, Gaithersburg, MD (1999).

[2] J. Jorzick, S.O. Demokritov, B. Hillebrands, M. Bailleul, C. Fermon, K.Y. Guslienko, A.N. Slavin, D.V. Berkov, N.L. Gorn, Phys. Rev. Lett. **88**, 047204 (2002).

MA 33.75 Fri 11:00 Poster B1

Spin-wave excitation in magnetic nano hybrid structures — Christopher Rausch, Sebastian J. Hermsdörfer, Philipp Pirro, Helmut Schultheiss, •Britta Leven, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We present a micromagnetic study of artificial spin-wave excitation in magnetic nano hybrid structures in order to identify reliable spin-wave sources for experimental application. A variety of magnetic hybrid structures have been investigated, either hybrid structures built of different materials or hybrid structures built of differently shaped elements of the same material. First we investigated NiFe nanowires combined with a periodic array of Cu lines crossing the magnetic layer. When we pass a DC current through this Cu/NiFe hybrid structure, propagating spin waves are excited due to the periodic modification of the internal magnetic field caused by the Cu lines. Second we studied the spin-wave emission of resonantly excited domain walls in cross-type and T-type NiFe wires. Applying an AC current to the structures, spin-wave excitation can be observed. The advantage of the T-type structure is that the spin waves propagate in the current free arm of the structure in contrast to the cross-type structure thus offering a more universal spin-wave source for further experiments. We acknowledge financial support by the DFG.

MA 33.76 Fri 11:00 Poster B1

Spin wave propagation in permalloy antidot lattices — •Georg Dürr, Sebastian Neusser, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Straße 1, D-85747 Garching b. München, Germany

We present spin-wave spectroscopy data obtained on $Ni_{80}Fe_{20}$ (permalloy) thin films with periodic arrays of holes (antidot lattices). Samples are prepared using focused ion beam (FIB) etching and optical lithography. The periods of holes with a diameter of 100 nm vary between 400 nm and 800 nm. Spatially separated coplanar waveguides used for all-electrical emission and detection of spin waves are integrated into the samples. Propagating spin wave spectroscopy and pulsed inductive microwave magnetometry measurement techniques are used in frequency and time domain, respectively. Propagating spin wave modes are compared to both reflected spin wave modes and micromagnetic simulations. We focus on small in-plane magnetic fields where the propagating spin wave modes exhibit a complex angular dependence due to the inhomogeneity of both the demagnetization fields and domain configuration. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under Grant Agreement n°228673 and the German excellence cluster "Nanosystems Initiative Munich (NIM)".

MA 33.77 Fri 11:00 Poster B1

Ultrafast Magnetization Dynamics of Fe and Fe Alloys Investigated with Time-Resolved X-ray Spectroscopy — •Andrea Eschenlohr[1], Christian Stamm[1], Niko Pontius[1], Torsten Kachel[1], Ilie Radu[2], and Hermann A. Dürr[1] — [1]Helmholtz Zentrum Berlin für Materialien und Energie, Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, 12489 Berlin — [2]Radboud University Nijmegen, Heijendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

The microscopic processes behind laser induced ultrafast demagnetization of ferromagnetic materials are still only partially understood [1, 2]. One particular issue is the femtosecond demagnetization of permalloy, which was shown to proceed much faster than that of pure Ni and Fe in all-optical experiments [2]. At the BESSY II Femtoslicing beamline, we measure x-ray magnetic circular dichroism with a time resolution of 100 fs, which enables us to study laser induced ultrafast demagnetization in an element specific way. Additional x-ray absorption measurements reveal transient, laser induced changes in the electronic structure, visible at the Fe L-edges. We discuss the results in context with previous work on Ni [3].

[1] B. Koopmans et al., Phys. Rev. Lett. 95, 267207 (2005); [2] I. Radu et al., Phys. Rev. Lett. 102, 117201 (2009); [3] C. Stamm et al., Nature Mater. 6, 740 (2007).

MA 33.78 Fri 11:00 Poster B1

Ultrafast Demagnetization in Heisenberg Ferromagnets — •Marko Wietstruk[1], Torsten Kachel[1], Niko Pontius[1], Christian Stamm[1], Hermann A. Dürr[1], Wolfgang Eberhardt[1], Cornelius Gahl[2], Martin Weinelt[2,3], Alexey Melnikov[3], and Uwe Bovensiepen[4] — [1]Helmholtz-Zentrum Berlin, BESSYII — [2]Max-Born-Institut Berlin — [3]Freie Universität Berlin, FB Physik — [4]Universität Duisburg-Essen, FB Physik

Gd and Tb are typical Heisenberg ferromagnets, consisting of RKKY-coupled localized $4f$ moments and polarized $5d$ valence electrons. In our time-resolved x-ray magnetic circular dichroism (TR-XMCD) experiment we excite the valence electrons with a 50 fs laser pulse and probe the $4f$ moment using 100 fs x-ray pulses from the BESSY II femtoslicing source.

In Gd we found two distinct demagnetization processes. The first, occurring on a 1 ps timescale, coincides with the relaxation of hot electrons via electron-phonon scattering. This supports the theory of demagnetization via Elliott-Yafet type spin-flip scattering [1]. As the process persists much longer than the laser pulse, a demagnetization by coherent laser excitation is unlikely [2]. The second process with a time constant of 40 ps in Gd is attributed to spin-lattice relaxation [3]. In Tb we found a much faster time constant of <5 ps, as expected from theory [3].

[1] B. Koopmans et al., PRL **95**, 267207 (2005)
[2] G.P. Zhang & W. Hübner, PRL **85**, 3025 (2000)
[3] W. Hübner & K.H. Bennemann, PRB, **53**, 3422 (1996)

MA 33.79 Fri 11:00 Poster B1

Magnetization dynamics control of a single ferromagnetic nanoparticle subjected to ultra-short magnetic fields — •Alexander Sukhov and Jamal Berakdar — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Str. 4, 06120 Halle/Saale

We consider theoretically the magnetization dynamics of a single ferromagnetic nanoparticle driven by ultra-short magnetic pulses. The macrospin approximation is employed based on a finite-temperature Landau-Lifshitz-Gilbert equation. For the case when the magnetic pulse duration is shorter than the field-free precessional period of the magnetization we utilize the local control theory [1] to obtain analytical expressions for the appropriate fields parameters that lead to swift magnetization switching or freezing [2]. The quality of this approximation and the reliability of the analytical expressions are endorsed by full numerical calculations that confirm our predictions. As an application we show how thermally assisted switching is realized by choosing the appropriate field parameters [3].

In the studies [2,3] the scheme was restricted to the case where the external fields were aligned in the plane perpendicular to the easy axis of the anisotropy. Recently we extended our study to the case where the field is applied at an arbitrary direction in space.

[1] R. Kosloff, A. D. Hammerich, D. Tannor, Phys. Rev. Lett. 69, 2172 (1992); [2] A. Sukhov and J. Berakdar, Phys. Rev. Lett. 102, 057204 (2009); [3] A. Sukhov and J. Berakdar, Phys. Rev. B 79, 134433 (2009).

MA 33.80 Fri 11:00 Poster B1

Optical detection of magnetoelastic interaction in a magnetic film — •Christian W. Sandweg, Benjamin Jungfleisch, Vitaliy I. Vasyuchka, Björn Obry, Helmut Schultheiss, Alexander A. Serga, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

The technique of parametric microwave pumping plays an important role for transferring energy to magnon systems. In the case of longitudinal pumping, when the microwave magnetic field is parallel to the bias magnetic field, a microwave photon splits into two magnons with half of the pumping frequency and opposite wave-vector. The exact spectral definition of the magnon groups created hereby is crucial for the deeper understanding of the energy transfer into a magnon gas and further applications. Here we report on the wave-vector sensitive detection of the magnons at half of the pumping frequency by means of Brillouin light scattering spectroscopy. We measured the wave number of these magnons from 0 to $1.75 \cdot 10^5$ cm^{-1} in a range of the bias magnetic field from 1560 to 1680 Oe. We present the experimental evidence of hybridization of parametrically pumped magnons with acoustic waves in Yttrium-Iron-Garnet films used in our experiment.

MA 33.81 Fri 11:00 Poster B1

Magnetotransmission of surface acoustic waves at the nickel / lithium niobate interface — •C. Heeg[1], M. Weiler[1], H. Söde[1], A. Brandlmaier[1], R. Huber[2], D. Grundler[2], M. S. Brandt[3], R. Gross[1], and S. T. B. Goennenwein[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik Department, TU München, 85748 Garching, Germany — [3]Walter Schottky Institut, TU München, 85748 Garching, Germany

Surface Acoustic Waves (SAWs) have found vast scientific interest in the past decades, mainly due to their application as bandpass filters for e.g. mobile phones. SAWs at ferromagnetic/piezoelectric interfaces can be used to investigate the interaction between mechanical waves and magnetic degrees of freedom.

We generate SAWs at a center frequency of 170 MHz on $LiNbO_3$ substrates by lithographically defining a delay line of two identical, single-finger interdigital transducers spaced approximately 500 μm apart. An approximately 50 nm thick and 100 μm wide nickel Hall bar is then deposited in the SAW propagation path. In these samples we have investigated the correlation between the DC magnetoresistance $R(H)$ in the Hall bar and the high frequency SAW transmission as a function of an applied magnetic field. We find that the SAW damping and velocity $\mathbf{S}_{21}(H)$ is dependent on the magnetization in the ferromagnetic thin film as evidenced by coinciding switching fields in $\mathbf{S}_{21}(H)$ and $R(H)$.

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MA 33.82 Fri 11:00 Poster B1

Construction of a SHG-FROG to characterize a laser amplifier system for higher harmonic generation (HHG) — •Nadine Keul, Patrik Grychtol, Roman Adam, and Claus M. Schneider — Institute of Solid State Research, IFF-9 "Electronic Properties", Research Center Juelich, D-52425 Juelich

Latest developments in nonlinear light sources are opening the door for employing ultra-short soft X-ray pulses in a laboratory environment and thus offering a compact tool for element-selective investigation of magnetic properties on a nanometer and femtosecond scale. To this end, ultrashort ($<$ 35 fs) laser pulses with peak-pulse energies exceeding 1 mJ are focused into a localized inert gas plasma generating higher harmonics (HHG) of the fundamental laser frequency. By this means ultrashort ($<$ 1 fs) coherent soft X-ray pulses with energies of up to 100 eV can be generated with moderate effort. The conversion efficiency depends on the special character (length, dispersion, amplitude, etc.) of the driving laser pulse. To characterize the pulse parameters of the amplifier system we assembled a SHG-FROG (Second Harmonic Generation - Frequency Resolved Optical Gating) set-up and investigated the HHG conversion efficiency depending on the shape of the laser pulse employing a X-ray CCD camera.

MA 33.83 Fri 11:00 Poster B1

Ab initio calculations of the electronic transport in MnAs nanoclusters — •Michael Czerner, André Simon, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany

Magnetic MnAs nanoclusters can be grown on a GaAs substrate in a controlled manner [1]. Such structures can be used to construct planar magnetic devices for spintronic applications. We perform ab initio calculations by means of the non-equilibrium Keldysh formalism implemented in the Korringa-Kohn-Rostoker Green's function method [2]. We study the spin-dependent transport of MnAs in the hexagonal NiAs structure along different crystallographic directions. Furthermore we discuss in detail the transport through interfaces formed by two MnAs clusters with different magnetic domains. We found a very large magnetoresistance ratio above 200% while the spin polarization is low, which is originated by the different Fermi surface topologies of the two spin channels.

[1] S. Ito, S. Hara, T. Wakatsuki and T. Fukui, Appl. Phys. Lett. 94, 243117 (2009)
[2] C. Heiliger, M. Czerner, B. Yu. Yavorsky, I. Mertig, M. D. Stiles, J. Appl. Phys. 103, 07A709 (2008)

MA 33.84 Fri 11:00 Poster B1

High frequency magnetotransport in ferromagnetic thin films — •M. Radlmeier, M. Weiler, H. Huebl, C. Heeg, A. Brandlmaier, R. Gross, and S. T. B. Goennenwein — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, D-85748 Garching

DC magnetotransport is an established technique to determine static magnetic properties of ferromagnetic thin films and to electrically read out magnetization states in nanostructures. As modern devices for information technology are operated at frequencies in the GHz regime, it is important to compare DC and HF transport characteristics. To gather further information on the physical mechanisms involved in HF magnetotransport, one needs to investigate and compare the temperature dependence of DC and HF transport as well. We have prepared Hall bars of Co and Ni thin films by optical lithography and electron beam evaporation. These are bonded onto slotted CPW carriers and then mounted on a magnet cryostat dipstick equipped with HF leads. This allows to measure DC and HF magnetotransport with 2 K$\leq T \leq$ 300 K and $\mu_0 H \leq$ 7 T. Furthermore, the sample can be rotated with respect to the magnetic field. A vector network analyzer is used to measure HF magnetotransport in a frequency range up to 8 GHz and the results are compared to DC magnetotransport measurements. While the DC magnetotransport provides information on static magnetic properties such as magnetization orientation and magnetic anisotropy, we discuss the features observed in HF magnetotransport in terms of giant magnetoimpedance and HF susceptibility.

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MA 33.85 Fri 11:00 Poster B1

Spin transport in a thin crystalline graphite flake — •Jose Barzola-Quiquia and Pablo Esquinazi — Abteilung Supraleitung und Magnetism, Universität Leipzig, 04103 Leipzig

Due to the large electron mobility and mean free path, thin crystalline graphite samples are expected to have some advantages for certain devices in comparison with single graphene layers fixed on dielectric substrates. In this work we have tested the spin transport on a 30 nm thick and several micrometer long single crystalline graphite flake using a spin-valve configuration with four ferromagnetic Co electrodes of different widths and several μm separation. A 5 nm thin Pt layer has been introduced in between the ferromagnetic Co injector/detector and the graphite surface. In spite of the conductivity mismatch problem, efficient electrical spin injection and detection in graphite has been achieved. The magnetoresistance in the local and half-local electrodes shows clear maxima with symmetry around zero field. The spin transport can be detected up to 150 K, the maximum temperature used.

MA 33.86 Fri 11:00 Poster B1

On the spin polarization of Co-Mn-Sb thin films — •Jan Schmalhorst, Markus Meinert, and Günter Reiss — Universität Bielefeld, Fakultät für Physik, Dünne Schichten und Physik der Nanostrukturen, 33615 Bielefeld

Thin Co-Mn-Sb films of different compositions were investigated and utilized as electrodes in alumina based magnetic tunnel junctions with CoFe counter electrode. The preparation conditions were optimized with respect to magnetic and structural properties. The Co-Mn-Sb / Al-O interface was analyzed by X-ray absorption spectroscopy and magnetic circular dichroism with particular focus on the elementspecific magnetic moments. Co-Mn-Sb crystallizes in different complex cubic structures depending on its composition. The magnetic moments of Co and Mn are ferromagnetically coupled in all cases. A tunnel magneto resistance ratio of up to 24% at 13K was found and indicates that Co-Mn-Sb is not a ferromagnetic half-metal. These re-

sults are compared to recent works on the structure and predictions of the electronic properties.

MA 33.87 Fri 11:00 Poster B1

Examination of spin currents in spin valve structures created by shadow lithography — •Andreas Lörincz[1], Jan Rhensius[1,2], Goran Mihajlović[3], Laura Heyderman[2], Axel Hoffmann[3], and Mathias Kläui[1] — [1]Universität Konstanz, 78462 Konstanz, Germany — [2]Paul Scherrer Institut, 5232 Villingen, Switzerland — [3]Argonne National Laboratory, Argonne, IL 60439-4806, USA

We investigate diffusive spin currents in copper conduits deposited on permalloy halfrings. The main focus on these investigations lies on the comparison with similar samples produced in a two-step lithography method. Structures created by the latter method experience surface oxidation due to exposure to air after the first deposition step, resulting in a contaminated interface. Standard characterizations for the magnetic and spin behaviour, such as GMR, nonlocal spin signal and Hanle measurements are presented in order to determine the differences between both deposition techniques. The effect of diffusive spin currents on magnetic domain walls due to strong surface torques on the magnetization of the affected material is discussed.

Considering the spin diffusion length, we compare these results with measurements on single- or multilayered graphene structures, which are a promising material as a spin conduit in future devices. To take advantage of the high spin diffusion length and the high electron mobility, the main challenge is to effectively inject spins into this two-dimensional conductor. A possible solution are tunnel barriers, which might lead to a larger injection efficiency.

MA 33.88 Fri 11:00 Poster B1

A variable-temperature ultra-high vacuum four-probe spin-polarized scanning tunnelling microscope — •Tobias Spitz, Shiro Yamazaki, Oswald Pietzsch, and Roland Wiesendanger — Institute of Applied Physics and Microstructure Advanced Research Center, University of Hamburg, Jungiusstraße 11, D-20355 Hamburg, Germany

A variable-temperature UHV four-probe spin-polarized scanning tunnelling microscope (SP-STM) is presented. The instrumental possibilities of a commercial system (Omicron's Nanoprobe) were substantially extended. Facilities for in-situ preparation of spin-polarized tips, as required for SP-STM and spin-resolved tunneling spectroscopy (SP-STS), were designed, built, and tested. An electron beam heating stage was constructed for removing surface oxides at the tip apex by flashing the tip to temperatures up to 2000K follwed by a subsequent magnetic thin film deposition process. It is a major challenge in transport experiments involving surface nanostructures to avoid leak currents through the underlying substrate. The necessary decoupling of the nanostructures and substrate can be achieved by a NaCl buffer layer as has been shown previously. The design of an appropriate home-built evaporator is presented.

MA 33.89 Fri 11:00 Poster B1

Transport properties of $La_{0.7}R_{0.3}MnO_3/SrTiO_3/La_{0.7}R_{0.3}MnO_3$ (R = Ca, Sr) magnetic tunnel junctions — •Patryk Nowik-Boltyk[1], Robert Werner[1], Lucero Alvarez[2], A. Yu. Petrov[2], Bruce A. Davidson[2], Reinhold Kleiner[1], and Dieter Koelle[1] — [1]Physikalisches Institut – Experimentalphysik II and Center for Collective Quantum Phenomena and their Applications, Universität Tübingen, Auf der Morgenstelle 14, D-72076, Germany — [2]INFM-TASC National Laboratory, Area Science Park, S.S. 14, Km 163.5, I-34012 Basovizza (TS), Italy

Half metals like the doped manganites $La_{0.7}Ca_{0.3}MnO_3$ (LCMO) and $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) are promising candidates for a very large tunneling magnetoresistance (TMR) effect due to their almost 100% spin-polarisation. However, weakening of the magnetic properties at the ferromagnet/insulator interfaces can cause a suppression of the TMR effect in magnetic tunnel junctions (MTJs) made of doped manganites. By introducing a doping profile in LRMO at the interface, the Mn valence can be controlled and the magnetization can be reinforced. We present results on the TMR in planar MTJs grown with different $SrTiO_3$ (STO) barrier thicknesses, as well as with different doping profiles within a few monolayers of LRMO at the interface. The LCMO trilayers were prepared using pusled laser deposition (PLD) while the LSMO trilayers were grown by molecular beam epitaxy (MBE). The MTJs where investigated in a temperature range $T = 4.2 - 300\,\mathrm{K}$ and characterized by differential conductance G vs voltage V and resistance R vs H measurements at different bias voltages.

MA 33.90 Fri 11:00 Poster B1

Measurements of the capacitance of magnetic tunnel junctions — •Ronald Lehndorff[1], Anna Gerken[1], Gerhard Jakob[2], Andreas Hütten[1], and Günter Reiss[1] — [1]Bielefeld University, D2 Physics, Bielefeld, Germany — [2]Mainz University, Institute of Physics, Mainz, Germany

Magnetic tunnel junctions (MTJ) based on CoFeB as ferromagnetic electrodes and MgO as insulating layer are important building blocks for current and future spintronics devices owing to their huge magnetoresistive effect. Electronically, they possess not only a resistive but also a capacitive component.

Here, we present a measurement setup build to evaluate the capacitance of MTJs in an external magnetic field using an ultra-precision capacitance bridge AH 2550 from Andeen-Hagerling, Inc. We show results measured on high-ohmic CoFeB/MgO MTJs with area resistances above 1 megaohm square micron and thoroughly discuss these and the precision of the measurements.

MA 33.91 Fri 11:00 Poster B1

Co/Pd multilayer based magnetic tunnel junctions with perpendicular magnetic anisotropy — •Zoë Kugler, Günter Reiss, and Andy Thomas — Bielefeld University, Department of Physics, Universitätsstr. 25, 33615 Bielefeld, Germany

Magnetic tunnel junctions with perpendicular magnetic anisotropy have recently attracted much attention due to their potential for higher storage densities and for reduced writing current densities in future magnetic memory applications. We present temperature dependent transport and magnetic measurements of MgO, Mg/MgO and Alumina based magnetic tunnel junctions with perpendicularly magnetized Co/Pd electrodes. The effect of annealing temperature, Co thickness in the lower and upper electrode and number of Co/Pd bilayers on the magnetoresistance were investigated. In order to characterize the electrodes we have calculated the volume and interface anisotropy from magnetic measurements with respect to the annealing temperature and the number of Co/Pd bilayers.

MA 33.92 Fri 11:00 Poster B1

Preparation and characterization of sputtered CoFeB/MgO/CoFeB-based TMR magnetic tunnel junctions (MTJs) — •Neda Sadrifar and Ulrich Herr — Institut für Mikro- und Nanomaterialien, Universität Ulm, 89081 Ulm

Magnetic tunnel junctions with crystalline (001)-oriented MgO tunnel barrier recently lead to achievement of extremely large tunneling magnetoresistance ratios (TMR) at room temperature. Arrays of such MTJ sensors are of great promise for the detection of magnetic or magnetically-labeled nanoparticles because of their high sensitivity and flexibility in resistance design. In this study, CoFeB/MgO/CoFeB-based MTJs were prepared by magnetron sputtering, standard photolithography and ion milling. First results show a TMR ratio of 32% at RT; which will be further improved. Characterization with respect to their microstructure and roughness was carried out by XRD, AFM, SEM and TEM. The goal is to build a detection system with high magnetic sensitivity which permits the detection and magnetic characterization of single magnetic nanoparticles.

MA 33.93 Fri 11:00 Poster B1

temperature dependence of transport properties of Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions — •Ayaz Arif Khan, Jan Schmalhorst, and Günter Reiss — Thin films and physics of Nano structures, Department of Physics, Bielefeld university, P. O. Box 100131, 33501 Bielefeld germany.

We have performed a systematic analysis of the voltage and temperature dependence of the tunneling magnetoresistance (TMR) in Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions (MTJs) with barrier thickness d_{MgO} between 1.8 and 4 nm. All the junctions show a comparable TMR of about 300 % at low temperature with low bias voltage. Both the junction resistance and magnetoresistance decreases with inceasing temperature or bias voltage. In the bias voltage range of ± 500 mV and temperature range of 13-330 K the strongest decrease of TMR with either increase in bias voltage (of about 98 %) or increase in temperature (of about 94 %) was observed for MTJ with 4.0 nm thick barrier. whereas for d_{MgO}= 1.8 nm the smallest drop of 51 % with increase in voltage and 43 % with rise of temperature was found. MTJs with 2.1 nm and 3.0 nm displayed an intermediate behaviour. This behaviour was analyzed in the framework of recently suggested models for the bias and temperature dependent transport. Especially,

the influence of unpolarized and polarized hopping conductance will be discussed.

MA 33.94 Fri 11:00 Poster B1

Optimization of the tunnel magnetoresistance of CoFeB/ MgO/ CoFeB - based magnetic tunnel junctions (MTJs) with e-beam evaporation barriers. — •Vladyslav Zbarskyy[1], Marvin Walter[1], Gerrit Eilers[1], Patrick Peretzki[2], Michael Seibt[2], and Markus Münzenberg[1] — [1]I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen — [2]IV. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen

The investigation of MTJs with a high tunnel magnetoresistance (TMR) is very important for the production of MRAM devices. All our CoFeB layers are prepared via magnetron sputtering and MgO barriers via e-beam evaporation. We investigate the magnetic switching properties of CoFeB/MgO/CoFeB MTJs with measurements of hysteresis curves - using the magneto-optical Kerr effect - and TMR curves, optimizing the thickness of the CoFeB layers. Another parameter we change to optimize the ferromagnetic CoFeB electrodes is the annealing temperature. Both influence the solid state epitaxy leading to crystallization directly at the MgO/CoFeB interface. The optimization of MgO barrier properties is also necessary for the quality of our devices. In this context we study the TMR behaviour with the variation of the sample temperature during the e-beam evaporation of MgO barrier. We thank the DFG for funding the research through SFB602.

MA 33.95 Fri 11:00 Poster B1

Influence of roughness at interfaces on tunneling magnetoresistance in Fe/MgO/Fe — •Saeideh Edalati Boostan[1,2], Hosein Moradi[2], and Christian Heiliger[1] — [1]I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany — [2]Department of Physics, Faculty of Sciences, Ferdowsi University of Mashhad, Mashhad, Iran

We propose a theoretical model for magnetic tunnel junction devices with rough interfaces based on a single-band tight-binding approximation. The high tunneling magnetoresistance (TMR) for crystalline MgO barrier was observed at room temperature which is desirable for magnetic random access memory (MRAM) applications. In real junctions the Fe and MgO atoms are interdiffussed at interfaces and the numbers of diffused Fe and MgO atoms are not the same. The interface disorder is modeled by considering replacement of MgO sites by Fe atoms with a probability of $n>0.5$. The non-equilibrium Green's function formalism is used to calculate transport in Fe/MgO/Fe junctions. We investigate the voltage dependencies of TMR and current densities for parallel and anti-parallel configurations for majority and minority spins. The results show that the roughness decreases the TMR. The current density for the parallel (antiparallel) orientations of magnetizations decreases (increases) by including roughness at the interface.