Magnetism Division
Fachverband Magnetismus (MA)

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Overview of Invited and Topical Talks, and Sessions

(lecture rooms H0112, H1012, EB202, EB301, and BH243; Poster A, Galerie 2. OG (100))

Keynote Talk related to MA

PV XIV	Wed	14:00–14:45	H 0105	**A Comprehensive Study of Exchange Bias: Towards a universal explanation.** — •Ivan Schuller

Invited and Topical Talks

(except focused sessions, see below for the focused session program)

MA 2.1	Mon	9:30–10:00	EB 301	**Reversible electrical switching of spin polarization in multiferroic tunnel junctions** — •Marin Alexe, Daniel Pantel, Silvana Götze, Dietrich Hesse
MA 9.1	Mon	15:00–15:30	EB 301	**Anisotropic conductance of ferroelectric domain walls** — •Dennis Meier
MA 15.1	Tue	9:30–10:00	H 1012	**Probing the timescale of exchange interaction in a ferromagnetic alloy** — •Stefan Mathias
MA 23.1	Wed	9:30–10:00	H 1012	**Uncovering the Ultrafast Angular Momentum Transfer on the Nanoscale in GdFeCo** — •A. Scherz, C. Graves, A.H. Reid, B. Wu, T. Wang, S. de Jong, K. Vahaplar, I. Radu, M. Messerschmidt, R. Coffee, M. Bionta, R. Hartmann, N. Kimmel, S. Epp, A. Tsukamoto, J. Turner, W.F. Schlotter, Y. Acremann, A. Kimel, A. Kirilyuk, J. Stöhr, T. Rasing, H. Dürr
MA 33.1	Wed	15:00–15:30	EB 202	**Exchange bias and domain evolution at 10 nm scales** — •Hans J. Hug, Miguel A. Marioni, Sara Romer, Sevil Oezer, Niraj Joshi
MA 35.1	Wed	15:00–15:30	H 0112	**Heusler compounds: theory and experiments on their electronic structure.** — •G. H. Fecher
MA 36.1	Thu	9:30–10:00	H 1012	**Tetragonal Heusler-like alloy films with perpendicular magnetic anisotropy for spin torque applications** — •Shigemi Mizukami, Terunobu Miyazaki
MA 36.2	Thu	10:00–10:30	H 1012	**The role of Heusler alloys in various applications** — •Andreas Hütten
MA 43.1	Thu	15:00–15:30	H 1012	**Spin transport in graphene** — •Bernd Beschoten
MA 43.2	Thu	15:30–16:00	H 1012	**Long spin relaxation times in epitaxial graphene on SiC(0001)** — •Thomas Maassen, Jan Jasper van den Berg, Natasja IJbema, Felix Fromm, Thomas Seyller, Rositsa Yakimova, Bart Jan van Wees

Invited talks of the joint symposium "Tailoring magnetism in $L1_0$ ordered nanostructures: Perspectives for magnetic recording beyond 1 Tb/in^2" (SYTM)

Organization: Helmut Kronmüller (MPI-IS Stuttgart), Rainer Birringer (Universität Saarbrücken), Jürgen Fassbender (HZ Dresden-Rossendorf)
See SYTM for the full program of the symposium.

SYTM 1.1	Mon	9:30–10:00	H 0105	**Thermally Assisted Magnetic Recording at 620 Gb/in^2 using Granular $L1_0$ FeCuPtAg-X Media** — •D. Weller, O. Mosendz, S. Pisana, T. Santos, G. Parker, J. Reiner, B. C. Stipe

SYTM 1.2	Mon	10:00–10:30	H 0105	**Large-area hard magnetic $L1_0$-FePt and composite $L1_0$-FePt based nanopatterns** — •Dagmar Goll, Thomas Bublat
SYTM 1.3	Mon	10:30–11:00	H 0105	**Electric field control of magnetic exchange coupling in FePt / Fe-O thin fims** — •Karin Leistner
SYTM 1.4	Mon	11:00–11:30	H 0105	**FePt-based exchange coupled composite media** — •Manfred Albrecht
SYTM 1.5	Mon	11:30–12:00	H 0105	**Optimization of FePt films for recording applications by micromagnetic modeling** — •Josef Fidler, Jehyun Lee, Barbara Dymerska, Dieter Suess

Topical Talks of the Joint Session "FePt Nanoparticles" (jointly with DS, MM)

Organization: Michael Farle (Univ. Duisburg-Essen)

MA 7.1	Mon	15:00–15:30	EB 202	**Prediction of morphology-, composition- and size-related trends in FePt nanoparticles from first principles** — •Markus Ernst Gruner
MA 7.2	Mon	15:30–16:00	EB 202	**Coulomb Blockade effects in FePt nanoparticles** — •Artur Erbe, Ulrich Wiesenhütter, Darius Pohl, Bernd Rellinghaus, Jürgen Fassbender
MA 7.3	Mon	16:00–16:30	EB 202	**Pt surface segregation and its impact on magnetism in FePt nanoparticles** — •Ulf Wiedwald
MA 7.4	Mon	16:30–17:00	EB 202	**Understanding the Metal-Carbon Interface in FePt terminated carbon nanotubes** — •Darius Pohl, Franziska Schäffel, Christine Täschner, Marc H. Rümmeli, Christian Kisielowski, Ludwig Schultz, Bernd Rellinghaus
MA 7.5	Mon	17:00–17:30	EB 202	**Atomistic characterisation of ultrahard nanomagnets** — •Carolin Antoniak

Invited and Topical Talks of the Focus Session "Topological Transport in Systems with broken Time Inversion Symmetry"

Organization: Stefan Blügel (FZ Jülich)

MA 10.1	Mon	15:00–15:30	H 1012	**Theory of the anomalous Hall effect: from the metallic fully ab-initio studies to the insulating hopping systems** — •Jairo Sinova
MA 10.2	Mon	15:30–16:00	H 1012	**Engineering topological transport via control of the spin-orbit interaction** — •Yuriy Mokrousov
MA 10.3	Mon	16:00–16:30	H 1012	**Topological phases with broken time-reversal symmetry in pyrochlore iridates** — •Shigeki Onoda
MA 10.4	Mon	16:30–17:00	H 1012	**Topological Hall effects of electrons and magnons** — •Yoshinori Onose, Yoshinori Tokura

Invited talks of the joint symposium "100 years of X-ray diffraction: from the Laue-experiment to new frontiers" (SYXD)

Organization: Leonore Wiehl (Universität Frankfurt), Gerhard Grübel (HASYLAB at DESY), Joachim Rädler (LMU München)

See SYXD for the full program of the symposium.

SYXD 1.1	Mon	15:00–15:30	H 0105	**Disputed discovery: The beginnings of X-ray diffraction in crystals** — •Michael Eckert
SYXD 1.2	Mon	15:30–16:00	H 0105	**Why are quasicrystals quasiperiodic?** — •Walter Steurer
SYXD 1.3	Mon	16:00–16:30	H 0105	**Coherent Diffraction Imaging with Free-Eletron Lasers** — •Massimo Altarelli
SYXD 1.4	Mon	16:30–17:00	H 0105	**X-ray free-electron lasers - emerging opportunities for structural biology** — •Ilme Schlichting
SYXD 1.5	Mon	17:00–17:30	H 0105	**Structure analysis by x-ray diffraction and x-ray imaging: beyond crystals, beyond averages, and beyond modeling** — •Tim Salditt

Invited talks of the joint symposium "Topological Insulators: Influence of Superconductivity, Magnetism and Extrinsic Spin-Orbit Interaction" (SYTI)

Organization: Oliver Rader (HZ Berlin), Philip Hofmann (Aarhus University, DK), Björn Trauzettel (Univ. Würzburg), Jan Minar (LMU München)
See SYTI for the full program of the symposium.

SYTI 1.1	Tue	9:30–10:00	H 0105	**Search for Majorana fermions in topological insulators** — •Carlo Beenakker
SYTI 1.2	Tue	10:00–10:30	H 0105	**Cooper Pairs in Topological Insulator Bi_2Se_3 Thin Films Induced by Proximity Effect** — •Jinfeng Jia
SYTI 1.3	Tue	10:30–11:00	H 0105	**Gate tunable normal and superconducting transport through a 3D topological insulator** — •Alberto Morpurgo
SYTI 1.4	Tue	11:00–11:30	H 0105	**Weyl Metal States and Surface Fermi Arcs in Iridates** — •Sergey Savrasov
SYTI 1.5	Tue	11:30–12:00	H 0105	**Engineering a Room-Temperature Quantum Spin Hall State in Graphene via Adatom Deposition** — •Marcel Franz

Invited and Topical Talks of the Joint Session "Soft X-ray Resonant Scattering for Complex Structural and Magnetic Investigations" (jointly with KR)

Organization: Eberhard Goering (MPI-IS Stuttgart)

MA 24.1	Wed	9:30–10:00	BH 243	**Soft X-ray Resonant Magnetic Reflectometry of Ferromagnet/Antiferromagnet Interfaces - Probing the Origin of Exchange Bias** — •Sebastian Brück, Gisela Schütz, Kannan M. Krishnan, Eberhard Goering
MA 24.2	Wed	10:00–10:30	BH 243	**Orbital reflectometry of nickelate heterostructures** — •Eva Benckiser
MA 24.3	Wed	10:30–11:00	BH 243	**Manipulating magnetic and electronic ordering phenomena by electric fields and electromagnetic radiation** — •Urs Staub
MA 24.4	Wed	11:15–11:45	BH 243	**Theory of resonant x-ray spectroscopy** — •M. W. Haverkort
MA 24.5	Wed	11:45–12:15	BH 243	**Cycloidal Magnetic Order and Ferroelectricity: Manipulation and Imaging with Soft X-Rays** — •Eugen Weschke, Enrico Schierle, Victor Soltwisch, Detlef Schmitz, Andrej Maljuk, Dimitri Argyriou

Invited and Topical Talks of the Focus Session "Spin Currents in Magnetic Nanostructures"

Organization: Mathias Kläui (Univ. Mainz)

MA 30.1	Wed	15:00–15:30	EB 301	**Spin transfer in conducting and insulating magnetic systems** — •Yaroslav Tserkovnyak
MA 30.2	Wed	15:30–16:00	EB 301	**Spin pumping with photons and phonons** — •Mathias Weiler, Franz D. Czeschka, Hans Huebl, Frederik S. Goerg, Matthias Althammer, Lukas Dreher, Martin S. Brandt, Rudolf Gross, Sebastian T. B. Goennenwein
MA 30.3	Wed	16:00–16:30	EB 301	**Generation of superdiffusive spin-currents through femtosecond laser excitation of ferromagnetic/non-magnetic hybrid structures** — •Peter M. Oppeneer, Marco Battiato, Karel Carva, Pablo Maldonado

PhD Symposium of the Division of Magnetism and the Young DPG: Spintronics on the way to modern storage technology

The discovery of the giant magnetoresistive effect (GMR) by P. Grünberg and A. Fert in 1988 triggered a scientific and industrial revolution in the field of magnetic storage media. Further development by switching from longitudinal to perpendicular recording in order to increase the storage density brings forth new engineering tasks: The design of materials, which keep magnetization robust to thermal fluctuations (pushing the super-paramagnetic limit), have low saturation magnetization, large coercive force, high Curie temperature and ensure fast read/write processes by possessing a low Gilbert damping constant.

A single femtosecond circularly polarized laser pulse can cause a well-controlled permanent magnetization reversal in materials typically used for data storage. Instant heat transfer makes a system susceptible to the magnetic moment inquired from the next coming circularly polarized pulse. Magnetization is controlled without any help of an external magnetic field. This, in turn, ensures magnetic stability of the neighboring domains as no stray fields affect them.

Along with the benefits of downscaling some significant obstacles such as heat dissipation are encountered. However, this drawback that limits the recording density can be solved in future by magnetically activated local cooling of an individual nanometer-sized area. Pure spin currents resulting from a spin Seebeck effect are not accompanied by a net charge transfer and provide more deep insight into the spin-dependent phenomena (spin-orbit coupling, role of spin in energy transfer, spin-spin interactions). In addition, a spin-polarized current can be utilized for magnetization manipulation, a phenomenon called spin torque transfer. An angular momentum from the polarized current is transferred to the free layer magnetization and switches it at a certain current strength. In contrast to the other magnetization switching mechanisms, the spin torque transfer has the highest potential for increasing memory capacity, atomic accuracy in resolution (spin-polarized STM, for example) and a low heat generation. As an advanced solution it can be implemented in a new state-of-the-art memory generation.

This symposium will provide an introduction into modern spintronics, covering their physical principles and the materials used for magnetic devices. After this introduction the magnetization dynamics and the mechanisms of magnetic switching will be discussed.

MA 40.1	Thu	10:00–10:30	BH 243	**Magnon Spintronics** — •Burkard Hillebrands, Andrii Chumak, Alexandr Serga, Benjamin Jungfleisch
MA 40.2	Thu	10:30–11:00	BH 243	**Functional materials for spintronics, magnetic devices and magnetization dynamics** — •Günter Reiss, Andreas Hütten, Jan Schmalhorst, Markus Meinert, Daniel Ebke, Andy Thomas, Hans-Werner Schumacher, Markus Münzenberg, Sergej Demokritov
MA 40.3	Thu	11:00–11:15	BH 243	**Revealing the significance of heating in the all-optical switching process** — •Sabine Alebrand, Daniel Steil, Alexander Hassdenteufel, Mirko Cinchetti, Martin Aeschlimann
MA 40.4	Thu	11:15–11:30	BH 243	**Large relaxation times in permalloy reprogrammable magnonic crystals** — •Rupert Huber, Thomas Schwarze, Georg Duerr, Dirk Grundler
MA 40.5	Thu	11:30–12:00	BH 243	**Spin wave propagation and excitation, microwave assisted switching and non-linear magnetic resonance** — •Georg Woltersdorf, Hans G. Bauer, Christian H. Back
MA 48.1	Thu	13:00–13:30	BH 243	**Ultrafast manipulation of magnetic order** — •Theo Rasing
MA 48.2	Thu	13:30–14:00	BH 243	**Spin-transfer processes: Magnetic coupling, spin-transfer torque, and pure spin currents** — •Daniel E. Bürgler
MA 48.3	Thu	14:00–14:15	BH 243	**Improved reliability of magnetic field programmable gate arrays through the use of memristive tunnel junctions** — •Jana Münchenberger, Patryk Krzysteczko, Günter Reiss, Andy Thomas
MA 48.4	Thu	14:15–14:30	BH 243	**Manipulation of Skyrmions created by opto-magnetic switching** — •Stefan Gerlach, Denise Hinzke, Ulrich Nowak
MA 48.5	Thu	14:30–15:00	BH 243	**Magnetoelastic Magnetization Control and Magnetization Dynamics at Low Temperatures** — •Hans Huebl, Andreas Brandlmaier, Christoph Zollitsch, Johannes Lotze, Mathias Weiler, Fredrik Hocke, Georg Woltersdorf, Ruldof Gross, Sebastian T.B. Goennenwein

Invited and Topical Talks of the Joint Session "Novel Spincaloritronic Devices: Control of Heat, Charge and Momentum Flow" (jointly with TT)

Organization: Markus Münzenberg (Univ. Göttingen), Mathias Weiler (WMI Garching)

MA 42.1	Thu	15:00–15:30	EB 301	**Spin Seebeck and spin Peltier effects in ferromagnetic-nonmagnetic devices** — •Bart van Wees
MA 42.2	Thu	15:30–16:00	EB 301	**Magneto Seebeck effect in tunnel junctions** — •Christian Heiliger
MA 42.3	Thu	16:00–16:30	EB 301	**Seebeck spin tunneling into silicon** — •Ron Jansen

MA 42.4	Thu	16:30–17:00	EB 301	**Spin currents in ferromagnetic insulator/normal metal hybrid structures** — •Sebastian T.B. Goennenwein, Franz D. Czeschka, Johannes Lotze, Georg Woltersdorf, Mathias Weiler, Michael Schreier, Matthias Althammer, Matthias Opel, Hans Huebl, Rudolf Gross
MA 42.5	Thu	17:00–17:30	EB 301	**Spin waves and spin currents in hybrid magnetic nanostructures** — •Sergej O. Demokritov

Sessions

MA 1.1–1.5	Mon	9:30–12:00	H 0105	**Joint Symposium "Tailoring Magnetism in $L1_0$-ordered Nanostructures: Perspectives for Magnetic Recording beyond 1 Tb/in^2" (SYTM)**
MA 2.1–2.11	Mon	9:30–12:45	EB 301	**Joint Session "Multiferroics I - Junctions and Thin Films / Magnetoelectric Coupling" (jointly with DF, DS, KR, TT), Organization: Manfred Fiebig (ETH Zürich)**
MA 3.1–3.11	Mon	9:30–12:30	EB 202	**Bio- and Molecular Magnetism**
MA 4.1–4.13	Mon	9:30–13:00	H 1012	**Spin-dependent Transport Phenomena**
MA 5.1–5.11	Mon	9:30–12:30	H 0112	**Spin Structures and Magnetic Phase Transitions**
MA 6.1–6.5	Mon	15:00–17:30	H 0105	**Joint Symposium (SYXD) "100 Years of X-ray Diffraction: From the Laue Experiment to new Frontiers" (jointly with KR, BP, CPP, DF, MA, MM, GP), Organization: Wiehl, Grübel, Rädler**
MA 7.1–7.5	Mon	15:00–17:45	EB 202	**Joint Session "FePt Nanoparticles" (jointly with DS, MM), Organization: Michael Farle (Univ. Duisburg-Essen)**
MA 8.1–8.6	Mon	17:45–19:15	EB 202	**Magnetic Particles / Clusters I**
MA 9.1–9.12	Mon	15:00–18:30	EB 301	**Joint Session "Multiferroics II - Hexagonal Manganites / Incommensurate Multiferroics" (jointly with DF, DS, KR, TT)**
MA 10.1–10.4	Mon	15:00–17:15	H 1012	**Focus Session "Topological Transport in Systems with broken Time Inversion Symmetry", Organization: Stefan Blügel (FZ Jülich)**
MA 11.1–11.2	Mon	17:15–17:45	H 1012	**Spin-dependent Transport Phenomena II**
MA 12.1–12.6	Mon	17:45–19:15	H 1012	**Joint Session "Topological Insulators I" (jointly with DS, HL, O, TT)**
MA 13.1–13.17	Mon	15:00–19:30	H 0112	**Magnetic Materials**
MA 14.1–14.5	Tue	9:30–12:00	H 0105	**Joint Symposium "Topological Insulators: Influence of Superconductivity, Magnetism and Extrinsic Spin-Orbit Interaction" (SYTI)**
MA 15.1–15.12	Tue	9:30–13:00	H 1012	**Magnetization / Demagnetization Dynamics I**
MA 16.1–16.8	Tue	9:30–11:45	EB 202	**Magnetic Particles / Clusters II**
MA 17.1–17.5	Tue	11:45–13:00	EB 202	**Magnetic Measurement Methods**
MA 18.1–18.12	Tue	9:30–12:45	H 0112	**Joint Session "Magnetic Semiconductors" (jointly with HL)**
MA 19.1–19.12	Tue	9:30–12:45	EB 301	**Joint Session "Multiferroics III - Strain / New Routes towards Multiferroicity" (jointly with DF, DS, KR, TT)**
MA 20.1–20.90	Tue	12:15–15:15	Poster A	**Poster I - Biomagnetism, FePt Nanoparticles, Magnetic Particles/Clusters, Magnetic Materials, Magnetic Semiconductors, Half-metals/Oxides, Multiferroics, Topological Insulators, Spin structures/Phase transitions, Electron theory/Computational micromagnetics, Magnetic coupling phenomena/Exchange bias, Spin-dependent transport, Spin injection/spin currents, Magnetization/Demagnetization dynamics, Magnetic measurement techniques**
MA 21	Tue	13:30–13:30	EB 301	**ThyssenKrupp Dissertationspreis der AG Magnetismus**
MA 22.1–22.13	Wed	9:30–13:00	EB 301	**Joint Session "Topological Insulators II" (jointly with DS, HL, O, TT)**
MA 23.1–23.12	Wed	9:30–13:00	H 1012	**Magnetization / Demagnetization Dynamics II**
MA 24.1–24.6	Wed	9:30–12:30	BH 243	**Joint Session "Soft X-ray Resonant Scattering for Complex Structural and Magnetic Investigations" (jointly with KR), Organization: Eberhard Goering (MPI-IS Stuttgart)**
MA 25.1–25.4	Wed	9:30–10:45	H 0112	**Electron Theory of Magnetism**

MA 26.1–26.6	Wed	10:45–12:15	H 0112	**Micromagnetism / Computational Magnetics**
MA 27.1–27.10	Wed	9:30–12:15	EB 202	**Half-metals and Oxides (jointly with TT)**
MA 28.1–28.1	Wed	14:00–14:45	H 0105	**Keynote Talk by Ivan Schuller**
MA 29.1–29.4	Wed	15:00–17:30	Poster E	**Poster related to SYXD: "100 Years since the Laue Experiment: Topical Aspects of Diffraction and Scattering" (jointly with KR, BP, CPP, DF, GP, MI, MM)**
MA 30.1–30.10	Wed	15:00–18:45	EB 301	**Focus Session "Spin Currents in Magnetic Nanostructures", Organization: Mathias Kläui (Univ. Mainz)**
MA 31.1–31.4	Wed	15:00–16:00	BH 243	**Magnetic Imaging**
MA 32.1–32.11	Wed	16:00–19:00	BH 243	**Joint Session "Surface Magnetism I" (jointly with O)**
MA 33.1–33.10	Wed	15:00–18:00	EB 202	**Magnetic Coupling Phenomena/ Exchange Bias**
MA 34.1–34.14	Wed	15:00–18:45	H 1012	**Magnetization / Demagnetization Dynamics III**
MA 35.1–35.10	Wed	15:00–18:00	H 0112	**Magnetic Heusler Compounds I**
MA 36.1–36.9	Thu	9:30–12:30	H 1012	**Magnetic Heusler Compounds II**
MA 37.1–37.13	Thu	9:30–13:00	EB 301	**Joint Session "Surface Magnetism II" (jointly with O)**
MA 38.1–38.13	Thu	9:30–13:00	H 0112	**MagneticThin Films I**
MA 39.1–39.13	Thu	9:30–13:00	EB 202	**Micro- and Nanostructured Magnetic Materials I**
MA 40.1–40.5	Thu	9:50–12:00	BH 243	**PhD Student Symposium: "Spintronics on the Way to modern Storage Technology I", Organization: "Univ. Mainz team"**
MA 41.1–41.7	Thu	10:15–12:00	H 0106	**Joint Session Magnetic Shape Memory Alloys I (jointly with DS, MM)**
MA 42.1–42.5	Thu	15:00–17:30	EB 301	**Joint Session "Novel Spincaloritronic Devices: Control of Heat, Charge and Momentum Flow" (jointly with TT), Organization: Markus Münzenberg (Univ. Göttingen), Mathias Weiler (WMI Garching)**
MA 43.1–43.4	Thu	15:00–16:45	H 1012	**Joint Session "Graphen: Spin Transport" (jointly with DS, DY, HL, O, TT)**
MA 44.1–44.9	Thu	16:45–19:00	H 1012	**Joint Session "Spins in Organic Materials" (jointly with DS)**
MA 45.1–45.14	Thu	15:00–18:45	H 0112	**Joint Session "Magnetic Shape Memory Alloys II" (jointly with DS, MM)**
MA 46.1–46.8	Thu	15:00–17:15	EB 202	**MagneticThin Films II**
MA 47.1–47.7	Thu	17:15–19:00	EB 202	**Micro- and Nanostructured Magnetic Materials II**
MA 48.1–48.5	Thu	13:00–15:00	BH 243	**PhD Student Symposium: "Spintronics on the Way to modern Storage Technology II", Organization: "Univ. Mainz team"**
MA 49.1–49.15	Thu	15:15–19:15	BH 243	**Joint Session "Surface Magnetism III" (jointly with O)**
MA 50.1–50.8	Fri	9:30–11:30	EB 301	**Joint Session "Spincaloric Transport" (jointly with TT)**
MA 51.1–51.9	Fri	9:30–11:45	H 1012	**Spin Excitations/ Spin Torque**
MA 52.1–52.67	Fri	11:00–14:00	Poster A	**Poster II - Magnetic Heusler compounds, Magnetic shape memory alloys, Thin Films, Micro-/Nano-structured magnetic materials, Graphene, Spins in organics, Magnetic imaging, Surface Magnetism, Spin excitations/Torque, Spincaloric transport**

Annual General Meeting of the Magnetism Division

Mittwoch 19:00–20:00 Raum H0112

- Bericht des Vorsitzenden
- Aussprache
- Verschiedenes

MA 1: Joint Symposium "Tailoring Magnetism in $L1_0$-ordered Nanostructures: Perspectives for Magnetic Recording beyond 1 Tb/in^2" (SYTM)

Time: Monday 9:30–12:00 Location: H 0105

Invited Talk MA 1.1 Mon 9:30 H 0105

Thermally Assisted Magnetic Recording at 620 Gb/in^2 using Granular $L1_0$ FeCuPtAg-X Media — •D. Weller, O. Mosendz, S. Pisana, T. Santos, G. Parker, J. Reiner, and B. C. Stipe — Hitachi Global Storage Technologies, San Jose Research Center, San Jose, CA USA

Highly $L1_0$-ordered FeCuPtAg-X (X=C, BN, ...) nano-granular thin films as potential thermally-assisted magnetic recording (TAR) media have been studied. These films are fabricated in a flexible sputter system allowing deposition of appropriate adhesion, heat sink and structural seed layers before growing FeCuPtAg-X at elevated temperature to induce chemical $L1_0$ ordering and to optimize grain size, grain distribution and texture. Typical seed layers are 5-10 nm thick MgO (002) with rocking curve widths of FWHM ∼4 deg. Granular FeCuPtAg-X films with thickness of ∼7 nm and well isolated grains have room temperature coercivities up to ∼5 T, depending on growth temperature and grain isolation. The Curie temperature is reduced to 600-650K by adding about 10 at% Cu, which is used to adjust (lower) the heating power needed during recording. So far, static tester experiments on our best optimized media using a TAR head demonstrate areal densities up to AD∼620-650 Gbits/in^2. The goal is to optimize media and extend AD beyond Tb/in^2, which is one of the key projects going forward.

While the focus of this talk is on heat assisted magnetic recording (HAMR or TAR), we will also mention alternative technologies to move beyond the superparamagnetic limit of today's perpendicular magnetic recording (PMR). These include Shingled Write Recording (SWR), Microwave Assisted Magnetic Recording (MAMR) and Bit Patterned Magnetic Recording (BPMR).

Invited Talk MA 1.2 Mon 10:00 H 0105

Large-area hard magnetic $L1_0$-FePt and composite $L1_0$-FePt based nanopatterns — •Dagmar Goll[1] and Thomas Bublat[2] — [1]Hochschule Aalen, Institut für Materialforschung, Aalen — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart

Bit-patterned media is a very promising concept for next generation ultrahigh density magnetic recording. Large-area hard magnetic $L1_0$-FePt based nanopatterns with dot sizes between 40 nm and 100 nm and out-of-plane texture were fabricated by using a top-down approach [1,2]. For the fabrication process ultraviolet nanoimprint lithography in combination with inductively coupled plasma reactive Ar-ion etching has been used. By this technique continuous epitaxially grown $L1_0$-FePt films were nanostructured into a regular arrangement of nanodots over an area of 4 mm^2. In the as-etched state the morphology of the dots corresponds to the morphology of phase graded $L1_0$-FePt/A_1-FePt composite particles with coercivities up to 1.7 T at RT. After post-annealing the morphology of the dots is of pure $L1_0$-FePt resulting in coercivities up to 4.4 T. Within the framework of micromagnetism the magnetic reversal mechanism of the different types of nanodots has been analyzed from the temperature dependence and angular dependence of the reversal field. For the as-etched dots magnetization reversal takes place by a domain wall induced process and for the post-annealed dots by a uniform nucleation process. Additionally composite $L1_0$-FePt/Fe nanopatterns were produced from continuous bilayers and characterized. [1] T. Bublat, D. Goll, Nanotechnology 22 (2011) 315301. [2] T. Bublat, D. Goll, J. Appl. Phys. 110 (2011) 073908.

Invited Talk MA 1.3 Mon 10:30 H 0105

Electric field control of magnetic exchange coupling in FePt / Fe-O thin fims — •Karin Leistner — IFW Dresden, 01171 Dresden, Germany

Electric control of magnetism is a vision which drives intense research on magnetic semiconductors and multiferroics. Recently, also ultrathin metallic films were reported to show magnetoelectric effects at room temperature. Here we demonstrate much stronger effects by exploiting phase changes in a naturally grown oxide layer exchange coupled to an underlying ferromagnet. For the exemplarily studied FePt/iron oxide composite, a large and reversible change of magnetic moment and anisotropy is obtained. As the principle can be transferred to various metal/oxide combinations, this versatile approach represents a key step towards multifunctional materials, applicable in magnetic data storage and nanoactuators.

Invited Talk MA 1.4 Mon 11:00 H 0105

FePt-based exchange coupled composite media — •Manfred Albrecht — Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany

In order to continue the areal density increase in magnetic hard disk drives, it is necessary to develop media that support very small bit sizes, while maintaining thermal stability as well as writability of the bits. One potential candidate as a recording layer are L10 chemically ordered FePt alloys which exhibit a huge magnetic anisotropy value. However, the magnetic field required to switch the magnetization of one individual FePt bit typically exceeds the maximum available write field. To solve this so called writability issue in magnetic data storage, a recording concept known as exchange coupled composite (ECC) media aiming to lower the switching field of individual bits was proposed. ECC films consist of a high anisotropy layer coupled to a low anisotropy layer and have been shown to combine both thermal stability and low coercivity for writability. Such ECC structures are also attractive for bit patterned media (BPM), where the bits are individual pillars of magnetic material that are defined by lithography.

In this presentation I will focus on L10 ordered FePt-based ECC thin films and nanostructures fabricated by nanoimprint lithography. Films were transformed to the L10 phase by rapid thermal annealing. I will show that the combination of ECC media with BPM reveals superior properties compared to single layer BPM, as it leads to a significant reduction in the switching field and a substantial narrowing of the switching field distribution.

Invited Talk MA 1.5 Mon 11:30 H 0105

Optimization of FePt films for recording applications by micromagnetic modeling — •Josef Fidler[1], Jehyun Lee[1,2], Barbara Dymerska[1], and Dieter Suess[1] — [1]TU Wien, Inst. für Festkörperphysik, Austria, — [2]Seoul National University, Rep Korea.

The ordered FePt/L10 phase with high magnetocrystalline anisotropy is a candidate for achieving an areal magnetic storage density beyond 1 Tbit/inch2. The switching field of individual grains and bits has to be reduced due to the limitations of the write head. Exchange coupled composite and graded media have been suggested to reduce the nucleation/coercive field and keeping the high thermal stability[1]. The present study will discuss the combination of the ordered fct FePt/L10 phase and the disordered fcc FePt/A1 phase[2]. TEM investigations revealed a complex transformation from the disordered to the ordered phase and a rough interphase including spikes/tips depending on the deposition temperature and cooling rate. Numerical FE micromagnetic simulations of such phase graded media show that the roughness strongly influences the domain wall propagation during the magnetic reversal process from the soft to the hard phase. As a result, the Hc of the phase graded media was reduced to 13 kOe which is 16% of FePt L10 single phase (79 kOe)[3].

This work was supported by the EU FP7 project TERAMAGSTOR under Project No. FP7-ITC-2007-2-224001.

[1] D. Suess et al., Appl Phys Lett 87 (1), 012504 (2005). [2] V. Alexandrakis et al., J Appl Phys 109, 07B729 (2011). [3] J. Lee et al., Appl Phys Lett 98 (22), 222501 (2011).

MA 2: Joint Session "Multiferroics I - Junctions and Thin Films / Magnetoelectric Coupling" (jointly with DF, DS, KR, TT), Organization: Manfred Fiebig (ETH Zürich)

Time: Monday 9:30–12:45 Location: EB 301

Topical Talk MA 2.1 Mon 9:30 EB 301

Reversible electrical switching of spin polarization in multiferroic tunnel junctions — •Marin Alexe, Daniel Pantel, Silvana Götze, and Dietrich Hesse — Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle

Spin polarized transport in ferromagnetic tunnel junctions, characterized by tunnel magnetoresistance, has already proven a high application potential in the field of spintronics and in magnetic random access memories (MRAM). Until recently, in such a junction the insulating barrier played only a passive role keeping apart the ferromagnetic electrodes in order to allow electron tunneling. However, a new dimension was added to these devices by replacing the insulator with a ferroelectric material, which possesses permanent dielectric polarization switchable between two stable states. The obtained multiferroic tunnel junction (MFTJ) is a non-volatile memory device with four states, given by two possible ferroelectric polarization directions in the barrier and two different magnetization alignments of the electrodes. Here, we will show that due to the coupling between magnetization and ferroelectric polarization at the interface between a magnetic electrode and the ferroelectric barrier of a MFTJ, the spin polarization of the tunneling electrons can be reversibly and remanently inverted by switching the ferroelectric polarization of the barrier. Selecting the spin direction of the tunneling electrons by short electric pulses in the nanosecond range rather than by an applied magnetic field is highly relevant for spintronics, especially for spin-based information technology.

MA 2.2 Mon 10:00 EB 301

First Principles Modelling of Spin Transport in Functional Oxide Tunnel Junctions — •Nuala M. Caffrey, Thomas Archer, Ivan Rungger, and Stefano Sanvito — School of Physics and CRANN, Trinity College Dublin, Ireland

Spin-dependent tunnelling between ferromagnetic electrodes separated by insulating oxide barriers has long attracted scientific and commercial interest. In the last decade it became evident that the insulating layer was more than just a simple barrier through which electrons tunnel. It is wave-function symmetry selective, making the tunnelling process sensitive to its electronic structure. The understanding of such a concept suggests that one can engineer the transport properties of a tunnel junction by carefully selecting the insulating barrier and the metallic electrodes. Ferroelectric materials are of particular interest as barriers due to additional functionality offered by the electric polarisation.

We investigate, from first-principles, the properties of a multifunctional tunnel junction combining two materials with different ferroic states (ferromagnetic and ferroelectric). We demonstrate massive tunnelling magnetoresistance (TMR) in a SrRuO3 / BaTiO3 / SrRuO3 junction. We also consider the implications of introducing structural asymmetry into this junction by using a thin layer of dielectric material at one interface. In such a junction we demonstrate a sizable tunnelling electroresistance (TER) that increases with the thickness of the dielectric layer.

MA 2.3 Mon 10:15 EB 301

FeO at Iron/Oxide interfaces — •Andrea Neroni, Daniel Wortmann, Ersoy Sasioglu, Stefan Blügel, and Marjana Ležaić — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We present density-functional theory (DFT) based first-principles calculations of tunneling and magnetoconductance properties of nanoferronic devices consisting of oxide barriers between iron contacts. Several experimental works have indicated the presence of an iron-oxide layer at the contacts of this barrier, that can significantly alter the tunneling properties of the junction. The effect of this layer is still unclear. From the theoretical point of view, one unexplored point are the electron correlations in the single FeO layer at the interface. We account for these correlations with a Hubbard U parameter determined by the constrained random phase approximation (cRPA) [1] and calculate the change of the tunneling magnetoresistance ratio under this condition, using the full-potential linearized augmented plane wave (FLAPW) method FLEUR [2]. The electronic transport properties of nanoferronic junctions have been investigated using an embedded Green-function approach [3].

Work is supported by Helmholtz Young Investigators Group Program VH-NG-409 .

[1] E. Şaşıoğlu, C. Friedrich, and S. Blügel, PRB **83**, 121101(R) (2011)
[2] www.flapw.de
[3] D. Wortmann, H. Ishida, and S. Blügel. PRB **66**, 075113 (2002)

MA 2.4 Mon 10:30 EB 301

Thermally stimulated currents in $BiFeO_3$ — •Akash Bhatnagar, Ayan Roy Chaudhuri, Dietrich Hesse, and Marin Alexe — Max Planck Institute of Microstructure Physics, Weinberg 2, Halle(Saale), Germany

Bismuth ferrite($BiFeO_3$)-BFO is a well known multiferroic material, with high ferroelectric Curie temperature (1103 K) and a saturated ferroelectric hysteresis with a remnant polarization of 100 C/cm^2. However, it has been found that pure BFO usually exhibits a high leakage current that could limit wide applications of this material. The thermally stimulated current (TSC) technique was used to get insights into the electronic origin of the leakage, which includes the study of energy levels that might be present in the band gap. These levels can act as trapping centers for charge carriers, thus affecting conductivity. Three systems of BFO, namely, single crystals, thin films and ceramics were studied. Measurements for ceramics and single crystals were performed in capacitor mode, whereas for thin films in-plane electrodes were made using a normal lift-off process. The effect of orientation of the electrodes with respect to domain patterns in thin films, have been investigated. Consequently, trap activation energies and density calculations were performed to fully characterize different levels. Photoconductive and photovoltaic properties were also investigated which corroborate the TSC data.

MA 2.5 Mon 10:45 EB 301

Preparation and characterization of multiferroic thin films grown with an Oxid-MBE — •Paul Zakalek, Markus Waschk, Alexander Weber, and Thomas Brückel — Jülich Centre for Neutron Science JCNS und Peter Grünberg Institut PGI, Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

An oxygen-assisted Molecular Beam Epitaxy (MBE) gives the possibility to engine artificial materials on a nanoscale with promising effects. With our machine it is possible to grow complex materials like $La_xSr_{1-x}MnO_3$ (LSMO) or $La_xBi_{1-x}MnO_3$ (LBMO) with remarkably good crystalline quality.

The materials show a variety of interesting effects. For example the La concentration affects the magnetic and electric properties of this systems. The LSMO and LBMO layers can either be antiferromagnetic, ferromagnetic or multiferroic, depending of the La concentration.

Different LSMO/LBMO systems were grown with oxygen-assisted MBE on a $SrTiO_3$ (STO) substrate with different La concentrations. We will present the preparation process and the structural in-house characterization of this systems. First results show good structural quality, like surface roughnesses of not more then one unit cell. Additionally magnetic and electric measurements of the samples will be shown.

15 min. break

MA 2.6 Mon 11:15 EB 301

Guest molecules in ABX3 metal-organic frameworks: multiferroicity and magnetoelectricity — •Alessandro Stroppa[1], Prashant Jain[2], Paolo Barone[1], Martijn Marsman[3], Juan Manuel Perez-Mato[4], Anthony K. Cheetham[5], Harold W. Kroto[2], and Silvia Picozzi[1] — [1]CNR-SPIN, L'Aquila, Italy — [2]Department of Chemistry and Biochemistry, Florida State University Tallahassee, FL 32306 (USA) — [3]University of Vienna, Faculty of Physics and Center for Computational Materials Science (Austria) — [4]Departamento de Fisica de la Materia Condensada Facultad de Ciencia y Tecnologia, UPV/EHU, Bilbao (Spain) — [5]Department of Materials Science and Metallurgy University of Cambridge (UK)

Metal-organic frameworks (MOFs) are increasingly regarded as promising materials. MOFs with perovskite architecture have recently

branched out into the field of multiferroics, materials which have both magnetic and ferroelectric orders. Here, we focus on a MOF compound and theoretically show that it is ferroelectric and this ferroelectricity is the cause of a weak ferromagnetic coupling. In inorganic perovskite-like compounds, octahedral tilting and Jahn-Teller distortions are usually non-polar modes. In this MOF, however, their cooperative link to A-groups via hydrogen bondings finally breaks inversion symmetry, and induces a ferroelectric polarization. We show that the switching of polarization direction implies the reversal of the weak ferromagnetic component, therefore allowing the long-sought electrical control of the magnetization.

MA 2.7 Mon 11:30 EB 301

magnetoelectric effects in the cubic ferrimagnet Cu_2OSeO_3 — •Maria Eleni Belesi[1,2], Mohamed Abid[1], Helmuth Berger[1], and Jean-Philippe Ansermet[1] — [1]Institute of Condensed Matter Physics, EPFL, Station 3, CH-1015 Lausanne, Switzerland — [2]Leibniz Institute for Solid State and Materials Research, Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany

We present magnetic and dielectric measurements in single crystals of the cubic magnetoelectric compound Cu_2OSeO_3. The magnetic measurements show a transition to a ferrimagnetic state at 60 K. This state shows a finite magnetocapacitance which is temperature dependent and varies significantly upon changing the direction of the magnetic field with respect to the crystallographic axes. The magnetocapacitance is also shown to vary with the relative orientation of the magnetic and electric fields. In addition, we found that the magnetically ordered state shows a magnetic field induced electric polarization, whose temperature dependence and anisotropic properties will be discussed.

MA 2.8 Mon 11:45 EB 301

Microscopic Mechanisms for Magnetoelectric Effect in $LiMPO_4$ (M=Mn,Fe,Co,Ni) — •Andrea Scaramucci, Eric Bousquet, and Nicola Spaldin — Materials Theory, Department of Materials, ETH Zurich, Zurich, Switzerland

We theoretically investigate the microscopic mechanisms leading to the linear magnetoelectric effect in the $LiMPO_4$ series. This is of particular interest since some of its constituents possess toroidal moments and shows large magnetoelectric effect.

By using symmetry analysis we obtain the microscopic couplings between spins and electric polarization responsible for each component of the magnetoelectric tensor. Furthermore, we identify couplings with exchange-strictive and relativistic origin. By using *ab initio* calculation and by enforcing numerous non collinear spin configurations we extract the strength of these couplings together with the exchange coupling constants. We use mean field approximation and Monte Carlo simulation to calculate the temperature evolution of magnetoelectric tensor. Our calculations explain the features of the temperature dependence found in experiments.

MA 2.9 Mon 12:00 EB 301

Manipulation of the antiferromagnetic structure in $LiNi_{(1-x)}Fe_xPO_4$ (x = 0.03, 0.2) by iron substitution — •Anne Zimmermann[1] and Manfred Fiebig[1,2] — [1]HISKP, University of Bonn, Germany — [2]Materials Department, ETH Zurich, Switzerland

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 order to investigate the interplay between the different types of spin order $LiNi_{(1-x)}Fe_xPO_4$ samples with different mixing ratios of nickel and iron were studied using optical second harmonic generation (SHG). SHG coupling linearly to the AFM order parameter was identified in spectroscopy measurements and used for domain imaging. A small iron substitution of $x = 0.03$ yields no change in the domain pattern as well as in the magnetic structure in contrast to pure $LiNiPO_4$. However, for an iron substitution of $x = 0.2$ the spin structure changes significantly: the spin direction lies in the yz-plane and thus between the two spin directions for $LiNiPO_4$ and $LiFePO_4$. The change in magnetic structure is revealed in a different domain pattern as well. Furthermore the order parameter exhibits an unusual, photosensitive temperature dependence which is discussed in detail.

- Work supported by the SFB 608 of the DFG.

MA 2.10 Mon 12:15 EB 301

Multiferroicity and magnetoelectricity in a doped topological ferroelectric — Marco Scarrozza, Maria Barbara Maccioni, Giorgia M. Lopez, Alessio Filippetti, and •Vincenzo Fiorentini — Dept of Physics, U of Cagliari and CNR-IOM, Cagliari, Italy

$La_2Ti_2O_7$ is a "topological" ferroelectric where dipoles are produced by antiferrodistortive rotations failing to compensate due to the layered structure. To turn on multiferroicity, we investigated magnetic doping from first-principles within density-functional theory. The isovalent substitution of Mn for Ti produces antiferromagnetism at all dopings as expected due to superexchange between Mn d^3 ions. In the fully-substituted compound $La_2Mn_2O_7$, many ordering patterns compete, the lowest being a variant of G-type antiferromagnetism. The same system is also magnetoelectric, because the rotations are involved in both magnetic and ferroelectric order: as a coercive field undoes the rotations and depolarizes ferroelectricity, magnetic coupling doubles in intensity. However, the ferromagnetic phase of $La_2Mn_2O_7$ is always much higher in energy. On the other hand, we find that heterovalent substitution of Ti with Cr, Sc, and V always yields robust ferromagnetism. In particular, V orders in rows orthogonal to the P direction, with a covalency gap of 0.2 eV: $La_2Ti_{2-x}V_xO_7$ is therefore properly multiferroic. We are currently investigating the magnetoelectric tensors.

MA 2.11 Mon 12:30 EB 301

***Ab initio* study of the properties of $BaTiO_3$/Co-Pt alloy interface** — •Konstantin Z. Rushchanskii, Stefan Blügel, and Marjana Ležaić — Peter Grünberg Institut, Forschungszentrum Jülich and JARA,52425 Jülich, Germany

Multiferroics are materials which exhibit more that one ferroic order parameter. They can be made of a single phase, where multiple ferroic order parameters co-exist simultaneously, or of composites, where different ferroic order parameters are combined in separate phases. Due to the limited number of known single phase multiferroics, most of which present multiple ordering only at low temperatures, engineering of composite junctions based on interfaces of magnetic and ferroelectric compounds are therefore of great scientific interest but are also promising due to their potential applications.

Cobalt-platinum alloys are known as compounds with a strong potential for applications in magnetic data storage, due to the strong exchange interactions and strong spin-orbit coupling (and, as a consequence, a large magnetocrystalline anisotropy energy). We present results of *ab initio* calculations based on density functional theory (DFT) of the magneto-electric coupling in cobalt-platinum alloys interfaced with $BaTiO_3$ ferroelectric.

We acknowledge the support by Helmholtz Young Investigators Group Program VH-NG-409.

MA 3: Bio- and Molecular Magnetism

Time: Monday 9:30–12:30 Location: EB 202

MA 3.1 Mon 9:30 EB 202

Influence of an intermediate oxygen layer on the magnetic and electronic properties of Fe and Co porphyrin molecules on Cu(001) — •Heike C. Herper[1,3], Matthias Bernien[2], Claudia Weis[1], Carolin Antoniak[1], Bernhard Krumme[1], Jorge Miguel[2], Sumanta Bhandary[3], Biplab Sanyal[3], Dieter Bovenschen[1], Olle Eriksson[3], Peter Entel[1], Wolfgang Kuch[2], and Heiko Wende[1] — [1]Faculty of Physics and CeNIDE, University of Duisburg-Essen, 47048 Duisburg — [2]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin — [3]Department of Physics and Astronomy, Uppsala University, 75120 Uppsala

The ongoing miniaturization of magnetic devices requires the search for new materials, e.g. functional molecules on surfaces. Here, the influence of an intermediate oxygen layer on Cu(001) on the magnetic

properties of Fe and Co octaethylporphyrin (OEP) molecules is studied. We have performed a combined study of X-ray absorption spectroscopy (XAS) and density functional theory calculations within the GGA+U method. The calculations reveal that Fe and Co OEP prefer Cu hollow site positions on the oxygen covered surface with an intermediate spin state. The XAS of Co OEP shows a detailed fine structure at the L_3 edge depending on the photon incidence angle. This can be related to the calculated density of states and the occupation of d orbitals with different symmetry. We also investigated the magnetic anisotropy in terms of 2nd order perturbation theory to understand the strong angular dependence of the magnetic dichroic signal of Fe OEP in presence of the oxygen layer. Supported through SFB 491 and SFB 658.

MA 3.2 Mon 9:45 EB 202

Magnetic measurements of a Nickel(II) Double Cubane — •Wolfgang Kroener[1], Andreas Scheurer[2], Klaus Gieb[1], Rolf W. Saalfrank[2], Michael Stocker[1], and Paul Müller[1] — [1]Department of Physics and Interdisciplinary Center for Molecular Materials (ICMM), Universität Erlangen-Nürnberg — [2]Department Chemie und Pharmazie, Lehrstuhl für Anorganische und Allgemeine Chemie, Universität Erlangen-Nürnberg

We investigated an octanuclear chloro-bridged nickel(II) double cubane $[(\{Ni^{II}_4(\mu_3\text{-}OH)Cl_3(HL)_3\}\mu_2\text{-}Cl)_2]$. Single crystal measurements were performed with a custom 2DEG Hall probe magnetometer. Powder measurements were performed with a commercial SQUID magnetometer. Magnetization measurements show two separated hysteresis loops. Temperature as well as sweep-rate dependencies show single-molecule magnet behavior. The loop around zero magnetic field vanishes at 0.9 K, whereas the one at higher fields closes at 1.3 K. This can be explained by anisotropic coupling of the cubane units with $S = 4$. Including this fact into the Hamiltonian, all principal features of the hysteresis curve can be described.

MA 3.3 Mon 10:00 EB 202

Spin densities in high-spin states of Mn(III) and Cu(II) tripelsalen model complexes — •Stefan Leiding[1], Dirk Andrae[2], Andrei Postnikov[3], and Jürgen Schnack[1] — [1]Universität Bielefeld — [2]Freie Universität Berlin — [3]Université de Lorraine, Metz, France

In order to investigate geometric and electronic effects on the ferromagnetic coupling via the spin-polarization mechanism [1], we study heptanuclear complexes related to molecular magnets like $[\{(talen^{t\text{-}Bu_2})\text{-}\{Mn^{III}(solv)_n\}_3\}_2\{Fe^{III}(CN)_6\}]^{3+}$ [2] and their fragments with Kohn-Sham density functional theory. Conjugated double bonds in these complexes affect the magnetic properties, like the spin polarization, mainly due to the switch in sequence of highest occupied molecular orbitals corresponding to two spin components. In order to identify, in each case, the state with the lowest energy, we carefully studied the effect of imposing, and lifting, the symmetry constraints specific to the molecular fragment in question onto the molecular orbitals.

[1] J. Cano, E. Ruiz, S. Alvarez, M. Verdaguer, Comments Inorg. Chem. **20** (1998) 27; [2] T. Glaser, M. Heidemeier, E. Krickemeyer, H. Bögge, A. Stammler, R. Fröhlich, E. Bill, J. Schnack, Inorg. Chem. **48** (2009) 607.

MA 3.4 Mon 10:15 EB 202

Magnetocaloric properties of gadolinium based heterometallic molecules studied by the finite-temperature Lanczos method — Christian Heesing[1], Oliver Wendland[1], Thomas N. Hooper[2], Euan Brechin[2], and •Jürgen Schnack[1] — [1]Universität Bielefeld, Universitätsstr. 25, D-33615 Bielefeld — [2]School of Chemistry, University of Edinburgh, Edinburgh, U.K.

The magnetocaloric effect enables one to heat or cool by varying the applied magnetic field. Magnetic molecules with a high density of low-lying high spin multiplets are especially desirable in this context since they lead to big entropy changes when sweeping the field isothermally. In this contribution we discuss gadolinium based heterometallic molecules that have been modeled by means of the finite-temperature Lanczos method [1]. This method generates very accurate approximations of thermal observables for Hilbert space dimensions of up to 10^{10}.

[1] J. Schnack, O. Wendland, Eur. Phys. J. B **78** (2010) 535-541

MA 3.5 Mon 10:30 EB 202

Coherent Manipulation of Electron Spins in a {Cu3} Spin Triangle Complex — •Choi K.-Y.[1], Kumar P.[2], Lemmens P.[2], Bassil B. S.[3], Kortz U.[3], Nojiri H.[4], Wang Z. X.[5], Tol J. van[5], and Dalal N. S.[5] — [1]Dpt. Physics, Chung-Ang Univ., Seoul, Korea — [2]IPKM, TU-BS, Germany — [3]Jacobs Univ., Bremen, Germany — [4]IMR, Tohoku Univ., Sendai, Japan — [5]NHMFL/FSU, Tallahassee, USA

Molecular magnets have been proposed as a promising candidate for spin-based qubits. As a test bed toward scalable qubits, we explore the isosceles antiferromagnetic spin triangle {Cu3-X} (X=As, Sb) impregnated in free standing nanoporous silicon. By using 240 GHz microwave pulses Rabi oscillations were observed and a spin memory time was measured to be T2=1066 ns at 1.5 K. This demonstrates that this hybrid material provides a promising scheme for implementing spin-based quantum gates. Comparing samples with different symmetries and environments we give evidence that spin chirality is the main decoherence source of spin triangle molecules unlike other molecular magnets. Acknowledgement: DFG and NTH

MA 3.6 Mon 10:45 EB 202

Propagation of spin information at supra-molecular scale through hetero-aromatic linkers — •Valerio Bellini[1], Th. B. Faust[2], G. A. Timco[2], G. Lorusso[1], A. Candini[1], F. Tuna[2], E. J. L. McInnes[2], R. G. Pritchard[2], S. J. Teat[3], W. Wernsdorfer[4], R. E. P. Winpenny[2,5], and M. Affronte[1,6] — [1]CNR - Istituto di Nanoscienze - S3, Modena, Italy — [2]School of Chemistry, The University of Manchester, Manchester, UK — [3]ALS, LBNL, Berkeley, USA — [4]Laboratoire L. Néel, Grenoble, France — [5]The Photon Science Institute, The University of Manchester, Manchester, UK — [6]Dipartimento di Fisica, Università di Modena e Reggio Emilia, Modena, Italy

By density-functional theory calculations, we rationalize the behavior of a series of Cr_7Ni dimers for which we are able to systematically change the aromatic linker thus tuning the strength of the magnetic interaction, as shown by EPR and microSQUID measurements [1,2]. We also predict a $\cos^2$ dependence of the magnetic coupling on the twisting angle between the aromatic cycles [3], a mechanism parallel to charge transport on similar systems [4]. These findings pave the way for a whole series of possible experimental investigations, by systematically varying the organic bridges and the magnetic frontier atoms, in order to tune and choose the appropriate coupling regime.

[1] F. Troiani, V. Bellini, et al., Nanotechnology 21, 274009 (2010). [2] V. Bellini, et al., Phys. Rev. Lett. 106, 227205 (2011). [3] Th. B. Faust, V. Bellini, et al., Published on line in Chem.-Eur. J. (2011) [DOI:10.1002/chem.201101785]. [4] L. Venkataraman, et. al., Nature 442, 904 (2006).

15 min. break

MA 3.7 Mon 11:15 EB 202

Magnetic coupling between metalloporphyrins and Ni films across a graphene sheet — •Christian Felix Hermanns[1], Kartick Tarafder[2], Mattias Bernien[1], Alex Krüger[1], Yin-Ming Chang[1], Anton Bruch[1], Peter Oppeneer[2], and Wolfgang Kuch[1] — [1]Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Department of Physics and Astronomy, Uppsala University, P.O. Box 516, S-75120 Uppsala, Sweden

We report on a combined experimental-theoretical study of Co and Fe octaetylporphyrin (CoOEP and FeOEP) molecules on a graphene sheet, supported by a ferromagnetic (FM) Ni film on W(110). Consistent with the results of angle-dependent X-ray absorption spectroscopy (XAS) at the N K edge, density functional theory (DFT+U) calculations show that both, CoOEP and FeOEP molecules, adsorb flat on the surface, while the porphyrine macrocycles are distorted due to the interaction with the substrate. By means of X-ray magnetic circular dichroism measurements at the Co and Fe $L_{2,3}$ edges we show that the FM Ni film induces a magnetic order on the Co and Fe ions of the porphyrins. According to DFT+U calculations the underlying mechanism is an indirect exchange coupling across the graphene layer. Angle dependent Co and Fe $L_{2,3}$ XA spectra resemble those of free molecules, indicating a physisorption of the metalloporphyrins. This is in line with the calculated distances between the porphyrins and the graphene plane of more than 3 Å for both types of metalloporphyrins. This work is supported by the DFG (Sfb 658), the Swedish-Indian Research Link Programme, the C. Tryggers Foundation, and the SNIC.

MA 3.8 Mon 11:30 EB 202

Direct observation of a ferri-to-ferromagnetic transition in a fluoride-bridged 3d-4f molecular cluster — •Jan Dreiser[1],

Kasper S. Pedersen[2], Cinthia Piamonteze[1], Stefano Rusponi[3], Zaher Salman[1], Md. Ehesan Ali[4], Magnus Schau-Magnussen[2], Christian Aa. Thuesen[2], Stergios Piligkos[2], Hoegni Weihe[2], Hannu Mutka[5], Oliver Waldmann[6], Peter Oppeneer[7], Jesper Bendix[2], Frithjof Nolting[1], and Harald Brune[3] — [1]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland. — [2]Dep. of Chemistry, Univ. of Copenhagen, 2100 Copenhagen, Denmark. — [3]Institute of Condensed Matter Physics, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland. — [4]Center f. Theoretical Chemistry, Ruhr-Univ. Bochum, 44801 Bochum, Germany. — [5]Institut Laue-Langevin, 38042 Grenoble, France. — [6]Physikalisches Institut, Univ. Freiburg, 79104 Freiburg, Germany. — [7]Dep. of Physics and Astronomy, Uppsala Univ., 751 20 Uppsala, Sweden.

We report on a X-ray magnetic circular dichroism (XMCD) study of the novel fluoride-bridged molecular nanomagnet DyCrDy. Element-specific magnetization curves allow us to directly observe the field-induced transition from a ferrimagnetic to a ferromagnetic arrangement of the Dy and Cr magnetic moments. By fitting a spin-Hamiltonian model to the XMCD data we extract the strength of the Dy-Cr exchange coupling. The value found from XMCD is consistent with SQUID magnetometry and inelastic neutron scattering measurements. Furthermore, based on this approach we investigate other 3d-4f molecular nanomagnets.

MA 3.9 Mon 11:45 EB 202

Ab initio inspection of magnetic and redox bistability — •Mikaël Kepenekian — CIN2, Bellaterra, Spain

Molecular materials have stimulated intense experimental and theoretical work over the last decades. Indeed, the nature of these materials allows one to take advantage of the chemical engineering in order to design systems of interest. After achievements in the fields of magnetism and conduction, molecular materials are now sought as they can associate these properties. Nevertheless, the simulation of such materials remains a problem since (i) different energetic scales are involved, and (ii) the mono-reference nature of DFT-based calculations prevent from an accurate description of properties such as magnetism. In contrast, multi-reference wavefunction-based calculations offer the opportunity to work with proper spin-states, and give access to excited states. These methods have proven their ability to provide a quantitative agreement with experience, particularly in the field of molecular magnetism.

In this work, we used multi-reference ab initio calculations to investigate the microscopic origin of the behavior exhibited by bistable molecular materials. Starting from the inspection of spin-crossover complexes we were able not only to identify a microscopic origin of the spin-crossover phenomenon but also to quantify the magnitude of the hysteresis width. More sophisticated scenario involving the simultaneous spin and charge distribution change can also be anticipated in porphyrin-based system. At the molecular level, the requirements for bistability can be foreseen and specific target objects can be proposed in the light of the electronic and structural modifications.

MA 3.10 Mon 12:00 EB 202

Quantized Ferromagnetic Spin Waves in Mn_7-Disks Identified by their Q Dependence in Inelastic Neutron Scattering Experiments — •Joscha Nehrkorn[1], Oliver Waldmann[1], Shreya Mukherjee[2], George Christou[2], Thierry Strässle[3], and Hannu Mutka[4] — [1]Physikalisches Institut, Universität Freiburg, Germany — [2]Department of Chemistry, University of Florida, USA — [3]LNS, ETH Zürich & Paul Scherrer Institut, Switzerland — [4]Institut Laue-Langevin, France

The concept of ferromagnetic spin waves was developed for extended systems in the early days of quantum mechanics and since then successfully applied in many cases. By limiting the number of spin centers the excitation spectrum becomes quantized. The quantized ferromagnetic spin wave (QFSW) model allows us to calculate those excitations of ferromagnetically coupled molecular nanomagnets exactly, which can be observed by inelastic neutron scattering (INS) at low temperatures. Such systems are an example of many-body physics in clusters containing only a few magnetic centers.

The two disk-like molecules $Mn_7$11 and $Mn_7$16 have an almost identical magnetic core. Surprisingly the exchange of a peripherical ligand changes the ground state spin from $S = 11$ for $Mn_7$11 to the maximal possible value $S = 16$ for $Mn_7$16. We studied them with INS on the spectrometers IN5 (ILL) and FOCUS (PSI). The ability of INS to probe the wave functions via the Q dependence allows us to identify the observed excitations as QFSW excitations. This fact was essential to model the magnetic properties of the two disks correctly.

MA 3.11 Mon 12:15 EB 202

Different magnetization blocking mechanisms in 3d4f heterometallic single-molecular magnets; an experimental study — •Alexander Sundt[1], K. C. Modal[2], Y. Lan[2], C. E. Anson[2], L. Ungur[3], A. K. Powell[2], L. Chibotaru[3], and Oliver Waldmann[1] — [1]Physikalisches Institut, Universität Freiburg — [2]Institute of Inorganic Chemistry, Karlsruhe Institute of Technologie — [3]Devision of Quantum and Physical Chemistry and INPAC, Katholieke Universiteit Leuven

The observation of slow relaxation and quantum tunneling of the magnetization at very low temperatures in the molecule Mn_{12} in 1993 opened the research field of single molecular magnets (SMM). Recently heterometallic SMMs of transition metal and rare earth ions have been a focus of research as the single-ion anisotropy and the large angular momentum of the rare earth ions is believed to positively contribute to the energy barrier U_{eff} for magnetization reversal. Relaxation studies reveal the presence of unexpected additional thermal relaxation process in these clusters.

In this talk we present magnetic studies on heterometallic clusters containing Dy^{III}, a highly anisotropic rare earth ion. DC magnetization, AC susceptibility, and magnetization relaxation data are recorded on e.g. the cluster Co_2Dy_2 for different temperatures, fields and AC frequencies. The experimental data show a crossover of the blocking mechanism for magnetization reversal with temperature. Our careful analysis allows us to determine them as an exchange- and a single-ion-based relaxation mechanism. Further systems will also be discussed.

MA 4: Spin-dependent Transport Phenomena

Time: Monday 9:30–13:00 Location: H 1012

MA 4.1 Mon 9:30 H 1012

Extrinsic spin Hall effect in metallic films from first principles — •Christian Herschbach[1,2], Martin Gradhand[3], Dmitry Fedorov[1,2], Peter Zahn[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Hall, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany — [3]H. H. Wills Physics Laboratory, University of Bristol, Bristol BS8 1TH, United Kingdom

We present ab initio calculations of the skew scattering contribution to the spin Hall effect for free-standing fcc Au(111) films with substitutional Pt impurities. Their thickness is varied between 1 and 32 monolayers. The calculated spin Hall angle changes drastically as a function of impurity position within the film. We show that adatoms play a special role. In particular, they cause a sign change of the spin Hall angle. Moreover, Pt adatoms on a 1 monolayer Au film give rise to a drastic enhancement of the spin Hall angle.

MA 4.2 Mon 9:45 H 1012

Investigation of the extrinsic spin Hall effect in transition metal alloys — •K Chadova, D Ködderitzsch, and H Ebert — Universität München, Department Chemie, Butenandtstr. 5-13, D-81377 München

The extrinsic spin Hall effect (SHE) can be controlled by manipulating the concentration of impurities or by changing the impurity and host materials. In the present work we investigate the extrinsic SHE in transition metal alloys in the dilute limit from first principles. The calculations were performed by using the fully relativistic Korringa-Kohn-Rostoker (KKR) Green's function method in combination with the Coherent Potential Approximation (CPA) alloy theory on the basis of the Kubo-Streda equation.

A large extrinsic SHE is observed when the spin-orbit coupling (SOC) strength of the impurity is substantially different from the host. The magnitude of the calculated extrinsic SHE is found to scale ap-

proximately with the ratio of SOC of impurity and the host materials. In particular, we observe a sign change in the extrinsic spin Hall conductivity for some impurities. The latter depends on the relation between SOC strengths of the host and the impurtity. These results are found in a reasonable agreement with available experimental data.

MA 4.3 Mon 10:00 H 1012

The Planar Hall Effect in exchange-biased nanocrystalline $Co_{60}Fe_{20}B_{20}$ — •Klaus Seemann[1], Frank Freimuth[2], Florian Kronast[3], Sergio Valencia[3], Hongbin Zhang[2], Stefan Blügel[2], Yuriy Mokrousov[2], Daniel Bürgler[1], and Claus Schneider[1] — [1]Peter Grünberg Institut (PGI-6) and Jülich-Aachen Research Alliance (JARA-FIT), Forschungszentrum Jülich, D-52425 Jülich, Germany — [2]Peter Grünberg Institut (PGI-1), Institute for Advanced Simulation, and Jülich-Aachen Research Alliance (JARA-FIT), Forschungszentrum Jülich, D-52425 Jülich, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

An angle dependent analysis of the planar Hall effect (PHE) in nanocrystalline single-domain $Co_{60}Fe_{20}B_{20}$ thin films is reported. In a combined experimental and theoretical study we show that the transverse resistivity of the PHE is entirely driven by anisotropic magnetoresistance (AMR). Our results for $Co_{60}Fe_{20}B_{20}$ obtained from first principles theory in conjunction with a Boltzmann transport model take into account the nanocrystallinity and the presence of 20 at. % boron. The ab initio AMR ratio of 0.12% agrees well with the experimental value of 0.22%. We demonstrate that the anomalous Hall effect contributes negligibly in the present case. We complete our study by field dependent and element specific microscopic investigations based on X-ray magnetic dichroism (XMCD-PEEM) of exchange biased $Co_{60}Fe_{20}B_{20}$.

[1] K. M. Seemann et al., Phys. Rev. Lett. 107, 086603, 2011

MA 4.4 Mon 10:15 H 1012

Side-Jump Scattering Contribution to Anomalous Hall Effect from Magnetic Impurities — •Jürgen Weischenberg, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Recently, within the full-potential linearized augmented plane-wave scheme (FLAPW), we have implemented a method that allows for a calculation of the intrinsic [1] and side-jump (SJC) scattering-independent contributions to the anomalous Hall effect (AHE) from the electronic structure of a perfect crystal alone [2], assuming that the disorder in the system is short-ranged. Although the SJC depends neither on the impurity concentration nor the scattering strength, it is sensitive to the spin structure of the impurity potential, which makes it possible to consider different scenarios for side-jump scattering from magnetic impurities. We extended and applied our method to study the effects of scattering from magnetic impurities on the AHE in a variety of ferromagnetic materials. We also analyze the role of spin-flip processes for the AHE, which have been considered previously for the intrinsic contribution. Financial support by the HGF-YIG Programme VH-NG-513 is gratefully acknowledged.

[1] H. Zhang, F. Freimuth, S. Blügel, Y. Mokrousov and I. Souza, PRL **106**, 117202 (2011)

[2] J. Weischenberg, F. Freimuth, J. Sinova, S. Blügel and Y. Mokrousov, PRL **107**, 106601 (2011)

MA 4.5 Mon 10:30 H 1012

Tunnel-induced spin-anisotropy in quantum dot spin valves — •Maciej Misiorny[1], Michael Hell[1], and Maarten Wegewijs[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich & JARA Jülich Aachen Research Alliance, 52425 Jülich, Germany — [2]Institute for Theory of Statistical Physics, RWTH Aachen, 52056 Aachen, Germany

Atomic-scale spintronic systems, such as single-molecule magnets (SMMs) and magnetic adatoms, have recently been studied intensely mainly because of their large spin-anisotropy arising from strong spin-orbit and ligand fields. We show that spin-anisotropy can also be generated in *spin-isotropic* systems by spin-dependent transport of electrons. For a generic spin-1 quantum dot tunnel coupled to two metallic ferromagnetic electrodes we show that quantum fluctuations induce a *quadrupolar exchange field*, generalizing the well established (dipolar) exchange field. This field generates a uniaxial spin-anisotropy barrier that increases with the tunnel coupling, achieving values comparable to that of SMMs, but with the added flexibility of electric and magnetic tuneability. Besides inducing it, the transport can also be used to directly read out the quadrupolar field, utilizing its competition with Kondo spin-exchange processes with the ferromagnets. In this regime the proximity-induced quadrupolar exchange field is found to dominate over the dipolar exchange field, strongly enhancing the low-temperature spin-filtering as compared to spin-1/2 quantum dot spin-valves. Consequently, not only do spin-quadrupole effects in spin-polarized transport seem inevitable in high-spin nanosystems, but they also offer new prospects for spintronic applications.

MA 4.6 Mon 10:45 H 1012

Spin polarized tunneling in MgO-based tunnel junctions with superconducting electrodes — •Oliver Schebaum[1], Günter Reiss[1], Jagadeesh S. Moodera[2], and Andy Thomas[1] — [1]Thin Films and Physics of Nanostructures, Physics Department, Bielefeld University, Germany — [2]Francis Bitter Magnet Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

We prepared magnetic tunnel junctions with one ferromagnetic and one superconducting Al-Si electrode. Pure cobalt electrodes were compared with a Co-Fe-B alloy and the Heusler compound Co_2FeAl. The polarization of the tunneling electrons was determined using the Maki-Fulde-model and is discussed along with the spin-orbit scattering and the total pair-breaking parameters. The junctions were post-annealed at different temperatures to investigate the symmetry filtering mechanism responsible for the giant tunneling magnetoresistance ratios in Co-Fe-B/MgO/Co-Fe-B junctions.

MA 4.7 Mon 11:00 H 1012

Ultrafast Transport of Laser-Excited Spin-Polarized Carriers in Metallic Multilayers — •Alexey Melnikov[1], Alexandr Alekhin[1], Tim O. Wehling[2], Vladimir V. Roddatis[3], Damian Bürstel[4], Detlef Diesing[4], Alexander I. Lichtenstein[2], and Uwe Bovensiepen[5] — [1]Fritz-Haber-Institut der MPG, Abt. Phys. Chemie — [2]Universität Hamburg, Theor. Phys. Institut — [3]CIC Energigune, Spain — [4]Universität Duisburg-Essen, Institut für Phys. Chemie — [5]Universität Duisburg-Essen, Fakultät für Physik

The ultrafast spin dynamics (SD) induced by a transport of spin polarized carriers is a hot topic motivated by the fundamental interest in magnetic excitations and applications like spintronics and data storage. To understand underlying elementary processes typically occurring on femtosecond time scales, we have developed a time-of-flight-like approach that probes SD induced by hot carriers (HC) and demonstrated a spin polarized HC transport through an epitaxial Au/Fe/MgO(001) structure. Using a back pump-front probe configuration, we establish that HC induced in Fe by the pump laser pulse can form a nearly ballistic spin current in Au: optical second harmonic (SH) generated at the Au surface by the probe pulse monitors the transient surface HC density and spin polarization formed by predominantly ballistic/diffusive spin-down/up carriers. Comparing the SH response of Fe to the direct optical excitation with that to the excitation by hot carriers generated in Au, we rule out coherent effects of the pump pulse and show that the HC-induced SD is the main origin of the ultrafast demagnetization. Financial support by the DFG through ME 3570/1-1 is acknowledged.

15 min. break

MA 4.8 Mon 11:30 H 1012

Static and dynamic properties of magnetic domain configurations in patterned La0.7Sr0.3MnO3 nanostructures — •Luís Peña[1], Carlos Vaz[1,2], Michael Förster[1], Jan Rhensius[2,3,4], Andrè Bisig[2,4,8], Phillip Wolhüter[2,4], Sebastian Schweitzer[4], Jakoba Heidler[2], Helmut Körner[2,4], Andrea Locatelli[5], Miguel Niño[5], Markus Weigand[6], Laurence Méchin[7], Fabien Gaucher[7], Eberhard Goering[8], Souliman Moussaoui[9], Frithjof Nolting[9], Laura Heyderman[3], and Mathias Kläui[1] — [1]Institut für Physik, JGU Mainz, Staudingerweg 7, D-55128 — [2]SwissFEL, PSI, CH-5232 — [3]Lab. for Micro- and Nanotech., PSI, CH-5232 — [4]Fachbereich Physik, Univ. Konstanz, Universitätsstraβe 10, D-78457 — [5]Sincrotrone Trieste, I-34149 — [6]HZB für Mater. und Energ. GmbH,D-12489 — [7]GREYC, 6 Blvd. du Maréchal Juin,FR-14050 — [8]Max-Plancx-Instute for Intelligent System, Heisenbergstrasse 3, D-70569 — [9]SLS-PSI, CH-5232

The static magnetic domain configuration in square- and ring-shape structures is investigated by direct high-resolution x-ray magnetic microscopy as a function of temperature and geometrical parameters. We show that the magnetic configurations evolve from multidomain

to flux-closure states with decreasing element size, with a thickness-dependent crossover at the micrometric scale. The flux-closure states are stable against thermal excitations up to near the Curie temperature. Through magnetotransport experiments on half-ring structures we investigate the dynamic properties of transversal domain wall depinning by current pulse injection.

MA 4.9 Mon 11:45 H 1012

Magnetotransport properties of Pd-rich PdFe alloys: effect of chemical ordering — •Josef Kudrnovsky[1], Ilja Turek[2], Vaclav Drchal[1], and Sergei Khmelevskii[3] — [1]Institute of Physics AS CR, Prague — [2]Institute of Physics of Materials AS CR, Brno — [3]CMS, University of Technology, Vienna

The electronic structure and transport properties of Pd-rich PdFe alloys are investigated as a function of the atomic and magnetic orders. The densities of states, magnetic moments, residual resistivites, anisotropic magnetoresistances (AMR), and the anomalous Hall effect (AHE) are calculated from first-principles. The atomic order is characterized by an amount of antisite Pd-Fe disorder on Pd- and Fe-sublattices. Both stoichiometric Pd3Fe and non-stoichiometric Pd(70)Fe(30) alloys are studied. The electronic structure is determined in the framework of the TB-LMTO method in which the effect of disorder is described by the coherent potential approximation (CPA). The conductivity tensor from which the AMR and AHE are calculated, is determined from relativistic generalization of the transport Kubo-Greenwood approach. The effect of the thermal magnetic disorder on the resistivity and the AMR has been studied in the framework of the disordered local moment approach based on CPA. Our results are in an overall good agreement with available experimental data.

MA 4.10 Mon 12:00 H 1012

$Mn_{3-x}Ga$ based magnetic tunnel junctions with perpendicular magnetic anisotropy — •Manuel Glas, Daniel Ebke, Markus Schäfers, Patrick Thomas, and Günter Reiss — Thin Films and Physics of Nanostructures, Bielefeld University, Germany

The integration of $Mn_{3-x}Ga$ thin films with perpendicular magnetic anisotropy into magnetic tunnel junctions was investigated. MgO (001) and $SrTiO_3$ (001) substrates were used to achieve epitaxial (001)-oriented thin films. Crystallographic and magnetic measurements were performed to characterize the $Mn_{3-x}Ga$ electrodes. A strong Mn oxidation at the barrier interface was found from X-ray absorption spectroscopy (XAS). Therefore, a thin protection layer of CoFeB or Mg was deposited to improve the quality of the interface between barrier and electrode. A magnetically perpendicular counter electrode was formed by Co/Pt multilayers. Major loop hysteresis measurements suggest a magnetic decoupling between the electrodes through the MgO barrier. First transport measurements showed a maximum room temperature TMR ratio of 18 % for $Mn_{2.3}Ga$/CoFeB/MgO/CoFeB/$\{Co/Pt\}_{10}$ on MgO and 14 % on $SrTiO_3$ substrates. The corresponding low temperature (13 K) TMR values reach 32 % for MgO and 26 % for $SrTiO_3$ substrates. The obtained transport properties will be compared to Co/Pd based magnetic tunnel junctions with perpendicular magnetic anisotropy.

MA 4.11 Mon 12:15 H 1012

Calculation of Fermi surfaces and Elliott-Yafet parameter from first principles — •B. Zimmermann, S. Heers, N. H. Long, Y. Mokrousov, P. Mavropoulos, and S. Blügel — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The knowledge of the Fermi surface (FS) is crucial for the understanding of many properties of metals. For example, spin-dependent electron transport phenomena are determined by the electronic structure of a material in the vicinity of its FS. In the first-principles Korringa-Kohn-Rostoker (KKR) Green-function method [1], the band structure is determined by the zeros of the determinant of the non-hermitian KKR matrix, $\det(\mathcal{M}(\mathbf{k}, E)) = 0$. Many $\mathbf{k}$-points are required to obtain an accurate description. Here, we report on the implementation of a tetrahedron method within the KKR framework in which the spin-orbit interaction has been included. Our approach is based on an interpolation of the complex eigenvalues of $\mathcal{M}$ at a fixed energy $E = E_F$ instead of an interpolation of $E(\mathbf{k})$. This allows for a fast and accurate calculation of complex FSs of slab and bulk systems. As an application of the method, we investigate the Fermi-surface topology and the Elliott-Yafet spin-mixing parameter of $5d$ transition metals.

We acknowledge funding under DFG project MO 1731/3-1 and HGF-YIG program VH-NG-513.

[1] N. Papanikolaou, R. Zeller, P. H. Dederichs, J. Phys.: Condens. Matter **14**, 2799 (2002).

MA 4.12 Mon 12:30 H 1012

Interlayer exchange coupling and transport properties of SrTiO3 based magnetic tunnel junctions — •Brahim Belhadji[1], Hongxin Yang[1], Julian Velev[2], and Mairbek Chshiev[1] — [1]Spintec, UMR, CEA/CNRS/UJF Grenoble, France — [2]University of Puerto Rico, San Juan, Puerto Rico 00931, USA

In view of further miniaturization of spintronic devices, alternative to MgO materials are required in order to maintain a high TMR as resistance-area product becomes smaller. A possible solution may be SrTiO3 due to its smaller bandgap compared to MgO. Here we present first-principle calculations of interlayer exchange coupling(IEC) and spin dependent transport in SrTiO3-based MTJs as a function of barrier thickness and electrode composition (Fe, FeCo and Co). We found that the IEC is antiferromagnetic for relaxed Co/SrTiO3/Co structures and decays exponentially as a function of SrTiO3 thickness and stronger compared to Fe|MgO|Fe. Furthermore, in case of CoFe|SrTiO3 MTJs the IEC amplitude has a clear tendency to decrease and even become positive as Fe content increases. Spin dependent transport calculations in these MTJs show that SrTiO3 seems not to be as good a spin filter as the MgO even though TMR values of 3000% for 9 monolayers of SrTiO3 (~ 1.6nm) were obtained for Co|SrTiO3|Co MTJs, in agreement with previous studies. We also calculated the dependence of TMR on the electrode composition and barrier oxidation conditions.

This work has been supported by French National Research Agency (ANR) Project CRYSTO and by Nanosciences Foundation in Grenoble, France.

MA 4.13 Mon 12:45 H 1012

***Ab initio* investigation of the Elliott-Yafet parameter in symmetric ultrathin W films** — •N. H. Long, P. Mavropoulos, S. Heers, B. Zimmermann, Y. Mokrousov, and S. Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The spin relaxation in non-magnetic metallic thin films is an important effect in spintronics [1]. In systems with space-inversion symmetry, the spin relaxation is mainly due to the Elliott-Yafet mechanism [2,3]: momentum scattering ($|\mathbf{k}\rangle \rightarrow |\mathbf{k}'\rangle$) at impurities or phonons can cause spin-flip scattering due to the presence of spin-orbit coupling of degenerate Bloch states, that entails a $\mathbf{k}$-dependent superposition of spin-up and -down states. Within this model, momentum- and spin-relaxation rate are proportional. The proportionality factor is the Elliott-Yafet parameter b^2, which quantifies the degree of admixture of states with different spin character in a crystal. In this work, we calculate the b^2 parameter of symmetric W(100) and W(110) ultrathin films using the Korringa-Kohn-Rostoker Green function method. Our results reveal an oscillation of the b^2 parameter as a function of thickness of the films, as well as a significant anisotropy. We discuss our findings in terms of the symmetry properties of bulk and surface states on the Fermi surface of the films. We acknowledge funding from DFG under MO 1731/3-1 and HGF-YIG Programme VH-NG-513.

[1] I. Žutić, J. Fabian, S. Das Sarma, Rev. Mod. Phys. **76**, 323 (2004).

[2] R. J. Elliott, Phys. Rev. **96**, 266 (1954).

[3] Y. Yafet, Solid State Physics, Vol. **14**, 2 (1963).

MA 5: Spin Structures and Magnetic Phase Transitions

Time: Monday 9:30–12:30 Location: H 0112

MA 5.1 Mon 9:30 H 0112

Structure and Phase Transitions of the Spiral Antiferromagnet $Ba_2CuGe_2O_7$ in Canted Magnetic Fields — •Sebastian Mühlbauer[1], Severian Gvasaliya[1], Eric Ressouche[2], Ekaterina Pomjakushina[3], and Andrey Zheludev[1] — [1]Neutron Scattering and Magnetism Group, Laboratory for Solid State Physics, ETH Zürich, Switzerland — [2]INAC/SPSMS-MDN, CEA/Grenoble, 38054 Grenoble Cedex 9, France — [3]Laboratory for Developments and Methods (LDM), Paul Scherrer Institute, Switzerland

Neutron diffraction in combination with measurements of the susceptibility and specific heat have been used to systematically study the different magnetic structures of the non-centrosymmetric tetragonal antiferromagnet (AF) $Ba_2CuGe_2O_7$, that evolve for different orientation of the magnetic field. For magnetic field close to the tetragonal c-axis, a phase transition from the soliton lattice to a recently reported incommensurate double-k AF-cone phase [1] is confirmed. In contrast, for large angles enclosed by the magnetic field and the c-axis, a smooth crossover to a complexly distorted non-sinusoidal structure is observed by neutron diffraction. Measurements of susceptibility and specific heat furthermore indicate the existence of a incommensurate/commensurate transition for magnetic fields ≈ 9 T applied in the basal (a, b)-plane. The results show a virtually identical behavior for the magnetic field confined in both a (1,0,0) and (1,1,0) crystallographic plane and agree with a non-planar, asymmetrically distorted cycloidal magnetic structure.

[1] S. Mühlbauer et al., Phys. Rev. B **84**, 180406 (2011)

MA 5.2 Mon 9:45 H 0112

Frustrated Ising spins simulated by spinless bosons in a tilted lattice: from disordered quantum liquids to antiferromagnetic order — •Susanne Pielawa[1,2], Erez Berg[1], and Subir Sachdev[1] — [1]Department of Physics, Harvard University, Cambridge MA 02138, USA — [2]Department of Condensed Matter Physics, The Weizmann Institute of Science, Rehovot, 76100 Israel

Recently a quantum antiferromagnetic spin chain has been simulated experimentally using spinless bosons in a tilted optical lattice [Nature 472, 307 (2011)]. Extending this idea to two dimensions, we theoretically analyze a setup of spinless bosons in a decorated square lattice tilted along the diagonal. This system simulates a quantum Ising model with antiferromagnetic interactions on a non-bipartite lattice. The lattice geometry thus prevents the system from ordering, even in the limit where the effective antiferromagnetic coupling is strong compared to the magnetic fields. This frustration can be reduced by changing the tilt angle slightly away from the diagonal, and the system undergoes a transition to an antiferromagnetically ordered state. We find that the disordered liquid-like state is continuously connected a the paramagnetic state. Using quantum Monte Carlo simulations and exact diagonalization we find that for realistic system sizes the antiferromagnetic order will appear to be one-dimensional; however in the thermodynamic limit the order is two-dimensional.

MA 5.3 Mon 10:00 H 0112

quantum phases in the S=1/2 heisenberg model on the cairo pentagonal lattice — •Ioannis Rousochatzakis[1,2], Andreas Laeuchli[1], and Roderich Moessner[1] — [1]Max Planck Institut für Physik Komplexer Systeme, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Institute for Theoretical Solid State Physics, IFW Dresden, 01171 Dresden, Germany

We present an extensive analytical and numerical exact diagonalization study of the spin S=1/2 antiferromagnetic Heisenberg model on the Cairo pentagonal lattice. This is the dual of the Shastry-Sutherland lattice and has been discussed as a possible new candidate for having a spin liquid ground state. More recently a close realization of this model has appeared in the S=5/2 compound $Bi_2Fe_4O_9$. Here we use a model with two different exchange couplings allowed by the symmetry of the lattice, and investigate the nature of the ground state as a function of their ratio x. After establishing the classical phase diagram we switch on quantum mechanics in a gradual way that highlights the different role of quantum fluctuations on the two inequivalent sites of the lattice. The most important findings include: (i) a surprising interplay between a collinear and a four-sublattice orthogonal phase due to an underlying order-by-disorder mechanism which is active at small x, and (ii) a non-magnetic and possibly spin-nematic phase with d-wave symmetry at intermediate x. The latter is driven by an effective 4-spin exchange term that first appears in fourth order perturbation theory in x.

MA 5.4 Mon 10:15 H 0112

Electrons confinement effect on orbital moment and magnetocrystalline anisotropy of Fe/Ag(001) — •Maciej Dabrowski[1], Uwe Bauer[1], Marek Przybylski[1], Takeshi Nakagawa[2], Yasumasa Takagi[2], Toshihiko Yokoyama[2], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Department of Materials Molecular Structure, Institute for Molecular Science, Myodaiji-cho, Okazaki, 444-8585, Japan

In a thin film, electron motion can be confined by potential barriers at the interfaces, resulting in the formation of quantum well states (QWS). In particular, in ferromagnetic thin films, the quantization of d-bands can lead to oscillations of the magnetocrystalline anisotropy as a function of film thickness [1,2].

Using x-ray magnetic circular dichroism (XMCD) and magneto-optic Kerr effect (MOKE), we demonstrate a relation between electrons confinement, magnetocrystalline anisotropy and orbital moment in Fe films grown on vicinal surfaces of Ag(001). We show that a spin reorientation transition from in-plane to out-of-plane simultaneously occurs with in-plane magnetization rotation, which is determined by the QWS contribution to the magnetocrystalline anisotropy.

[1] J. Li, M. Przybylski, F. Yildiz, X. D. Ma, and Y. Z. Wu, Phys. Rev. Lett. 102, 207206 (2009)

[2] U. Bauer M. Dabrowski, M. Przybylski, and J. Kirschner, Phys. Rev. B 84, 144433 (2011)

MA 5.5 Mon 10:30 H 0112

Modulated states in chiral helimagnets with easy-plane anisotropy — •Anna B. Butenko[1], Alexei N. Bogdanov[1], Ulrich K. Rößler[1], Eric A. Karhu[2], Michael D. Robertson[3], and Theodore L. Monchesky[2] — [1]IFW Dresden, Germany — [2]Dalhousie University, Halifax NS, Canada — [3]Acadia University, Wolfville NS, Canada

A surface-induced uniaxial anisotropy of easy-axis type can stabilize hexagonal Skyrmion lattices in nanostructures of isotropic or cubic chiral magnets. In these modulated states with field applied along the anisotropy axis, the Skyrmions run along the axis. This effect explains experimental observations of Skyrmion lattices in thin layers of cubic helimagnets (Fe,Co)Si and FeGe. We find that another type of Skyrmion lattice can be stabilized in uniaxial magnets of easy-plane type, when the field is applied perpendicularly to the axis. Detailed results from calculations of the magnetic phase diagram for the model of an isotropic chiral helimagnet with induced easy-plane uniaxial anisotropy are presented. Depending on the strength of the anisotropy, different sequences of magnetization processes can occur with phase transitions between helicoidal transverse modulations, elliptically distorted conical helices and Skyrmion lattices. The theoretical results are shown to be relevant for epitaxial MnSi (111) thin films with strain-induced easy-plane anisotropy. Ab initio calculations confirm the easy-plane character of the induced magnetic anisotropy in rhombohedrally distorted MnSi (111) with isotropic and tensile strains in the basal plane.

MA 5.6 Mon 10:45 H 0112

High-field magnetism and magneto-acoustics in UCo_2Si_2 — •S. Yasin[1], A.V. Andreev[2], Y. Skourski[1], S. Zherlitsyn[1], and J. Wosnitza[1] — [1]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Institute of Physics ASCR, Na Slovance 2, 18221 Prague 8, The Czech Republic

We report results of magnetization and magneto-acoustic studies on a UCo_2Si_2 single crystal in high magnetic fields. This compound orders antiferromagnetically at the Néel temperature $T_N = 83$ K and shows at low temperatures a first-order metamagnetic transition (MT) at 45 T with very small hysteresis ($\mu_0 \Delta H_{cr} = 0.16$ T) to a ferrimagnetic state seen as a sharp jump in the magnetization when the magnetic field is applied along the c direction. The magnetization curve measured along

the a axis shows no transition and is linear up to 60 T. The acoustic properties exhibit drastic anomalies in the vicinity of both magnetic phase transitions; the spontaneous and the field-induced one. At T_N, a pronounced change in the sound velocity Δv/v accompanied with a peak in the attenuation $\Delta\alpha$ has been observed. Whereas $\Delta\alpha$ only shows a very sharp peak at the MT, Δv/v displays a more complicated behavior; it has a non-monotonous temperature evolution with maximum effects at 30 K, which can be due to the transition changing from first to second order. Our results enabled us to map the phase diagram of UCo_2Si_2 in fields applied along the c axis. We discuss our observations in relation to the magnetism on the U site and the magneto-elastic interaction in this material. *Part of this work was supported by EuroMagNET under the EU contract No. 228043.

15 min. break

MA 5.7 Mon 11:15 H 0112

Magnetic phase diagram of $Eu_{1-x}Gd_xS$ — •Roman Rausch[1], Wolfgang Nolting[2], and Michael Potthoff[1] — [1]I. Institut für Theoretische Physik, Universität Hamburg — [2]Festkörpertheorie, Institut für Physik, Humboldt-Universität Berlin

We present self-consistent RKKY calculations of the critical temperatures of the antiferromagnetic phases within the pure Kondo-lattice model (sc and fcc lattices). Extending the results to chemical and magnetic disorder, we are able to calculate the phases of the concentrated spin system $Eu_{1-x}Gd_xS$ which agree well with the experiment. This substance also shows a spin-glass phase whose origin is briefly discussed from a proposed microscopic principle.

MA 5.8 Mon 11:30 H 0112

Phase diagram of hard-core bosons on clean and disordered 2-leg ladders: Mott insulator, Luttinger liquid, Bose glass — •Francois Crepin[1], Nicolas Laflorencie[2], Pascal Simon[3], and Guillaume Roux[4] — [1]Institute for Theoretical Physics and Astrophysics, University of Würzburg, 97074 Würzburg, Germany — [2]LPT, Université de Toulouse, UPS (IRSAMC), Toulouse, France — [3]LPS, Université Paris-Sud, UMR-8502 CNRS, F-91405 Orsay, France — [4]LPTMS, Université Paris-Sud, UMR-8626 CNRS, F-91405 Orsay, France

While one-dimensional free fermions and hard-core bosons are often considered to be equivalent, coupling only two chains enables particle exchange and leads to totally different physics for free fermions and HC bosons. Combining analytical (strong coupling, field theory) and numerical (quantum Monte Carlo, DMRG) approaches, we study the apparently simple but nontrivial model of HC bosons in a two-leg ladder geometry. At half-filling, while a band insulator appears for fermions at large interchain hopping $t_\perp > 2t$ only, a Mott gap opens up for bosons as soon as $t_\perp \neq 0$ through a Kosterlitz-Thouless transition. Away from half-filling, a gapless Luttinger liquid mode emerges in the symmetric sector with a nontrivial filling-dependent Luttinger parameter $1/2 \leq K_s \leq 1$. We discuss consequences for experiments on spin ladders in a magnetic field and cold atoms, as well as disorder effects. Indeed, a quantum phase transition at finite disorder strength is expected, between a 1D superfluid and an insulating Bose glass phase. F. Crépin *et al.*, Phys. Rev. B, **84**, 054517 (2011)

MA 5.9 Mon 11:45 H 0112

Z2 vortices in 2D triangular Cr-spin lattices — •Mamoun Hemmida, Hans-Albrecht Krug von Nidda, and Alois Loidl — Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany

Using Electron-Spin-Resonance spectroscopy, we discovered a universal spin-spin relaxation law in two-dimensional frustrated triangular lattice antiferromagnets. The rock salt compounds HCrO2, LiCrO2, and NaCrO2 as well as the delafossite compounds CuCrO2, AgCrO2, and PdCrO2 show a characteristic temperature dependence of the resonance linewidth, indicating relaxation via a certain kind of magnetic vortices, the so-called Z2 vortices. These vortices have been suggested originally by Kawamura and Miyashita (KM) [1]. Their work is an extension to the well-known Berezinskii-Kosterlitz-Thouless (BKT) scenario [2]. Indeed, as it is currently well established [4], the KM scenario seems to be an analogue to the earlier extension of BKT scenario, i.e. Kosterlitz-Thouless-Halperin-Nelson-Young (KTHNY) model [3], which describes successfully the melting process in a two-dimensional liquid crystal. In the frame of this presentation other recent experimental results obtained by Nuclear-Magnetic-Resonance (NMR) and Muon-Spin-Rotation (μSR) as well as current theoretical studies will be included to promote the interpretation of the up-to-date ESR results. References: [1] H. Kawamura, and S. Miyashita, J. Phys. Soc. Jpn. 53, 4138 (1984). [2] J. M. Kosterlitz and D. J. Thouless, J. Phys. C 6, 1181 (1973). [3] B. I. Halperin and D. R. Nelson, PRL. 41, 121 (1978). [4] M. Hemmida, et al., J. Phys. Soc. Jpn. 80, 053707(2011).

MA 5.10 Mon 12:00 H 0112

Atomic Scale Magnetic Dissipation from Spin-Dependent Adhesion Hysteresis — •Elena Y. Vedmedenko, Q. Zhu, U. Kaiser, A. Schwarz, and R. Wiesendanger — Institute of Applied Physics, University of Hamburg Jungiusstr. 11, 20355 Hamburg, Germany

The experimental observation of atomic scale magnetic dissipation by magnetic exchange force microscopy [1] on NiO(001) with an Fe-coated tip is reported. The origin of the dissipation signal has been investigated using Monte-Carlo energy minimization techniques and compared with experimental results. The calculations predict that the Caldeira-Leggett-type dissipation proposed previously [2] is a special case of the general phenomenon of adhesive hysteresis. According to our calculations the adhesion hysteresis is distance as well as spin dependent and should be measurable not only above magnetic Ni but also on paramagnetic O atoms. The energy released during binding or the unbinding process may then be dissipated via spin flips or phonons. Considering the simplicity of our theoretical model, the calculated energy dissipation agrees surprisingly well with the measured energy dissipation.
[1] U. Kaiser, A. Schwarz, R. Wiesendanger, Nature, 446, (522), (2007)
[2] F. Pellegrini, G. E. Santoro, E. Tosatti, Phys. Rev. Lett. 105, (146103), (2010)

MA 5.11 Mon 12:15 H 0112

Neutron reflectometry of Fe_3O_4 thin films through the Verwey Transition — •Mehrdad Baghaie Yazdi[1], Marton Major[1], Andrew Wilders[2], Wolfgang Donner[1], and Lambert Alff[1] — [1]Technische Universität Darmstadt, Darmstadt, Deutschland — [2]ILL, Grenoble, Frankreich

The Verwey transition in magnetite, Fe_3O_4, is still a not-understood phenomenon. At the Verwey point - which is a first-order-transition - a series of physical property changes, such as conductivity, crystal structure, and magnetization. We have grown epitaxial thin films on (100) MgO substrates by rf-magnetron sputtering. These films show extremely large changes in the magnetization at the Verwey transition making them ideal study objects. We have applied neutron reflectometry through the Verwey transition to understand the nature of the changes in magnetization. One important question addressed is the possibility of magnetic axes switching as origin of the steep drop in magnetization.

MA 6: Joint Symposium (SYXD) "100 Years of X-ray Diffraction: From the Laue Experiment to new Frontiers" (jointly with KR, BP, CPP, DF, MA, MM, GP), Organization: Wiehl, Grübel, Rädler

Time: Monday 15:00–17:30 Location: H 0105

Invited Talk MA 6.1 Mon 15:00 H 0105

Disputed discovery: The beginnings of X-ray diffraction in crystals — •Michael Eckert — Deutsches Museum, Forschungsinstitut, Museumsinsel 1, D-80538 München

The discovery of X-ray diffraction in crystals was based on misconceptions about the nature of X-rays. The background of "Laue's discovery" and its early repercussions are described from the perspective of contemporary views in 1912. The riddle concerned the origin

of the monochromacy observed in the Laue spots.

Invited Talk MA 6.2 Mon 15:30 H 0105
Why are quasicrystals quasiperiodic? — •Walter Steurer — Laboratorium für Kristallographie, ETH Zürich, Wolfgang-Pauli-Strasse 10, 8093 Zürich, Schweiz

It took more than two years until Dan Shechtman could publish his finding of a rapidly solidified Al-Mn phase with sharp Bragg reflections and icosahedral point group symmetry. His results were not accepted, initially, since they seemed to contradict fundamental laws of crystallography. A further twenty-seven years had to pass by until his discovery of quasicrystals was honoured by the Nobel Prize in 2011. This discovery was fundamental because quasiperiodic order represents a novel equilibrium state of solid matter fundamentally different from the common periodic one.

At present, stable quasicrystals have been found in more than fifty binary and ternary intermetallic systems. They show mostly decagonal or icosahedral diffraction symmetry contrary to soft quasicrystals. These are mainly qasiperiodic structures resulting from the self-assembly of either micelles in a liquid or of terpolymers with dodecagonal symmetry. The so far most promising applications of quasiperiodic structures seem to be in the field of photonic and phononic crystals.

The focus of the talk will be on the driving forces for the formation and stablization of quasiperiodic structures.

Invited Talk MA 6.3 Mon 16:00 H 0105
Coherent Diffraction Imaging with Free-Eletron Lasers — •Massimo Altarelli — European XFEL GmbH, 22607 Hamburg

One hundred years after the discovery of x-ray diffraction from crystals, spatially coherent, ultra-brilliant and ultra-short pulses of x-ray radiation from free electron lasers (FEL's) open the way to structure solution without the hurdle of crystallization. Biological objects such as cells, viruses, possibly down to individual macromolecules and to atomic resolution, and individual nanostructures in material sciences are eligible for these novel studies. An overview of the x-ray FEL sources and their basic physical principles and properties, of the strategies for sample handling and data collection and a glimpse of the necessary algorithms to phase the diffraction patterns are given. Example of results from the soft x-ray FLASH source in Hamburg and from the Linac Coherent Light Source in Stanford are illustrated. The perspectives and the challenges of the high repetition rate (up to 27 000 pulses/s) of the European XFEL, under construction in the Hamburg region, are also briefly discussed

Invited Talk MA 6.4 Mon 16:30 H 0105
X-ray free-electron lasers - emerging opportunities for structural biology — •Ilme Schlichting — Max Planck Institute for Medical Research, Heidelberg, Germany

X-ray crystallography is a mature yet still advancing method for structure determination of molecules with any molecular weight. Facilitated greatly by synchrotron X-ray sources, the method is limited only by the quality and size of the crystals and by radiation damage. Free-electron lasers (FELs) provide orders of magnitude brighter and shorter X-ray pulses than conventional synchrotron sources. It has been proposed that radiation damage, which limits the high resolution imaging of soft condensed matter, can be "outrun' by using ultrafast and extremely intense X-ray pulses that pass the sample before the onset of significant radiation damage [1]. Thus, one of the most promising scientific applications of XFELs is in sub-nanometer resolution imaging of biological objects, including viruses, macromolecular assemblies, and nanocrystals. The concept of "diffraction-before-destruction" has been demonstrated recently at the Linac Coherent Light Source (LCLS) [2], the first operational hard X-ray FEL, for protein micro- and nanocrystals [3] and single mimivirus particles [4]. These experiments and recent developments and progress will be presented.

[1]. Neutze et al., Nature 406, 752-757 (2000). [2]. Emma, Nature Photonics 4, 641-647 (2010). [3]. Chapman et al., Nature 470, 73-77 (2011). [4]. Seibert et al., Nature 470, 78-81 (2011).

Invited Talk MA 6.5 Mon 17:00 H 0105
Structure analysis by x-ray diffraction and x-ray imaging: beyond crystals, beyond averages, and beyond modeling — •Tim Salditt — Georg-August-Universität Göttingen, Institut für Röntgenphysik, Friedrich-Hund-Platz 1, 37077 Göttingen

Classical x-ray diffraction has been based on three constraints: (i) averages over macroscopic accumulation time and sample sizes, which are many orders of magnitude larger than the structures to be resolved; (ii) homeogeneous "well ordered" samples which are - if not crystalline - characterized by well-defined correlation functions; (iii) data analysis by fitting to modeled diffraction data. However, many condensed matter problems, in particular in functional materials, soft matter and biomolecular samples, address non-equilibrium states with competing length scales, hierachical structures, and intrinsic dynamics. Progress in x-ray sources and optics has helped to meet these challenges. Conceptually often still close to the Laue experiment, far-field diffraction data can now be collected in controllable field of vies, with highly focused beams reaching the 10 nm range. Biomolecular diffraction signals can be recorded from hierachical structures such as a biological cells. Perhaps most importantly, fully coherent illumination enables data inversion without prohibitive model building. How these advances serve science, will be illustrated by examples in neuro-biophysics. We present experiments addressing different structural levels and bridging length scales, from proteins and lipid assemblies up to a complete organelle such as the synaptic vesicle, from an isolated axon up to an unsliced nerve, from tissue slice to the sensory organ.

MA 7: Joint Session "FePt Nanoparticles" (jointly with DS, MM), Organization: Michael Farle (Univ. Duisburg-Essen)

Time: Monday 15:00–17:45 Location: EB 202

Topical Talk MA 7.1 Mon 15:00 EB 202
Prediction of morphology-, composition- and size-related trends in FePt nanoparticles from first principles — •Markus Ernst Gruner — Faculty of Physics and Center for Nanointegration CeNiDE, University of Duisburg-Essen, 47048 Duisburg

Owed to the large magneto-crystalline anisotropy (MCA) of bulk FePt alloys, nanostructures with effective diameters as small as 4 nm are considered for ultra-high density recording applications. Structural defects as multiple twinning, segregation and partial ordering effectively reduce the MCA and thus severely limit the integration density. First principles calculations in the framework of density functional theory permit independent insight into the size-dependent interrelation between composition, structural stability and magnetism granting access to the electronic level. Site-resolved orbital moments and MCA are obtained a fully relativistic treatment including spin-orbit interaction.

Large scale calculations with up to 1415 atoms demonstrate that for diameters around 4 nm a close competition between multiply twinned and single crystalline morphologies is present, while the low energy of Pt surfaces enhances segregation. The systematic variation of 3*d* and 5*d* components reveals that especially addition of Mn can reduce twinning, while complicating the magnetic configuration. Structural and electronic changes which may degrade the magnetic properties must also be expected from a protective encapsulation with main group elements.

Topical Talk MA 7.2 Mon 15:30 EB 202
Coulomb Blockade effects in FePt nanoparticles — •Artur Erbe[1], Ulrich Wiesenhütter[1], Darius Pohl[2], Bernd Rellinghaus[2], and Jürgen Fassbender[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]IFW Dresden

In order to correlate the size and crystallinity of FePt nanoparticles with their respective electrical and mangeto-electrical properties individual nanoparticles are contacted using electron beam lithography. The particles are prepared from gas phase on electron transparent SiN membranes which allows the transmission electron microscopy of the same nanoparticle which is characterized electrically. The fabrication results in junctions, in which single FePt nanoparticles are connected to external leads. These junctions are tested electronically by measuring the current-voltage characteristics at various gate voltages, temperatures and magnetic fields. We observe Coulomb Blockade effects

which are in agreement with the dimensions obtained from the TEM studies. The results of the magnetic nanoparticles are compared to measurements taken on Au nanoparticles of similar sizes.

Topical Talk MA 7.3 Mon 16:00 EB 202

Pt surface segregation and its impact on magnetism in FePt nanoparticles — •Ulf Wiedwald — Institut für Festkörperphysik, Universität Ulm, Albert-Einstein-Allee 11, 89069 Ulm, Germany

The appealing magnetic properties of chemically ordered FePt alloys strongly depend on composition. In nanoparticles with diameters below 10 nm the relative number of surface-near atoms strongly increases, thus any tendency of segregation will significantly change the stoichiometry of the interior. As a result, magnetic moments as well as magnetic anisotropy may vary compared to the bulk. In the frame of the collaborative research center SFB 569 we prepared size-selected, hexagonally arranged metallic particles by precursor loaded reverse micelles and plasma etching [1]. Pt segregation [2] and its impact on magnetism were examined in-situ for naked, non-interacting FePt particles on Si/SiO_2 as function of size (2-10nm) by photoelectron spectroscopy and x-ray magnetic circular dichroism. For partially $L1_0$-ordered particles we observe reduced spin moments with decreasing diameter while the orbital moment is found rather independent of size. As connected to the orbital magnetism, the effective magnetic anisotropy is also conserved for decreasing diameters, though reduced relative to the bulk [3]. Reasons for these astonishing observations are discussed.

[1] A. Ethirajan, U. Wiedwald, et al., Adv. Mater. 19, 406 (2007).
[2] L. Han, U. Wiedwald, B. Kuerbanjiang, P. Ziemann, Nanotechnology 20, 285706 (2009).
[3] U. Wiedwald, L. Han, J. Biskupek, U. Kaiser, P. Ziemann, Beilstein J. Nanotechnol. 1, 24 (2010).

Topical Talk MA 7.4 Mon 16:30 EB 202

Understanding the Metal-Carbon Interface in FePt terminated carbon nanotubes — •Darius Pohl[1], Franziska Schäffel[1], Christine Täschner[1], Marc H. Rümmeli[1], Christian Kisielowski[2], Ludwig Schultz[1], and Bernd Rellinghaus[1] — [1]IFW Dresden, P.O. Box 270116, Dresden, D-01171, Germany — [2]Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

Plasma-enhanced chemical vapour deposition (PE-CVD) onto FePt catalyst films is used to synthesize carbon nanotubes (CNT) which are teminated with L10-ordered FePt nanomagnets with high magnetic anisotropy [1]. The CNT are characterized by means of low voltage aberration-corrected HRTEM. To gain a deeper insight into the growth mechanism and in order to understand the relative crystallographic orientation of the particles with respect to the CNT axes structural investigations are conducted with a strong focus on the atomically resolved characterisation of the FePt-CNT interface. An interface-near expansion of the metal lattice is observed and attributed to a segregation of Pt towards the surface of the catalyst particle. Detailed statistical HRTEM analyses of these interfaces reveal that the CNT preferentially emanate from {111} facets of the catalyst particle. Molecular dynamic simulations were conducted to estimate the desorption energy of carbon atoms for various surfaces. Our results indicate that the physical principle based upon which the interfacial metal facet is chosen is a reduction of the desorption energy for carbon [2].

[1] F. Schäffel et al., Appl. Phys. Lett. 94 (2009) 193197.
[2] D. Pohl et al., Phys. Rev. Lett. 107 (2011) 185501.

Topical Talk MA 7.5 Mon 17:00 EB 202

Atomistic characterisation of ultrahard nanomagnets — •Carolin Antoniak — Experimentalphysik/AG Wende and Center for Nanointegration Duisburg-Essen (CeNIDE), Universität Duisburg-Essen, Lotharstr. 1, 47057 Duisburg

A combination of x-ray absorption spectroscopy (XAS) and density functional theory (DFT) has been used to study the magnetic properties like spin and orbital magnetic moments and effective magnetocrystalline anisotropy of chemically ordered FePt nanoparticles on an atomistic lengthscale. By choosing the appropriate capping material, these properties can be tuned between hard and soft magnetic with either high or low magnetic moments [1]. Focus of this talk will be the results of XAS allowing for an element-specific analysis of magnetic properties. Complemented with DFT calculations, it helps to gain more insight to the mutual influence of nanoparticles and capping material allowing to state design guidelines for improved materials which will be presented in this contribution.

This work was done in collaboration with M.E. Gruner, M. Spasova, A. Rogalev, F. Wilhelm, A.V. Trunova, F.M. Römer, A. Warland, B. Krumme, K. Fauth, S. Sun, P. Entel, M. Farle, and H. Wende. We thank the HZB-BESSYII and ESRF staff as well as the staff of the Jülich Supercomputing Center, and P. Vezolle of IBM for their kind support. Funded by BMBF (05 ES3XBA/5), EU and DFG (SFB445, SPP1239)

[1] C. Antoniak, M.E. Gruner et al., Nature Comm. 2, 528 (2011)

15 min. break

MA 8: Magnetic Particles / Clusters I

Time: Monday 17:45–19:15 Location: EB 202

MA 8.1 Mon 17:45 EB 202

X-ray magnetic circular dichroism of size-selected CoRh clusters — •Torben Beeck[1], Ivan Baev[1], Kai Chen[2], Michael Martins[1], and Wilfried Wurth[1] — [1]Institut für Experimentalphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institut für Werkstoffforschung, Max-Planck-Straße 1, 21502 Geesthacht

At the UE52 SGM beamline at BESSY II we investigated mass-selected Co_xRh_y clusters with up to four atoms per cluster. The clusters were deposited in situ via soft landing on a remanently magnetized Ni/Cu(100) surface and probed with left and right circular polarized light at the Co $L_{2,3}$ edges. The magnetic response varying with different Co/Rh compositions showing none, weak or strong dichroism. For Co_1Rh_2 it appears that the coupling to the substrate is changed to antiferromagnetic. Because of the rapid changes in dichroism and the small atomic numbers these type of clusters are suitable for comparison with complex theoretical calculations.

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

MA 8.2 Mon 18:00 EB 202

XMCD studies of Ni nanoclusters on a graphene moiré template at the new WERA/MPI-IS 7T XMCD end station at ANKA — •Thomas Tietze[1], Philipp Leicht[2], Muriel Sicot[2], Mikhail Fonin[2], Peter Nagel[3], Stefan Schuppler[3], Michael Merz[3], and Eberhard Goering[1] — [1]Max-Planck-Institut für Intelligente Systeme, 70569 Stuttgart — [2]Fachbereich Physik, Universität Konstanz, 78464 Konstanz — [3]Karlsruher Institut für Technologie, Institut für Festkörperphysik, 76021 Karlsruhe

Graphene grown on noble metal surfaces like Rhodium or Iridium can serve as a template for the growth of magnetic nanoparticles, e.g. Ni nano islands and ellipsoids. Here, we investigated the magnetic properties of in-situ grown Ni nanostructures on a graphene Moiré template on an Ir (111) single crystal by means of x-ray magnetic circular dichroism (XMCD). We investigated nanoclusters of different shapes, triangular (length 10 nm, height 2 nm) and spherical (diameter 4-5 nm), at different nominal coverage from only 0.2 to 1 monolayer, respectively. To reveal the magnetic behavior, we measured the Ni L2,3 edge XMCD signal at low temperatures (15 K) and at various applied magnetic fields up to 7 Tesla with the new fast switching MPI-IS XMCD end station at the WERA beamline at ANKA. We used sum rules to extract spin and orbital magnetic moments and found enhanced orbital moments for low nominal coverage. In order to study the magnetic anisotropy we performed XMCD measurements in different geometries to probe the in- and out-of-plane components of the Ni magnetic moments.

MA 8.3 Mon 18:15 EB 202

Site specific spin canting in Fe oxide nanoparticles — •Anne Warland[1], Carolin Antoniak[1], Masih Darbandi[1], Detlef Schmitz[2], Tobias Euwens[1], and Heiko Wende[1] — [1]Fakultät für Physik und CeNIDE — [2]Helmholtz-Zentrum Berlin für Materialien und Energie

It is well known that Fe oxide nanoparticles can hardly be saturated due to spin canting at the surface. From our Mössbauer spectroscopy measurements we obtained indications that the canting takes place mainly at the Fe sites which are octahedrally surrounded by the oxygen. Contrary, the Fe spins at tetrahedral sites are only slightly canted. Explanations for this canting effect are vacancies and missing bonds at the particles surface. XMCD spectroscopy at the Fe $L_{3,2}$ absorption edges allows to separate the magnetic contributions of Fe^{2+} and Fe^{3+} ions at tetrahedral and octahedral sites. We used this technique to determine the field dependent magnetization and to monitor the spin canting site specifically. Bare iron oxide nanoparticles of different sizes (3nm, 6nm and 9nm) have been investigated in magnetic fields up to 5T. This work is supported by DFG(WE2623/3-1)

MA 8.4 Mon 18:30 EB 202

Self assembled Iron Oxide Nanoparticles - From a 2D powder to a single crystal — •Elisabeth Josten[1], Ulrich Rücker[1], Manuel Angst[1], Paul Zakalek[1], Doris Meertens[2], Erik Wetterskog[3], Oliver Seeck[4], Florian Menau[5], Lennard Bergström[3], and Thomas Brückel[1] — [1]JCNS-2 and PGI-4, Forschungszentrum Jülich, Germany — [2]ER-C and PGI-5, Forschungszentrum Jülich, Germany — [3]Stockholm Universitet, Department of Materials and Environmental Chemistry, Stockholm, Sweden — [4]DESY, Hamburg, Germany — [5]Synchrotron Soleil, Gif-sur-Yvette, France

Fundamental research on magnetic nanostructures is an important part of todays science in the field of information technology. Highly ordered 3 dimensional structures of nanoparticles are model systems to study the magnetic inter-particle interactions.

In this context, monodisperse Fe_2O_3 nanoparticles have been deposited on a substrate to form highly ordered superstructures (mesocrystals) using a drop casting method. In a first step, structural characterization was carried out by SEM, AFM, TEM and GISAXS. Due to the arbitrary orientation of the mesocrystals on the substrate the grazing incidence scattering experiments cannot yield the full supercrystal structure information, only a powder average. In this study a single mesocrystal was detached from the sample using focused ion beam preparation techniques, and was investigated with small angle diffraction for its structure.

MA 8.5 Mon 18:45 EB 202

Tunable colloidal superlattice growth modes using iron oxide nanoparticles — •David Greving[1], Oleg Petracic[1], Durga Mishra[1], Giovanni A. Badini Confalonieri[1], Jan Perlich[2], Boris P. Toperverg[1], and Hartmut Zabel[1] — [1]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum — [2]HASYLAB at DESY, Notkestrasse 85, 22603 Hamburg

The self-organization of nanoparticles (NPs) shows a comparable behavior to the crystalline growth of atoms. Therefore, systematically investigating those parameters influencing the colloidal growth is an important task when aiming at novel magnetic or electronic materials composed from NPs. To this end we employed two different self-assembly techniques, i.e. spin-coating and sedimentation of chemically synthesized iron oxide NPs with a mean diameter of 20 nm. We used various substrates, i.e. Si, Si with thermal oxide, Si with PMMA coating, Al, Al_2O_3 and MgO, to specifically influence the particle-to-substrate forces, thus tuning one of the main factors determining the corresponding growth mode. We were able to observe all three NP growth modes analogous to that found in classical thin film growth, i.e. Vollmer-Weber-, Frank-v.d.-Merwe- and Stranski-Krastanov. The systems are structurally and magnetically characterized using scanning electron microscopy, grazing incidence small angle x-ray scattering (GISAXS) and superconducting quantum interference device magnetometry, respectively.

MA 8.6 Mon 19:00 EB 202

Correlation of superparamagnetic relaxation with magnetic dipole and exchange interaction in capped iron-oxide nanoparticles — •Joachim Landers, Frank Stromberg, Masih Darbandi, Werner Keune, and Heiko Wende — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CeNIDE), University of Duisburg-Essen

Iron-oxide nanoparticles with a mean diameter of 6 nm capped with organic surfactants and/or silica shells of various thicknesses have been prepared by a microemulsion method. The resulting different particle distances imply a tunable contribution of magnetic dipole interaction to the effective magnetic anisotropy. Bare particles of the same size were used as a reference. To determine superparamagnetic relaxation parameters temperature dependent Mössbauer spectra were measured in the range of 4.2 - 300 K. Calculations using a many state relaxation model of magnetic orientations were done to estimate effective anisotropies which are influenced by surface and interaction contributions. A decrease of the blocking temperature with progressive coating thicknesses was observed by several FC-ZFC magnetization measurements in good agreement with Mössbauer results. Calculated values of the relaxation frequency were compared with AC susceptibility and thermoremanent relaxation measurement (TRM) data in attempt to obtain information about surface and volume contributions to the distribution of anisotropy energies. Supported by DFG (WE 2623/3-1)

MA 9: Joint Session "Multiferroics II - Hexagonal Manganites / Incommensurate Multiferroics" (jointly with DF, DS, KR, TT)

Time: Monday 15:00–18:30 Location: EB 301

Invited Talk MA 9.1 Mon 15:00 EB 301

Anisotropic conductance of ferroelectric domain walls — •Dennis Meier — Dept. of Physics, University of California, Berkeley, USA

Domain walls are natural interfaces that can exhibit structural, physical, and chemical properties which drastically differ from the surrounding bulk material. This applies to a large variety of phenomena including chemical/electrical transport, multiferroicity, or superconductivity. In addition to the fascinating physical properties domain walls are small in size and their position can be controlled rendering them interesting for future device design. In my talk I report on the exotic nature of trimerization-polarization domain walls in hexagonal $ErMnO_3$. Using piezoforce-response microscopy and conductive atomic force microscopy we revealed that the domain walls represent a structural discontinuity being electrically dressed. While the structural component basically guarantees stability, the electrical dressing generates interesting and new nanoscale physics that I will discuss. The ferroelectric domain walls in $ErMnO_3$ for instance exhibit highly anisotropic electrical properties resulting in directional domain wall conductance. Remarkably, the local electrical conductance is a continuous function of the domain wall orientation which can be explained as a combined consequence of electrostatic and band-structure changes at the walls.

MA 9.2 Mon 15:30 EB 301

Structures and energetics of domain walls in polar hexagonal manganites — •Yu Kumagai and Nicola Spaldin — Department of Materials, ETH Zurich

We use first-principles density functional calculations to study the domain walls in the multiferroic hexagonal manganites, h-$R$$MnO_3$ (R=Sc, Y, Dy–Lu). These materials show an improper ferroelectricity induced by structural trimerization, resulting in $2 \times 3 = 6$ domains (2 for ferroelectricity and 3 for trimerization origin) below the Curie temperature with an intriguing cloverleaf pattern of domains [1,2]. Our calculations explain the observation that ferroelectric (FE) domain walls exist only in combination with antiphase DWs. We find that interlocked ferroelectric and antiphase domain walls have lower energies than typical FE domain walls in conventional ferroelectrics, as well as a much narrower wall width; both factors result from the layered geometry of the h-$R$$MnO_3$ structure.

[1] T. Choi *et al.*, Nature Mater. 9, 253 (2010).
[2] T. Jungk *et al.*, Appl. Phys. Lett. 97, 012904 (2010).

MA 9.3 Mon 15:45 EB 301

Hexagonal $InMnO_3$ - An Outsider Among The Family Of Multiferroic Hexagonal Manganites — •Martin Lilienblum[1], Yu Kumagai[1], Alexei A. Belik[2], Naemi Leo[1], Nicola A.

Spaldin[1], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich — [2]International Center for Materials Nanoarchitectonics, NIMS

So far, it was believed that hexagonal (h-) $InMnO_3$ exhibit the same type of multiferroic order as the other compounds from the h-$RMnO_3$ family (R = Sc, Y, Dy - Lu), including, in particular, a unit-cell-tripling improper ferroelectric order. Here we present experimental evidence for the *absence* of ferroelectricity in hexagonal $InMnO_3$ based on three different techniques: x-ray diffraction (XRD), piezoresponse force microscopy (PFM) and optical second harmonic generation (SHG). XRD data are ambiguous because they can be described likewise by the non-ferroelectric $P\bar{3}c$ structure and by the ferroelectric $P6_3cm$ structure present in the other h-$RMnO_3$ compounds. However, PFM at room temperature and SHG measurements at low temperature uniquely reveal the absence of ferroelectric order in $InMnO_3$. We therefore propose that $InMnO_3$ exhibits antiferrodistortive, but non-ferroelectric order according to the $P\bar{3}c$ symmetry. Density functional calculations show that the relative energy between the $P\bar{3}c$ and $P6_3cm$ structures is determined by a competition between electrostatic and covalency effects, with an *absence* of covalency favoring the ferroelectric structure. We gratefully acknowledge the support by DFG through SFB 608.

MA 9.4 Mon 16:00 EB 301

Direct observation of multiferroicity in $TbMnO_3$ thinfilms — •Artur Glavic[1], Jörg Voigt[1], Enrico Schierle[2], Eugen Weschke[2], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszeutrum Jülich GmbH, Jülich, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, BESSY II, Albert-Einsteinstr. 15, Berlin, Germany

Multiferroic rare earth manganites as $TbMnO_3$ have been studied a lot in the past ten years because of their complex magnetic structure, which leads to a ferroelectric polarization. So far investigations on $TbMnO_3$ thin films grown on $LaAlO_3$ or $SrTiO_3$ showed an emergent ferromagnetism, destroying the multiferroic properties.

We have investigated $TbMnO_3$ films grown with sputter deposition on $YAlO_3$ substrates using soft x-ray resonant magnetic scattering with linear and circular polarized light. By measuring the circular dichroism originating from the chirality of the magnetic structure we could directly observe multiferroic domains in the thin films. Although the transition temperatures found were comparable to bulk, an additional influence of the Tb magnetic order on the ferroelectricity was observed.

MA 9.5 Mon 16:15 EB 301

Sinusoidal electromagnon in $R$$MnO_3$: Indication of anomalous magnetoelectric coupling — •Markku Stenberg[1] and Rogério de Sousa[2] — [1]Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Department of Physics and Astronomy, University of Victoria, Victoria, B.C., V8W 3P6, Canada

The optical spectra in the family of multiferroic manganites $R$$MnO_3$ is a great puzzle. Current models can not explain the fact that two strong electromagnons are present in the non-collinear spin cycloidal phase, with only one electromagnon surviving the transition into the collinear spin sinusoidal phase. We show that this is a signature of the presence of anomalous magnetoelectric coupling that breaks rotational invariance in spin space and generates oscillatory polarization in the ground state.

MA 9.6 Mon 16:30 EB 301

Neutron scattering studies on chiral multiferroics: magnetic structure and excitations — •Max Baum[1], Thomas Finger[1], Jeannis Leist[2], Karin Schmalzl[3], Paul Steffens[3], Petra Becker[4], Ladislav Bohatý[4], Götz Eckold[2], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Physikalische Chemie, Georg-August-Universität Göttingen — [3]Institut Laue Langevin (ILL), Grenoble — [4]Institut für Kristallographie, Universität zu Köln

Multiferroic materials or compounds with a strong magnetoelectric effect posses a large application potential in data storage techniques. Quite recently, systems with a peculiar spiral magnetic order were shown to directly induce a spontaneous electric polarisation and to exhibit giant magnetoelectric effect. Neutron scattering with spherical polarisation analysis gives access to the chiral component of the magnetic structure which is directly linked to the electric polarisation. Therefore, it is possible to control the chiral components by an external electric field. We present neutron scattering experiments on IN14 and IN20 using spherical polarisation analysis documenting the poling of the elastic magnetic chiral terms for MnWO4, TbMnO3 and Ni3V2O8 by cooling in an electric field. In addition, it is possible to switch the chiral components by varying the electric field at constant temperature; thereby measuring multiferroic hysteresis curves. For MnWO4, this experiment was performed with time resolution detecting the typical relaxation times. Tor TbMnO3 we discuss a newly discovered excitation which exhibits a chirality opposite to the static one.

MA 9.7 Mon 16:45 EB 301

Theoretical study of Magnetoelectric effects in Multiferroic RMn2O5 — •Safa Golrokh Bahoosh[1], Julia Wesselinowa[2], and Steffen Trimper[3] — [1]Max Planck Institute of Microstructure Physics, 06099 Halle, Germany — [2]Department of Physics, University of Sofia, 1164 Sofia, Bulgaria — [3]Institute of Physics, Martin-Luther-University, 06120 Halle, Germany

The magnetoelectric behavior of the rare-earth RMn2O5 perovskites is studied theoretically using a quantum model. Whereas the magnetic subsystem is described by nearest-neighbor ferromagnetic coupling and next nearest neighbor antiferromagnetic order, the ferroelectric subsystem is characterized by an Ising model in a transverse field.

Due to frustration, the magnetic system offers spiral structures. The coupling between both systems is a symmetry-allowed linear coupling.

Using Green*s functions we find analytically the temperature and wave vector dependent elementary excitation of the Magnetoelectric system, the polarization and the magnetization for different magnetoelectric coupling strengths.

Lowering the temperature, the system undergoes a magnetic transition at TN and a further reduction of the temperature leads to a ferroelectric transition at TC < TN. The magnetoelectric coupling is manifested as a kink in both the magnetization and the elementary excitation at TC. The polarization is enhanced under the presence of a finite external magnetic field. In the same manner the magnetization is slightly changed by an applied electric field near to TC.

15 min. break

MA 9.8 Mon 17:15 EB 301

Origin of spin canting in multiferroic perovskites — •Carlo Weingart, Eric Bousquet, and Nicola Spaldin — Materials Department, ETH Zurich, Switzerland

In magnetic perovskites with oxygen octahedral distortions, it is usually admitted that the Dzyaloshinsky-Moriya interaction (DM) is responsible for the spin canting. This statement is however partially true since the single-ion anisotropy (SIA) can also allow for similar spin canting. By decomposing the different magnetic interactions (exchange, DM and SIA) from first-principles calculations, we show that depending on the magnetic cation, the DM and the SIA can be of similar amplitude. This allow us to reconsider the origin of the weak ferromagnetism in multiferroics.

MA 9.9 Mon 17:30 EB 301

A further step of understanding the complex magnetic order in magnetoelectric Co_3TeO_6 — •Vera Carolus[1], Thomas Lottermoser[2], Matthias Hudl[3], Pierre Tolédano[4], and Manfred Fiebig[2] — [1]HISKP, University of Bonn, Germany — [2]Department of materials, ETH Zurich, Switzerland — [3]Department of Engineering Sciences, Uppsala University, Box 534, SE-751 21 Uppsala, Sweden — [4]Laboratory of Physics of Complex Systems, University of Picardie, 33 rue Saint-Leu, 80000 Amiens, France

Like most of the known magnetoelectric multiferroics, Co_3TeO_6 exhibits a complex spin structure with a series of consecutive phase transitions. Contrary to common compounds, Co_3TeO_6 possesses two independent commensurate k-vectors in the multiferroic low-temperature phase. In addition, magnetic-field dependent measurements of the ferroelectric polarization show a strongly anisotropic behaviour.

Here we show our results using spatially resolved optical second harmonic generation (SHG) under external magnetic and electric fields in the multiferroic low-temperature phase. However, the SHG gives only access to the magnetic subsystem. Like the ferroelectric polarization, the magnetic structure shows strongly anisotropic behaviour. In crossed magnetic and electric fields we were able to reach a single-domain state, while a magnetic field solely always leads to distinctively different multi-domain states. Most remarkably, for a certain direction of magnetic field, we were able to invert the multi-domain state.

Furthermore, this behaviour indicates the existence of a pronounced memory effect.

MA 9.10 Mon 17:45 EB 301

The multiferroic, geometric frustrated $CuCrO_2$ compound: a case of the $p-d$ hybridization spin-charge coupling? — •Matthias Frontzek, Georg Ehlers, and Andrey Podlesnyak — Neutron Scattering Science Division, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA

Multiferroic materials have become of interest for their unusual low-temperature properties in general, and in particular for the observation that one can affect their magnetic structure through an electric field and their electric polarization through a magnetic field. The delafossite $CuCrO_2$, which crystallizes in the rhombohedral $R\bar{3}m$ space group, is a multiferroic compound with an apparent strong coupling of spin and charge. In contrast to other multiferroic compounds $CuCrO_2$ shows a spontaneous electric polarization upon antiferromagnetic ordering without an accompanying structural phase transition, although a slight in-plane lattice distortion has been measured.

In our contribution, we present a detailed study on $CuCrO_2$ single crystals using neutron diffraction and spectroscopy as well as pulsed magnetic field measurements up to 60 T of the electric polarization. Based on our study we will show a revised magnetic structure model and present a model Hamiltonian including in-plane next-next nearest neighbor and inter-layer exchange interaction. We will stress the importance of the latter for the multiferroic properties and will show evidence based on the high field polarization measurements that the proposed $p-d$ hybridization spin-charge coupling mechanism needs to be modified.

MA 9.11 Mon 18:00 EB 301

Theory of High-Temperature Multiferroicity in CuO — •Naëmi Leo[1,2], Pierre Tolédano[3], Dmitry D. Khalyavin[4], and Manfred Fiebig[1,2] — [1]ETH Zurich, Switzerland — [2]HISKP, Universität Bonn, Germany — [3]University of Picardie, France — [4]ISIS, United Kingdom

Spin-spiral multiferroics offer strong magnetoelectric coupling, although most of them have low transition temperatures which make them undesirable for technical applications. Cupric oxide is a remarkable exception with its high Curie temperature of 230 K. Understanding the interactions leading to such a high-T_C magnetically induced ferroelectricity is very desirable for future room-temperature magnetoelectric multiferroics devices.

Here we present a Landau theory analysis of the multiferroic properties of CuO [1]. Using a multi-dimensional order parameter expansion of the free energy we examine the sequence of phase transitions: The unusual direct transition to the multiferroic phase is induced by the simultaneous onset of two order parameters, enabled by the strong Cu-O superexchange. Expressing the order parameter in terms of spins we determine theoretically the magnetic structure in the spin-spiral phases. Furthermore we identify the microscopic interactions responsible for the magnetically induced spontaneous polarization.

The work in Bonn was supported by the DFG through the SFB 608.

[1] P. Toledano, N. Leo, D.D. Khalyavin, L.C. Chapon, T. Hoffmann, D. Meier, and M. Fiebig, Phys. Rev. Lett. **106**, 257601 (2011).

MA 9.12 Mon 18:15 EB 301

Resonant Elastic X-ray Scattering Studies of Multiferroic $NdFe_3(BO_3)_4$ — •Sven Partzsch[1], Jorge Enrique Hamann-Borrero[1], Claudio Mazzoli[2], A. Vasiliev[3], L. Bezmaternikh[4], Bernd Büchner[1], and Jochen Geck[1] — [1]IFW, Dresden, Germany — [2]ESRF, Grenoble, France — [3]Moscow State University, Moscow, Russia — [4]L. V. Kirensky Institute of Physics, Russian Academy of Sciences, Krasnoyarsk, Russia

Multiferroic $NdFe_3(BO_3)_4$ exhibits a strong magnetoelectric coupling, since at 2K the electric polarization raises rapidly to 400 $\mu C/m^2$ upon increasing the applied magnetic field to 2T [1]. We study this coupling by resonant x-ray scattering at the Nd L- and Fe K edges as a function of temperature and applied magnetic field. Employing full polarization control, the field dependence of the different magnetic phases has been characterized at the Nd L_2 edge. We find that the commensurate phase at 20K and no magnetic field is different from the commensurate phase induced by the magnetic field at 2K [2].

[1] A. Zvezdin et al., JMMM, 300, 224 (2006)

[2] J. E. Hamann-Borrero et al., Phys. Rev. B, 82, 094411 (2010)

MA 10: Focus Session "Topological Transport in Systems with broken Time Inversion Symmetry", Organization: Stefan Blügel (FZ Jülich)

Time: Monday 15:00–17:15 Location: H 1012

Invited Talk MA 10.1 Mon 15:00 H 1012

Theory of the anomalous Hall effect: from the metallic fully ab-initio studies to the insulating hopping systems — •Jairo Sinova — Department of Physics, Texas A&M University, College Station, Texas 77843-4242, USA

A consistent description of spin-dependent Hall transport in the spin-orbit coupled systems has been a challenge for many decades. The theory of the anomalous Hall effect (AHE) and its non-magnetic counterparts involves a description of transport in multi-band system with inter-band coherent. It is only over the past couple of years that a clear theoretical picture has emerged recently. Within the metallic regime these pictures are robust and there is now an full formulation of the scattering-independent contributions in the metallic regime which is amenable to ab-initio studies [1]. We report on first-principles calculations of the side-jump contribution to the anomalous Hall conductivity directly from the electronic structure of a perfect crystal. We implemented our approach in elemental bcc Fe, hcp Co, fcc Ni, and L10 FePd and FePt alloys and are able to capture systematically the experimental observations [2]. On a different part of the phase diagram of AHE transport, we have developed a full theory of the AHE in the hopping regime [3]. The theory fully captures the observed anomalous scaling behavior in different insulating ferromagnetic thin films, completing the understanding of the AHE phase diagram.

[1] A. A. Kovalev, et al, Phys. Rev. Lett. 105, 036601 (2010). [2] Juergen Weischenberg, et al, Phys. Rev. Lett. 107, 106601 (2011). [3] Xiong-Jun Liu, et al, Phys. Rev. B 84, 165304 (2011).

Topical Talk MA 10.2 Mon 15:30 H 1012

Engineering topological transport via control of the spin-orbit interaction — •Yuriy Mokrousov — Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Germany

The spin-orbit interaction (SOI) in a crystal plays a central role in various phenomena ranging from spin-relaxation in metals to the emergence of non-trivial topological phases in insulators. Here, we analyze how the origin of SOI, its spin-conserving and spin-non-conserving nature, as well as its interplay with impurity scattering can affect the topological transport properties in metals and insulators. In particular we focus on the case of the anomalous Hall effect in metallic ferromagnets [1, 2] and quantum anomalous Hall effect in two-dimensional topological insulators [3], suggesting how via control of the SOI non-trivial topological states can be stabilized, and their experimental observation made simpler.

[1] H. Zhang, F. Freimuth, S. Blügel, Y. Mokrousov and I. Souza, Phys. Rev. Lett. **106**, 117202 (2011)

[2] J. Weischenberg, F. Freimuth, J. Sinova, S. Blügel and Y. Mokrousov, Phys. Rev. Lett. **107**, 106601 (2011)

[3] H. Zhang, C. Lazo, S. Blügel, S. Heinze and Y. Mokrousov, arXiv:1108.5915v1 (2011)

Invited Talk MA 10.3 Mon 16:00 H 1012

Topological phases with broken time-reversal symmetry in pyrochlore iridates — •Shigeki Onoda — Condensed Matter Theory Laboratory, RIKEN, Wako, Japan

Possible topological phases in pyrochlore iridates are invistigated theoretically. An effective single-orbital tight-binding model is derived by extracting Wannier functions from first-principles band calculations on hypothetical $La_2Ir_2O_7$ with varying crystal parameters, which mimics the changes only in the radius of rare-earth ions R for $R_2Ir_2O_7$. Then, introducing the on-site Coulomb repulsion, we solve the effective Hubbard model with the Hartree-Fock approximation. As a function

of the Coulomb repulsion, the bandwidth, and the strength of the trigonal distortion, the ground state can exhibit not only metal and Weyl semimetal but also a canted antiferromagentic insulator showing a nonzero uniform magnetization. This is a so-called Chern insulator in three spatial dimensions and exhibits a quantum anomalous Hall effect. Properties of the phase transitions and relevance to experimental systems are also discussed.

Invited Talk MA 10.4 Mon 16:30 H 1012

Topological Hall effects of electrons and magnons — •Yoshinori Onose and Yoshinori Tokura — Department of Applied Physics, Universtiy of Tokyo, Tokyo, Japan

While the Hall effect is usually driven by the Lorentz force in an external magnetic field, it can also be induced by the Berry phase due to the topological structure of electronic and/or magnetic states. In this talk, we present two examples of such "topological" Hall effects. The first example is the topological Hall effect in Skyrmion crystal phase. Quite recently, the crystallization of Skyrmions, which are the topological magnetic textures with spin chirality, was found in B20 transition metal compounds such as MnSi and $Fe_{1-x}Co_xSi$[1]. In this talk, we present the Hall effect caused by the Berry phase originating from the topological spin arrangement of Skyrmion[2]. The second topic in this talk is our recent finding of the Hall effect of magnons. The Berry phase induced Hall effect is also expected for charge neutral particles such as magnons. Recently, we have succeeded in observing the magnon Hall effect in terms of thermal transport[3]. The effect of the lattice geometry for the magnon Hall effect will also be discussed.

These works were done in collaboration with X. Z. Yu, N. Kanazawa, T. Ideue, H. Katsura, Y. Shiomi, S. Ishiwata, D. Okuyama, S. Wakimoto, T. Arima, J. H. Han, K. Kakurai, and N. Nagaosa.

[1] X. Z. Yu, Y. Onose *et al.,* Nature 465, 901 (2010). [2] N. Kanazawa, Y. Onose *et al.,* Phys. Rev. Lett 106, 156603 (2011). [3] Y. Onose *et al.,* Science 329, 297 (2010).

15 min. break

MA 11: Spin-dependent Transport Phenomena II

Time: Monday 17:15–17:45 Location: H 1012

MA 11.1 Mon 17:15 H 1012

Electronic and magnetic phase separation in semimetallic ferromagnet EuB_6 — •Pintu Das[1], Adham Amyan[1], Jens Brandenburg[1], Peng Xiong[2], Stefan von Molnár[2], Zachary Fisk[3], and Jens Müller[1] — [1]Institute of Physics, Max von Laue Str. 1, J. W. Goethe University, 60438 Frankfurt (M), Germany — [2]Department of Physics, Florida State University, Tallahassee, USA — [3]Department of Physics, University of California, Irvine, USA

EuB_6 is a semimetallic correlated electron system, which undergoes an interesting paramagnetic to ferromagnetic transition displaying two consecutive features (at $\sim$15.5 K and $\sim$12.5 K) in electrical transport, magnetic properties and specific heat. Although widely studied, this complex nature of the magnetic ordering and its interplay with the colossal magnetoresistance effect is far from being understood and is currently being actively investigated [1]. In this work, we have carried out fluctuation spectroscopy and non-linear electrical transport measurements in order to investigate the dynamical behaviour of charge carriers in the vicinity of the phase transitions and to understand the microscopic nature of the carrier transport properties. Our results indicate that a magnetically driven percolation occurs at the lower transition temperature which is consistent with the scenario in which the magnetic phase transition involves the formation of magnetic polarons.

[1] X. Zhang et al., Phys. Rev. Lett. **103**, 106602 (2009).

MA 11.2 Mon 17:30 H 1012

Spin-orbit scattering in molecular transport — •Pengxiang Xu, Daniel Wortmann, and Stefan Blügel — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Spin-orbit interaction generally does not play an important role in molecular junctions since many molecules considered for molecular transport devices typically contain only light elements. Therefore, the use of heavier elements in molecules proposed for magnetic transport setups can lead to interesting behavior in spin-polarized transport due to the coupling of the spins to the electric polarization of the molecule.

Applying ab-initio density functional theory in the framework of the linearized-augmented plane-wave method [1] and the Green function formalism for transport [2], we study some model systems with different magnetization states (collinear/non-collinear) and molecular dipole moment. We report on our investigations of transport through molecules with ferromagnetic transition-metal centers and demonstrate that angular magnetoresistance (AMR) can be found in the transmission properties of the molecule under the influence of the spin-orbit coupling.

This work is supported by DFG priority program 1243.

[1]http://www.flapw.de
[2]D. Wortmann, H. Ishida, S. Blügel. PRB **66**, 075113 (2002)

MA 12: Joint Session "Topological Insulators I" (jointly with DS, HL, O, TT)

Time: Monday 17:45–19:15 Location: H 1012

MA 12.1 Mon 17:45 H 1012

Atom-specific spin mapping and buried topological states in a homological series of topological insulators — Sergey V. Eremeev[1,2], Gabriel Landolt[3,4], Tatiana V. Menshchikova[1,2], Bartosz Slomski[3,4], Yury M. Koroteev[1,2], Ziya S. Aliev[5], Mahammad B. Babanly[5], •Jürgen Henk[6], Arthur Ernst[6], Luc Patthey[4], Andreas Eich[7], Alexander A. Khajetoorians[7], Julian Hagemeister[7], Oswald Pietzsch[7], Jens Wiebe[7], Roland Wiesendanger[7], Pedro M. Echenique[2], Stepan S. Tsirkin[1,2], Imamaddin R. Amiraslanov[8], J. Hugo Dil[3,4], and Evgueni V. Chulkov[2] — [1]Tomsk State University, Russian Federation — [2]Donostia International Physics Center, San Sebastián, Spain — [3]Universität Zürich, Switzerland — [4]Paul-Scherrer-Institut, Villigen, Switzerland — [5]Baku State University, Azerbaijan — [6]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [7]Universität Hamburg, Germany — [8]Azerbaijan National Academy of Science, Baku, Azerbaijan

By *ab-initio* calculations and spin-resolved photoemission experiments we demonstrate that a homological series of topological insulators—the binary chalcogenides Bi_2Te_3, Bi_2Se_3, and Sb_2Te_3 with the addition of a group IV element—can be tuned in such a way that ideal and isolated Dirac cones are located within the topological transport regime [1]. These compounds exhibit exotic buried topological states strongly protected against surface perturbations and with complex spin textures.

[1] S. V. Eremeev *et al*, Nature Comm. (2011), in press.

MA 12.2 Mon 18:00 H 1012

In-plane anisotropy of Fe atoms on Bi_2Se_3(111) — J. Honolka[1], A. A. Khajetoorians[2], V. Sessi[3], T. O. Wehling[4], S. Stepanow[1], J. Mi[5], B. B. Iversen[5], •T. Schlenk[2], J. Wiebe[2], N. Brookes[3], A. I. Lichtenstein[4], P. Hofmann[5], K. Kern[1], and R. Wiesendanger[2] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, 70569 Stuttgart, Germany — [2]Institute for Applied Physics, Universität Hamburg, D-20355 Hamburg, Germany — [3]ESRF, Grenoble, France — [4]1. Institut für Theoretische Physik I, Universität Hamburg, D-20355 Hamburg, Germany — [5]Interdisciplinary Nanoscience Center, Aarhus University, Denmark

Topological insulators exhibit a linearly dispersing gapless topological surface state where both the spin and momentum degrees of freedom are locked. The topological nature of this state results in interesting effects such as suppression of back-scattering. Recently, the robustness of these surface states against magnetic order has been investigated intensively. Here, we explore the magnetic properties of single Fe adatoms on the Bi_2Se_3 surface, in the coverage range $< 1\%$, with combined non-local x-ray magnetic circular dichroism techniques and local low temperature scanning tunneling spectroscopy. We show that the Fe adatoms relax into the surface and exhibit a magnetic easy axis within the surface-plane, contrary to recent reports. Futhermore, we show how *ab-initio* approaches can give a reorientation of the easy axis from out-of-plane to in-plane when considering the interplay of Coulomb interactions, spin orbit coupling, and dynamic hybridization effects.

MA 12.3 Mon 18:15 H 1012

Ab initio study of Rashba splitting of 2DEG at the surfaces of topological insulators — Sergey V. Eremeev[1,2], •Maia G. Vergniory[3,4], Tatiana V. Menshchikova[2], and Evgueni V. Chulkov[4,5,6] — [1]Institue of Strength and Materials Science, Tomsk, Russia — [2]Tomsk State University, Tomsk, Russia — [3]Max Planck Institute of Microstructure Physics, Halle, Germany — [4]Donostia International Physics Center, Donostia, Spain — [5]Departamento de Fisica de Materiales UPV/EHU, Donostia, Spain — [6]Centro de Fisica de Materiales CFM-MPC and Centro Mixto CSIC-UPV/EHU, Donostia, Spain

The surface of three dimensional topological insulators (TI) holds a metallic surface state (SS) with Dirac dispersion. Recently it has been demonstrated by using Angle Resolved Photoemission Spectroscopy (ARPES) that besides de Dirac cone 2D electron gas (2DEG) arise at the surface of Bi2Se3 and Bi2Te3 after a few hours of exposition in vacuum or upon deposition of atoms. In this work by means of DFT ab initio calculations we present a new interpretation for the driving mechanism of the simultaneous formation and evolution of the parabolic and M-shaped 2D electron gas (2DEG) bands at the surface of Topological Insulators. As it has been probed in previous publications [7,8] it might be due to an expansion of the van der Waals spacing produced by impurities intercalation. We will show the effect of these expansions on the spatial relocalization of the Dirac cone and we will compare our results with some experimental data for different binary and ternary compounds.

MA 12.4 Mon 18:30 H 1012

Reactive chemical doping of the Bi_2Se_3 topological insulator — •Hadj Mohamed Benia, Chengtian Lin, Klaus Kern, and Christian R. Ast — Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart, Germany

We studied the evolution of the surface electronic structure of the topological insulator Bi_2Se_3 as a function of water vapor exposure using angle resolved photoemission spectroscopy. We find that a surface reaction with water induces a band bending, which shifts the Dirac point deep into the occupied states and creates quantum well states with a strong Rashba-type splitting. The surface is thus not chemically inert, but the topological state remains protected. The band bending is traced back to Se-abstraction leaving positively charged vacancies at the surface. Due to the presence of water vapor, a similar effect takes place when Bi_2Se_3 crystals are left in vacuum or cleaved in air, which likely explains the aging effect observed in the Bi_2Se_3 band structure.

MA 12.5 Mon 18:45 H 1012

Unoccupied electronic states of topological insulators — •Christian Langenkämper[1], Anna Zumbülte[1], Sune N. P. Wissing[1], Anke B. Schmidt[1], Markus Donath[1], Peter Krüger[2], Richard C. Hatch[3], Philip Hofmann[3], Kenta Kuroda[4], Koji Miyamoto[5], and Akio Kimura[4] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Germany — [2]Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Germany — [3]Department of Physics and Astronomy, Aarhus University, Denmark — [4]Graduate School of Science, Hiroshima University, Japan — [5]Hiroshima Synchrotron Radiation Center, Hiroshima University, Japan

We report on the first investigation of the unoccupied electronic states of materials which are currently discussed in the context of topological insulators: Bi_2Se_3(111), Sb(111) and $TlBiSe_2$(111). First, different preparation methods (sputter-annealing, cleaving with scotch-tape) will be compared with regard to the surface quality of the samples, i.e. crystallographic order and chemical composition. Second, spin-resolved inverse-photoemission data will be presented. The experimental requirements concerning energy and momentum resolution will be addressed. Our first results show predominantly bulk-derived features with only small spin asymmetries. The experimental data will be discussed along with theoretical calculations for the unoccupied states.

MA 12.6 Mon 19:00 H 1012

Quantization of conduction and valence band states through adsorption of nonmagnetic impurities on Bi_2Se_3 — •Marco Bianchi[1], Richard Hatch[1], Zakaria Abd El-Fattah[3], Jianli Mi[2], Bo Brummerstedt Iversen[2], and Philip Hofmann[1] — [1]Department of Physics and Astronomy, Interdisciplinary Nanoscience Center, Aarhus University, 8000 Aarhus C, Denmark — [2]Departamento de Física de Materiales CSIC-UPV/EHU-Materials Physics Center, E-20018 Donostia-San Sebastián, Spain — [3]Center for Materials Crystallography, Department of Chemistry, Interdisciplinary Nanoscience Center, Aarhus University, 8000 Aarhus C, Denmark

Angle-resolved photoemission (ARPES) can give detailed information on the surface electronic structure of materials. Here we present an ARPES study of the adsorption-induced changes in the electronic structure of the topological insulator Bi_2Se_3(111). Exposure to CO results in strong shifts of the features observed by ARPES. The spectral changes can be explained by a simultaneous confinement of the bulk conduction band and valence band states. This is only possible because of the unusual bulk electronic structure of Bi_2Se_3. The valence band quantization leads to spectral features which resemble those of a band gap opening at the Dirac point. Similar effects are observed when Rb is adsorbed on the surface. In this case up to seven quantum well states are found in the valence band, both above and below the Dirac point.

MA 13: Magnetic Materials

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

MA 13.1 Mon 15:00 H 0112

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

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

MA 13.2 Mon 15:15 H 0112

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

We have studied the influence of single and multi-shot femtosecond annealing of magnetic Co/Pt multilayers using infrared and x-ray pulses. Prior to annealing the multilayers have been demagnetized using in-plane or out-of-plane external magnetic fields thus conditioning stripe

or maze domain patterns with magnetization normal to the sample surface. We performed annealing series employing a Ti:Sa Laser at 800 nm at different fluences and observed irreversible changes in the average domain size.
We compare the optical annealing experiments with results obtained by annealing identical samples with high-power shots of the free-electron Laser FLASH at Hamburg operating at 20.8 nm wavelength, e.g. the cobalt M absorption energy. The thermally induced changes were investigated with respect to the magnetic anisotropy (via MOKE) and the resulting domain patterns (via MFM).

MA 13.3 Mon 15:30 H 0112

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

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

MA 13.4 Mon 15:45 H 0112

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

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

MA 13.5 Mon 16:00 H 0112

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

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

MA 13.6 Mon 16:15 H 0112

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

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

MA 13.7 Mon 16:30 H 0112

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

In order to address the strategic resource problems related to permanent magnet's development for electro motors the specific modification of the grain boundary by the heavy rare earth Dy is a possible solution. For that reason the magnets have been prepared by means of hot pressing Nd-rich melt-spun ribbons of MQU-F type. The treatment with DyF_3 powder was done in two ways: (a) by coating the compact magnet with DyF_3 and subsequent annealing and (b) by mixing DyF_3 with the melt-spun powder and subsequent hot pressing at 725°C. Permagraph measurements have been carried out to characterize the magnetic properties whereas the microstructure was investigated with high-resolution scanning electron microscopy.

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

MA 13.8 Mon 16:45 H 0112

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

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

MA 13.9 Mon 17:00 H 0112

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

of Physics, Southern Federal University, Rostov on Don, Russia — [5]Institut of Physics, Zagreb, Croatia — [6]I. Physikalisches Institut, Universität Stuttgart, Germany

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

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

15 min. break

MA 13.10 Mon 17:30 H 0112

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

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

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

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

MA 13.11 Mon 17:45 H 0112

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

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

MA 13.12 Mon 18:00 H 0112

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

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

MA 13.13 Mon 18:15 H 0112

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

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

MA 13.14 Mon 18:30 H 0112

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

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

MA 13.15 Mon 18:45 H 0112

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

The correlated motion of electrons in multi-orbital metallic ferromagnets is investigated in terms of a realistic Hubbard model

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

MA 13.16 Mon 19:00 H 0112

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

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

MA 13.17 Mon 19:15 H 0112

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

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

MA 14: Joint Symposium "Topological Insulators: Influence of Superconductivity, Magnetism and Extrinsic Spin-Orbit Interaction" (SYTI)

Time: Tuesday 9:30–12:00 Location: H 0105

Invited Talk MA 14.1 Tue 9:30 H 0105

Search for Majorana fermions in topological insulators — •Carlo Beenakker — Instituut-Lorentz, Leiden University, The Netherlands

Majorana fermions (particles which are their own antiparticle) may or may not exist in Nature as elementary building blocks, but in condensed matter they can be constructed out of electron and hole excitations. What is needed is a superconductor to hide the charge difference, and a topological (Berry) phase to eliminate the energy difference from zero-point motion. We discuss strategies to detect Majorana fermions at the edge of a 2D topological insulator and on the surface of a 3D topological insulator.

Invited Talk MA 14.2 Tue 10:00 H 0105

Cooper Pairs in Topological Insulator Bi_2Se_3 Thin Films Induced by Proximity Effect — •Jinfeng Jia — Key Laboratory of Artificial Structures and Quantum Control (Ministry of Education), Department of Physics, Shanghai Jiao Tong University, 800 Dongchuan Road, Shanghai 200240, China

Three dimensional topological insulators (TIs), a new state of matter, have recently become a fertile farmland in which plenty of exotic quantum physical phenomena can grow. Among them, the interplay between topologically ordered states and symmetry-breaking states such as magnetism and superconductivity (SC) is particularly fascinating and has attracted extensive research activities. By introducing superconducting states into a TI via superconducting proximity effect, namely Cooper pairs tunneling into TI at TI/SC interface, the interplay between TI and SC can lead to the Majorana Fermion (MF) - quasiparticle that is its own antiparticle. MFs in solids obeys non-Abelian quantum statistics, are considered as the most promising candidate for fault-tolerant quantum computation. Here we report scanning tunneling microscopy observation of Cooper pairs formation on Bi_2Se_3 thin films grown on BCS type s-wave superconductor $NbSe_2$ by molecular beam epitaxy technique. Our data show that the Cooper pairs persist in the thickness regime from one quintuple layer (QL) up to seven QL of Bi_2Se_3 where topological order forms. This observation lays the groundwork for experimentally realizing MFs in condensed matter physics.

Invited Talk MA 14.3 Tue 10:30 H 0105

Gate tunable normal and superconducting transport through a 3D topological insulator — •Alberto Morpurgo — University of Geneva

We report on transport experiments though very thin Bi_2Se_3 layers, exfoliated from high quality single crystals and transferred onto a Si/SiO_2 substrate acting as a gate. Low-temperature magneto-resistance measurements exhibit clear Shubnikov de Haas oscillations, which can be tuned by applying a gate voltage. The plot of the resistance as a function of magnetic field and gate voltage exhibit a fan diagram of Landau levels originating from both electrons and holes at the surface closer to the gate electrode, whose quantitative analysis allows us to determine the Dirac character of the charge carriers. Shubnikov de Haas oscillation due to carriers on the surface far away from the gate are also observed as features in the fan diagram that do not depend on the gate voltage (which is screened by the first and by carriers in the bulk). Our analysis also shows that an impurity band is present inside the gap of the bulk bands of Bi_2Se_3, with a large density of states that coexist with the surface states. Finally, as the devices are fabricated with superconducting contacts, we succeeded in observing Andreev reflection and proximity induced supercurrent. The critical current is gate tunable and exhibits a bipolar behavior, with a minimum at the same gate voltage observe from extrapolating the fan diagram of Landau levels. This observation indicates that at least part of the supercurrent is carried by Dirac electrons and holes at the surface.

Invited Talk MA 14.4 Tue 11:00 H 0105

Weyl Metal States and Surface Fermi Arcs in Iridates — •Sergey Savrasov — University of California, Davis

We investigate[1] novel phases that emerge from the interplay of electron correlations and strong spin-orbit interactions. We focus on describing the topological semimetal, a three-dimensional phase of a magnetic solid, and argue that it may be realized in a class of pyrochlore iridates (such as Y2Ir2O7) based on calculations using the LDA + U method. This state is a three-dimensional analog of graphene with linearly dispersing excitations and provides a condensed-matter realization of Weyl fermions that obeys a two-component Dirac equation. It also exhibits remarkable topological properties manifested by surface states in the form of Fermi arcs, which are impossible to realize in purely two-dimensional band structures. For intermediate correlation strengths, we find this to be the ground state of the pyrochlore iridates, coexisting with noncollinear magnetic order. A narrow window of magnetic *axion* insulator may also be present. An applied magnetic field is found to induce a metallic ground state.

[1] Xiangang Wan, Ari M. Turner, Ashvin Vishwanath, Sergey Savrasov, Physical Review B 83, 205101 (2011)

Invited Talk MA 14.5 Tue 11:30 H 0105

Engineering a Room-Temperature Quantum Spin Hall State in Graphene via Adatom Deposition — •Marcel Franz — University of British Columbia

Using symmetry arguments, density functional theory, and tight-binding simulations, we predict that graphene endowed with certain heavy adatoms realizes a two-dimensional topological insulator phase with substantial band gap. For indium and thallium, our most promising adatom candidates, a modest coverage of 6% produces an estimated gap near 80K and 240K, respectively, which should be detectable in transport or spectroscopic measurements. Engineering such a robust topological phase in graphene could pave the way for a new generation of devices for spintronics, ultra-low-dissipation electronics and quantum information processing.

MA 15: Magnetization / Demagnetization Dynamics I

Time: Tuesday 9:30–13:00 Location: H 1012

Topical Talk MA 15.1 Tue 9:30 H 1012

Probing the timescale of exchange interaction in a ferromagnetic alloy — •Stefan Mathias — University of Kaiserslautern and Research Center OPTIMAS — JILA, University of Colorado and NIST

Rapid progress in ultrafast X-ray science worldwide, both in high-harmonic generation (HHG) and X-ray free-electron laser sources, has paved the way for a completely new generation of experiments investigating ultrafast magnetic processes in complex materials with ultrahigh time-resolution and element-specificity. In the presented work, we use extreme ultraviolet (XUV) pulses from a femtosecond HHG as an element-specific probe of ultrafast, optically driven, demagnetization in a ferromagnetic alloy (Permalloy). We show that on femtosecond timescales, the demagnetization dynamics of the constituent elements Fe and Ni in Permalloy are delayed with respect to each other, despite the strong exchange coupling that aligns their magnetic moments in thermodynamic equilibrium. We can further enhance this effect by lowering the exchange energy by diluting the Permalloy with Cu. Our measurement explores the consequences of the fundamental exchange interaction on femtosecond magnetic dynamics in strongly coupled 3d-ferromagnetic systems, showing that distinct magnetization dynamics of the individual elements can be observed on timescales corresponding to the characteristic exchange time.

MA 15.2 Tue 10:00 H 1012

Ultrafast Demagnetization in Ferromagnetic Materials — •Benedikt Y. Mueller, Tobias Roth, Mirko Cinchetti, Martin Aeschlimann, and Bärbel Rethfeld — Department of Physics and Optimas Research Center, University of Kaiserslautern, Germany

Ultrafast demagnetization due to laser irradiation has been studied for more than two decades [1,2,3]. Up to now, no theory explains the large variety of effects on equal footing microscopically. In our model we apply a kinetic approach based on a combination of the Stoner model and the Boltzmann equation [4]. This results in a spin-resolved Boltzmann equation considering three reservoirs: up-electrons, down-electrons and the phononic system. The coupling between these reservoirs is described by electron-electron and electron-phonon collisions whereby spin-flips are realized by Elliott-Yafet type spin-flip scattering. In this spirit, we trace nonequilibrium electrons during and after laser irradiation and additionally this provides a dynamical description for magnetism. We show the solution of the spin-resolved Boltzmann equation for the example of Nickel by implementing the density of states [5] into our model. As a result of our effective two band model, the demagnetization is driven by the equilibration process of the electron temperatures and the chemical potentials of up and down electrons.

[1] E. Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996)
[2] J. Hohlfeld et al., Phys. Rev. Lett. 78, 25 (1997)
[3] B. Koopmans et al., Nature Materials 9, 3 (2010)
[4] B. Rethfeld et al., Phys. Rev. B 65, 214303 (2002)
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MA 15.3 Tue 10:15 H 1012

Theoretical study of the time evolution of magnetization induced via the ultrafast inverse Faraday effect — •Daria Popova, Andreas Bringer, and Stefan Blügel — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Ultrafast optical control of the magnetic state of a medium is a subject that attracts much scientific interest. Manipulation of the magnetic order by light on sub-picosecond time scales can be realized by the inverse Faraday effect (IFE) [1]. In these experiments circularly polarized high-intensity laser pulses with the length of several tens of femtoseconds are used to excite the magnetic system of the sample. The important principles of this effect are still unclear.

We describe the IFE via the stimulated Raman-like scattering process, which was suggested to be responsible for the magnetization reversal by light [2]. We show [3] that a system is brought to a new magnetic state after the action of a femtosecond circularly polarized laser pulse due to this process. We solve the time-dependent Schrödinger equation to model the IFE in atoms coupled with the exchange interaction in a crystal field environment. We study the time evolution of the magnetization during the action of light and magnetic oscillations, which are excited in the system.

We are thankful for the support by the FANTOMAS project.

[1] A. Kimel *et al.*, Nature **435**, 655 (2005).
[2] F. Hansteen *et al.*, Phys. Rev. B **73**, 014421 (2006).
[3] D. Popova, A. Bringer, S. Blügel, accepted to Phys. Rev. B.

MA 15.4 Tue 10:30 H 1012

Momentum dependent ultrafast electrondynamics in antiferromagnetic $EuFe_2As_2$ — Laurenz Rettig[1,2], Rocio Cortés[1,3], Setti Thirupathaiah[4], Philipp Gegenwart[5], HiraleS. Jeevan[5], Martin Wolf[3], Jörg Fink[4], and •Uwe Bovensiepen[1,2] — [1]Freie Universität Berlin, FachbereichPhysik — [2]Universität Duisburg-Essen,Fakultät für Physik — [3]Fritz-Haber-Institut der MPG — [4]IFW Dresden — [5]UnversitätGöttingen, I. Physikalisches Institut

The response and relaxation dynamics of magnetically ordered materials upon optical excitation is highly interesting from a scientific and an application point of view. Up to now most studies have focussed on ferro- or ferrimagnetic ordered materials. Fe pnictides are metallic, present antiferromagnetic order below the Néel temperature T_N, and become superconducting upon doping. Here, we present results obtained for antiferromagnetic $EuFe_2As_2$ by femtosecond time- and angle-resolved photoelectron spectroscopy. Employing the momentum-sensitivity of the technique we separate the electron-phonon mediated relaxation from transient changes of the magnetic order. We assign the relaxation time of 200 fs observed at 30 K in a single particle region of the electronic band structure at $k_{||} = 0.25$ Å^{-1} to relaxation mediated by e-ph scattering. Antiferromagnetic order is established by backfolding bands from X to Γ. Relaxation monitored at Γ occurs with a time constant of 800 fs and is assigned to the transient magnetic order. The merging of these different times for $T > T_N$ evidences our conclusion.

This work was supported by the DFG through SPP 1458 and the Alexander von Humboldt Foundation.

MA 15.5 Tue 10:45 H 1012

Ultrafast element specific demagnetisation dynamics of Fe and Ni in FeNi Alloys — •Denise Hinzke[1], Unai Atxitia[2], Oksana Chubykalo-Fesenko[2], Karel Carva[3], Peter Oppeneer[3], and Ulrich Nowak[1] — [1]Universität Konstanz, 78457 Konstanz, Germany — [2]Instituto de Ciencia de Materiales de Madrid, 28049 Madrid, Spain — [3]Uppsala University, 75120 Uppsala, Sweden

Since the first observation of the quenching of magnetisation in Ni on the sub-ps timescales [1], ultrafast demagnetisation was intensively studied, both experimentally and theoretically. Recently, element-specific techniques were used to observe the element-resolved dynamics after optical excitation on fs timescales [2,3]. In order to get an deeper insight of the underlying mechanism we perform atomistic spin model simulations of fcc Permalloy.

We model FeNi using a classical spin Hamiltonian with exchange integrals constructed on the basis of spin density functional theory. Langevin dynamics simulation, i. e. simulations of the stochastic Landau-Lifshitz-Gilbert equation of motion are performed. The differences of the dynamics of Fe and Ni sublattices on the fs timescale is investigated for different model assumptions such as temperature and damping and compared with the dynamics gained in the framework of a two sublattices Landau-Lifshitz-Bloch equation of motion.

[1] E. Beaurepaire et al., Phys. Rev. Lett. **76**, 4250 (1996). [2] C. La-O-Vorakiat et al., Phys. Rev. Lett. **103**, 257402 (2009). [3] I. Radu et al., Nature **472**, 205 (2011). Funding from EC collaborative project FP 7 (FemtoSpin) and the CAP Konstanz is acknowledged.

MA 15.6 Tue 11:00 H 1012

The influence of electron-phonon-scattering on the ultrafast demagnetization of ferromagnetic metals — •Sven Essert[1] and Hans Christian Schneider[2] — [1]Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Technische Universität Kaiserslautern, 67653 Kaiserslautern, Germany

The demagnetization of ferromagnetic metals after the irradiation with a femtosecond light pulse is believed to be decisively influenced by an Elliott-Yafet type process, i.e., by spin-flip scattering in a band structure which is spin-mixed due to spin-orbit coupling. There have been different proposals for the underlying scattering mechanism, e.g., electron-phonon-, electron-electron- or electron-impurity-scattering.

We numerically investigate the contribution of electron-phonon-scattering to the Elliott-Yafet demagnetization scenario in a fixed band structure by calculating the carrier-dynamics using ab-initio data. With realistic parameters for the laser excitation, we find a magnetization change which is far smaller than the one observed in experiment.

We also show via an energy argument, that the simple picture of scattering in a fixed band structure is insufficient to describe the experimentally observed strong demagnetization. This result is not limited to electron-phonon-scattering but is also valid for most other scattering mechanisms. We conclude that a realistic model that tries to explain the demagnetization in terms of an Elliott-Yafet process should include a dynamical change of the magnetic order beyond a redistribution of carriers in a fixed band structure.

[1] S. Essert and H.C. Schneider, arXiv:1108.4454 (2011)

15 min. break

MA 15.7 Tue 11:30 H 1012

Ab-initio investigation of the Elliott-Yafet electron-phonon mechanism in laser-induced ultrafast demagnetization — Karel Carva[1,2], Marco Battiato[1], and •Peter M. Oppeneer[1] — [1]Uppsala University, S-75120 Uppsala, Sweden — [2]Charles University, CZ-12116 Prague, Czech Republic

The spin-flip Eliashberg function is calculated from first principles for ferromagnetic Ni to accurately establish the contribution of Elliott-Yafet electron-phonon spin-flip scattering to Ni's femtosecond laser-driven demagnetization. This is used to compute the spin-flip probability and demagnetization rate for laser-created thermalized as well as non-equilibrium electron distributions /1/. Increased spin-flip probabilities are found for thermalized electrons, but the induced demagnetization rate is extremely small. A larger electron-phonon mediated demagnetization rate is obtained for *non-equilibrium* electron distributions, but its contribution is too small to account for the observed femtosecond demagnetization.

/1/ K. Carva, M. Battiato, P.M. Oppeneer, Phys. Rev. Lett. **107**, 207201 (2011).

MA 15.8 Tue 11:45 H 1012

Ultrafast lattice dynamics in FeRh during a laser-induced magnetic phase transition — •Florian Quirin, Michael Vattilana, Uladzimir Shymanovich, Abd-Elmonien El-Kamhawy, Matthieu Nicoul, Alexander Tarasevitch, Dietrich von der Linde, and Klaus Sokolowski-Tinten — Universität Duisburg-Essen, Duisburg, Germany

FeRh exhibits an anti-ferromagnetic to ferromagnetic phase transition upon heating to temperatures above 353 K, which is accompanied by an iso-structural increase in volume of about 1%. Recent results of time-resolved magneto-optical experiments gave indication that after intense optical excitation ferromagnetic order starts to build up on sub-ps time-scales [1,2]. We have used time-resolved X-ray diffraction with fs X-ray pulses from a laser-produced plasma to directly follow the lattice response of FeRh after optical excitation. From experimental data obtained at different starting temperatures below and above the phase transition temperature we have to conclude that the fast changes of the magnetic properties do not lead to the corresponding structural changes as under equilibrium conditions.

1 G. Ju, J. Hohlfeld, B. Bergman, R. J. M. van deVeerdonk, O. N. Mryasov, J.-Y. Kim, X. Wu, D. Weller, and B. Koopmans, Phys. Rev. Lett. 93, 197403 (2004).

2 J.-U. Thiele, M. Buess, and C. H. Back, Appl. Phys. Lett. 85, 2857 (2004).

MA 15.9 Tue 12:00 H 1012

Ab-initio calculation of the demagnetization time in Ni after fs laser pulse excitation — •Christian Illg[1], Bernd Meyer[2], and Manfred Fähnle[1] — [1]Max-Planck-Institut für Intelligente Systeme, Heisenbergstr. 3, 70569 Stuttgart — [2]Interdisziplinäres Zentrum für Molekulare Materialien und Computer-Chemie-Centrum, Universität Erlangen-Nürnberg

It is believed that an ultimate time limit for the macroscopic manipulation of the magnetization is achieved by exposing a ferromagnetic film to an intense sub-100 fs pulse of laser light [1]. The result of this exposure is a demagnetization within few 100 fs for Ni, e.g., and a subsequent remagnetization on a longer time scale. Since the first experiments by Beaurepaire et al. in 1996 [2] a lot of research activities have been done but the underlying mechanisms are still not clarified.

We calculate the demagnetization time T_1 within the Elliott-Yafet theory which we have generalized for ferromagnets [3]. In order to calculate electron-phonon scattering rates, we use realistic electronic states which we calculate with the ab-initio spin-density-functional theory, and realistic phonon states obtained from a force-constant approach with force constants from ab-initio calculations. We present first results for the demagnetization time T_1 within the generalized Elliott-Yafet theory for Ni.

[1] M. Fähnle, C. Illg, J. Phys.: Condens. Matter **23**, 493201 (2011)
[2] E. Beaurepaire et al., Phys. Rev. Lett. **76**, 4250 (1996)
[3] D. Steiauf, C. Illg, M. Fähnle, J. Magn. Magn. Mater. **322**, L5 (2010)

MA 15.10 Tue 12:15 H 1012

Ultrafast and Distinct Spin Dynamics in Magnetic Alloys — •Ilie Radu[1,2], Christian Stamm[2], Andrea Eschenlohr[2], Kadir Vahaplar[1], Torsten Kachel[2], Niko Pontius[2], Rolf Mitzner[2], Karsten Holldack[2], Alexander Föhlisch[2], Florin Radu[2], Richard Evans[3], Thomas Ostler[3], Johan Mentink[1], Roy Chantrell[3], Arata Tsukamoto[4], Akiyoshi Itoh[4], Andrei Kirilyuk[1], Alexey Kimel[1], and Theo Rasing[1] — [1]Radboud University Nijmegen, The Netherlands — [2]Helmholtz-Zentrum Berlin, BESSY II, Germany — [3]University of York, United Kingdom — [4]Nihon University, Japan

Recent time-resolved XMCD investigations of magnetization reversal in ferrimagnetic GdFeCo alloy have shown [1] the intriguing possibility of manipulating the magnetic order on the ultrafast timescales pertinent to the exchange interaction. In particular, we have demonstrated that the antiferromagnetically coupled Fe and Gd sublattices had very distinct demagnetization times and reversed via a transient ferromagnetic state. Here we report on a systematic study of femtosecond laser-induced spin dynamics in several ferromagnetic and ferrimagnetic alloys and reveal that such distinct spin dynamics in magnetic alloys is a general phenomenon [2]. We demonstrate that the demagnetization of the constituent magnetic sublattices evolves on significantly different timescales which depend on their elemental magnetic moments and exchange interaction. Funding through EU UltraMagnetron program is acknowledged. [1] I. Radu et al., Nature 472, 205 (2011) [2] I. Radu et al., submitted (2011)

MA 15.11 Tue 12:30 H 1012

Ultrafast Demagnetization by a Laser-Generated Hot Electron Pulse — •Christian Stamm, Andrea Eschenlohr, Niko Pontius, and Torsten Kachel — Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Str. 15, 12489 Berlin, Germany

Ultrafast demagnetization usually is triggered by a fs laser pulse. Here we demonstrate that a pulse of hot electrons is equally capable of causing a sizeable ultrafast demagnetization. We use a fs laser pulse to generate hot electrons in a 30 nm thick Au layer on top of a 15 nm Ni film. The laser pulse energy is absorbed to 90% in the Au, and hot electrons traveling from Au into the Ni film cause its magnetization to decrease down to 20% of the original value. The demagnetization time of the Au/Ni sample is slightly slower than the one of a Ni reference, but still in the fs range. This is in accordance with a superdiffusive transport mechanism for the hot electrons.

MA 15.12 Tue 12:45 H 1012

Magnetization Dynamics in FeCuNi and FeRuNi Multilayers - Influence of the Spacer Layer — •Roman Adam[1], Dennis Rudolf[1], Chan La-O-Vorakiat[2], Patrik Grychtol[1], Bastian Heller[1], Emrah Turgut[2], Stefan Mathias[3], Moritz Plötzing[1], Zbigniew Celinski[4], Justin Shaw[5], Hans Nembach[5], Tom J. Silva[5], Martin Aeschlimann[3], Henry Kapteyn[2], Margaret Murnane[2], and Claus M. Schneider[1] — [1]1Peter Grünberg Institut, PGI-6, Forschungszentrum Jülich, 52425, Jülich, Germany — [2]Department of Physics and JILA, University of Colorado, Boulder, CO, USA — [3]TU Kaiserslautern und Forschungszentrum OPTIMAS, Kaiserslautern, Germany — [4]Center for Magnetism and Magnetic Nanostructures, UCCS, Colorado Springs, CO 80918, USA — [5]Electromagnetics Division, NIST, Boulder, CO, USA

We performed time-resolved pump-probe measurements on Ni/Ru/Fe and Ni/Cu/Fe multilayers, testing magnetization dynamics on the femtosecond time scale using either visible or extreme ultraviolet (XUV) radiation, as a probe. In the latter experiments, laser-generated XUV radiation was tuned to the M absorption edges of Fe (53eV) and Ni (67eV). By exploiting strong signal enhancement at these resonance conditions, we obtained a clear element- and layer-selective magnetic contrast upon magnetization reversal of magnetic layers comprising the multilayers. Our measurements demonstrate that laser-based high-harmonic experiments employing XUV wavelengths can yield layer-selective information about the magnetization, contributing to detailed understanding of femtosecond switching in magnetic multilayers.

MA 16: Magnetic Particles / Clusters II

Time: Tuesday 9:30–11:45 Location: EB 202

MA 16.1 Tue 9:30 EB 202

Switching of single-domain magnetic particles under the influence of thermal fluctuations — •Leoni Breth[1,2], Dieter Suess[2], Christoph Vogler[2], Bernhard Bergmair[2], Markus Fuger[2], Rudolf Heer[1], and Hubert Brückl[1] — [1]AIT - Austrian Institute of Technology, Health and Environment Dept.,Vienna, Austria — [2]Vienna University of Technology, Solid State Physics Dept., Vienna, Austria

The switching behavior of nanometer scale magnetic particles is of interest for various applications working at room temperature that reach from biomedicine to magnetic recording technologies. At finite temperature thermal fluctuations assist the magnetization to overcome the energy barrier separating its two stable states. The transition rate described by the Arrhenius-Néel law is exponentially decreasing with higher energy barriers. Starting from a master equation for the not-switching probability we derive a probability density function that corresponds to the switching field distribution of a single-domain particle originating solely from the presence of thermal fluctuations of the magnetization along its spatial orientation, as stated in the Néel-Brown model. Using the distribution function we are able to calculate rate-dependent coercivity and the corresponding standard deviation. Furthermore, we give mathematical arguments for the range of validity of the Néel-Brown model and we present single-spin Monte-Carlo and micromagnetic Langevin dynamics simulation data that show excellent agreement when taking into account the field-dependence of the attempt frequency in the Arrhenius-Néel law.

MA 16.2 Tue 9:45 EB 202

Time-resolved measurements of domain wall movement assisted particle transport on magnetically patterned samples — •Daniel Lengemann[1], Dennis Holzinger[1], Larysa Baraban[2], Dieter Engel[1], and Arno Ehresmann[1] — [1]Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden (IFW), Dresden, Helmholtzstraße 20, D-01069 Dresden

IrMn/CoFe exchange biased layers were patterned into artificial parallel stripe magnetic domains with alternating magnetization directions in adjacent stripes perpendicular to the long axis of the stripes. In remanence superparamagnetic particles have been trapped in the inhomogeneous stray fields of Bloch domain walls. The different magnetization reversal mechanisms in each hysteresis loop branch cause a stepwise movement of the trapped particles [1].

Time-resolved measurements with synchronization of the video feed and the magnetic field pulses in x- and z-direction were performed to measure the particle velocity, the movement type and the magnetic field range where the movement takes place.

[1] Ehresmann, A., Lengemann, D., Weis, T., Albrecht, A., Langfahl-Klabes, J., Göllner, F. and Engel, D., Advanced Materials, doi: 10.1002/adma.201103264 (2011)

MA 16.3 Tue 10:00 EB 202

Magnetization reversal of individual Co nanoislands — •Safia Ouazi[1], Sebastian Wedekind[1], Guillemin Rodary[1,2], Hirofumi Oka[1], Dirk Sander[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle (Saale), Germany — [2]Laboratoire de Photonique et Nanostructures/CNRS, Marcoussis, France

We investigate the field induced magnetization reversal of individual Co islands on Cu(111) in the size range of 700 to 18000 atoms by spin-polarized scanning tunneling microscopy at 8 K. The switching field Hsw changes with island size in a non-monotonous manner: it increases with island size and reaches a maximum value of 2.4 T at 5500 atoms, and it decreases for larger islands. We extract the energy barrier for magnetization reversal as a function of island size. Our analysis reveals that the Co islands are magnetically inhomogeneous. The outer rim is magnetically soft, whereas the center region is magnetically hard. Thus, Co islands may be regarded as an exchange spring nanomagnet [1]. For larger islands, we propose that the magnetization reversal occurs by domain nucleation and growth. Our results elucidate a crossover of the magnetization reversal from an exchange spring behavior to domain wall formation with increasing size.

[1] H. Zeng, J. Li, J. Liu, Z. Wang, and S. Sun, Nature 420, 395 (2002).

MA 16.4 Tue 10:15 EB 202

Microfluid mixing due to domain wall movement assisted transport of superparamagnetic beads — •Dennis Holzinger, Daniel Lengemann, Dieter Engel, and Arno Ehresmann — Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

Domain wall movement assisted transport (DOWMAT) of superparamagnetic particles[1] using a magnetic parallel-stripe patterned exchange bias layer system with head-to-head and tail-to-tail orientation of the magnetization in adjacent domains is shown to be an outstanding tool for active mixing in a microfluidic device. The controlled stepwise movement of complete particle rows increases the interface between the two fluids. The particles acting as active micro-stirrers accelerate dramatically the mixing speed as compared to thermal diffusion. Moreover, the mixing speed is precisely controllable by modification of the particle rows movement sequences.

[1] Ehresmann, A., Lengemann, D., Weis, T., Albrecht, A., Langfahl-Klabes, J., Göllner, F. and Engel, D., Advanced Materials, doi:

10.1002/adma.201103264 (2011)

MA 16.5 Tue 10:30 EB 202

GMR-effects in jelly-like structures — •Judith Meyer, Markus Schäfers, and Andreas Hütten — Bielefeld University, Universitätsstr. 25, 33615 Bielefeld, Germany

The GMR-effect was found and originally studied in magnetic multilayer systems [1,2]. In 1992, it was also independently reported within granular systems by several research groups who had embedded magnetic particles in a metallic matrix [3,4]. In contrast to previous granular layered systems prepared by the use of sputtering or metallurgical procedures, we have chosen a nonmagnetic conductive water-based gel as carrier substance for the magnetic nanoparticles. By doing so, GMR effects of up to several hundred percent have been measured for both Co- and Heusler based nanoparticles. By choosing gel matrices conductivity and hence the GMR-effect amplitude can be adjusted. Regarding future applications, the possibility of printing gel would allow the realization of a granular GMR sensor without employing photo- or e-beam lithography.

[1] G. Binasch, P. Grünberg, F. Saurenbach, W. Zinn, Phys. Rev. B, 39, 4828 (1989)

[2] M. N. Baibich, J. M. Broto, A. Fert, F. Nguyen Van Dau, F. Petroff, Phys. Rev. Lett. 61, 2472 (1988)

[3] A. E. Berkowitz, J. R. Mitchell, M. J. Carey, A. P. Young, S. Zhang, F. E. Spada, F. T. Parker, A. Hütten, G. Thomas, Phys. Rev. Lett., 68, 3745 (1992)

[4] J. Q. Xiao, J. S. Jiang, C. L. Chien, Phys. Rev. Lett., 68, 3749 (1992)

MA 16.6 Tue 10:45 EB 202

Magnetic Nanorods in Ferrofluids: A Novel Template-Directed Synthesis Route — •Robert Zierold[1], Soham Banerjee[1], Martin Waleczek[1], Josep M. Montero Moreno[1], Detlef Görlitz[1], Carl E. Krill III[2], and Kornelius Nielsch[1] — [1]University of Hamburg — [2]Ulm University

In this contribution a novel synthesis route for the preparation of nickel nanorod suspensions is presented, which might allow realization of new magnetic fluids displaying novel properties. Firstly, multi-segmented magnetic nanowires with a diameter of 40 nm are synthesized by electro-deposition of alternating segments of Ni and Cu into porous alumina membranes from a single electrolyte. The length of the particular phases can be tuned individually. Secondly, the release of the multi-segmented nanowires from the alumina matrix and,thirdly, the selective etching of the copper phases finally result in a novel ferrofluidic suspension in a carrier fluid. The magnetic behavior of the short nanorods (aspect ratios 2–10) is characterized in the oxide matrix as well as in liquid suspension. Furthermore, it is proven that subjecting the nanorod ferrofluid to an external magnetic field increases its (magneto)viscosity. Moreover, we find that nanorod suspensions reveal differences in shear-thinning behavior—the decrease in the magnetoviscous effect as a function of shear-frequency—compared to a ferrofluid consisting of spherical nanoparticles.

The authors gratefully acknowledge the DAAD RISE program and the State of Hamburg—throuh the Excellence Cluster "Nanotechnology in Medicine"—for financial support.

MA 16.7 Tue 11:00 EB 202

Double exchange mediated ferromagnetic coupling between transition metal atoms in di-metal complexes — •Kalpataru Pradhan[1,2] and Purusottam Jena[1] — [1]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany — [2]Physics Department, Virginia Commonwealth University, Richmond, VA 23284 USA

Recent discoveries of ferromagnetic ordering in mixed-valence di-metal [1] [2] complexes show that ferromagnetic double exchange in molecular magnets can indeed be achieved via charge disproportionation between valence-variable transition metal ions. Realization of the full technological potential of molecular magnets requires a fundamental understanding of the origin of magnetic coupling in molecular systems. Using gradient corrected density functional theory and Cl as a ligand we find that the magnetic coupling between transition metal atoms in a di-metal complex can be manipulated. Our calculations show that the ferromagnetic (FM) states of Co_2Cl_6 and Co_2Cl_7 are 0.07 eV and 0.20 eV lower in energy than their respective antiferromagnetic (AFM) states but they are nearly degenerate in Co_2Cl_8. The origin of ferromagnetic coupling is explained using the double exchange model caused by charge disproportionation.

[1] B. Bechlars *et al.*, Nat. Chem. 2, 362 (2010).

[2] Lin He and Lin Guo, Appl. Phys. Lett. 97, 182509 (2010).

MA 16.8 Tue 11:15 EB 202

Mn_4 clusters covalently bonded to carbon nanotubes — •Carola Meyer[1], Robert Frielinghaus[1], Anna-Katharina Saelhoff[1], Claire Besson[1], Henrik Flötotto[1], Lothar Houben[2], Paul Kögeler[1], and Claus M. Schneider[1] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich and JARA Jülich Aachen Research Alliance, 52425 Jülich, Germany — [2]Peter Grünberg Institut (PGI-5), Forschungszentrum Jülich and Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, 52425 Jülich, Germany

Depending on the coordination, manganese polymetallic complexes form single molecule magnets (SMMs). The exchange coupling between the Mn atoms is mediated by the bridging ligands. Therefore, ligand exchange can be used to change the magnetic properties of such Mn SMMs. Carbon nanotubes (CNTs), on the other hand, are expected to possess large spin coherence lengths and long spin relaxation times. Thus, spin transport through CNTs could be used to probe the magnetic properties of attached magnetic molecules. Here, we present the functionalization of carbon nanotubes (CNTs), which provide a 1-dimensional template for the alignment of molecules, with Mn_4 complexes. Raman spectroscopy is used to show the successful covalent bonding using ligand exchange with the oxidized CNTs. Transmission electron microscopy including elemental analysis by EDX and EELS reveals the functionalization on a molecular level. Finally, the changes in the magnetization behavior of the Mn_4 complexes bonded to the CNTs are analyzed using data obtained in SQUID measurements.

15 min. break

MA 17: Magnetic Measurement Methods

Time: Tuesday 11:45–13:00 Location: EB 202

MA 17.1 Tue 11:45 EB 202

Single magnetic particle detection using TMR sensor arrays — •Peter Hedwig[1], Camelia Albon[1], Alexander Weddemann[1,2], and Andreas Hütten[1] — [1]Bielefeld University, Department of Physics — [2]Massachusetts Institute of Technology

Biomolecule detection or biorecognition has gained high interest for medical applications like immunoassays and also in fundamental research to study biochemical processes and transport phenomena. Functionalized magnetic particles and beads as markers open up the possibility for biomolecule detection by using magnetic field sensors like giant-magnetoresistive (GMR) and tunneling-magnetoresistive (TMR) elements.

We present high density TMR sensor arrays with linearised submicron elliptical elements and only 1.2 μm distance on the array. In this context we discuss design constraints for TMR sensor arrays for single bead detection in the limits of noise and sensor geometry. Related to this, field and voltage modulation techniques and also Heusler based magnetic tunnel junctions (MTJ) will be presented to improve the signal to noise ratio and therefore the sensitivity of such systems.

MA 17.2 Tue 12:00 EB 202

Determining the cone angle of magnetization via magnetoresistance measurements — •Matthias Hille, Axel Frauen, Björn Beyersdorf, André Kobs, Simon Hesse, Robert Frömter, and Hans Peter Oepen — Institut für Angewandte Physik, Hamburg, Germany

Magnetic thin film systems like Co/Pt multilayers undergo a spin-reorientation transition via the canted phase [1]. In the cone state it is difficult to determine the angle of magnetization as the area-averaged

value in remanence can be altered by the decomposition of the ferromagnet into domains. We present a method to accurately determine the canting angle of Co/Pt multilayers. We use the recently published Anisotropic Interface Magnetoresistance (AIMR) [2] where an increase in the magnetoresistance is observed when rotating the magnetization from the transversal in-plane to the out-of-plane direction. In our method a magnetic field is rotated in 1° steps from in-plane to perpendicular orientation. For each angle the longitudinal resistance is measured at varying field values (from 168 mT to 92 mT). In general an external field leads to a change of the direction of magnetization, except for the case that the external field is aligned parallel to the internal anisotropy field (which defines the orientation of the canting angle). In this case the resistance difference between two field values that prevent domain decay becomes zero. This allows us to determine the canting angle with an accuracy of 2°.

[1]: Frömter et al, Phys. Rev. Let. 100, 207202 (2008)
[2]: Kobs et al, Phys. Rev. Let. 106, 217207 (2010)

MA 17.3 Tue 12:15 EB 202

Atomic Force Microscopy Incorporated with Magnetic Sample Modulation: a new approach to detect the magnetic nanomaterials — •Matthias A. Fenner[1], Jing-jiang Yu[2], and Jayne C. Garno[3] — [1]Agilent Technologies, Lyoner Str. 20, 60528 Frankfurt, Germany — [2]Nanotechnology Measurement Division, Agilent Technologies, Inc., Chandler, AZ 85226, USA — [3]Department of Chemistry, Louisiana State University, Baton Rouge, LA 70803, USA

A new atomic force microscopy (AFM) method for detecting magnetic nanomaterials with much higher spatial resolution and sensitivity is presented [1]. It is referred to as magnetic sample modulation (MSM), since an AC magnetic field excites mechanical oscillations of magnetic nanomaterials on surfaces during imaging. The AFM operates in contact mode using a nonmagnetic tip. Frequency and amplitude of the mechanical response of the sample are detected by changes in tip deflection. Thus, the AFM tip serves as a force and motion sensor for mapping the response of magnetic nanomaterials. The investigations are facilitated by nanofabrication methods combining particle lithography with organic vapor deposition and electroless deposition of iron oxide, to prepare designed test platforms of magnetic materials at nanometer length scales. Examples of detecting magnetic nanoparticles and magnetic biospecies at single molecular level will be presented.

[1] Anal. Chem. 2009, 81, 4792-4802

MA 17.4 Tue 12:30 EB 202

Estimation of the shear modulus of hydrogels by magneto-optical transmission measurements using ferromagnetic nanorods as probes — •Christoph Schopphoven, Andreas Tschöpe, Philipp Bender, and Rainer Birringer — Universität des Saarlandes, Saarbrücken, Deutschland

Nickel nanorods are synthesized by electrodeposition of nickel into porous alumina templates, and released by dissolving the alumina, using a surfactant to prevent agglomeration. The rods are then dispersed in gelatin sols at 60°C and alligned by applying a magnetic field, which is maintained during subsequent cooling to obtain magnetically textured ferrogels. When a transversal magnetic field is applied perpendicular to the rod axis, a magnetic torque rotates the particles in field direction. With increasing rotation angle the mechanical torque associated with the elastic deformation of the matrix increases until a balance between mechanical and magnetic torque is reached. Due to their cylindrical shape, the nanorods also exhibit significantly different electrical polarizabilities along the principal axes. As a result, the extinction of polarized light depends on the orientation of the nanorods with respect to the polarization direction of the incident light, which allows to determine the equilibrium rotation angle of the nanorods. Measurements of optical transmission as a function of applied magnetic field are exploited to obtain the shear modulus of the gel matrix.

MA 17.5 Tue 12:45 EB 202

Estimation of the local elastic properties of gelatine gels by magnetization measurements using nickel nanorods as probes — •Philipp Bender, Andreas Tschöpe, and Rainer Birringer — Universität des Saarlandes FR 7.2 Experimentalphysik, Saarbrücken, Deutschland

In recent years particle-based micro- and nanorheology became an emerging field of interest. In particular the investigation of the local structure of heterogenous networks such as physical hydrogels offers new inside into their microstructural makeup.

The present study focuses on the estimation of the local shear modulus of gelatine gels with nickel nanorods as magnetic phase via magnetization measurements. The nanorods were synthesized by electrodeposition of nickel into porous alumina templates, released into aqueous dispersion by dissolution of the alumina layer and further processed to gelatine-based ferrogels. The nanorods are mechanically linked to the polymer network and exhibit - without further pretreatment - isotropic orientation distribution. However, applying an external homogenous magnetic field during the gelation process enabled the preparation of magnetically textured ferrogels. Depending on the ferrogels elastic compliance the nanorods can rotate in field direction in a homogenous magnetic field, working against the mechanical torque, which is caused by the shear deformation of the gel matrix. In this presentation it will be shown that the shear modulus of the surrounding gel matrix can be estimated from the rotation angle of the nanorods as a function of the magnetic torque.

MA 18: Joint Session "Magnetic Semiconductors" (jointly with HL)

Time: Tuesday 9:30–12:45 Location: H 0112

MA 18.1 Tue 9:30 H 0112

Growth of high-quality EuO films by rf-sputtering — •Thomas Mairoser[1], Alexander Melville[2], Artur Glavic[3], Jürgen Schubert[3], Darrell G. Schlom[2], and Andreas Schmehl[1] — [1]Universität Augsburg — [2]Cornell University, USA — [3]Forschungszentrum Jülich

The ferromagnetic semiconductor europium oxide exhibits a multitude of giant physical properties, such as a metal-to-insulator transition, colossal magneto-resistance, and pronounced magneto-optic effects. Its spin-polarization of >90% in the ferromagnetic state [A. Schmehl *et al.* , Nature Materials **6**, 882 (2007)] and its excellent electronic compatibility with Si have spawned new interest in EuO in the rapidly growing field of spin-electronics.

Because of instability in air the growth of thin films of this highly versatile material is challenging. Up to now high-quality films were only accessible by UHV deposition techniques like molecular beam epitaxy or UHV pulsed laser deposition. Previous film growths using co-sputtering from multiple targets (Eu and Eu_2O_3) resulted in polycrystalline films with second phases.

Here we report the growth of high-quality epitaxial films on (110) oriented $YAlO_3$ substrates using rf-sputtering from a single Eu_2O_3 target. The structural and magnetic properties of the commensurately strained films match those of the best EuO films reported in literature.

MA 18.2 Tue 9:45 H 0112

Ultrafast Enhancement of Ferromagnetism via Photoexcited Carriers in EuO — •Masakazu Matsubara[1], Andreas Schmehl[2], Jochen Mannhart[3], Darrell G. Schlom[4], Mauricio Trujillo Martinez[5], Johann Kroha[5], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zürich, Switzerland — [2]Institut für Physik, Universität Augsburg, Germany — [3]Max Planck Institute for Solid State Research, Germany — [4]Department of Materials Science and Engineering, Cornell University, USA — [5]Physikalisches Institut, Universität Bonn, Germany

EuO is a magnetic semiconductor, which undergoes a ferromagnetic transition at the Curie temperature (T_C) of 69 K. Electron doping to the stoichiometric compound greatly enhances the T_C and is accompanied by a nearly 100% spin polarization of the charge carriers in the ferromagnetic state, which makes electron-doped EuO a very attractive candidate for spintronics applications.

Here we have explored the possibility of the ultrafast control of magnetic properties of EuO via photoexcited carriers by a femtosecond pulse laser irradiation. Ultrafast spin dynamics was investigated in a variety of Gd-doped EuO ($Eu_{1-x}Gd_xO$) films with different carrier densities and T_C, exploiting the time-resolved magnetization-induced second-harmonic generation. The results show the ultrafast increase of magnetization, with a characteristic temperature dependence, in

low/medium Gd-doped samples. This is attributed to the increase of the indirect exchange interaction mediated by the photoexcited carriers.

MA 18.3 Tue 10:00 H 0112

EuO on Silicon for spintronics investigated by HAXPES — •C. Caspers[1], M. Müller[1], A. Gloskovskii[2], M. Gorgoi[3], C.S. Fadley[4], and C.M. Schneider[1,5] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich — [2]Analytische und Anorganische Chemie, Johannes Gutenberg-Universität, Mainz — [3]Helmholtz-Zentrum für Materialien und Energie, BESSY II, Berlin — [4]Department of Physics, University of California Davis, USA — [5]Fakultät für Physik and Center for Nanointegration Duisburg-Essen

Magnetic oxides combine electrical insulation and spin selectivity, qualifying them as highly efficient spin-selective tunnel barriers on silicon. Our approach joins two beneficial aspects: EuO is predicted to be the only magnetic oxide thermodynamically stable on silicon, the mainstay of semiconductors; moreover we are holding full control over structural, chemical, and magnetic properties of the MBE-grown EuO.

EuO thin films were synthesized by Oxide-MBE. RHEED pattern confirm the epitaxial growth of EuO on clean Si(100). A bulk-sensitive HAXPES study revealed an integral Eu(2+) valency (ferromagnetic) of 4 nm thick EuO/Si heterostructures with less than 4% antiferromagnetic Eu(3+). A depth-dependent HAXPES investigation with optimized interface sensitivity provided the optimum chemical parameters for the EuO/Si transport interface: The formation of EuSix can be minimized to less then 10% coverage of the interface, and SiOx is found to be $< 20\%$. Concluding, we succeeded in preparing EuO/Si heterostructures with high-quality magnetic, structural and chemical properties, being promising as spin filter contacts to silicon.

MA 18.4 Tue 10:15 H 0112

Magnetization of Mn implanted Ge annealed by flash lamp — •Zenan Jiang, Danilo Bürger, Slawomir Prucnal, Kun Gao, Wolfgang Skorupa, Heidemarie Schmidt, Manfred Helm, and Shengqiang Zhou — Helmholtz Zentrum Dresden Rossendorf, Inst Ion Beam Phys & Mat Res, Dresden, Germany

Ge-based diluted magnetic semiconductors (DMS) have drawn extensive attentions over the past decades due to the potential to be applied in spintronic devices and to be integrated with the mainstream Si microelectronics. The hole-mediated effect in DMS provides the possibility to realize the control of magnetic properties by the electrical control of free carriers. In this contribution, Mn implanted Ge with the Mn concentrations between 2 and 10% and annealed subsequently with flash lamp was investigated and discussed. All samples show ferromagnetism with the Curie temperature in the range from 250 to 300 K which may be interpreted as the co-contribution of the Ge matrix diluted with Mn ions and of Mn-rich nanoclusters[1]. SQUID measurements show evidence that the Mn-rich nanoclusters may have multiple distinct magnetic phases or a bimodal size distribution. It is also inferred that more Mn atoms are possibly incorporated into the Ge lattice with higher annealing energy using flash lamp annealing at 3 ms time scale. The enhancement of magnetoresistance is consistent with the magnetization as well as the inhomogeneous nature of the implanted layer.

[1] Shengqiang Zhou et al., PHYSICAL REVIEW B 81, 165204 (2010)

MA 18.5 Tue 10:30 H 0112

Magnetic Mn-Doped Indium Tin Oxide Films Prepared by Vacuum Thermal Evaporation — •Scarlat Camelia[1], Xu Qingyu[2], Shalimov Artem[1], Voelskow Matthias[1], Fronk Michael[3], Salvan Georgeta[3], Zahn R.T. Dietrich[3], Helm Manfred[1], and Iacomi Felicia[4] — [1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany — [2]Southeast University, China — [3]Semiconductor Physics, Chemnitz University of Technology, Germany — [4]Al. I. Cuza University, Iasi, Romania

The optical and electrical properties of indium tin oxide (ITO) thin films are highly dependent on the deposition parameters. Undoped and Mn doped ITO thin films were grown on SiO_2/Si substrates by vacuum thermal evaporation (VTE) using different atomic sources ratio. In order to have practically stress-free ITO films, all the samples were annealed at 450°C for 2 hours in air. The Mn-doped ITO films exhibit room temperature ferromagnetism after annealing. We analyzed the magnetization data from SQUID measurements using simulations based on the Preisach approach and derived the magnetic parameters of superparamagnetic nanoparticles in the Mn-doped ITO films, namely, the magnetization of individual particles and the distribution of coercive fields. The Mn-content in Mn-doped ITO films was investigated by Rutherford backscattering spectrometry and analysed using the RUMP data processing computer code. Results from magneto-optical and magneto-electrical measurements are presented. Magneto-transport measurements reveal negative magnetoresistance, while no anomalous Hall effect is observed.

MA 18.6 Tue 10:45 H 0112

Multiband V-J model for dilute magnetic semiconductors — •Stefan Barthel[1], Gerd Czycholl[1], and Georges Bouzerar[2,3] — [1]Institute for Theoretical Physics, University of Bremen, Otto-Hahn-Allee 1, D-28359 Bremen, Germany — [2]Institut Néel, 25 avenue des Martyrs, B.P. 166, 38042 Grenoble Cedex 09, France — [3]School of Engineering and Science, Jacobs University Bremen, Campus Ring 1, D-28759 Bremen, Germany

A multiband empirical tight-binding model for magnetically doped group-III-V-semiconductors with zincblende structure (e.g. $Ga_{1-x}Mn_xAs$,etc.) is applied to the calculation of effective Mn-Mn exchange couplings J_{ij}. The pd-coupling is treated non-perturbatively and nonmagnetic scattering is included. A polynomial expansion of the spectral density allows for the study of orbital-resolved exchange couplings for very large system sizes, which can be directly mapped on a disordered Heisenberg model. Finally a comparison of our findings using realistic input parameters (bandstructure, impurity concentration, pd-coupling, impurity potential) to available ab-initio data (LDA, LDA+U) is made. Our approach seems promising to bridge the gap between model and ab-initio methods.

15 min. break

MA 18.7 Tue 11:15 H 0112

Magnetism in Phase Change Materials Doped with Magnetic Impurities — •Wei Zhang[1], Yan Li[1,2], and Riccardo Mazzarello[1,2] — [1]Institute for Theoretical Solid State Physics, RWTH Aachen, Aachen, Germany — [2]JARA Fundamentals of Future Information Technology, Aachen, Germany

Chalcogenide phase-change materials undergo fast and reversible transitions between the amorphous and crystalline phase upon heating. This property is exploited in rewritable optical discs and nonvolatile phase-change memories, which are based on the strong optical and electronic contrast between the two phases respectively. Recently, phase change materials doped with magnetic impurities have drawn interest from both experimental and theoretical sides. In this work, we investigate the structural, electronic and magnetic properties of $Ge_2Sb_2Te_5$, a prototypical phase-change material, doped with several types of magnetic impurities, namely Cr, Mn, Co, Ni, by *ab initio* simulations. Both amorphous and crystalline (hexagonal and cubic rocksalt) phases of $Ge_2Sb_2Te_5$ were considered. We show that, when $Ge_2Sb_2Te_5$ is doped with Cr or Mn, the system displays a strong magnetic contrast between the crystalline phases and the amorphous phase. This behavior is similar to that of Fe-doped $Ge_2Sb_2Te_5$, which was recently investigated experimentally and theoretically. On the contrary, $Ge_2Sb_2Te_5$ doped with Co or Ni turns out to be non-magnetic in the amorphous phase. Our results indicate that Cr and Mn impurities can be used to dope $Ge_2Sb_2Te_5$, with the goal of exploiting the phase-change behavior for magnetic switching applications.

MA 18.8 Tue 11:30 H 0112

Anomalous hysteretic Hall effect in a ferromagnetic, Mn-rich, amorphous Ge:Mn nano-network — •Danilo Bürger, Shengqiang Zhou, Marcel Höwler, Xin Ou, György Kovacs, Helfried Reuther, Arndt Mücklich, Wolfgang Skorupa, Manfred Helm, and Heidemarie Schmidt — Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany

The read out of the magnetization state in magnetic semiconductors by electrical Hall resistance measurements makes it possible to use ferromagnetic semiconductors in nonvolatile memories. In a previous work [1], we fabricated ferromagnetic Ge:Mn by Mn ion implantation and pulsed laser annealing (PLA) and observed hysteretic Hall resistance below 10 K. By applying different PLA conditions we fabricated a percolating, Mn-rich, amorphous Ge:Mn nano-network with hysteretic Hall resistance up to 30 K. This nano-network is embedded in crystalline Ge:Mn between 5 nm and 40 nm under the sample surface. We applied chemical and physical etching to confirm the contribution of

the nano-network to the magnetic properties. The nanonet has a significant influence on the correlation between magnetism and anomalous Hall resistance. In the future such nano-networks may be used to spin-polarize free charge carriers in semiconductors at room temperature.
[1] S. Zhou *et al.*, Phys. Rev. B **81**, 165204 (2010)

MA 18.9 Tue 11:45 H 0112

Transition metal doped ZnO: Studies from DFT with various types of exchange-correlation treatment — •Sanjeev K. Nayak, Markus E. Gruner, Heike C. Herper, and Peter Entel — Faculty of Physics, University of Duisburg-Essen

Transition metal (TM) doped ZnO has been a long-standing problem. Since the density functional theory (DFT) with local density approximation (LDA) as the exchange-correlation potential underestimates the optical band gap, the impurity state is more likely to overlap with the valence or conduction band and thus the identification of the type of magnetic interaction is hampered. We have used different correction schemes to the exchange-correlation potential to improve the optical band gap of ZnO, namely by adding a orbital specific Hubbard U correlation to the d-orbitals of Zn and TM and by treating the exchange-correlation by the Hartree-Fock exchange through the Heyd-Scuseria-Ernzerhof (HSE) screened hybrid-functional. We focus on the nearest neighbor (n.n.) interactions of TM (TM = Cr, Mn, Fe, Co and Ni) occupying the cationic Zn sites, because in absence of carriers and any lattice defects the n.n. magnetic interaction strength is expected to be the highest. Our preliminary results show that most of the TM in ZnO favor antiferromagnetic interaction. Thus, in the quest for ferromagnetism in ZnO based DMS, focus should be on the role of lattice defects and additional impurities.

MA 18.10 Tue 12:00 H 0112

Ferromagnetische Resonanz an Chromspinellen — •Dieter Ehlers, Hans-Albrecht Krug von Nidda, Vladimir Tsurkan und Alois Loidl — Lst. für Experimentalphysik V, Universität Augsburg, 87435 Augsburg

Am ferromagnetischen Spinell $CdCr_2S_4$, an dem Ferroelektrizität sowie eine goße magnetokapazitive Kopplung nachgewiesen worden ist [Hem], haben wir die magnetokristalline Anisotropie mithilfe der ferromagnetischen Resonanz vermessen und untersucht. Aufgrund der Probenpräparation konnte ausgeschlossen werden, dass die Anisotropie von Verunreinigungen wie Cr^{2+} auf Oktaederplätzen oder Fe^{2+} auf Tetraederplätzen [Hoe, Pin] ausgeht, d. h. sie ist eine intrinsiche Eigenschaft der Verbindung. Weiterhin konnte das Modell der kubischen Anisotropie für das System verfeinert werden, indem eine uniaxiale Anisotropie für Cr^{3+} zusammen mit der Austauschverschmälerung angenommen wurde. Damit lassen sich beobachtete Anomalien der Linienbreite in den ⟨111⟩-Richtungen temperaturabhängig beschreiben.

[Hem] J. Hemberger, P. Lunkenheimer, R. Fichtl, H.-A. Krug von Nidda, V. Tsurkan, A. Loidl, Nature **434**, 364 (2005)

[Pin] H. L. Pinch, S. B. Berger, J. Phys. Chem. Solids **29**, 2091 (1968)

[Hoe] B. Hoekstra, R. P. van Stapele, Phys. Stat. Sol. **55**, 607 (1973)

MA 18.11 Tue 12:15 H 0112

Electronic structure study of the ferrospinel NiFe2O4 — •Martina Müller[1], Christian Caspers[1], Stephan Kramer-Sinzinger[1], Sven Döring[2,4], Michaela Gorgoi[3], Carsten Westphal[2], and Claus M. Schneider[1,4] — [1]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich — [2]Experimentelle Physik 1 und DELTA, Technische Universität Dortmund — [3]Helmholtz-Zentrum für Materialien und Energie, BESSY II, Berlin — [4]Fakultät für Physik and Center for Nanointegration, Universität Duisburg-Essen

The ferrospinel NiFe2O4 is an insulating oxide with high magnetic ordering temperature. This rare combination makes it very attractive for application as magnetic building blocks in spintronics devices, i.e. as spin filter contacts to semiconductors or in artificial multiferroic heterostructures. We succeeded in growing NiFe2O4 (NFO) epitaxial thin films on SrTiO3 substrates. Since the electronic and magnetic properties of NFO thin films can strongly depend on substrate, film thickness and eventually differ from the bulk material, we clarified their electronic properties by means of photoemission spectroscopy in the soft and hard X-ray regime. This (HAX)PES study allows to element-specifically probe the chemical state of the Fe, Ni and O valence bands and core levels both in the bulk and surface-near regions. In particular, analyzing the Fe, Ni 2p and 3p states gives information on the depth-dependent cation stoichiometry and lattice site distribution, which we correlate with NFO/STO structural and magnetic properties.

MA 18.12 Tue 12:30 H 0112

Antiferromagnetism in CuMn-V compounds: from semimetal to semiconductor antiferromagnets — •Frantisek Maca, Jan Masek, and Tomas Jungwirth — Institute of Physics ASCR, Prague, Czech Republic

We report on a theoretical study of CuMn-V antiferromagnets. Previous works showed low-temperature antiferomagnetism and semimetal electronic structure of the semi-Heusler CuMnSb. We present theoretical predictions of high-temperature antiferromagnetism in the stable orthorhombic phases of CuMnAs and CuMnP. The electronic structure of CuMnAs is at the transition from a semimetal to a semiconductor and we predict that CuMnP is a semiconductor.

We show that the transition to a semiconductor-like band structure upon introducing the lighter group-V elements is present in both the metastable semi-Heusler and the stable orthorhombic crystal structures. On the other hand, the orthorhombic phase is crucial for the high Néel temperature. The first experimental results are consistent with the theory predictions.[1]

[1] F. Maca, J. Masek, O. Stelmakhovych, X. Marti, K. Uhlirova, P. Beran, H. Reichlova, P. Wadley, V. Novak, T. Jungwirth, J. Magn. Magn. Mater. (2011) in print.

MA 19: Joint Session "Multiferroics III - Strain / New Routes towards Multiferroicity" (jointly with DF, DS, KR, TT)

Time: Tuesday 9:30–12:45 Location: EB 301

MA 19.1 Tue 9:30 EB 301

Substrate influence on the strain in epitaxially grown $BiCrO_3$ thin films investigated using Raman spectroscopy and X-ray diffraction — •Andreas Talkenberger[1], Cameliu Himcinschi[1], Kannan Vijayanandhini[2], David Rafaja[3], Ionela Vrejoiu[2], Torsten Weissbach[1], Christian Röder[1], and Jens Kortus[1] — [1]TU Bergakademie Freiberg, Institute of Theoretical Physics, D-09596 Freiberg — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle — [3]TU Bergakademie Freiberg, Institute of Materials Science, D-09596 Freiberg

$BiCrO_3$ (BCO) is an interesting candidate for multiferroic applications. Therefore a deep understanding of the material properties and the fabrication of high quality epitaxial thin films is necessary. In this work we investigated epitaxially grown BCO thin films fabricated by pulsed laser deposition on $SrTiO_3$, LSAT, $NdGaO_3$ and $DyScO_3$ by means of Raman spectroscopy and X-ray diffraction (XRD). The shift of phonon modes at room temperature indicates different strains in the BCO films grown on the different substrates. Primarily, the XRD experiments helped to quantify the elastic lattice strains caused by the lattice misfit between the substrate and the thin films. The reciprocal space mapping was employed to follow the relaxation of the lattice strain through the formation of microstructure defects. This data was correlated to the observed Raman shifts. Using density functional theory the shifts of the Raman peaks were calculated for different strain states, and compared to the experimentally observed ones. This work is supported by the German Research Foundation DFG HI 1534/1-1.

MA 19.2 Tue 9:45 EB 301

Directly probing the effect of strain on magnetic exchange interactions — •Kathrin Dörr[1,2], Andreas Herklotz[2], Hans-Martin Christen[3], and Michael Biegalski[3] — [1]MLU Halle Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle — [2]IFW Dresden, Postfach 270116, 01171 Dresden — [3]CNMS, Oak Ridge National Laboratory, Oak Ridge, TN 37830, USA

Thin films of transition metal oxides of the perovskite type ABO_3 (B = 3d or 4d metal) have revealed abundant examples for strain-driven

changes of magnetic ordering. In spite of strong efforts, the theoretical treatment of magnetic exchange in complex oxides has remained a challenge, and experiments continue to show unpredicted large effects of the epitaxial strains in films. In order to provide meaningful experimental data on strain dependences, epitaxial thin films should be grown in various coherent strain states on different substrates without changing anything but the strain. This is inherently difficult: possible problems arise from a strain-dependent oxidation level or microstructure. As a complementary approach, the in-plane strain of epitaxial oxide films can be controlled reversibly by 0.1-0.2 percent using a piezoelectric substrate. I will address reversible-strain studies on $La_{0.7}Sr_{0.3}MnO_3$, $La_{1-x}Sr_xCoO_3$ (x = 0, 0.2, 0.3) und $SrRuO_3$ films, showing the strain response of the magnetic Curie temperature and the magnetization and discussing the current understanding of the strain effects on magnetic ordering.

MA 19.3 Tue 10:00 EB 301

Induced magnetoelectric response in Pnma perovskites — •Eric Bousquet and Nicola Spaldin — Materials Department, ETH Zurich, Switzerland

We use symmetry analysis to show that the *G*, *C* and *A*-type antiferromagnetic *Pnma* perovskites can exhibit magnetoelectric (ME) responses when a ferroelectric instability is induced with epitaxial strain. Using first-principles calculations we compute the values of the allowed ME response in strained $CaMnO_3$ as a model system. Our results show that large linear and non-linear ME responses are present and can diverge when close to the ferroelectric phase transition. By decomposing the electronic and ionic contributions, we explore the detailed mechanism of the ME response.

MA 19.4 Tue 10:15 EB 301

Search for strain-induced ferroelectricity in EuO films — •Carsten Becher[1], Masakazu Matsubara[1], Andreas Schmehl[2], Jochen Mannhart[3], Darrell G. Schlom[4], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zürich, Switzerland — [2]Institut für Physik, Universität Augsburg, Germany — [3]Max Planck Institute for Solid State Research, Germany — [4]Department of Materials Science and Engineering, Cornell University, USA

Ferromagnetic EuO arouses a lot of interest due to a multitude of extreme properties, such as an insulator-metal transition, a colossal-exceptional magnetoresistance effect, and nearly 100 % spin polarization of the conduction electrons in the ferromagnetic state. In addition, recent theories predict that EuO becomes ferroelectric under epitaxial strains $\geq$ 4.2 %, suggesting a route to novel multiferroics combining ferromagnetic and ferroelectric order. Here, we use optical second harmonic generation (SHG) to detect changes of the electric as well as magnetic order of EuO thin films. In search of a strain-induced spontaneous polarization, we vary the sample temperature, apply electric and magnetic fields in various configurations, and use different photon energies of the incident laser pulses. So far, we verified that samples strained below 4 % do not display ferroelectricity. However, a new sample batch allows us to present results from EuO films with tensile strains up to 7 %.

MA 19.5 Tue 10:30 EB 301

On the lattice engineering of magnetoelectric couplin — •Michael Fechner and Nicola Spaldin — ETH Zurich, Department for Material Theory,CH-8093 Zurich, Switzerland

We present results of first-principles calculations of the microscopic origin of the linear magnetoelectric (ME) effect in Cr_2O_3. In general such magnetoelectric responses – that is the electric polarization created by an applied magnetic field – are small. Since they are composed of both electronic- and lattice-mediated contributions, however, an increase in the response can in principle be achieved by phonon engineering. Here we investigate this possibility by first calculating how the magnetic interaction parameters are affected by phonon modes of different symmetry, focussing particularly on those that are active in the ME coupling. We find that the exchange interactions are most strongly modified in the non-IR active rotational phonon modes which do not contribute to the ME response. We then calculate the effect on the ME response if these phonons are disabled. Based on our results we suggest new routes for engineering materials with enhanced ME couplings.

MA 19.6 Tue 10:45 EB 301

First principles study of Mn_2O_3 under pressure: Competition between Jahn-Teller distortion and charge disproportionation — •Carmen Quiroga and Rossitza Pentcheva — Dept. of Earth and Environmental Sciences, University of Munich

Contrary to most sesquioxides, which naturally occur in the corundum structure, Mn_2O_3 has a complex crystal structure corresponding to an orthorhombically distorted bixbyite [1], associated with the presence of the Jahn-Teller active Mn^{3+} cation. It has been suggested that the Jahn-Teller effect is inhibited under pressure, which could induce a phase transition to the corundum structure [2], from where the general transformation sequence of sesquioxides to perovskite and post-perovskite should follow. So far, however, only the post-perovskite has been reported experimentally above 27 GPa [3].

Using density functional theory calculations including an on-site Coulomb repulsion term, we explore the stability of the ambient phase α-Mn_2O_3 (*Pbca*) and candidate high-pressure polymorphs: corundum ($R\bar{3}c$), perovskite phases of Rh_2O_3 II (*Pbcn*) and $GdFeO_3$ (*Pbnm*) type and post-perovskite (*Cmcm*). In particular we focus on the effect of pressure on the charge, spin and structural degrees of freedom. Parallels to the pressure induced phase transitions in $MnTiO_3$ are discussed.

Funding by DFG SPP1236 (PE883/8-1) is acknowledged.

[1] S. Geller. Acta Crystallogr. **B27**, 821 (1971).
[2] C.T. Prewitt et al. Inorg. Chem. **8**, 1985 (1969).
[3] J. Santillán et al. Geophys. Res. Lett. **33**, L15307 (2006).

MA 19.7 Tue 11:00 EB 301

Investigation of Magnetoelectric Coupling in Self Assembled Ferromagnetic/Ferroelectric Heterostructures — •Fikret Yildiz[1], Chan-Ho Yang[2], Sinan Kazan[1], Yoon-He Jeong[2], and Bekir Aktas[1] — [1]Gebze Institute of Technology, Department of Physics, 41400 Gebze-Kocaeli, Turkey — [2]Pohang University of Science and Technology, Department of Physics, Pohang, 790-784 S. Korea

Creating ferromagnetic/ferroelectric heterostructures is a way for developing multifunctional materials which is called multiferroics. Exchange bias may be used to couple a normal ferromagnet to a ferroelectric antiferromagnet and thus create a multiferroic system with nonzero magnetization. In implementing this idea we developed a synthesis method for composite films of MnFe2O4 embedded in BiFeO3 [1]. The method utilizes the Bi volatility to obtain the composite films via thermal annealing of multilayer composed of BiFeO3 and BiMnO3. SEM measurements showed that the cluster size varies depending on the film thickness. The composite films possess both ferroelectric and ferromagnetic properties [1]. Magnetoelectric coupling (MEC) was investigated by Ferromagnetic resonance (FMR) technique. Analysis of FMR data showed that resonance field can be controlled by GHz range electric fields.

[1] C.H. Yang, F. Yildiz, S.H. Lee, Y.H. Jeong, U. Chon, T.Y. Koo, Apply Phys. Lett. 90, 163116 (2007).

MA 19.8 Tue 11:15 EB 301

Strain Determination in Magnetoelectric Composite Systems by X-ray Diffraction Methods — •Christian Koops[1], Madjid Abes[1], Stjepan Hrkac[1], Bridget Murphy[1], Olaf Magnussen[1], Eric Woltermann[2], Henry Greve[2], and Eckhard Quandt[2] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, Germany — [2]Institut für Materialwissenschaft, Christian-Albrechts-Universität zu Kiel, Germany

Understanding the coupling at the interface between magnetostrictive and piezoelectric components in magnetoelectric composites (ME) is essential for the optimization of these composites for sensor applications. A large ME response is only possible if the lattice deformation induced by an external magnetic field in the magnetostrictive material can be transferred efficiently to the piezoelectric material. To study this coupling at the burried interface of ME composites we measured the lattice deformation in ZnO as the piezoelectric component by grazing incidence X-ray diffraction in an external magnetic field, using the high-resolution and high intensity X-ray beam provided by the Diamond Light Source (I16) and PETRA III (P08). We employ samples with thin layers of different magnetostrictive materials, $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$ and Terfenol-D, on the (001) surface of high quality, single crystalline ZnO substrates. From the Bragg peak positions we determined the interplanar spacings in the ZnO substrates close to the interface and the corresponding strain as a function of the applied magnetic field.

15 min. break

MA 19.9 Tue 11:45 EB 301

Relaxor ferroelectricity in pure and doped magnetite — •Eugen Ruff[1], Florian Schrettle[1], Stephan Krohns[1], Peter Lunkenheimer[1], Victor A. M. Brabers[2], and Alois Loidl[1] — [1]Experimental Physics V, University of Augsburg, 86135 Augsburg, Germany — [2]Department of Physics, Eindhoven University of Technology, 5600 MB Eindhoven, Netherlands

A possible example for a multiferroic material is the extensively studied magnetite Fe_3O_4, which shows charge-order (CO) below the Verwey transition at $T_V \approx 120\,K$ and is ferrimagnetically ordered below $500\,K$[1]. As shown in the present contribution, dielectric spectroscopy reveals a relaxation below T_V, indicating relaxorlike polar order in Fe_3O_4[2]. We find long-range ferroelectric order to be impeded by the continuous freezing of polar degrees of freedom and the formation of a tunneling-dominated glasslike state of electrons at low temperatures. To reveal the origin of the ferroelectric state, whose dielectric signature is partly superimposed by a so called Maxwell-Wagner (MW) relaxation, we have investigated doped samples with Al, Ga, and Mg. The dielectric spectra of these doped samples ($< 2\%$) provide further evidence for the relaxor ferroelectric state of Fe_3O_4 and demonstrate the influence of the MW relaxation.

[1]D. I. Khomskii, J. Magn. Magn. Mater. **306**, 1 (2006).
[2]F. Schrettle *et al.*, Phys. Rev. B **83**, 195109 (2011).

MA 19.10 Tue 12:00 EB 301

Full-potential DFT+U study of orbitally ordered systems: the importance of non-spherical contributions and double counting — •Adam Jakobsson[1,2], Biplab Sanyal[1], Ivetta Slipukhina[2], Marjana Ležaic[2], Ersoy Sasioglu[2], Gustav Bihlmayer[2], and Stefan Blügel[2] — [1]Department of Physics and Astronomy, Uppsala University, 75120 Uppsala, Sweden — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

DFT+U has for many years been a standard method to calculate properties of strongly correlated systems. Initially the method [1] was implemented in DFT-codes using the atomic sphere approximation (ASA) but was later also implemented into full potential DFT-codes. Various flavours of the double counting corrections used in the DFT+U method further add to the variety of different DFT+U functionals. The double counting corrections originally derived in the context of ASA are now routinely applied in full potential codes. Using the FLEUR code [2], we have investigated the importance of the non-spherical potential and the issue of double counting for orbital ordering and magnetism, i.e. properties that play a crucial role in many multiferroic materials. A recent implementation [3] of the constrained-RPA method was used to obtain parameters for the DFT+U calculations. This work was supported by the Young Investigators Group Program of the Helmholtz Association, Germany, contract VH-NG-409.
[1] V. I. Anisimov et al. PRB **44**, 943-954 (1991) [2] www.flapw.de [3] E. Şaşıoğlu et al. PRB **83**, 121101(R) (2011).

MA 19.11 Tue 12:15 EB 301

Ab initio **calculations of the magnetic properties of ordered perovskites** — •Igor Maznichenko[1], Alberto Marmodoro[2], Martin Lüders[3], Zdzislawa Szotek[3], Walter Temmerman[3], Ingrid Mertig[1,2], and Arthur Ernst[2] — [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

Perovskites are of particular interest in condensed matter physics due to their remarkable electronic and magnetic properties. Colossal magnetoresistance, ferroelectricity, multiferroicity, superconductivity, charge ordering, orbital ordering, metal-insulator transition, Jahn-Teller, and other effects are observed in perovskites. All these properties are strongly depending on the type of cations. Here we present a first-principles study of electronic and magnetic properties of $La_{2/3}Sr_{1/3}MnO_3$ (LSMO), which is a strongly correlated $3d$ transition metal oxide with a Curie temperature of 370 K. For varying La/Sr ratios different types of antiferromagnetism are observed. Using a self-consistent KKR Green function method, we show how the electronic and magnetic properties of LSMO depend on the valency of Mn, ordering of different cations in the lattice, and their relative orientation to each other. The influence of the Mn–O–Mn angle on the double-exchange coupling was examined.

MA 19.12 Tue 12:30 EB 301

Crystal growth and scattering investigations of $YFe_2O_{4-\delta}$ — •Thomas Müller[1], Joost de Groot[1], Jörg Strempfer[2], and Manuel Angst[1] — [1]Peter Grünberg Institut PGI and Jülich Centre for Neutron Science JCNS, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Deutsches Elektronen-Synchrotron DESY, D-22607 Hamburg, Germany

$LuFe_2O_4$ is attracting attention as proposed multiferroic compound, but there is much less known about other isostructural rare-earth ferrites. We have grown single-crystals of $YFe_2O_{4-\delta}$ in a CO/CO_2-atmosphere to tune δ. Optimized crystals exhibit a magnetic behaviour identical to highly stoichiometric powder samples, i.e. two hysteretic phase transitions at 228 K and 180 K upon cooling.

Corresponding to these phases single-crystal x-ray-diffraction shows 3D-charge-ordered states, partially not compatible with the phases observed by electron diffraction [1]. At least one additional transition below 160 K, not present in magnetisation, is found in x-ray-diffraction. On one sample we found reflections at $(\frac{1}{3}, \frac{1}{3}$,half-integer) at 10 K , identical to the superstructure reflections of $LuFe_2O_4$. Nevertheless sample differences, due to different δ, have to be reviewed.

We further searched for anisotropy by resonant x-ray diffraction and full polarization analysis on superstructure reflections at PETRA III-P09. As for $LuFe_2O_4$ no anisotropy is observed. Although YFe_2O_4 has the same structure as $LuFe_2O_4$, the phases between 100 K and 230 K are totally different, showing much more complex incommensurate ordering. [1] N. Ikeda et al. Ferroelectrics **272**, 309 (2002)

MA 20: Poster I - Biomagnetism, FePt Nanoparticles, Magnetic Particles/Clusters, Magnetic Materials, Magnetic Semiconductors, Half-metals/Oxides, Multiferroics, Topological Insulators, Spin structures/Phase transitions, Electron theory/Computational micromagnetics, Magnetic coupling phenomena/Exchange bias, Spin-dependent transport, Spin injection/spin currents, Magnetization/Demagnetization dynamics, Magnetic measurement techniques

Time: Tuesday 12:15–15:15 Location: Poster A

MA 20.1 Tue 12:15 Poster A

Spin-resolved photoemission spectroscopy of $[\mathbf{Mn_6^{III}Cr^{III}}]^{3+}$ single-molecule magnets (SMM) deposited on surfaces and of Mn compounds as reference substances, cross comparison with XMCD — •Andreas Helmstedt[1], Aaron Gryzia[1], Niklas Dohmeier[1], Norbert Müller[1], Armin Brechling[1], Marc Sacher[1], Ulrich Heinzmann[1], Veronika Hoeke[2], Erich Krickemeyer[2], Thorsten Glaser[2], Mikhail Fonin[3], Samuel Bouvron[3], Philipp Leicht[3], Thomas Tietze[4], and Manfred Neumann[5] — [1]Faculty of Physics, Bielefeld University — [2]Faculty of Chemistry, Bielefeld University — [3]Department of Physics, University of Konstanz — [4]Max-Planck-Institut für Intelligente Systeme, Stuttgart — [5]Department of Physics, University of Osnabrueck

The properties of the Mn-based single-molecule magnet $[\mathbf{Mn_6^{III}Cr^{III}}]^{3+}$ deposited on surfaces are studied. This molecule exhibits a large spin ground state of S_T=21/2 and contains six Mn centres in two bowl-shaped Mn_3-triplesalen units linked by a hexacyanochromate. A preparation method for large-scale homogeneous samples needed for sample scanning to avoid radiation damage will be presented. The spin polarization of Auger electrons emitted from the manganese centres in $[\mathbf{Mn_6^{III}Cr^{III}}]^{3+}$ SMM after excitation with circularly polarized synchrotron radiation has been measured in the paramagnetic phase at selected excitation energies in the Mn-$L_{2,3}$ region. These results will be compared to XMCD data obtained at approx.

2K and 7T. Spin polarization data from Mn_2O_3 and Mn(II)acetate references after excitation at the Mn-$L_{2,3}$ edge are presented as well.

MA 20.2 Tue 12:15 Poster A

High-field ESR and magnetization of a Mn(III)-based single chain magnet — •Y. Krupskaya[1], Z. Tomkowicz[2], M. Rams[2], M. Balanda[3], S. Foro[4], Y. Skourski[5], J. Wosnitza[5], S.K. Nayak[6], J.V. Yakhmi[7], W. Haase[6], V. Kataev[1], and B. Büchner[1] — [1]IFW Dresden, Dresden, Germany — [2]Institute of Physics, Jagiellonian University, Kraków, Poland — [3]H. Niewodniczański Institute of Nuclear Physics PAN, Kraków, Poland — [4]Clemens-Schöpf-Institut für Organische Chemie und Biochemie, Technische Universität Darmstadt, Darmstadt, Germany — [5]Dresden High Magnetic Field Laboratory, Rossendorf, Germany — [6]Eduard-Zintl Institut für Anorganische und Physikalische Chemie, Technische Universität Darmstadt, Darmstadt, Germany — [7]Technical Physics and Prototype Engineering Division, Bhabha Atomic Research Centre, Mumbai, India

We present high-field magnetic study of a Mn(III)-based molecular chain. The compound shows a ferromagnetic hysteretic behavior of the magnetization at relatively high temperatures (up to 3 K). High-field/high-frequency ESR measurements were performed at the excitation frequencies between 332 and 528 GHz in magnetic fields up to 15 T. The frequency dependence of the ESR spectrum yields a g-factor of 1.8 and a negative effective magnetic anisotropy D of around -6.37 K. In addition, pulsed field (up to 60 T) magnetization measurements enabled determination of the effective spin value corresponding to the ground state of the chain. In conclusion, our experimental results indicate the single molecular chain magnet behavior of the studied compound.

MA 20.3 Tue 12:15 Poster A

EPR study of hyperfine interactions in Cu(II)- bis(oxamato) complexes — •A. Aliabadi[1], A. Petr[1], M. A. Abdulmalic[2], T. Rüffer[2], V. Kataev[1], and B. Büchner[1] — [1]IFW Dresden, Dresden, Germany — [2]Institute of Chemistry, Chemnitz University of Technology, Chemnitz, Germany

The hyperfine (HF) coupling of two Cu(II)-bis(oxamato) complexes containing four nitrogen ligands has been investigated using EPR spectroscopy at 10 GHz. The EPR spectra were modeled in order to determine the g-factor and the HF coupling values. First, measurements were performed on a liquid solution at room temperature to obtain isotropic g-factor and HF coupling constants for Cu and N. From the EPR measurements on powder samples we were able to extract the g-tensor and the Cu HF coupling tensor. In addition, the angular dependence of the EPR spectra was studied by rotation of a single crystal in three mutually perpendicular planes. From that the Cu HF coupling tensor was further refined and the N HF coupling tensor was determined. The results indicate that the difference between the determined parameters for two complexes is not significant. However, these parameters are smaller compared to a previous study of Cu(II)-bis(oxamato) complex containing two nitrogen ligands [1]. The results of this work should enable the determination of the spin density distribution between the central metal ion and the ligands in the studied molecules.

[1] B. Bräuer, T. Rüffer, R. Kirmse, J. Griebel, F. Weigend, G. Salvan, Polyhedron. 26 (2007) 1773.

MA 20.4 Tue 12:15 Poster A

Magnetic properties of a mixed valence Ni(II)-Ni(III)-complex as probed by the ESR spectroscopy and static magnetization measurements — •Jaena Park[1,3], Yulia Krupskaya[1], Vladislav Kataev[1], Bernd Büchner[1], Frederik Schleife[2], Berthold Kersting[2], and Rüdiger Klingeler[3] — [1]Leibniz Institute for Solid State and Materials Research IFW Dresden, Dresden, Germany — [2]Institute of Inorganic Chemistry, University of Leipzig, Leipzig, Germany — [3]Kirchhoff Institute for Physics, University of Heidelberg, Heidelberg, Germany

We investigated magnetic properties of a mixed valence Ni(II)-Ni(III)-complex by means of high-field electron spin resonance spectroscopy and static magnetization measurements. The metal core of the complex contains one Ni^{2+} ion ($S = 1$) and one Ni^{3+} ion ($S = 1/2$) coupled by three sulphur bridges. The magnetic field dependence of the magnetization at low temperatures and the temperature dependence of the static magnetic susceptibility reveal a ferromagnetic coupling between the Ni-spins. The high-field frequency tunable electron spin resonance measurements enable determination of the g-factor and magnetic anisotropy values for the studied complex. In addition, we compare the magnetic properties of the Ni(II)-N(III)-complex with those of the similar structure Ni(II)-N(II)-complex having both Ni ions in the 2+ oxidation state.

MA 20.5 Tue 12:15 Poster A

Electrical characterization of intermetallic FePt nanoparticles — •Ulrich Wiesenhütter[1], Darius Pohl[2], Bernd Rellinghaus[2], Jürgen Fassbender[1], and Artur Erbe[1] — [1]Helmholtz-Zentrum Dresden Rossendorf, D-01328 — [2]Leibniz-Institut für Festkörper- und Werkstoffforschung, D-01069

Magnetic nanoparticles have a large potential for applications such as medical diagnosis and therapy, (bio-)sensors or magnetic recording. Conventional techniques, e.g., MFM, electron holography or Lorentz microscopy are only suited to determine magnetical properties of macroscopic particle ensembles. In order to investigate the electrical and magnetic properties of a single, free-standing FePt nanoparticle two nano-sized Au electrodes that are fabricated by electron beam lithography, are used.The full characterization of the particle is carried out by electron microscopy and by recording current-voltage characteristics. As a result Coulomb-blockade effects have been observed at low temperatures. The capacitance of the nanoparticles is derived from the I/V characteristics.

MA 20.6 Tue 12:15 Poster A

Cobalt-Gold Core-Shell Nanoparticles as Probes for Quantitative MFM — •Tino Uhlig[1], Ulf Wiedwald[2], Denny Köhler[1], Paul Ziemann[2], and Lukas Eng[1] — [1]Institut für Angewandte Photophysik, TU Dresden — [2]Institut für Festkörperphysik, Universität Ulm

We present an easy, fast and reliable method for the preparation of magnetic force microscopy (MFM) probes based on single magnetic nanoparticles. Due to their dipole like characteristics, these kind of magnetic probes open up possibilities for quantitative measurements of magnetizations on the nano-scale. Our fabrication method is based on the deposition of cobalt nanoparticles (diameter 30 nm) on a Si substrate and subsequent photochemical deposition of a gold layer on the particle surface. Single particles were attached to standard silicon AFM tips with the aid of a linker molecule (APTMS). The applicability of the fabricated probes was tested by imaging the magnetic domains of a hard disk drive sample. Furthermore a calibration method, using the deflection of the AFM cantilever in an external magnetic field, is presented.

MA 20.7 Tue 12:15 Poster A

Shift of the blocking temperature of Co nanoparticles by Cr capping — •Melanie Ewerlin[1], Derya Demirbas[1], Leonardo Agudo[2], Gunther Eggeler[2], and Oleg Petracic[1] — [1]Institut für Experimentalphysik / Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany — [2]Institute for Materials, Department of Material Science, Ruhr-Universität Bochum, 44780 Bochum, Germany

We have prepared Co nanoparticles (NPs) on Al_2O_3 buffer layers and studied the effect of capping with various amounts of Cr onto the magnetic properties. Structural and magnetometric characterization was performed using TEM and SQUID magnetometry, respectively. The uncapped Co NPs show superparamagnetic behavior with a blocking temperature of T_B=14K. The magnetic properties are strongly influenced by the Cr capping resulting in a decrease of T_B for nominal thicknesses of Cr up to 0.15nm. However, for larger values the blocking temperature increases again. XMCD measurements at the Cr edge indicate an anti-parallel alignment of the magnetic moments in the Cr layer with respect to the moments in the Co particle, which leads to a decrease of the effective magnetic volume and hence to a decrease of T_B. The second regime is governed by inter-particle coupling via Cr-bridges.

MA 20.8 Tue 12:15 Poster A

Interaction effects between self-assembled Co nanoparticles — •Astrid Ebbing[1], Leonardo Agudo[2], Gunther Eggeler[2], and Oleg Petracic[1] — [1]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum — [2]Institut für Werkstoffe, Ruhr-Universität Bochum, 44780 Bochum

In this work we present the influence of Pt on self-assembled Co nanoparticles (NPs). We show that capping the Co NPs with Pt results in strong changes in the magnetic properties. With increasing Pt capping we observe a transition from 'demagnetizing' (viz. dipolar) toward 'magnetizing' (e.g. polarization type) interactions between the

NPs. We performed magnetization hysteresis, ZFC/FC vs. temperature and delta(M)-measurements using a superconducting quantum interference device magnetometer to investigate the nature of coupling between the NPs. The measurements show negative delta(M)-values for small amounts of Pt capping material and positive values for 0.53 nm Pt or more, which indicates a magnetizing interaction between the NPs via the Pt-bridges.

MA 20.9 Tue 12:15 Poster A

Characterization of superparamagnetic nanoparticles for bone tissue engineering — •M. Uhlarz[1], T. Herrmannsdörfer[1], R. De Santis[2], M. Sandri[3], A. Tampieri[3], E. Figallo[4], T. D'Alessandro[4], S. Keshari-Samal[5], G. Rischitor[6], and the MAGISTER collaboration[7] — [1]Hochfeld-Magnetlabor Dresden, HZ Dresden-Rossendorf — [2]IMCB-CNR, Napoli, Italia — [3]ISTEC-CNR, Faenza, Italia — [4]Fin-Ceramica SpA, Faenza, Italia — [5]ISMN-CNR, Bologna, Italia — [6]Western General Hospital, University of Edinburgh, UK — [7]Europäische Kommission, Bruxelles, Belgique

Currently, large bone or cartilage defects are stabilized by massively-invasive surgery. The permanent implants used for this purpose are either metallic prostheses, or body tissue taken elsewhere from the patient. In a novel tissue-engineering approach, autologous tissue regeneration is guided by implanted magnetic scaffolds under external magnetic field. These scaffolds attract superparamagnetic Fe_3O_4 (magnetite) nanoparticles tagged with Vascular Endothelial Growth Factor (VEGF) molecules. Release of the growth-factor molecules at the scaffold (optionally triggered by ac-field induced hyperthermia) attracts autologous chondrocytes and osteoblasts, which build up fresh bone and cartilage tissue. We report on the magnetic characterization of several biocompatible and biodegradable materials that might serve as scaffold materials.

This project is supported by the European Union's FP7-Cooperation Programme through the MAGISTER project (Magnetic Scaffolds for in-vivo Tissue Engineering), Large Collaborative Project FP7 - 21468.

MA 20.10 Tue 12:15 Poster A

Hall effect in nanodimensional multilayers based on island films of Pd and Fe — •Sergej A. Nepijko[1], Dmytro Kutnyakhov[1], Olena Tkach[2], Larysa Odnodvorets[2], Ivan Protsenko[2], and Gerd Schönhense[1] — [1]Institute of Physics, University of Mainz, 55099, Mainz, Germany — [2]Sumy State University, 40007, Sumy, Ukraine

Nanodimensional n-layers systems of $[Pd/Fe]_n/SiO_2/Si$, where $3 \leq n \leq 10$, were used to examine the Hall effect. Effective thickness of separate layers of Pd and Fe changed in the range from 0.4 to 1.4 nm (Pd) and from 0.6 to 0.9 nm (Fe). Electron microscopic studies indicate that the layers have island structure and their composition corresponds to fcc-Pd and bcc-Fe. Solid solutions of Pd-Fe with fct-lattice are formed only when the thickness of layers $\geq$ 3 nm and after annealing at $\geq$ 790 K. Measurement of Hall coefficient R_H indicate that its value monotonically decreases with increasing number of layers n. For example, for multilayer Pd(1.1 nm)/Fe(0.9 nm) R_H decreases from 5.5×10^{-9} m^3/C (n=2) to 3.97×10^{-9} m^3/C (n=10). A size dependence of R_H is observed also at fixed Fe layer thickness and variable thickness of Pd. For multilayer $[Pd(x)/Fe(0.6)]_{10}$ the Hall coefficient decreases from 4.80×10^{-9} m^3/C to 3.69×10^{-9} m^3/C while increasing the effective thickness of Pd from x= 0.4 to 1.4 nm.

MA 20.11 Tue 12:15 Poster A

Spin-fluctuation energies in $3d$ transition-metal clusters deposited on Pt (111) — •Sergej Riemer[1], Gustavo Pastor[2], Jesus Dorantes-Dávila[3], and Raul Garibay-Alonso[4] — [1]Universität Kassel, Germany — [2]Universität Kassel, Germany — [3]UASLP, San Luis Potosí, Mexico — [4]Universidad Autónoma de Coahuila, Mexico

A functional-integral theory of itinerant magnetism is applied to transition-metal clusters deposited on Pt (111). The low temperature limit of the local spin-fluctuation energies $\Delta F_l(\xi)$ at different atoms l is determined as a function of the exchange field ξ by using a real-space recursive expansion of the local Green's functions. The size, structural, and local-environment dependence of $\Delta F_l(\xi)$ is calculated for representative examples of Fe_N, Co_N and Ni_N with $N \leq 13$ atoms. The interplay between fluctuations of the module and of the relative orientation of the local magnetic moments is analyzed. Comparison between free and deposited clusters having the same structure and interatomic distances reveals remarkable changes in the spin-excitation spectrum of the clusters as a result of the hybridizations with the metallic support. For instance, in the case of small Fe clusters on Pt (111) one observes that the spin-flip energies are reduced by more than an order of magnitude as a consequence of deposition. A similar important reduction of the Curie temperature is expected. This contrasts with the results for the ground-state magnetic moments and magnetic order, which are essentially the same in the free and deposited configurations.

MA 20.12 Tue 12:15 Poster A

Coupling behavior in iron-oxide nanoparticle/Py thin film composite systems — •Caroline Fink[1], Philipp Szary[1], Giovanni Badini Confalonieri[1], Durgamadhab Mishra[1], Maria Benitez[1,2], Mathias Feyen[2], An-Hui Lu[2], Leonardo Agudo[3], Gunther Eggeler[3], and Oleg Petracic[1] — [1]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Max-Planck-Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr, Germany — [3]Institut für Werkstoffe, Ruhr-Universität Bochum, D-44780 Bochum, Germany

We have investigated the magnetic and electrical transport properties of iron-oxide nanoparticle/Py thin film composite systems. Ultrathin films of Permalloy (Py) have been prepared by means of UHV ion beam sputtering and subsequently covered by one monolayer of iron-oxide nanoparticles. Post-annealing of the samples under controlled atmospheric conditions allows us to transform the particles into a mixed wüstite/magnetite (FexO/Fe3O4) phase showing intra-particle exchange bias. A slight variation of the NP type yields systems of different coupling behavior. Performing magnetometry and transport measurements we observe either a strong or weak coupling between the Py film and the NPs depending on the NP type. Moreover, a strongly decoupled behavior can be observed when adding a sapphire (Al2O3) layer separating the particles from the Py. Results have been compared with reference systems consisting of only NPs or only Py.

MA 20.13 Tue 12:15 Poster A

Magnetoresistance properties of Fe_3O_4 nanoparticles in a Cu matrix — •Sergej A. Nepijko[1], Dmytro Kutnyakhov[1], Maxym Demydenko[2], Serhiy Protsenko[2], Dmytro Kostyuk[2], and Gerd Schönhense[1] — [1]Institute of Physics, University of Mainz, 55099, Mainz, Germany — [2]Sumy State University, 40007, Sumy, Ukraine

The aim of the work was the manufacturing of ordered arrays of magnetic Fe_3O_4 nanoparticles, the investigation of their structural and phase state and magneto-resistance in a wide range of annealing temperatures. Nanoparticles were prepared by chemical synthesis and drop deposited onto a Si substrate. After deposition the ordered nanoparticle array was observed by TEM. Nanoparticle sizes changed from 6.0 nm (as deposited) to 11.6 nm (after annealing at 1200 K). The phase state of the nanoparticles was cubic (spinel type) with lattice parameter varying from 0.811 nm (as-deposited) to 0.840 nm (1200 K). The magnetoresistance was measured using nanostructured systems of $Au(2nm)/Cu(20nm)/Fe_3O_4$(nanoparticles)$/SiO_2/Si$ with varying the angle between magnetic field direction and substrate plane from 0° to 90°. The resulted maximum value of magnetoresistance was about 2 %.

MA 20.14 Tue 12:15 Poster A

^{57}Fe Mössbauer spectroscopy on ferrite nanoparticles — •Mathias Kraken[1], Jochen Litterst[1], Ilka-Marina Grabs[2], Ingke-Christine Masthoff[2], Isabel Christina Souza Dinóla[3], Julian Andres Munevar Cagigas[3], Wiliam Trujillo Herrera[3], and Elisa Maria Baggio Saitovitch[3] — [1]Institut für Physik der kondensierten Materie | TU Braunschweig | Germany — [2]Institut für Partikeltechnik | TU Braunschweig | Germany — [3]Centro Brasileiro de Pesquisas Físicas | Rio de Janeiro | Brazil

Due to its specific timescale, Mössbauer spectroscopy is highly suitable to investigate the dynamic properties of magnetic nanoparticles. The hyperfine magnetic spectra between the blocking temperature and very low temperatures may exhibit a broad variety of different shapes. Accordingly, to describe this rich behaviour a whole range of different, controversially discussed models can be found in literature (1-3).

We performed ^{57}Fe Mössbauer measurements on $ZnFe_2O_4$ nanoparticles, prepared by a non-aqueous sol gel method and characterized by different techniques. The spectra were taken on strongly and weakly interacting particles and the fits to the spectra with the different models are compared in order to gain information about their suitability.

(1) D.H. Jones et al., J. Magn. Magn. Mater. 78, 320 (1989).

(2) S. Mørup et al., J. Magn. Magn. Mater. 40, 163 (1983).

(3) S. Bocquet et al., J. Magn. Magn. Mater. 109, 260 (1992).

MA 20.15 Tue 12:15 Poster A

Preparing of $La_{1/3}Sr_{2/3}FeO_3$ targets for sputtering of thin films — •Thomas Breuer, Thomas Brueckel, Joerg Voigt, and Joerg Persson — Peter Gruenberg Institut PGI and Juelich Centre for Neutron Science JCNS, JARA-FIT, Forschungszentrum Juelich GmbH, 52425 Juelich, Germany

$La_{1/3}Sr_{2/3}FeO_3$ is a transition metal oxide (TMO) with a perovskite structure. It exhibits strong electronic correlations, visible e.g. in a Verwey metal-insulator transition accompanying the antiferromagnetic phase transition at about $T_C = 200\,K$.
While the material has been investigated extensively in bulk form, the aim of the present study is to clarify its properties as thin epitaxial films. We have prepared ceramic sputter targets of $La_{1/3}Sr_{2/3}FeO_3$ in a solid state reaction and characterized them by means of chemical analysis, powder x-ray diffraction and magnetic measurements by a Vibrating Sample Magnetometer on PPMS. The material tends to lose oxygen during calcination and sintering at temperatures above 600 K which was detected by thermogravimetric analysis. Significant changes in structure and magnetic response are being observed for oxygen deficits as low as 2 %. Finally, the progress in the preparation and characterization of thin epitaxial films will be reported.

MA 20.16 Tue 12:15 Poster A

The first principle study of Cu-based hybrids — •Pegah Zolfaghari[1], Gilles A de Wijs[1], and Robert A de Groot[1,2] — [1]Electronic Structure of Materials, Institute for Molecules and Materials, Faculty of Science, Radboud University Nijmegen, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands — [2]Solid State Materials for Electronics, Zernike Institute for Advanced Materials, Rijksuniversiteit Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands

Hybrids, organic-inorganic materials, in the perovskite-type layer structures with the general formula $(C_nH_{2n+1}NH_3)_2MCl_4$ in which $n = 0, 1, 2, ...$, and M represents a divalent transition metal ion, have been extensively studied in recent years. Among these series of hybrids, the copper compounds are the most interesting ones. Firstly, the divalent metal Cu^{2+} is a strong Jahn-Teller ion, as a result different structual transitions in these materials occur. Secondly, the magnetic intra-layer interactions are ferromagnetic.

The density functional (DFT) calculations were applied to study the $(NH_4)_2CuCl_4$ and $(C_2H_5NH_3)_2CuCl_4$ compounds. The magnetic and electronic properties were investigated. The calculations reveal that the compounds have a stable, layered ferromagnetic ground state that is consistent with experimental results.

MA 20.17 Tue 12:15 Poster A

Synthesis and magnetic properties of cobalt ferrite nanoparticles — •Morad F. Etier[1], Vladimir V. Shvartsman[1], Frank Stromberg[2], Joachim Landers[2], Heiko Wende[2], Fábio G. Figueiras[3], and Doru C. Lupascu[1] — [1]Institute for Materials Science, University of Duisburg-Essen, Essen, Germany — [2]Faculty of physics and Center for Nanointegration (CeNIDE) Duisburg-Essen, University of Duisburg-Essen, Duisburg, Germany — [3]Department of Physics, CICECO, University of Aveiro, Aveiro, Portugal

Cobalt ferrite is one of the most widely used materials in magnetic recording devices due to its high coercivity (about 5400 Oe), moderate magnetization (84 emu/g), and good chemical stability. Below Tc = 820 K cobalt ferrite is in a ferrimagnetic state. The magnetic properties of cobalt iron oxide nanoparticles mainly depend on the annealing temperature and particle size.

Nanoparticles of cobalt ferrite were successfully fabricated by the co-precipitation method. The crystal structure was confirmed by X-ray diffraction, the composition by energy dispersive spectroscopy, and phase changes by thermogravimetric differential thermal analysis. The particle morphology was analyzed by scanning electron microscopy. Magnetic properties were investigated by magnetometry and Mössbauer spectroscopy. Particle size is in the range of 24 to 44 nm. Both the particle size and agglomeration level are controlled by the amount of sodium hydroxide used. Dependence of remnant magnetization and coercive field on particle size is analyzed.

MA 20.18 Tue 12:15 Poster A

Magnetic and Electronic properties of Mn-stabilized Zirconia (MnSZ) — •Jan Zippel[1], Michael Lorenz[1], Anette Setzer[1], Holger Hochmuth[1], Pablo Esquinazi[1], Nikolai Sobolev[2], Alexandre Jacquot[3], and Marius Grundmann[1] — [1]Universität Leipzig, Fakultät für Physik und Geowissenschaften, Institut für Experimentlaphysik II, Linnéstrasse 5, 04103 Leipzig, Germany — [2]Universidade de Aveiro, Departamento de Fisica, Campus de Santiago, 3810-193 Aveiro, Portugal — [3]Fraunhofer Institut für Physikalische Messtechnik, Heidenhofstrasse 8, D-79110 Freiburg, 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], MnSZ is proposed as a ferromagnetic semiconductor with a Curie temperature T_C above room temperature. As recently shown, a Mn related ferromagnetism has not been observed yet [2]. By applying an annealing step in oxygen defficient ambient at about $T_{\text{ann}} \approx 700°$ C to the MnSZ thin films grown by pulsed-laser deposition (PLD), we observe a ferromagnetic behavior in superconducting quantum interference device (SQUID) measurements at about $T = 60$ K. In addition, electron paramagnetic resonance (EPR) suggests a change of the Mn oxidation state from an EPR silent Mn^{3+} to Mn^{2+}. Seebeck-effect measurements verify a transition from p–type conductivity to n–type conductivity around 500 K. [1] S. Ostanin et *al.*, Phys. Rev. Lett. **98**, 016101 (2007). [2] J. Zippel et *al.*, Phys. Rev. B **82**, 125209 (2010).

MA 20.19 Tue 12:15 Poster A

The magneto-impedance of iron whiskers at low temperature — •Matthäus Langosch, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D-66041, Saarbrücken, Germany

In order to understand all aspects of the AC transport behavior of a ferromagnetic material in an external magnetic field at low temperature, iron single crystals (iron whiskers) were grown as specific samples to investigate the magneto-impedance (MI) effect at 4.2 K. The MI measurements were performed as a function of the magnitude of the driving current and its frequency. The chosen frequencies were up to 100 kHz, where domain wall motion takes place and contributes to the MI effect. The measured low temperature impedance changes are on the order of hundreds of percent and are much higher than that at room temperature. This behavior can mainly be attributed to a large mean free electronic path on the one hand and the skin effect on the other hand.

MA 20.20 Tue 12:15 Poster A

Structural and magnetic analysis of Vanadates — •Christine Tölzer[1], Johanna Brand[1], Masahiko Isobe[2], Karsten Binder[1], Timo Taetz[3], María Teresa Fernández-Díaz[5], Angela Möller[3,4], Yutaka Ueda[2], and Markus Braden[1] — [1]II. Institute of Physics, University of Cologne — [2]Institute for Solid State Physics, University of Tokyo — [3]Institute of Inorganic Chemistry, University of Cologne — [4]Department of Chemistry and Texas Center for Superconductivity, University of Houston — [5]Institute Laue-Langevin, Grenoble

We present the analysis of three different Vanadates: $InCu_{2/3}V_{1/3}O_3$, $Rb_2V_8O_{16}$ and ZnV_2O_4. The layered compound $InCu_{2/3}V_{1/3}O_3$ is a representative of the quasi two-dimensional S=1/2 honeycomb lattice due to the ordering of Cu and V. A Néel-temperature near 38 K was deduced from anomalies in the magnetic susceptibility. We have studied the magnetic structure in $InCu_{2/3}V_{1/3}O_3$ by neutron diffraction on the high-flux powder diffractometer D20. A rise in scattering upon cooling indicates magnetic ordering to set in near the anomaly observed in the susceptibility. Furthermore, we discuss the charge and orbital ordering in $Rb_2V_8O_{16}$ and in ZnV_2O_4, as analysed by single-crystal x-ray diffraction as function of temperature.

MA 20.21 Tue 12:15 Poster A

Normal and anomalous Hall effect in $NbFe_2$ — •Sven Friedemann[1], Manuel Brando[2], William J Duncan[3], Andreas Neubauer[4], Christian Pfleiderer[4], and Malte Grosche[1] — [1]University of Cambridge, Cavendish Laboratory, JJ Thomson Avenue, CB3 0HE Cambridge, United Kingdom — [2]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Strasse 40, 01187 Dresden, Germany — [3]Department of Physics, Royal Holloway, University of London, Egham TW20 0EX, United Kingdom — [4]Physik Department E21, Technische Universität München, James-Franck-Strasse, D-85748 Garching, Germany

The intermetallic system $NbFe_2$ exhibits ferromagnetic and antiferromagnetic order, which can be suppressed by slight changes to the composition within the $Nb_{1-y}Fe_{2+y}$ homogeneity range. A quantum

critical point (QCP) arises at slight Nb excess of about $y = 0.015$. In proximity to its QCP $NbFe_2$ exhibits non-Fermi-liquid behaviour, which makes this material the first clear candidate for a three dimensional ferromagnetic QCP in a clean transition metal compound at ambient pressure. We present Hall effect measurements on several single crystals chosen from the $Nb_{1-y}Fe_{2+y}$ solution series. The data are analysed in terms of anomalous and normal contributions to the Hall voltage. We find anomalous contributions arising from both Side Jump and Skew Scattering with distinct changes in their relative strength as a function of Nb content. The normal contribution reflects the electronic structure.

MA 20.22 Tue 12:15 Poster A

First principles studies of complex magnetism in Mn nanostructures on Fe(001) surface — •Ricardo Noboru Igarashi[1], Angela Burlamaqui Klautau[2], and Helena Maria Petrilli[1] — [1]Instituto de Física, Universidade de São Paulo, CP 66318, 05315-970, São Paulo, SP, Brazil — [2]Faculdade de Física, Universidade Federal do Pará, Belém, PA, Brazil

The magnetic properties of Mn nanostructures on Fe(001) surface have been studied using the noncollinear first-principles RS-LMTO-ASA (Real-Space Linear Muffin Tin Orbital Atomic Sphere Approximation) [1] method within density functional theory. We have considered a variety of nanostructures such adsorbed wires, pyramids, flat and intermixed clusters of sizes varying from two and nine atoms. Our calculations of interatomic exchange interactions reveal the long range nature of exchange interactions between Mn-Mn and Mn-Fe atoms. We have found that the strong dependence of these interactions of the local environment and the effect of spin-orbit coupling lead to the possibility of realizing complex magnetic structures such as helical and half skyrmion.

[1] S. Frota-Pessôa, Phys. Rev. B 69, 104401 (2004); Phys. Rev. B 46, 14570 (1992); P. R. Peduto, S. Frota-Pessôa and M. S. Methfessel, Phys. Rev. B 44, 13 283 (1991).

MA 20.23 Tue 12:15 Poster A

Incorporation of N codopants in Co:ZnO investigated by X-ray absorption spectroscopy — •Daniel Schauries[1], Andreas Ney[1], Verena Ney[1], Fabrice Wilhelm[2], Andre Rogalev[2], and Flora Yakhou[2] — [1]Fakultät für Physik, Universität Duisburg-Essen, Lotharstr. 1, D-47057 Duisburg, Germany — [2]European Synchrotron Facility, 6 Rue Jules Horowitz, BP 220, 38043 Grenoble Cedex, France

p-doping of ZnO in general remains a grand challenge for material science. In particular p-type ZnO is of interest to investigate the perspectives for obtaining RT-ferromagnetism in p-type Co:ZnO.

We have grown Co:ZnO:N(0001) on sapphire substrates using reactive magnetron sputtering from Co/Zn targets at Co concentrations of 10, 15 and 20% and different $Ar : O_2 : N_2$ sputter gas compositions.

The structure was studied by synchrotron-based element specific X-ray absorption spectroscopy. All edges were measured with the electric field of the X-rays perpendicular and parallel to the c-axis to obtain X-ray Linear Dichroism (XLD). Subsequently all spectra for the Zn, Co, O and N-K-edge were simulated with FDMNES[1] to determinate the positions of the species. While Co only occupies Zn-sites, the situation turned out to be more complex for N — for low N_2-concentration in the sputter gas probably incorporated N_2 was formed, high N_2-levels also led to the formation of substitutional N atoms on O-sites.

The resulting magnetic properties of Co:ZnO:N will be discussed as well. We greatfully acknowledge financial support from the DFG through the Heisenberg Programme.

[1] Y. Joly, Phys. Rev. B **63**, 125120-125129 (2001).

MA 20.24 Tue 12:15 Poster A

Polarized Neutron Reflectometry of Rare-Earth Nitride Thin Films — •Sebastian Brück[1,2], David Cortie[2], Josh Brown[3], Thomas Saerbeck[2], Clemens Ulrich[1], Frank Klose[2], and James Downes[3] — [1]School of Physics, University of New South Wales, Sydney, Australia — [2]Australian Nuclear Science and Technology Organization, Lucas Heights, Australia — [3]Department of Physics, Macquarie University, Australia

Rare-earth monopnictides like HoN, DyN, or ErN are semiconductors with typical band gaps between 0.73 and 1.3eV. The fact that they exhibit ferromagnetic ordering at low temperatures makes them possible candidates for an intrinsically ferromagnetic semiconductor. Thin, polycrystalline rare-earth nitride films of 15 to 40nm thickness were grown onto c-plane sapphire substrates using low-energy ion assisted deposition. A temperature- and field-dependent polarized neutron reflectometry study in combination with SQUID magnetometry was carried out to characterize the magnetic properties of these films in a depth resolved way. The investigated samples show a homogeneous distribution of the magnetic moment throughout the film with ferromagnetic ordering temperatures comparable to the bulk materials. ErN and HoN films do not show an opening of the magnetic hysteresis loop even for the lowest measured temperature of T=2K. DyN on the other hand clearly shows a coercive field and remnant magnetization at 5K.

MA 20.25 Tue 12:15 Poster A

ZnO Metal Semiconductor Field Effect Transistor with magnetic channel — •Tim Kaspar, Danilo Bürger, Ilona Skorupa, Vicki Kühn, Artur Erbe, Manfred Helm, and Heidemarie Schmidt — Helmholtz-Zentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany

We focus on the development of transparent semiconductor spintronics devices. Our work is motivated by the observation of s-d exchange inducted spin polarization in magnetic ZnO:(Co, Mn) thin films below 50 K and related magnetoresistance effect [1]. Our aim is to control the conductance in ZnO Metal Semiconductor Field Effect Transistors (MESFET) with magnetic channel by external electrical AND magnetic fields. The magnetic ZnO:(Co, Mn) channel layers have been deposited by pulsed laser deposition on c-plane sapphire substrates. Gate, source, and drain contacts have been structured by optical lithography. The gate contact has been fabricated by reactive sputtering of Ag/Au [2]. Source and drain contacts have been fabricated from high conducting transparent ZnO. The characteristics of the ZnO-based MESFETs with magnetic channel in external perpendicular magnetic fields ranged from -1.8T to +1.8T are presented.

[1] Qingyu Xu, *et al.*, Phys. Rev. Lett. **101**, 076601 (2008)
[2] H.Frenzel *et al.*, Appl. Phy. Lett. **92**, 192108 (2008

MA 20.26 Tue 12:15 Poster A

Anomalous hysteretic Hall effect in a ferromagnetic, Mn-rich, amorphous Ge:Mn nano-network — •Danilo Bürger, Shengqiang Zhou, Marcel Höwler, Xin Ou, György Kovacs, Helfried Reuther, Arndt Mücklich, Wolfgang Skorupa, Manfred Helm, and Heidemarie Schmidt — Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, P.O. Box 510119, 01314 Dresden, Germany

The read out of the magnetization state in magnetic semiconductors by electrical Hall resistance measurements makes it possible to use ferromagnetic semiconductors in nonvolatile memories. In a previous work [1], we fabricated ferromagnetic Ge:Mn by Mn ion implantation and pulsed laser annealing (PLA) and observed hysteretic Hall resistance below 10 K. By applying different PLA conditions we fabricated a percolating, Mn-rich, amorphous Ge:Mn nano-network with hysteretic Hall resistance up to 30K. This nano-network is embedded in crystalline Ge:Mn between 5 nm and 40 nm under the sample surface. We applied chemical and physical etching to confirm the contribution of the nano-network to the magnetic properties. The nano-network has a significant influence on the correlation between magnetism and anomalous Hall resistance. In the future such nano-networks may be used to spin-polarize free charge carriers in semiconductors at room temperature. [1] S. Zhou *et al.*, Phys. Rev. B **81**, 165204 (2010)

MA 20.27 Tue 12:15 Poster A

Optical and Magneto-optical Properties of ZnO(0001) Single Crystals Implanted with Fe and Co Ions — •Scarlat Camelia[1], Zhou Shengqiang[1], Gordan Ovidiu[2], Fronk Michael[2], Zahn R. T. Dietrich[2], Helm Manfred[1], Schmidt Heidemarie[1], and Salvan Georgeta[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Germany — [2]Semiconductor Physics, Chemnitz University of Technology, Germany

ZnO is a transparent wide-band-gap semiconductor which has been intensively investigated in the view of (magneto-) and (opto-)electronic applications. In this work the (magneto-)optical properties of unimplanted ZnO(0001) single crystals and single crystals implanted with ^{57}Fe and Co ions were investigated at room temperature by means of Raman spectroscopy, spectroscopic ellipsometry, and magneto-optical Kerr effect (MOKE) spectroscopy. The ZnO (0001) single crystals were coimplanted with ^{57}Fe and Co ions at 623 K with same fluence respectively. After implantation the samples were annealed in a high-vacuum furnace at 1073 K for different annealing time. The Raman spectra measured in resonance with an excitation energy of 3.82 eV exhibit higher order scattering by LO phonons. The increase in the

ratio between the second and the first order phonon peak intensities for long annealing time can be correlated with a reduction in the number of defects and with improved crystallinity. The implanted ZnO crystals exhibit magneto-optical activity in two broad spectral ranges centered around 3 eV and around 4.3 eV, the strength of which also varies significantly with the annealing time.

MA 20.28 Tue 12:15 Poster A

Bipolar resistive switching at manganite/manganite interfaces — •Christin Kalkert, Jon-Olaf Krisponeit, Vasily Moshnyaga, Bernd Damaschke, and Konrad Samwer — I. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen

Bipolar resistive switching stands for remanent switching of resistivity by application of electric fields reversible by opposite polarities. This phenomenon is observed in a wide variety of perovskite materials and holds the potential of creating new resistive random access memory devices. $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) manganite films were prepared by using the metalorganic aerosol deposition technique. On Al_2O_3 substrates the manganite films show nanocolumnar growth with different growth orientations as determined by x-ray diffraction and TEM analysis. The films were structured by electron beam lithography into LSMO paths/bridges between larger LSMO contact areas; after a second lithography step Au/Cr films were deposited onto the contact areas. These structures show bipolar resistive switching, which can also be induced and probed by means of conductive AFM. The C-AFM measurements show that the switching takes place at the manganite/manganite interfaces, i.e. at the boundaries of the nanocolumns. The resistive switching of the structures and the C-AFM measurements are discussed in terms of a local structural transformation at the manganite/manganite interfaces. (APL 99, 132512, (2011))

Financial support by DFG via SFB 602, TPA2 and the Leibniz Program is ackowledged.

MA 20.29 Tue 12:15 Poster A

Ultrafast Spin-Lattice Coupling in Transition Metal Oxides — •Lena Maerten, André Bojahr, Marc Herzog, Daniel Schick, and Matias Bargheer — Insitut für Physik und Astronomie, Universität Potsdam, Germany

Understanding the interplay of the electronic, lattice and spin degrees of freedom in solids is essential for devising future nanoelectronic applications. Nanostructured transition metal oxides provide an ideal test ground for studying the interaction of the contributing subsystems on an ultrafast time scale.

We use femtosecond optical and infrared pump probe spectroscopy and time resolved x-ray diffraction techniques to investigate the electronic and lattice dynamics in $SrRuO_3/SrTiO_3$ and $(LaSr)MnO_3/SrTiO_3$ superlattices. Sub-picosecond buildup of magnetostrictive stress has been found in a $SrRuO_3/SrTiO_3$ nanolayer [1]. We show additional temperature- and fluence-dependent reflectivity data revealing further insight into the demagnetization process and discuss the coupling of the magnetic and structural degrees of freedom for the different materials by means of x-ray diffraction results.

[1]C. v. Korff Schmising et al., PRB 78, 060404 (2008)

MA 20.30 Tue 12:15 Poster A

Colossal Magnetoelastic Effects at the Phase Transition of (La, Pr, Ca)MnO_3 — •Markus Michelmann, Christoph Meyer, Vasily Moshnyaga, and Konrad Samwer — I. Physikalisches Institut, Universität Göttingen, Friedrich-Hund-Platz 1, 37707 Göttingen

A strong coupling of charge, spin and lattice degrees of freedom in perovskite manganites, i.e. (La, Pr, Ca)MnO_3, results from the competition between the ferromagnetic double exchange and charge/orbital ordering, promoted by the electron-phonon interaction. Therefore, the paramagnetic-ferromagnetic (PM-FM) phase transition is clearly reflected in the behavior of the elastic constants. Here, we report ultrasound velocity and attenuation in polycrystalline $(La_{1-y}Pr_y)_{0.7}Ca_{0.3}MnO_3$ bulk samples (y = 0, 0.4, 0.5, 1) as a function of temperature, $T = 10 - 300$ K, and magnetic field, $B = 0 - 7$ T, with special focus on the hysteresis effects and metamagnetism at the 1st order PM-FM transition. Close to the Curie point modest magnetic fields, $B = 1 - 5$ T, induce a large increase of shear stiffness and a strong softening of bulk modulus by about 10%. A minimum in bulk modulus and a peak in longitudinal sound attenuation were observed at the phase transition and attributed to a coupling between the lattice and spin fluctuations. The magnitude of this softening is maximized at a certain temperature and magnetic field, indicating a critical end point of the magnetic transition. Support by Deutsche Forschungsgemeinschaft via SFB 602, TP A2 is acknowledged.

MA 20.31 Tue 12:15 Poster A

Magneto-optical Studies on Transition Metal doped Zinc Oxid — •Stephanie Jankowski[1], Sebastian Geburt[2], Carsten Ronning[2], and Wolfram Heimbrodt[1] — [1]Department of Physics and Material Science Center, Philipps- University Marburg, Renthof 5, D-35032 Marburg, Germany — [2]Physikalisch-Astronomische Fakultät, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, D-07743 Jena, Germany

We present the results of magneto photoluminescence on ZnO-bulk doped with the magnetic ions Co and Mn. The measurements have been performed in magnetic fields up to 7 Tesla in a temperature range 1.8-300 K. Zeeman spectroscopic in the excitonic region have been used to determine the g-factors of the samples. Normally the g-factor of II-VI diluted magnetic semiconductor is very high because of the Giant Zeeman effect. Even in case of transition metal doped ZnO surprisingly small Zeeman-splitting has been found. In comparison to other Mn- and Co-doped II-VI semiconductors the optical 3d intra-ionic transitions are very weak. The physical reasons for these phenomena will be discussed.

MA 20.32 Tue 12:15 Poster A

Microscopic and macroscopic studies on the magnetoelectric coupling in chiral multiferroics — Max Baum[1], •Jonas Stein[1], Simon Holbein[1], Thomas Finger[1], Navid Qureshi[1], Jeannis Leist[3], Joachim Hemberger[1], Petra Becker-Bohatý[2], Ladislav Bohatý[2], Götz Eckold[3], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln — [3]Institut für Physikalische Chemie, Universität Göttingen

In the chiral magnets $MnWO_4$ and $TbMnO_3$ ferroelectric polarisation is directly induced by the non-collinear magnetic structure. We present microscopic neutron scattering studies and macroscopic measurements of the ferroelectric polarisation and of the magnetic structure in these materials. Using a stroboscopic method the control of the chiral magnetism by an external electric field is analysed with polarised neutrons finding unexpectedly large relaxation times. Measurements of the pyrocurrent on $MnWO_4$ confirm these long time scales. In addition we discuss the magnetic excitations at the incommensurate zone centre of $MnWO_4$, a low energy mode should posses electromagnon character. The magnetic structure of $NaFe(WO_4)_2$ was studied by neutron diffraction. At zero magnetic field we find an incommensurate structure which transforms to commensurate order upon the application of moderate fields.

MA 20.33 Tue 12:15 Poster A

On the ferroelectric phase transition of boracites — •Michael Fechner and Nicola Spaldin — ETH Zurich, Department for Material Theory,CH-8093 Zurich, Switzerland

We present results of first-principles electronic structure calculations for the Cl and I boracites. The boracites[1] are a class of ferroelectric minerals with formula $Me_2B_7O_{12}X$, where Me is a bivalent metal (Fe, Co, Zn) and X a halogen (Cl, Br or I). All boracites are cubic at high temperature, and undergo a phase transition on cooling first to an orthorhombic phase and in some cases subsequently to a triclinic phase. Boracites with magnetic ions further develop magnetic ordering and become multiferroic. Here we investigate the mechanism for the ferroelectric phase transition from the cubic high symmetry phase to the orthorhombic ferroelectric intermediate and triclinic low temperature phase. Finally we found a dominant unstable phonon mode at the Γ point which drives the phase transition. However this mode couples with modes at the zone boundary making the boracites improper ferroelectrics.

[1] Nelmes, R., 1974. Structural Studies of Boracites - Review of Properties of Boracites. Journal Of Physics C-Solid State Physics, 7(21), pp.3840-3854.

MA 20.34 Tue 12:15 Poster A

XAS and XMCD of ultrathin Fe layers on $BaTiO_3$(001): Experiment and Theory — •Stephan Borek[1], Angelika Chassé[1], Guntram Fischer[1], Wolfram Hergert[1], Remya Kunjuvettil Govind[1], Karl-Michael Schindler[1], Vasili Hari Babu[2], Joachim Gräfe[2], Martin Welke[2], and Reinhard Denecke[2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg — [2]Wilhelm-Ostwald-Institut für Physikalische und Theoretische

Chemie, Universität Leipzig

Promising candidates for switching the magnetization using voltages are multiferroic systems. As a model system we studied ultrathin Fe layers on $BaTiO_3$(001). Using x-ray absorption spectroscopy as a powerful method to investigate structural, electronic and magnetic properties simultaneously, the circular dichroism in x-ray absorption (XMCD) and x-ray absorption as such were used to determine the remanent magnetization as a function of film thickness. The onset of ferromagnetism at a temperature of 150 K was found for 5±1 layers. Using a Heisenberg-model in the framework of Monte-Carlo-Simulations shows that up to 3 monolayers the critical temperature is around 170 K. In addition the contribution of each layer could be separated using a fully relativistic multiple scattering formalism. Different magnetic structures and their impact on the spectroscopic properties, as well as the anisotropic behaviour of the multiferrroic systems have been investigated theoretically. The spin and orbital moments as obtained from the XMCD experiments and DMFT calculations will be compared.

MA 20.35 Tue 12:15 Poster A

Ferroelectricity and Magnetic Structure of Mn Moments in Multiferroic $GdMnO_3$ — •Enrico Schierle[1], Victor Soltwisch[1], Christoph Trabant[1,2], Alex Frano[1,3], Detlef Schmitz[1], Fabiano Yokaichiya[1,6], Andrej Maljuk[1,4], Dimitri Argyriou[1,5], and Eugen Weschke[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [2]II. Physikalisches Institut, Universität zu Köln, Germany — [3]MPI-FKF Stuttgart, Germany — [4]IFW, Dresden, Germany — [5]European Spallation Source, Lund, Sweden — [6]Laboratrio Nacional de Luz Sincrotron, Campinas-SP, Brasil

Orthorhombic $REMnO_3$ oxides can show strongly coupled ferroelectric (FE) and magnetic order, with FE polarization P induced by magnetic cycloids of the Mn spins[1,2]. However, from recent X-ray diffraction studies, there is growing evidence for a decisive role of ordering of the RE-4f moments as well and it seems that a large part of P can be explained by ionic displacements not necessarily connected with cycloidal magnetic order of Mn moments[3,4,5]. We employed Resonant Soft X-Ray Scattering at the Mn-$L_{2,3}$ resonance to prove the existence of a ferroelectric phase at the surface of $GdMnO_3$ even in zero external magnetic field and to examine its connection to the magnetic structure of the Mn moments in an element specific way.

[1] Kimura et al., Nature **426**, 55-58 (2003) [2] Kenzelmann et al., PRL **95**, 087206 (2005) [3] Schierle et al., PRL **105**, 167207 (2010) [4] Feyerherm et al., Journal of Physics: Conference Series **200**, 012032 (2010) [5] Walker et al., Science **333**, 1273 (2011)

MA 20.36 Tue 12:15 Poster A

Electronic and magnetic properties of $LuFe_2O_4$ — •Christine Derks[1], Karsten Kuepper[2], Manfred Neumann[1], Dharmalingam Prabhakaran[3], Stephen J. Blundell[3], Andrei Rogalev[4], and Fabrice Wilhelm[4] — [1]Fachbereich Physik, Universität Osnabrück, Germany — [2]Institut für Festkörperphysik, Universität Ulm, Germany — [3]Department of Physics, University of Oxford, United Kingdom — [4]ESRF, Grenoble, France

$LuFe_2O_4$ is a compound showing fascinating magneto electric coupling via charge ordering. Electronic and magnetic properties of the charge ordered phase of LuFe2O4 have been investigated by means of x-ray spectroscopic and theoretical electronic structure approaches [1]. Using hard x-ray radiation of the ESRF ID12 circular polarisation beamline, Fe K-edge and Lu L-edge spectra have been detected. The Fe K-edge spectra will be discussed in comparison to the former Fe L-edge spectra. The Lu L-edge spectra show very interesting XMCD signals from which a small magnetic moment could be deduced.

[1]Kuepper et al. Phys. Rev. B, Vol. 80, 22, 220409

MA 20.37 Tue 12:15 Poster A

Influence of the strength of the magnetoelectric coupling on the electric field induced magnetization reversal in a composite multiferroic chain — Paul P. Horley[1], Alexander Sukhov[2], Chenglong Jia[2], Eduardo Martinez[1], and •Jamal Berakdar[2] — [1]Centro de Investigacion en Materiales Avanzados (CIMAV S.C.), Chihuahua/Monterrey, 31109 Chihuahua, Mexico — [2]Institut für Physik, Martin-Luther Universität Halle-Wittenberg, 06120 Halle/Saale, Germany

A theoretical study of the multiferroic dynamics in a composite one-dimensional system consisting of unstrained $BaTiO_3$ multiferroically coupled to an iron chain is presented. The method [1] is based on the thermodynamical treatment of the magnetization and the polarization quantitatively described via the Landau-Lifshits-Gilbert and the Landau-Khalatnikov equations (both at T=0 K) coupled via an additional term in the total free energy. The coupling originates from the screening charge induced in the ferromagnet by the ferroelectric polarization in a very narrow interfacial layer. For real parameters corresponding to the rhombohedral phase of $BaTiO_3$ and for bcc iron and for a wide range of strengths of this coupling we predict the possibility of obtaining a well-developed hysteresis in the ferromagnetic part of the system induced by an external electric field. We also inspect the dependence of the reversal modes on the electric field frequency and predict a considerable stability of the magnetization reversal for frequencies in the range of 0.5÷12[GHz]. [1] A. Sukhov *et al.,* J. Phys.: Cond. Matter **22**, 352201 (2010); Ferroelectrics (at press).

MA 20.38 Tue 12:15 Poster A

Electric field controlled manipulation of the magnetization in $BaTiO_3$ based ferroelectric/ferromagnetic hybrid structures — •Stephan Geprägs, Matthias Opel, Sebastian T. B. Goennenwein, and Rudolf Gross — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching

Multiferroic materials, which simultaneously possess at least two long-range ordering phenomena in the same phase, have attracted widespread interest over the last years. In particular, the coexistence and cross-coupling of ferroelectric and ferromagnetic ordering in magnetoelectric multiferroics could offer the possibility to electrically read and write the magnetic state in future non-volatile memory cells. Unfortunately, these materials are scarce in nature. Attractive alternatives are composite material systems, in which ferromagnetic and ferroelectric compounds are combined. Such extrinsic multiferroic structures enable large and robust magnetoelectric effects at room temperature due to the elastic coupling between the ferroic constituents.

Here, we report on the electric field control of the magnetization in ferromagnetic/ferroelectric hybrid structures based on $BaTiO_3$ single crystals, using different materials as ferromagnetic layer, such as polycrystalline Ni and $Fe_{50}Co_{50}$ as well as epitaxial Fe_3O_4 and Sr_2CrReO_6 thin films. In these hybrid structures, reversible and irreversible changes of the magnetization as a function of the applied electric field were found, which are discussed in the framework of a theoretical model based on molecular dynamics simulations.

MA 20.39 Tue 12:15 Poster A

Interfacial effects on $[(SrMnO_3)_j/(LaMnO_3)_k]_N$ multilayers — •Markus Waschk, Paul Zakalek, Alexander Weber, and Thomas Brückel — Jülich Centre for Neutron Science JCNS-2 and Peter Grünberg Institut PGI-4, Forschungszentrum Jülich GmbH, D-52425 Jülich

On the search for new storage devices, the combination of ferroelectric and ferromagnetic properties in metal-oxide layers opens a wide field of new non-volatile memory devices, which show low energy consumption. Here we combine $LaMnO_3$ (LMO) and $SrMnO_3$ (SMO), which both are antiferromagnetic bulk insulators, while a multilayer stack behaves as ferromagnetic conductor for very small bilayer thicknesses. The ferromagnetism of the lower LMO layer is induced by the interface to the upper SMO layer. The influence is strongly dependent on the roughness of the interface, and was not yet observed in the opposite boundary. Our multilayers are grown epitaxially on $SrTiO_3$ (STO) (100) single crystals by an oxygen-assisted Molecular Beam Epitaxy System and alternatively, to compare both preparation methods, by a high pressure oxide sputtering system. Within our very smooth layers with interfacial roughness of the order of a unit cell we study the influence of the interface quality on the magnetic behaviour. We present the preparation method from first steps to a complex multilayer and the results of our in-house characterisation methods. Further we show our first results of a polarized neutron reflectometry study at D-17 of the ILL in Grenoble which show depth resolved the magnetic properties of the single layers and interfaces.

MA 20.40 Tue 12:15 Poster A

Fe-Cr cation ordering in PLD grown thin-films of multiferroic double perovskite Bi_2FeCrO_6 — •Vikas Shabadi, Philipp Komissinskiy, Mehran VafaeeKhanjani, Aldin Radetinac, and Lambert Alff — Institut für Materialwissenschaft, Technische Universität Darmstadt, Petersenstraße 23, 64287 Darmstadt, Germany

Co-existence of magnetism and ferroelectricity was theoretically predicted in the ordered double perovskite Bi_2FeCrO_6 [1]. We report epitaxial BFCO thin-films grown by pulsed laser deposition from a 20 % Bi-rich ceramic target on single crystal $SrTiO_3$(100) substrates.

The degree of the Fe-Cr cation ordering in the BFCO films was comparatively calculated based on the X-ray diffraction patterns. The magnetic moments of the BFCO films were measured with a SQUID magnetometer and analyzed as a function of the Fe-Cr ordering. We believe that the discrepancies in the previously reported values of the magnetic moment of BFCO are connected to the varying degree of Fe-Cr cation ordering [2,3]. Further motivation has been derived from a recent experiment that achieved more than 90 % spontaneous B-site ordering in a similar Fe-Cr based double perovskite system [4].

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The authors would like to acknowledge the support from DAAD.

MA 20.41 Tue 12:15 Poster A

Chemical solution deposition of multiferroic La0.7Sr0.3MnO3, BaTiO3 thin films prepared by ink plotting — •Anke Kirchner[1], Melis Arin[2], Petra Lommens[2], Xavier Granados[3], Susagna Ricart[3], Bernhard Holzapfel[1], and Isabel van Driessche[2] — [1]IFW Dresden, Institute for Metallic Materials, Helmholtzstr. 20, 01069 Dresden, Germany — [2]SCRiPTs, Department of Inorganic and Physical Chemistry, Ghent University, Krijgslaan 281 (S3), 9000 Ghent, Belgium — [3]Materials Science Institute of Barcelona, CSIC-ICMAB, Campus Universitat Autònoma de Barcelona, 08193 Bellaterra, Spain

Ferroelectric BaTiO3 (BTO) as well as ferromagnetic La0.7SrMnO (LSMO) thin films were prepared by chemical solution deposition (CSD). Based on these, a multiferroic architecture stack of La0.7Sr0.3MnO3 / BaTiO3 layers was developed. Aqueous, environmentally friendly precursor solutions were formulated for both materials. These are used for ink plotting on SrTiO3 (100) substrates. Films were subjected to a subsequent thermal treatment at the corresponding crystallization temperature. The structural as well as the magnetic and electric properties are presented. The Curie temperature of the ferromagnetic LSMO layer with a film thickness of only 60 nm was determined to 360 K. The magnetization curve indicates a hysteresis loop with a saturation magnetization above 400 emu/cm3. The ferroelectric character of the BTO films was demonstrated by polarization curves.

MA 20.42 Tue 12:15 Poster A

Diffraction Anomalous Fine Structure of Ho_2PdSi_3 and $YMn_{2-\xi}Fe_\xi O_5$ — •Melanie Nentwich[1], Matthias Zschornak[1], Carsten Richter[1,2], and Dirk C. Meyer[1] — [1]TU Bergakademie Freiberg, Institut für Experimentelle Physik, Leipziger Straße 23, 09596 Freiberg — [2]Hamburger Synchrotronstrahlungslabor HASYLAB at DESY

Diffraction Anomalous Fine Structure (DAFS) is a site-selective method for studying local electronic structures. As an advantage over X–ray Absorption Fine Structure (XAFS) it is possible to differentiate between atoms of the same kind but different Wyckoff positions which is especially useful for site–ordered mixed valence systems. Here, this method was applied to study the substitution of Mn atoms with Fe on the octahedral and pyramidal sites in $YMn_{2-\xi}Fe_\xi O_5$ [2]. Further, the *c*–ordering of Pd substitutes on Si sites according to a super structure proposal from F. Tang et al. [1] was investigated for the intermetallic compound Ho_2PdSi_3. Theoretical modelling was performed using the FDMNES code [3]. The measurements of the experimental data have been carried out at beamline E2 of DESY/HASYLAB Hamburg.
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MA 20.43 Tue 12:15 Poster A

Synthesis and characterisation of $BaTiO_3$ nanopowders and $CoFe_2O_4/BaTiO_3$ nanocomposites — •Yanling Gao, Morad Etier, and Doru C. Lupascu — Institute for Materials Science, University Duisburg-Essen, Universitätsstrasse 15, 45141 Essen, Germany

Multiferroic materials have drawn much attention, because they display the coexistence of ferroelectric and magnetic properties. In this study, we have succeeded in the synthesis and characterization of the $BaTiO_3$ nanocrystals by the low cost and straightforward auto-combustion process of amorphous organic precursor. In the following, $CoFe_2O_4/BaTiO_3$ nanocomposites with core/shell structures were also obtained by using this process. The particles are systematically characterized by powder X-ray diffraction (XRD), scanning electron microscopy (SEM), thermogravimetric, differential thermal analyses (TGA/DTA), and infrared spectroscopy (IR). The XRD results confirm the presence of both the spinel and the perovskite phases. The SEM-EDX and the atomic force microscopy (AFM) micrographs of $CoFe_2O_4/BaTiO_3$ show two-phase composite nanostructures of a cobalt ferrite core coated with a $BaTiO_3$ shell. The weight fraction of $CoFe_2O_4$ and the size of nanocomposites are the keys to the dielectric and magnetic properties of $CoFe_2O_4/BaTiO_3$ nanocomposites.

MA 20.44 Tue 12:15 Poster A

Topology of spin polarization of the 5d states on W(110) and Al/W(110) surfaces — •Artem G. Rybkin[1], E. E. Krasovskii[2,3,4], D. Marchenko[5], E. V. Chulkov[2,4,6], A. Varykhalov[5], O. Rader[5], and A. M. Shikin[1] — [1]St. Petersburg State University — [2]University of the Basque Country, San Sebastián — [3]IKERBASQUE Bilbao — [4]Donostia International Physics Center — [5]Helmholtz-Zentrum Berlin — [6]Materials Physics Center, CSIC-UPV/EHU, San Sebastián

The spin polarization of W(110) and Al/W(110) surfaces is studied by spin- and angle-resolved photoemission. On both surfaces distinct $E(\mathbf{k}_\parallel)$ dispersions are identified with an unusual topology: a single spectral branch is spin polarized antisymmetrically relative to the $\bar{\Gamma}$ point, and two spin-polarized branches cross at $\bar{\Gamma}$. Based on *ab initio* theory coupled with one-step photoemission calculations, we show that the measured spin polarization is a property of the ground state and identify the effect as the counterpart of the recently discovered Rashba-polarized bulk states but with a distinct non-Rashba topology. We address also the question of topological protection.

MA 20.45 Tue 12:15 Poster A

STM studies on the ternary topological insulator $PbBi_4Te_7$ — •Andreas Eich, Alexander Ako Khajetoorians, Julian Hagemeister, Oswald Pietzsch, Jens Wiebe, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany

Topological insulators are a new class of materials with a bulk band gap like an ordinary insulator but exhibit a gapless surface state where the spin and momentum are locked. This topological surface state which results from a combination of spin-orbit interactions and time-reversal symmetry exhibits exotic spin-dependent transport phenomena at the surface. Nevertheless, the electronic properties of these surface states can be influenced by adsorbates. By adding a third component to a binary topological insulator it is also possible to influence both the energetic position of the Dirac cone and the surface state localization. Here we show STM measurements of the structure of a ternary topological insulator, namely $PbBi_4Te_7$. It has a hexagonal unit cell and contains five-layer (5L) and seven-layer (7L)-blocks with the atomic layer sequence, Te-Bi-Te-Bi-Te (5L) and Te-Bi-Te-Pb-Te-Bi-Te (7L). Theory predicts that not only the position of the Dirac cone relative to the Fermi energy is changed but that the surface states are localized in the 7L-block, leading to buried surface-states in the case of a 5L-terminated surface. We review the growth properties of this crystal and comment on the topological properties of these layers.

MA 20.46 Tue 12:15 Poster A

Bose-Hubbard model on two-dimensional line graphs — •Johannes Motruk and Andreas Mielke — Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 19, D-69120 Heidelberg

We investigate the positive hopping bosonic Hubbard Model on line graphs of finite 2-connected planar bipartite graphs. The model on these lattice geometries exhibits flat bands and the single- as well as many-particle ground states are highly degenerate. Using notions from graph theory, we are able to give a basis for the space of many-particle ground states. The particles in these states are localized on vertices of the line graph which are edges of the original graph belonging to edge-disjoint cycles. This construction works up to a certain critical filling factor at which the cycles are close-packed. We rigorously show the linear independence of these states and prove that they span the space of many-particle ground states.

Furthermore, we establish that the entropy per lattice site in the ground state with constant (except critical) filling factor remains finite in the thermodynamic limit. Some of our findings can be applied

to spin models of quantum antiferromagnets at high fields on the considered lattices.

MA 20.47 Tue 12:15 Poster A

Growth, Annealing and Characterization of $Sr_3Fe_2O_{7-\delta}$ — •Darren Peets[1], Junghwa Kim[1], Andrey Maljuk[1,2], Chengtian Lin[1], and Bernhard Keimer[1] — [1]MPI-FKF, Heisenbergstr. 1, D-70569 Stuttgart — [2]IFW Dresden, Helmholtzstr. 20, D-01069 Dresden

Iron(IV)- and ruthenium(IV)-containing perovskite-related phases have proven rich in novel physics. $SrFeO_{3-x}$ exhibits a wide variety of unusual magnetic phases, from five distinct types of helical magnetism at $x = 0$ [1] to a phase with frustrated, disordered Fe^{4+} moments at $x = 0.25$ [2]. The Ru-based intergrowth phase $Sr_3Ru_2O_7$ exhibits metamagnetic quantum critical points in field. However, the magnetic phase diagram of its Fe^{4+} analogue $Sr_3Fe_2O_{7-\delta}$ remains largely unexplored. We report the crystal growth, oxygen annealing, and characterization of large single-crystalline samples of $Sr_3Fe_2O_{7-\delta}$ suitable for neutron diffraction experiments. This work lays the foundation for comprehensive doping-dependent studies of $Sr_3Fe_2O_{7-\delta}$'s magnetic phase diagram and magnetic excitations.

[1] S. Ishiwata *et al.*, Phys. Rev. B **84**, 054427 (2011)
[2] M. Schmidt *et al.*, J. Phys.: Condens. Matter **15**, 8691 (2003)
[3] R.A. Borzi *et al.*, Science **315**, 214 (2007)

MA 20.48 Tue 12:15 Poster A

Finite-temperature density-functional theory of the Hubbard model — •Tobias Müller and Gustavo Pastor — Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

The finite temperature properties of the Hubbard model are investigated in the framework of lattice density-functional theory (LDFT). The single-particle density matrix γ_{ij} with respect to the lattice sites is considered as the basic variable of the many-body problem. Following Mermin's theorem the free energy $F = E - TS = K + W - TS$ at temperature T is regarded as a functional of γ, where $K[\gamma]$, $W[\gamma]$ and $S[\gamma]$ stand for the kinetic-energy, Coulomb-energy and entropy functionals, respectively. A finite-temperature extension of Levy's constraint search approach is formulated. In this framework exact numerical results for W and S are obtained as a function of the nearest-neighbor γ_{ij} and T for different system sizes at half-band filling. The properties of these functionals are discussed in some detail. On the basis of this analysis we propose a simple explicit approximation to $W[\gamma]$ and $S[\gamma]$ which is relevant to arbitrary lattices. The method is finally applied to one-dimensional systems and the accuracy of the derived equilibrium properties is discussed

MA 20.49 Tue 12:15 Poster A

Green function of the single-site full-potential scattering problem including scalar-relativistic and spin-orbit effects — •David Bauer, Phivos Mavropoulos, Rudolf Zeller, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich

We present a method for the solution of the scalar-relativistic equation for a finite-range non-spherical potential and with the option of including spin-orbit coupling. Our scope is to determine the Green function for the single-site scattering problem, which is used in the multiple-scattering Korringa-Kohn-Rostoker Green function method for electronic structure calculations of impurity atoms embedded in a crystalline host.

The Green function can be written in a semi-separable form where the regular and irregular radial solutions of the scalar-relativistic operator are used. Also the right- and left-hand-side solutions are needed, which are not necessarily identical and can differ for example when including spin-orbit coupling as a pertubative term. The radial functions are calculated by a direct solution of a generalized Lippmann-Schwinger (LS) integral equation by employing a Chebyshev expansion. To save computational time, we proceed in a two step approach. First a LS equation is solved for the spherically symmetric case. The result is used to determine the Green function of the spherical problem, which in a second step is used in a new LS equation that includes non-spherical and spin-orbit terms. The latter has a special structure which allows a reduction of the computational time.

MA 20.50 Tue 12:15 Poster A

Micromagnetic Simulations of Spin Dynamics in Magnetic Nanodots — •Robert Rückriem[1], Philipp Krone[1], Thomas Schrefl[2], and Manfred Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, Chemnitz, Germany — [2]St. Pölten University of Applied Science, St. Pölten, Austria

Micromagnetic simulations were performed to investigate the spin dynamics in a single magnetic nanodot varying diameter ($50 - 150$ nm), thickness ($5-20$ nm), saturation magnetization ($0.5-2.0$ T) and uniaxial anisotropy ($0-250$ kJ/m^3). Using a finite element based three step simulation technique, the spatial distribution of excited spin waves as well as their frequency spectra was obtained. The occurring spin wave modes were identified as edge modes which are strongly influenced by demagnetizing field effects [1] and center modes which oscillate in the whole nanodot. By changing the magnetic and geometric parameters of the nanostructure, the precession frequency can be tuned which is important for magnetic engineering for instance in the field of microwave assisted magnetic recording [2].

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[2] J.-G. Zhu, X. Zhu, Y. Tang, IEEE Trans. Magn. 44, 125 (2008)

MA 20.51 Tue 12:15 Poster A

Pairs of diverging-converging spin vortices in biquadratically interlayer exchange coupled elements — •Sebastian Wintz[1], Christopher Bunce[1], Anja Banholzer[1], Thomas Strache[1], Michael Körner[1], Sibylle Gemming[1], Artur Erbe[1], Jeffrey McCord[2], Jörg Raabe[3], Christoph Quitmann[3], and Jürgen Fassbender[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Christian-Albrechts-Universität zu Kiel, Kiel, Germany — [3]Swiss Light Source, Paul Scherrer Institut, Villigen, Switzerland

Spin structures have been a relevant topic of magnetism research for many years. In particular, magnetic vortices have attracted much attention, due to their non-trivial topology and the various dynamic modes they exhibit [1]. A magnetic vortex consists of a planar, flux-closing magnetization curl that turns out of the plane in the central nanoscopic core. For a single layer structure, the curl's radial components typically cancel each other out. Recent investigations show that this holds also true for multilayer vortex systems comprising bilinear interlayer exchange coupling (IEC) [2]. In this contribution we report on pairs of diverging-converging spin vortices occurring in biquadratically coupled systems. Using magnetic x-ray microscopy we directly observe that the individual vortices of such pairs possess a residual radial magnetization component. From this $\nabla \mathbf{M}_{xy} \neq 0$, an additional perpendicular magnetization divergence $\nabla \mathbf{M}_z$ is analytically deduced. We compare our continuous model with discrete micromagnetic simulations. [1] S.-B. Choe et al., Science 304, 420 (2004). [2] S. Wintz et al., Appl. Phys. Lett. 98, 232511 (2011).

MA 20.52 Tue 12:15 Poster A

Structural, electronic, and magnetic properties of CoO/Ni interfaces — •Udo Schwingenschlögl, Sergiy Grytsyuk, and Fabrizio Cossu — KAUST, PSE Division, 23955-6900 Thuwal, Kingdom of Saudi Arabia

We study the CoO/Ni interface. Since the lattice mismatch of Ni with respect to CoO is about 21% we use a large supercell for our first-principles calculations, which reduces the lattice mismatch to 0.8%. We investigate the structural, electronic, and magnetic properties of two CoO/Ni interfaces: (1) An O layer mediates the coupling between Ni and Co and (2) direct Ni-Co contact. Our results indicate that the magnetization is reduced by 19% in the first case, while in the second case it increases by 106% as compared to bulk Ni. The magnetic moments of the Ni atoms are larger if the exchange coupling is mediated by O atoms, while for direct contact with the Co atoms they become smaller than in the bulk. The Co 3d local density of states of the second interface shows surprisingly small deviations from the corresponding bulk results, although the first coordination sphere is no longer octahedral.

MA 20.53 Tue 12:15 Poster A

Exchange-bias effects in Co/$YMnO_3$ bilayer: Magnetization and magneto-transport measurements — •J. Barzola-Quiquia, A. Lessig, C. Zandalazini, G. Bridoux, and P. Esquinazi — Division of Superconductivity and Magnetism, University of Leipzig, D-04103 Leipzig, Germany

The exchange bias effects in a bilayer composed by the antiferromagnetic o-$YMnO_3$ and ferromagnetic Co thin films have been investigated through SQUID magnetometry and magneto-transport measurements. Magnetization hysteresis loops and magneto-transport properties show pronounced asymmetries in the field and magnetization axis. Both ex-

change bias parameters, the exchange bias field $H_E(T)$ and the magnetization shift $M_E(T)$, vanish around the Néel temperature $T_N \simeq 45$ K. The magnetization shift is also measured by a shift in the longitudinal and Hall resistances showing a similar temperature dependence as the one obtained from magnetization measurements. Because the o-$YMnO_3$ film is highly insulating, our results demonstrate that the M_E shift is related to the pinned moments within the ferromagnetic Co layer at the interface.

MA 20.54 Tue 12:15 Poster A

Perpendicular exchange bias in ferrimagnetic spin valves — •Radu Abrudan[1], Ilie Radu[2], Detlef Schmitz[3], Hartmut Zabel[1], and Florin Radu[3] — [1]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany — [2]Radboud University Nijmegen, Institute for Molecules and Materials, Heyendaalseweg 135, 6525 AJ Nijmegen,The Netherlands — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Strasse 15, 12489 Berlin, Germany

Exchange bias effect refers to the shift of the hysteresis loop of a ferromagnet which is in direct contact to an antiferromagnet. For applications in spintronics a robust and tunable EB effect is required. We present experimental evidence for perpendicular EB in ferrimagnetic spin valves in a $DyCo_5$/Ta/$Fe_{76}Gd_{24}$ prototype trilayer, where the $DyCo_5$ alloy plays the role of a hard ferrimagnet and the Fe_76Gd_{24} is a soft ferrimagnet. Taking advantage of the tunability of the exchange coupling between the ferrimagnetic layers by means of thickness variation of an interlayer spacer, we show that perpendicular exchange bias can be induced with desirable absolute values at room temperature with no field cooling procedure. Moreover, the shift of the hysteresis loop can be reversed with relatively low magnetic fields of several hundred Oersteds. This flexibility in controlling a robust perpendicular EB at room temperature may be of crucial importance for applications.

MA 20.55 Tue 12:15 Poster A

Renormalization of exchange coupling parameters in systems with coexisting strong and induced magnetic moments — •Phivos Mavropoulos, Marjana Ležaić, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich

In magnetic systems with coexisting strong and induced (weak) magnetic moments, it is often the case that the magnetic excitations change the direction and magnitude of the weak moments but only the direction of the strong moments. It is also often the case that the energy landscape can be parametrised by a quadratic dependence on the weak-moments magnitude in addition to a Heisenberg expression for the strong-moments direction. We show that under these conditions the weak moments can be completely eliminated as degrees of freedom in favour of renormalized exchange coupling parameters among the strong moments. We further show that this renormalization is also valid at elevated temperatures. The thermodynamic properties (including all correlation functions) of the full system, where the strong and weak moments are independent degrees of freedom, can be derived from the correlation functions of the renormalized system, where only the strong moments are accounted for as degrees of freedom. A prerequisite for the latter theorem is a quadratic measure in the phase space of the weak moments. The theorem justifies certain schemes for the derivation of exchange parameters and can also be of practical use for reducing the numerical load in calculations.

MA 20.56 Tue 12:15 Poster A

Coupling Single Molecule Magnets to Ferromagnetic Substrates — Alberto Lodi Rizzini[1], Cornelius Krull[1], •Timofey Balashov[1], Jerald Kavich[1], Aitor Mugarza[1], Piter Miedema[2], Pardeep Thakur[3], Violetta Sessi[3], Svetlana Klyatskaya[4], Mario Ruben[4], Sebastian Stepanow[5], and Pietro Gambardella[1] — [1]ICN, Barcelona, Spain — [2]Utrecht University, Utrecht, The Netherlands — [3]ESRF, Grenoble, France — [4]Institute of Nanotechnology, KIT, Germany — [5]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany

We investigate the interaction of $TbPc_2$ single molecule magnets (SMMs) with ferromagnetic Ni substrates. Using element-resolved x-ray magnetic circular dichroism, we show that $TbPc_2$ couples antiferromagnetically to Ni films through ligand-mediated superexchange. This coupling is strongly anisotropic and can be manipulated by doping the interface with electron acceptor or donor atoms. We observe that the relative orientation of the substrate and molecule anisotropy axes critically affects the SMM magnetic behavior. $TbPc_2$ complexes deposited on perpendicularly magnetized Ni films exhibit enhanced magnetic remanence compared to SMMs in the bulk. Contrary to paramagnetic molecules pinned to a ferromagnetic support layer, we find that $TbPc_2$ can be magnetized parallel or antiparallel to the substrate, opening the possibility to exploit SMMs in spin valve devices.

MA 20.57 Tue 12:15 Poster A

Zero bias anomalies and magnon excitation in tunnel junctions with magnetic and nonmagnetic electrodes — •Volker Drewello, Zoë Kugler, Günter Reiss, and Andy Thomas — Universität Bielefeld, Fakultät für Physik, Dünne Schichten und Physik von Nanostrukturen, Universitätsstr. 25, 33615 Bielefeld

In order to understand the tunneling spectra of magnetic tunnel junctions, tunnel junctions are fabricated in which one or both ferromagnetic electrodes were replaced by non-magnetic metal (tungsten). The bias dependence of these junctions is investigated with high accuracy by inelastic electron tunneling spectroscopy. Both types of junctions exhibit a zero bias anomaly that is different in size and sign compared to those of magnetic tunnel junctions, that is, junctions with two ferromagnetic electrodes. A pronounced difference is also found depending on the material that the electrons tunnel into, which is attributed to the excitation of magnons.

MA 20.58 Tue 12:15 Poster A

Electrical characterization of nanoscaled CoFeB|MgO|CoFeB-based magnetic tunneljunctions (MTJs) for thermal spin-transfer-torque (TST) — •Johannes Christian Leutenantsmeyer[1], Marvin Walter[1], Vladyslav Zbarsky[1], Patrick Peretzki[2], Henning Schuhmann[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

MTJs are of general interest because of their quantum mechanical properties such as the tunnel-magnetoresistance (TMR), spin-transfer-torque and the recently measured magneto Seebeck effect.

Here we present the studies about our nanoscaled MTJs. The junctions are grown in UHV at base pressures around 5×10^{-10} mbar. The thin films are deposited by magnetron sputtering (Ta, CoFeB) and E-Beam evaporation (MgO, Ru). After annealing, the samples are patterned with bondpads via optical lithography, which enable us to contact sub-micron-scaled junctions. The MTJ itself is written by e-beam lithography and etched by argon-ion milling. With a high resolution e-beam resist, we reach a junction size of approximately 50 nm. The smaller junctions require the transition to thinner barriers (down to 3 monolayers), which we develop for the observation of new phenomena, like the theoretically predicted TST. Characterization shows TMR of up to 230% and large magneto Seebeck effect.

We gratefully acknowledge the funding of Deutsche Forschungsgemeinschaft through SFB 602 and SPP SpinCaT.

MA 20.59 Tue 12:15 Poster A

Spin transport and tunnel magnetoresistance of MgO-based magnetic tunnel junctions with different CoFeB compositions — •Vladyslav Zbarsky[1], Marvin Walter[1], Gerrit Eilers[1], Markus Münzenberg[1], Patrick Peretzki[2], Michael Seibt[2], and Johannes Leutenantsmeyer[1] — [1]I. Phys. Inst., Universität Göttingen, Germany — [2]IV. Phys. Inst., Universität Göttingen, Germany

The optimization of MTJs is necessary for increasing the TMR and therefore is very important for the production of MRAM devices. The quality of the tunnel barrier of our CoFeB/MgO/CoFeB MTJs is essential for getting high TMR. For this reason we minimized the roughness of MgO layer on the TMR. Another important parameter which we could optimize is the choice and preparation of the buffer layer. For example we compared two sorts of Ta buffer layers: prepared via magnetron sputtering and via e-beam evaporation. Already by optimizing these two parameters we could increase the TMR from 80% to above 220%. The next important step is further optimization of annealing parameters, because annealing influences the crystallisation behaviour of our MTJs. In this case, we investigate the influence of the annealing temperatures and annealing duration on the TMR. For the magneto-Seebeck effect a strong dependence on the choice of CoFeB composition is theoretically predicted. A change in the composition is of strong interest since the Fe to Co ratio gradually tunes the Fermi level by electron doping. In this context, we investigate the behaviour of TMR and spin transport for different CoFeB alloys.

MA 20.60 Tue 12:15 Poster A

Domain wall dependent magnetoresistance at zero field in electromigrated ferromagnetic nanocontacts. — •Mohamad-Assaad Mawass[1,5], Robert M. Reeve[1], Jakoba Heidler[2], Jan Rhensius[2,3], Laura J. Heyderman[2], Regina Hoffmann[4], André Bisig[2,3], and Mathias Kläui[1,2,3] — [1]Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Paul Scherrer Institut, Villigen, Switzerland — [3]Universität Konstanz, Konstanz, Germany — [4]Physikalisches Institut and DFG-Center for Functional Nanostructures, Karlsruhe Institute of Technology, Karlsrue, Germany — [5]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany

Magnetotransport measurements of magnetic nanocontacts have been studied with the aim to understand the interactions between spin-polarized charge carriers and magnetization on the nanoscale. Here, we study the evolution of magnetoresistance (MR) in electromigrated ferromagnetic break junctions obtained in clean ultra-high vacuum (UHV) conditions. While previously permalloy (Ni80Fe20) nanocontacts with variable constriction width have been investigated [A. Patra et al., PRB 82, 134447 (2010)], the question of the influence of the alloy nature on the observed MR effects remains. The in-situ controlled electromigration of notched half ring structures under UHV conditions for pure Ni and Fe contacts was investigated and similarly large effects could be observed. In particular, large MR effects at remanence are found in contacts that approach the atomic limit. Additionally, our measurements show a sign-change of the MR at low conductance levels and this is compared to recent theoretical predictions.

MA 20.61 Tue 12:15 Poster A

Anomalous Hall effect as a Fermi surface property — •Alexander Mook[1], Falko Pientka[1,2], Ingrid Mertig[1,3], and Peter Zahn[1] — [1]Institut für Physik, Martin-Luther-Universität, Von-Seckendorff-Platz 1, D-06120 Halle — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle — [3]Fachbereich Physik, Freie Universität, D-14195 Berlin

Already Haldane has shown in a seminal paper that the intrinsic anomalous Hall conductivity can be expressed as an integral over the Fermi surface as expected for a Fermi liquid property [1].

The anomalous Hall conductivity can be expressed either by a volume integral of the occupied states in the Brillouin zone or a Fermi surface integral with a thorough treatment of the Brillouin zone boundaries. We implemented both methods and applied them to a tight-binding Hamiltonian including exchange splitting and spin-orbit coupling.

Our investigations show that both results agree well. Details of the integration procedure have to be optimized to obtain a satisfying agreement for cases where avoided band crossings occur close to the Fermi level. The surface integration replaces the time consuming volume integration over the Fermi sea [2]. The method is applicable to advanced ab initio electronic structure schemes which provide besides the band energies also the Berry curvature.

[1] F. D. M. Haldane, *Phys. Rev. Lett.* **93**, 206602 (2004). [2] M. Gradhand, D. V. Fedorov, F. Pientka, P. Zahn, I. Mertig, and B. L. Göyrffy, *Phys. Rev. B* **84**, 075113 (2011).

MA 20.62 Tue 12:15 Poster A

Structural, electronic and transport properties of platinum-based chains: an ab initio study — •Ilia Sivkov, Kun Tao, and Valeri Stepanyuk — Max-Planck-Institut für Mikrostrukturphysik Weinberg 2, D-06120 Halle, Germany

We have investigated the structural, electronic and magnetic properties of platinum-based chains. Both pure platinum chains and chains with 3d impurities have been considered. The calculations of these properties were performed using methods based on the density functional theory.We show that the magnetic anisotropy energy of such chains strongly depends both on their shape, and on the impurities involved. Furthermore, transport calculations based on the non-equilibrium Green's function formalism have been performed.

MA 20.63 Tue 12:15 Poster A

Magnetic and transport properties of a series of dinuclear Nickel(II) complexes — •Claudia Loose[1], Torsten Hahn[1], Jens Kortus[1], Jochen Lach[2], and Berthold Kersting[2] — [1]TU Bergakademie Freiberg, Fakultät für Chemie und Physik — [2]TU Leipzig, Fakultät für Chemie und Mineralogie

Using first-principle density functional theory (DFT) we examined four different dinucklear Nickel(II) complexes [1] in order to obtain the electronic and magnetic structure with a special focus on spin-dependent transport through these molecules.

We compare results from different exchange correlation functionals (PBE/B3LYP) as implemented in two different packages (NRLMOL/ORCA). Furthermore we investigate the transport properties of those complexes using methods of the non equilibrium Green's function formalism (NEGF).

[1] Coord. Chem. Rev. 253 (2009) 2244 - 2260

MA 20.64 Tue 12:15 Poster A

Optimization of spin-valve structures for spin-pumping experiments — •Christian Swoboda, Nils Kuhlmann, Andreas Vogel, Toru Matsuyama, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

In recent years, high-frequency phenomena of magnetic nanostructures have been studied intensively since they are expected to provide new technological applications as well as fundamental understanding of spin dynamics. Currently, the combination of magnetization dynamics and spin transport, the spin-pumping effect [1, 2], is of great interest. First experimental results including the detection of pure spin currents have been presented [3]. The aim of our work is to build an all-metal lateral spin-valve [4], where the spins are injected into an adjacent normal-metal via a ferromagnet with precessing magnetization at ferromagnetic resonance (spin-pumping). The lateral spin-valve device enables to detect and to quantify the pure spin current via a second ferromagnet. Besides the basic concept of a lateral spin-valve device operated by spin-pumping, we present a detailed study of the magnetization dynamics of the ferromagnetic electrodes. We optimized geometry and center-to-center distance of the electrodes in order to enhance the spin-pumping efficiency.

[1] Y. Tserkovnyak et. al., PRL 88, 117601 (2002); [2] A. Brataas et. al., PRB 66, 060404 (2002); [3] M.V. Costache et. al., PRB 78, 064423 (2008); [4] A. Vogel et. al., APL 94, 122510 (2009)

MA 20.65 Tue 12:15 Poster A

Spin density distribution and Hanle lineshapes of injected spins into n-GaAs — •Bernhard Endres, Mariusz Ciorga, Robert Wagner, Sebastian Ringer, Martin Utz, Dominique Bougeard, Dieter Weiss, Christian H. Back, and Günther Bayreuther — Universität Regensburg

Spin extraction into a ferromagnetic GaMnAs contact from an n-GaAs channel across an Esaki diode structure was measured by cross-sectional imaging of the spin polarization in GaAs [1,2]. The resulting spin density distribution in the 1 μm thick GaAs channel shows a strong bias dependence with the maximum polarization at the contact edge opposite to the maximum charge current. This behavior cannot be described by a frequently used one-dimensional model whereas two-dimensional numerical simulations of the electron drift and spin diffusion reproduce the observed distribution quite well. Even at the nominally field-free contact edge electron drift must be taken into account because of the inhomogeneous current density. As a consequence, if Hanle measurements are fitted with a one-dimensional drift-diffusion function as usually done they yield spin lifetimes which may strongly depend on the distance to the contact and the applied bias voltage. In contrast, a two-dimensional fit including the nonuniform current density provides spin lifetimes nearly independent of bias and contact distance. The remaining variations can be explained by electric fields around the contact area. [1] P. Kotissek et al., Nature Phys. 3, 872 (2007) [2] B. Endres et al., J. Appl. Phys. 109, 07C505 (2011)

MA 20.66 Tue 12:15 Poster A

Fe_3O_4/ZnO: A high-quality magnetic oxide-semiconductor heterostructure by reactive deposition — •Ozan Kirilmaz[1], Sebastian Brück[1,2], Markus Paul[1], Andreas Müller[1], Eberhard Goering[3], Jo Verbeeck[4], He Tian[4], Michael Sing[1], and Ralph Claessen[1] — [1]Experimentelle Physik 4, Universität Würzburg, D-97074 Würzburg, Germany — [2]University of New South Wales, School of Physics, Sydney NSW 2052, Australia — [3]Max Planck Institute for Intelligent Systems, D-70569 Stuttgart, Germany — [4]Electron Microscopy for Materials Science, University of Antwerp, 2020 Antwerp, Belgium

Magnetite (Fe_3O_4) is ranked among the most promising materials to be used as a spin injector into a semiconducting host. We demonstrate epitaxial growth of Fe_3O_4 films on ZnO which presents a further step for polarized spin injection into semiconductors. Regarding volume properties of the films, X-ray photoelectron spectroscopy evidences that the iron-oxide is phase-pure and stoichiometric mag-

netite. Diffraction measurements indicate highly oriented epitaxy and complete structural relaxation. The magnetic behavior shows a slow approach to saturation at high fields in comparison with bulk crystals. The typical (111) surface structure of Fe_3O_4 is observed already at the early growth stage. Due to island growth, domain boundaries form upon coalescence of the islands. The island growth enables partial relaxation of the misfit strain. X-ray resonant magnetic reflectometry reveals that only the very first monolayers of Fe_3O_4 at the interface exhibit a reduced magnetization, presumably related to the presence of the ZnO substrate.

MA 20.67 Tue 12:15 Poster A

Spin Injection and Spin Transport in Zinc Oxide — •Matthias Althammer, Eva-Maria Karrer-Müller, Sebastian T. B. Goennenwein, Matthias Opel, and Rudolf Gross — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching

The wide bandgap semiconductor zinc oxide is interesting for semiconductor spintronics because of its small spin-orbit coupling implying a large spin coherence length. We investigate the injection, transport, and detection of spin-polarized charge carriers in ZnO utilizing all-electrical, vertical spin valve devices with ferromagnetic electrodes. Using pulsed laser deposition and electron-beam evaporation, we fabricated epitaxial multilayers of TiN/Co/ZnO/Ni/Au on (0001)-oriented Al_2O_3 substrates with different thicknesses of the ZnO spacer layer ranging from 5 nm to 100 nm. The multilayers were patterned into vertical mesa structures with junction areas between 100 μm^2 and 400 μm^2. Magnetotransport measurements show a clear spin valve behavior. The switching fields correspond to the coercive fields of the ferromagnetic layers as determined by SQUID magnetometry. For a ZnO thickness of 15 nm, the magnetoresistance (MR) increases from 0.8% at 200 K to 8.5% at 1.8 K. We analyze the maximum MR at low temperatures as a function of the ZnO thickness in the framework of a two spin channel model with a spin-dependent interface resistance and obtain a spin drift length for ZnO of 14.3 nm.

This work was supported by the Deutsche Forschungsgemeinschaft via SPP 1285 (project no. GR 1132/14).

MA 20.68 Tue 12:15 Poster A

Spindynamics of microstructured permalloy systems — •Sven Stienen[1], Ralf Meckenstock[1], Jürgen Lindner[1], Nathalie Reckers[1], Kai Wagner[1], Florian Römer[1], Zheng Duan[2], and Michael Farle[1] — [1]Universität Duisburg-Essen, Fakultät für Physik and CeNIDE, Lotharstraße 1, 47057 Duisburg — [2]University of California, Department of Physics and Astronomy, Irvine, USA

We model a ferromagnetic resonance (FMR) measurement by micromagnetic simulations using the 3D Object Orientated Micromagnetic Framework (OOMMF) code to investigate spinwave modes in permalloy (Py) microstripes. Dispersion relations (3-12GHz) were calculated with different directions (0°/90°) of the external magnetic field (0-400mT) applied in the sample plane. The major magnetic anisotropy in the Py-stripe is the demagnetisation field. The simulations allow the visualization and identification of the excitations in the time and space domain. Quasi uniform, edge and not-aligned modes are observed. The simulations were compared with the FMR results obtained by anisotropic magneto resistance[1]. The position and shape of all modes can be explained by specific aspects of the demagnetisation field and are in qualitativly good agreement with simulations. This work has been supported by the Deutsche Forschungsgemeinschaft (DFG) via SFB 491.

[1]A. Banholzer et al, Nanotechnology, 22,(2011) 295713

MA 20.69 Tue 12:15 Poster A

Imaging of magnetisation dynamics of coupled vortices in trilayer systems — •Anja Banholzer[1], Sebastian Wintz[1], Christopher Bunce[1], Thomas Strache[1], Michael Körner[1], Arthur Erbe[1], Aleksandr Puzic[2], Jörg Raabe[2], Christoph Quitmann[2], Kilian Lenz[1], and Jürgen Fassbender[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Paul Scherrer Institut, 5232 Villigen, Switzerland

Magnetic vortices recently gained interest as potential storage media. Different control methods are used to manipulate the vortex states. We now use scanning transmission x-ray microscopy (STXM) to image the magnetic configurations within the different layers of a Co/Cu/NiFe trilayer system. The dominant coupling mechanisms here are the magneto-dipolar interaction and interlayer exchange coupling. The corresponding magnetization configurations under a static magnetic field, as well as ac magnetic fields are investigated. The emerging motion of the core is tunable by the amplitude and frequency of the field. The interactions of the two cores and their individual resonance frequencies are studied. This implies a corresponding resistance change of different configurations at different magnetic fields and currents as well as the displacement of the core.

MA 20.70 Tue 12:15 Poster A

Oersted field contribution on the magnetic vortex core dynamics probed by homodyne detection — •June-Seo Kim[1,5], Martin Stärk[1], Mathias Kläui[1,5], Florian Kronast[2], Roland Mattheis[3], Christian Ulysse[4], and Giancarlo Faini[4] — [1]Fachbereich Physik, Universität Konstanz, Universitätsstr. 10, D-78457 Konstanz, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany — [3]Institut für Photonische Technologien e.V., Jena, Germany — [4]Phynano Team, Laboratoire de Photonique et de Nanostructures, CNRS, Marcoussis, France — [5]Institut für Physik, Johanes Gutenberg-Universität Mainz, D-55099, Mainz, Germany

When injecting spin-polarized currents into magnetic discs, both spin torque and Oersted fields can manipulate magnetic vortex structures. The Oersted field contribution due to the inhomogeneous current distribution in the magnetic vortex core structure is experimentally determined by using a homodyne detection scheme. We find that the amplitude of the vortex core gyration increases for vortices located close to the current injection contacts due to the enhancement of the Oersted field contribution. From systematic phase measurements as a function of microwave frequency, two remarkable phenomena are observed: (i) the trajectory of the vortex core gyration is distorted by the interaction with the disc edge leading to non-linear oscillations (ii) the interplay between spin torque and Oersted field depends sensitively on the exact vortex core position.

MA 20.71 Tue 12:15 Poster A

Ultrafast, layer-selective dynamics of interlayer exchange-coupled Fe-Ru-Ni-trilayers — •Dennis Rudolf[1], Patrik Grychtol[1], Roman Adam[1], Bastian Heller[1], Moritz Plötzing[1], Christian Weier[1], Claus M. Schneider[1], Chan La-O-Vorakiat[2], Emrah Turgut[2], Henry C. Kapteyn[2], Margaret M. Murnane[2], Stefan Mathias[3], Martin Aeschlimann[3], Justin M. Shaw[4], Hans Nembach[4], and Thomas J. Silva[4] — [1]Peter Grünberg Institut, PGI-6, Research Center Jülich, 52425, Jülich, Germany — [2]Department of Physics and JILA, University of Colorado, Boulder, Colorado 80309-0440, USA — [3]University of Kaiserslautern and Research Center OPTIMAS, 66606, Kaiserslautern, Germany — [4]Electromagnetics Division, National Institute of Standards and Technology, Boulder, Colorado, 80305-3328, USA

Using ultrafast light pulses of laser-generated high harmonics between 20 eV and 70 eV, we investigated static and dynamic properties of interlayer exchange-coupled thin Fe-Ru-Ni-trilayers with varying Ru thickness. In the static case we observed layer-selective switching of Fe- and Ni-layers. We studied the magnetization dynamics on the fs-timescale using a pump-probe technique with 1,5 eV-pump and high harmonics-probe and observed layer-selective dynamics of Fe- and Ni-layers at the M absorpion edges (54 eV for Fe and 66 eV for Ni). A comparison of the demagnetization times for parallel and antiparallel magnetization alignment of the Fe- and Ni-layers provides insight into the role of exchange interaction and spin transport in femtomagnetism.

MA 20.72 Tue 12:15 Poster A

Element-resolved Ultrafast Spin Dynamics in Multi-component Ferromagnets and Ferrimagnets — •Andrea Eschenlohr[1], Ilie Radu[1,2], Christian Stamm[1], Kadir Vahaplar[2], Torsten Kachel[1], Niko Pontius[1], Rolf Mitzner[1], Karsten Holldack[1], Alexander Föhlisch[1], Florin Radu[1], Richard F. L. Evans[3], Thomas A. Ostler[3], Johan Mentink[2], Roy W. Chantrell[3], Arata Tsukamoto[4,5], Akiyoshi Itoh[4], Andrei Kirilyuk[2], Alexey V. Kimel[2], and Theo Rasing[2] — [1]Helmholtz Zentrum Berlin für Materialien und Energie GmbH, Germany — [2]Radboud University Nijmegen, The Netherlands — [3]University of York, UK — [4]Nihon University, Chiba, Japan — [5]Japan Science and Technology Agency, Saitama, Japan

With 100 fs soft x-ray pulses generated by the Femtoslicing facility at the BESSY II storage ring we measure element-resolved transient x-ray magnetic circular dichroism in ferromagnetic NiFe alloys, as well as ferrimagnetic GdFeCo alloy after laser excitation. We find time constants of demagnetization that are not only different for each magnetic sublattice in our alloy samples, but also different from the time con-

stants found for respective pure element samples. Supported by phenomenological considerations and atomistic simulations we conclude that sub-picosecond magnetization dynamics is sensitive to both the magnetic moment and exchange interaction between the sublattices in multi-component magnets.

MA 20.73 Tue 12:15 Poster A

Gyration of magnetic vortices in anharmonic potentials — •Christian Adolff, Michael Martens, Thomas Kamionka, Ulrich Merkt, and Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiustr. 11, 20355 Hamburg, Germany

Magnetic vortices inherently form in soft ferromagnetic thin-film elements. They can be described as quasiparticles in confining potentials with eigenfrequencies in the sub-gigahertz range [1, 2]. We investigate the excitation of magnetic vortices in permalloy squares with side lengths of up to five micrometers. Strongly excited vortex cores move near to the edges of the squares where significant deviations from a parabolic potential occur. Analyzing the eigenfrequency of the vortex for different geometries, i.e. side lengths and thicknesses, gives insight into isotropic and anisotropic terms of the potential. These are studied by means of ferromagnetic resonance spectroscopy, micromagnetic simulations and analytical calculations.

[1] A. Thiele, J. Appl. Phys. 45, 377 (1974)
[2] B. Krüger et al., Phys. Rev. B 76, 224426 (2007)

MA 20.74 Tue 12:15 Poster A

Magnetization dynamics in Ni on the picosecond timescale — •Martin Lüttich[1], Jakob Walowski[1], Andreas Mann[1], Markus Münzenberg[1], Unai Atxitia[2], and Oksana Chubykalo-Fesenko[2] — [1]I. Physikalisches Institut, Universität Göttingen — [2]Instituto de Ciencia de Materiales de Madrid

Magnetization dynamics of polycrystalline nickel films are measured using the all-optical pump-probe technique for various pump pulse fluences. The parallel treatment of photons, electrons, phonons and magnetic correlations of the system amounts a challenge to the microscopic theoretical description. At the same time different length and time scales are involved.

We investigate the influence of hot electrons on the relative demagnetization. Performing the experiment for different pump fluences, we measure a higher relative demagnetization at higher fluences. These results are compared to simulations with the Landau-Lifshitz-Bloch equation, which is based on a thermal model, and featured by the consideration of two electron temperature dependent relaxation times $\tau_\perp$ and $\tau_{||}$. The electron temperature needed as input for the simulations is extracted from experiments.

MA 20.75 Tue 12:15 Poster A

Ultrafast Demagnetization Dynamics in $Ni_{1-x}Pd_x$ alloys — •Moritz Plötzing[1], Patrik Grychtol[1], Roman Adam[1], Claus M. Schneider[1], Hans Nembach[2], Justin Shaw[2], Tom Silva[2], Oliver Schmitt[3], Daniel Steil[3], Mirko Cinchetti[3], and Martin Aeschlimann[3] — [1]Peter Grünberg Institut, PGI-6, Research Center Jülich, 52425, Jülich, Germany — [2]Electromagnetics Division, National Institute of Standards and Technology, Boulder, Colorado 80305-3328, USA — [3]University of Kaiserslautern and Research Center OPTIMAS, 67663, Kaiserslautern, Germany

In the presented work, we investigated alloys of Ni and Pd with varying mixing ratios focusing on the magnetization dynamics on different timescales. For this purpose, we characterized the samples using a vibrating sample magnetometer and ferromagnetic resonance in order to determine the Curie temperature T_C and the picosecond dynamics, respectively. The latter is described by the Gilbert damping parameter α. Both quantities depend strongly on the stoichiometry and can be tuned very precisely over a wide range by changing the Pd concentration. Additionally, we carried out a thorough investigation of the laser-induced demagnetization time τ_M on the femtosecond timescale employing a time-resolved MOKE setup. According to the theoretical model published in [1], the dynamics on both timescales is related and the proportionality is mainly defined by T_C. Using the measured values for α and τ_M, we study the applicability of the theory for a ferromagnetic d-alloy and consequently the underlying fundamental processes.

[1] Koopmans et al., Phys. Rev. Lett. 95, 267207 (2005)

MA 20.76 Tue 12:15 Poster A

Ultrafast magnetization dynamics of FePt:Cu — •Daniel Steil[1], Sabine Alebrand[1], Oliver Schmitt[1], Mirko Cinchetti[1], Martin Aeschlimann[1], Fabian Ganss[2], Christoph Brombacher[2], and Manfred Albrecht[2] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Physics, Chemnitz University of Chemnitz, 09107 Chemnitz, Germany

$L1_0$ ordered FePt compounds with out of plane anisotropy are one future candidate as a storage layer for the next generation of hard disc drives, due to their very high anisotropy energy. As these compounds typically have very high coercivity, they are best used in combination with heat assisted recording (HAMR) [1]. We have studied the demagnetization dynamics in the alloy system FePt:Cu following impulsive laser excitation. In particular we also investigated the helicity dependence of the magnetization dynamics. By adding copper to FePt it is possible to tune anisotropy and Curie temperature, which allows to study the influence of both parameters on magnetization dynamics. We find a fast and strong demagnetization for all sample compositions, leading to a long lasting multidomain state for high enough excitation fluences in remanence. Additionally we observe a small influence of light helicity on the magnetization dynamics for at least one of the samples, whose origin will be discussed.

Funding by the EU within the FP7 project UltraMagnetron is kindly acknowledged.

[1] D. Weller et al., Annu. Rev. Mater. Sci. 30, 611-644 (2000)

MA 20.77 Tue 12:15 Poster A

Angular and Temperature dependent Ferromagnetic Resonance (FMR) measurements on FeRh thin films — •Eduardo Mancini, Federico Pressacco, Markus Härtinger, Georg Woltersdorf, and Christian Back — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Deutschland

We report the results of FMR investigations performed on $Fe_{0.5}Rh_{0.5}$(30 nm)/MgO below and above the critical temperature (around 400 K) at which the magnetic order changes from the antiferromagnetic- to the ferromagnetic phase. From these measurements we extract the amplitude, the position and the linewidth of the resonance line. For the amplitude the heating and cooling branches display the hysterestic behavior which is expected for this material with a difference in their critical temperatures of about 10 K. In the ferromagnetic phase (T=450 K), we observe an easy plane anisotropy for the magnetization from the analysis of the resonance position as a function of the external field orientation. From the linewidth of the resonance we extract the damping of the magnetization and discuss its temperature dependence in the neighborhood of the critical temperature.

MA 20.78 Tue 12:15 Poster A

Time-resolved Scanning-Kerr-Microscope on Rolled-Up-Ferromagnetic-Microstructures — •Daniel Mellem, Sebastian Mansfeld, Jan-Niklas Toedt, Felix Balhorn, Lennard Moldenhauer, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik, Jungiusstr. 11, D-20355 Hamburg

Our time-resolved Scanning-Kerr-Microscope (TR-SKM) [1] is used to directly image propagating spin waves. We introduce the working principle of our Microscope and present first measurements of spin waves in rolled-up ferromagnetic structures, which were recently introduced as a novel type of flexible spin wave resonator by our group [2].

We gratefully acknowledge support by the DFG via SFB668 and GrK 1286.

[1] S. Mansfeld et al., Physical Review Letters, in press (2011)
[2] F. Balhorn et al. PRL 104, 037205, 2010

MA 20.79 Tue 12:15 Poster A

Spin-Wave Confinement in Rolled-Up Permalloy Nano-Stripes in Various Magnetization Configurations — •Lennart Moldenhauer, Felix Balhorn, Daniel Mellem, Sebastian Mansfeld, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiustr. 11, 20355 Hamburg, Germany

A variety of planar systems consisting of magnetic nano- and microstripes have recently been investigated in terms of their magnetodynamic behavior [1]. Using the concept of self-rolling strained layers [2] we realized rolled-up Permalloy (Py) stripes.

We studied the spin-wave behavior in these three dimensional self-organized structures in different magnetic configurations and for varying geometrical stripe parameters via broadband microwave absorption spectroscopy. We discuss our measurements in terms of azimuthal and axial spin-wave confinement. We compare our results to previous experiments on planar stripes and rolled-up films [3].

[1] J. Topp et al., PRB **78**, 024431 (2008); [2] V. Y. Prinz et al., Physica E **6**, 828-831 (2000); [3] F. Balhorn et al., PRL **104**, 037205 (2010)

MA 20.80 Tue 12:15 Poster A

Ultrafast magnetic dynamics in EuTe thin films — •Niko Pontius[1], Christoph Trabant[1,2], Enrico Schierle[1], Eugen Weschke[1], Torsten Kachel[1], Christian Schüßler-Langeheine[1], Rolf Mitzner[1], Günther Springholz[3], and Karsten Holldack[1] — [1]Helmholtz-Zentrum Berlin — [2]II. Physikalisches Institut, Universität zu Köln — [3]Institut für Halbleiterphysik, Johannes Kepler Universität, Linz, Austria

Ultrafast control of magnetic materials and structures are a key prerequisite for developing advanced magnetic storage devices with increased speed and decreased dimensions. To this end, investigations of confined magnetic structures behaviour apart from equilibrium with sufficient spatial and temporal resolution under as defined conditions as possible are essential.

Here we investigate the fs temporal non-equilibrium evolution of the antiferromagnetic (AFM) order in EuTe thin films through resonant soft x-ray diffraction after laser excitation. Momentum resolved scans across the Bragg reflection provide information on the thin film magnetic profile evolution during the ultrafast quenching and recovery of the AFM order. They reveal that the magnetic profile is modified in a completely different way than for elevated temperatures in thermal equilibrium. Since the AFM structure of EuTe sensitively depends on the ionic distances, this study also provides new information on the interplay between structural and magnetic degrees of freedom. The measurements were performed at the FemtoSPEX facility at the HZB.

MA 20.81 Tue 12:15 Poster A

Temperature dependence of the magnon dispersion relation in low-dimensional transition-metal systems: A first-principles investigation — •Waldemar Töws and Gustavo M. Pastor — Universität Kassel, Heinrich-Plett-Str. 40, 34132 Kassel

The influence of Stoner excitations on the spin-wave spectrum of one- and two-dimensional 3d transition metals has been investigated. The physical situations represented by the Stoner excitations correspond to extreme nonequilibrium states, which can be induced by strong ultrashort laser pulses. In this work we quantify to what extent an important increase of the electronic temperature T_e describing Stoner excitations affects the stability of magnetism within the metal. For this purpose, we perform numerical calculations in the framework of *ab initio* density-functional theory with a generalized gradient approximation to the exchange and correlation energy. The free energy of frozen-magnon states as a function of spin-wave vector q and T_e have been systematically studied for V, Fe, Co and Ni wires and monolayers with various nearest-neighbor distances. First of all, we demonstrate that the local magnetic moments are extremely stable even at temperatures T_e much larger than the Curie temperature T_C. The T_e-dependence of the magnetic couplings between the local moments is quantified by fitting the effective exchange couplings J_{ij} to the free-energy dispersion relation in the framework of a classical spin model. One actually finds that electronic temperatures T_e well above T_C are needed to change the nature of the magnetic order within the metal. The consequences for the theory of laser-induced magnetization dynamics are discussed.

MA 20.82 Tue 12:15 Poster A

Time Resolved Scanning Kerr Microscopy of Structures in thin ferromagnetic Films — •Jan-Niklas Toedt, Sebastian Mansfeld, Jesco Topp, Kim Martens, Daniel Mellem, Wolfgang Hansen, Detlef Heitman, and Stefan Mendach — Institute of Applied Physics, University of Hamburg

We study the behavior of planar Damon-Eshbach spin-waves in thin structured ferromagnetic films utilizing time resolved scanning Kerr microscopy (TR-SKM) [1]. We have investigated spin waves incident on a range of structures including gratings, double slits and modulated films. We show that the underlying physics can be explained by the anisotropy of the dispersion relation leading, e.g., to sub wavelength imaging [2, 3].

We gratefully acknowledge support by the DFG via SFB 668, SFB 508, GrK 1286, and by the City of Hamburg via the Cluster of Excellence Nano-Spintronics.

[1] Freeman et al., Journal of Applied Physics **79**, 5898 (1996); [2] Liu et al., Science **315**, 1686 (2007); [3] Mansfeld et al., Physical Review Letters, in press (2011) - arXiv:1108.5883v1

MA 20.83 Tue 12:15 Poster A

Field-induced magnetization dynamics in dot patterned CoB/Pt multilayer structures — •F. Büttner[1,2,3,4], C. Moutafis[2,3], A. Bisig[1,2,3,6], C.M. Günter[4], J. Geilhufe[5], M. Schneider[4], C. v. Korff Schmiesing[4], M. Hantschmann[4], M. Riemeier[4], J. Mohanty[4], S. Schaffert[4], J. Franken[7], R. Lavrijsen[7], H. J. M. Swagten[7], H. Stoll[8], M. Weigand[5,8], M. Kläui[1,2,3,6], and S. Eisebitt[4,5] — [1]Uni Mainz, 55128 Mainz, Germany — [2]PSI, 5232 Villigen, Switzerland — [3]EPF Lausanne, 1015 Lausanne, Switzerland — [4]TU Berlin, 10623 Berlin, Germany — [5]HZB, 12489 Berlin, Germany — [6]Uni Konstanz, 78457 Konstanz, Germany — [7]TU Eindhoven, 5612 AZ Eindhoven, Netherlands — [8]MPI für Metallforschung, 70569 Stuttgart, Germany

The controlled movement of nanometer sized magnetic domains on the (sub-) nanosecond time scale is of key importance for the development of new magnetic devices in storage and computing technology. While magnetization dynamics in in-plane magnetized materials has been intensely studied, domain sizes are too large for most state-of-the-art applications. In out-of-plane materials, however, we find narrow domains and domain walls, but these are much more sensitive to local pinning, thus making controlled displacements extremely challenging. We present here high resolution magnetic images of low pinning CoB/Pt multilayer structures and demonstrate the suitability of this material for controlled and reproducible field-induced dynamics of the magnetic domains on the nanosecond time scale.

MA 20.84 Tue 12:15 Poster A

Spin-wave tunneling through a mechanical gap in microstructured $Ni_{81}Fe_{19}$-stripes — •Thomas Langner[1], Björn Obry[1], Philipp Pirro[1], Thomas Brächer[1,2], Katrin Vogt[1,2], Britta Leven[1], and Burkard Hillebrands[1] — [1]TU Kaiserslautern, Fachbereich Physik and Forschungszentrum OPTIMAS, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Straße 47, 67663 Kaiserslautern

The manipulation of the propagation properties of spin waves is of high importance to develop systems that can transport information using the spin wave as information carrier. One way to manipulate these properties is the use of magnetic tunnel barriers. We investigated the tunneling of spin waves through a mechanical gap in microstructured stripes made of $Ni_{81}Fe_{19}$. The focus of this work is on the investigation of the transmission of spin waves with varying wavelengths through a tunnel barrier with respect to the position of the gap. It is shown that quantization effects play an important role in the transmission behavior of tunneling spin waves in microscaled systems. The region between the excitation antenna and the gap acts as a spin-wave resonator. It has a large influence not only on the excitation properties but also on the transmission characteristics. We present Brillouin light scattering microscopy measurements revealing a strong influence of pinning effects of standing spin-wave modes inside this resonator on the tunneling efficiency.

MA 20.85 Tue 12:15 Poster A

Spin-wave logic elements based on ferromagnetic microstructures — •Jan Westermann[1], Philipp Pirro[1], Thomas Brächer[1,2], Björn Obry[1], Katrin Vogt[1,2], Roland Neb[1], Britta Leven[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Material Science in Mainz, 67663 Kaiserslautern, Germany

The investigation of propagating spin waves in micron-sized metallic ferromagnetic structures is subject of different experimental studies due to their potential application in spin-wave logic devices. Using the amplitude and the phase of the spin waves, these devices may provide outstanding performance, especially when operated with multiple frequencies.

We present micro-magnetic simulations focused on the feasibility of micro-structured spin-wave logic elements as well as an experimental investigation of short wavelength spin waves. The controlled excitation and the propagation of those spin waves is essential for efficiently work-

ing spin-wave logic elements. To analyze the excitation spectrum we use phase resolved Brillouin Light Scattering Microscopy to observe the spin waves in single micro-structures. For these experiments, we excite spin waves using different kinds of microwave antennas which show geometry dependent excitation spectra. Our experimental and numeric investigations show that magnetic micro-structures are promising candidates for wave-logic based elements. Financial support by Carl-Zeiss-Foundation, MAINZ and DFG is gratefully acknowledged.

MA 20.86 Tue 12:15 Poster A

Quantitative modeling of elastically driven ferromagnetic resonance — •Matthias Pernpeintner[1], Mathias Weiler[1], Lukas Dreher[2], Hans Huebl[1], Christian Heeg[1], Rudolf Gross[1], Martin S. Brandt[2], and Sebastian T. B. Goennenwein[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Walter Schottky Institut, Technische Universität München, 85748 Garching, Germany

In conventional ferromagnetic resonance (FMR) experiments, an external radio frequency magnetic field drives the magnetization precession. Recently, it has been shown that FMR can be excited all elastically by means of coherent phonons [1]. In this acoustically driven FMR, the magnetoelastic coupling of surface acoustic waves (SAW) in the GHz frequency range with a thin ferromagnetic film is exploited.

Here we show that acoustically driven FMR can be phenomenologically modeled using a modified Landau-Lifshitz-Gilbert approach in which the SAW induces an internal, virtual magnetic driving field. In a quantitative analysis, the magnetization dynamics are calculated as a function of external magnetic field magnitude and orientation. Full quantitative agreement of this simulation and SAW transmission experiments performed in a $Ni/LiNbO_3$ hybrid device is shown, using a set of parameters consistent with literature data.

This opens the path for further experimental studies of resonant magnon-phonon coupling and acoustic spin current generation using elastically driven magnetization dynamics.

[1] M. Weiler *et al.*, Phys. Rev. Lett. **106**, 117601 (2011).

MA 20.87 Tue 12:15 Poster A

Microscopic magnetic structuring of spin-wave wave- guides by ion implantation in a $Ni_{81}Fe_{19}$ layer — •Thomas Meyer[1], Björn Obry[1], Philipp Pirro[1], Thomas Brächer[1,2], Roland Neb[1], Julia Osten[3], Thomas Strache[3], Jürgen Fassbender[3], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, 67663 Kaiserslautern, Germany — [3]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Ion implantation of ferromagnetic films has proven to be a promising tool for the fabrication of fully planar samples with a microscopic magnetic substructure. A waveguide-like propagation of spin waves in a $Ni_{81}Fe_{19}$ film which was locally patterned by ion implatation could be observed. The investigations have been performed using Brillouin light scattering microscopy on samples patterned with varying ion fluences. Further investigations on the coupling behaviour of two parallel stripes in this fully planar structures have been performed. The presented fabrication technique of spin-wave waveguides provides much lower stray fields and better heat conduction. Especially the latter is a matter of interest when the objects are exposed to intense microwave fields (excitation of spin waves) or investigated by laser spectroscopy like Brillouin light scattering. Financial support by the DFG (GRK 792) is gratefully acknowledged.

MA 20.88 Tue 12:15 Poster A

Thermally modulated ferromagnetic resonance in planar microresonator — •Puchong Kijamnajsuk[1,2], Christian Schöppner[1], Sven Stienen[1], Detlef Spoddig[1], Ralf Meckenstock[1], and Josef Pelzl[2] — [1]Universität Duisburg-Essen, Standort Duisburg, Institut für Physik und CeNIDE, AG Farle, Lotharstr. 1, 47048 Duisburg — [2]Institute of Experimental Physics, Ruhr University Bochum

A novel approach based on the combination of two scanning thermal near field techniques: the thermally modulated ferromagnetic resonance (FMR) by the probe of a scanning thermal wave microscope and the 3ω-signal from the same thermal probe. The simultaneous detection of the thermally modulated microwave absorption and of the 3ω-response of the nano-probe offers a means to control the thermal contact between probe and sample. To enhance the sensitivity of the FMR detection for the single 30nm x 30nm x 30nm ferromagnetic Heusler alloy $Ni_{45}Mn_{37}In_{13}Co_5$, we have designed a microresonator setup. The constant amplitude microwave field is generated inside the resonator at the position of the sample at a fixed frequency 14GHz. To observe the FMR we apply the fixed external magnetic field and modulate the sample temperature by joule heating from the probe. With the microresonator we demonstrate the detection of FMR of a single nano-sized cube.

MA 20.89 Tue 12:15 Poster A

Broadband Electron Spin Resonance Experiments using superconducting Coplanar Waveguides — •Conrad Clauss[1], Daniel Bothner[2], Lapo Bogani[1], Marc Scheffler[1], Dieter Koelle[2], Reinhold Kleiner[2], and Martin Dressel[1] — [1]1. Physikalisches Institut, Universität Stuttgart, D-70550 Stuttgart, Germany — [2]Physikalisches Institut - Experimentalphysik II and Center for Collective Quantum Phenomena in LISA+, Universität Tübingen, D-72076 Tübingen, Germany

In recent years superconducting coplanar devices operating at microwave/GHz frequencies are employed in more and more experimental studies.

Here, we present electron spin resonance (ESR) experiments using a superconducting coplanar waveguide to provide the RF field to drive the spin flips. In contrast to conventional ESR studies this allows broadband frequency as well as magnetic field swept observation of the spin resonance.

We show experimental data of the spin resonance of the organic radical NitPhoMe (2-(4'-methoxyphenyl)-4,4,5,5-tetra-methylimidazoline-1-oxyl-3-oxide) for frequencies in the range of 1 GHz to 40 GHz and corresponding magnetic fields up to 1.4 T (for g=2). In addition we show the temperature dependence of the ESR signals for temperatures up to 30 K, which is well above the critical temperature of the niobium superconductor.

MA 20.90 Tue 12:15 Poster A

Studying magnetic nanostructures and the local magnetic induction of bulk samples by micro-Hall magnetometry — •Merlin Pohlit[1], Pintu Das[1], Adham Amyan[1], Yuzo Ohno[2], Hideo Ohno[2], and Jens Müller[1] — [1]Physikalisches Institut, Goethe-Universität, Frankfurt (M), Germany — [2]Laboratory for Nanoelectronics and Spintronics, Tohoku University, Sendai, Japan

Hall magnetometers based on high-mobility two-dimensional-electron systems in GaAs/AlGaAs heterostructures are powerful tools for studying individual magnetic structures on the micro- and nanoscale [1]. In particular, the devices can be used in a wide temperature and magnetic field range. Besides the possibility to position magnetic structures directly on top of the lithographically defined Hall crosses, bulk magnetic and superconducting samples may be placed on the magnetometers for local magnetic induction measurements. Here, a series of adjacent Hall crosses allows for spatially-resolved measurements with micron-size resolution. The versatility of the devices can be demonstrated by different measuring techniques including eight-terminal Hall gradiometry, magnetic flux noise measurements and the use as susceptometers. We discuss various examples for these methods, e.g. on the ferromagnetic semimetal EuB_6, where two consecutive transitions occur at 15.5K and 12.6K.These are related to electronic and magnetic phase separation and bulk magnetic ordering, but the details are not yet fully understood. We perform stray field calculations in order to simulate our results and find good agreement with the experimental data. [1] P. Das et al., APL 97, 042507 (2010)

MA 21: ThyssenKrupp Dissertationspreis der AG Magnetismus

Time: Tuesday 13:30–13:30 Location: EB 301

Der ThyssenKrupp Dissertationspreis der AG Magnetismus wird in 2012 nicht verliehen. Nominierungen für 2012 können 2013 zusammen mit neuen Nominierungen wieder vorgelegt werden.

MA 22: Joint Session "Topological Insulators II" (jointly with DS, HL, O, TT)

Time: Wednesday 9:30–13:00 Location: EB 301

MA 22.1 Wed 9:30 EB 301

Topologically-related properties in presence of disorder. First-principle study — •Stanislav Chadov — Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden

The presence of disorder is often seen as a destructive mechanism which must be reduced by any means. In present study we attempt to make it constructive due to the robustness of the spin current in topological insulators with respect to the time-reversal symmetric perturbations. Based on the first-principle calculations involving the Coherent Potential Approximation (CPA), we inspect the disorder-affected transport properties of the random alloys between topologically non-trivial and trivial materials. The subsequent analysis encounters few interesting aspects: the way how to increase the Hall angle by using random disorder and an indication for the topological Anderson insulator. In addition CPA provides an alternative recipe to validate the non-trivial topological state of the material based on a purely bulk information.

MA 22.2 Wed 9:45 EB 301

Probing the topological states of Sb_2Te_3 by spin polarized photoemission spectroscopy — •Christian Pauly[1], Gustav Bihlmayer[2], Marcus Liebmann[1], Dinesh Subramaniam[1], Martin Grob[1], Alexander Georgi[1], Markus Scholz[3], Jaime Sanchez Barriga[3], Stefan Blügel[2], Oliver Rader[3], and Markus Morgenstern[1] — [1]II. Physikalisches Institut B, RWTH Aachen University and JARA-FIT, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA-FIT, Germany — [3]Helmholtz-Zentrum für Materialien und Energie, Berlin, Germany

Using high resolution spin- and angle-resolved photoemission spectroscopy, we map the electronic structure and spin texture of the surface states of the topological insulator Sb_2Te_3. Similar to the well explored Bi_2Te_3 and Bi_2Se_3 which possess TI properties with the most simple electronic structure [1], we directly show that Sb_2Te_3 exhibits Z_2 topological properties with a single spin-Dirac cone at the Γ-point. In addition, a strongly spin-orbit split surface state is observed at lower energy. In Γ-K direction, the band is located within a spin-orbit gap, governing the energy position of the state. In combination with DFT calculation, we provide direct evidence for an argument given by Pendry [2], that there must be at least one surface state inside a SO gap, if the gap is located in the zone. Thus, similar to the topological state, this state is protected by symmetry. [1] H. Zhang et al., Nature Phys. 5, 438 (2009) [2] J. B. Pendry et al., Surf. Sci. 49, 87 (1975)

MA 22.3 Wed 10:00 EB 301

Electronic properties and magnetic anisotropy of individual Co adatoms adsorbed on topological insulator surfaces — •T. Eelbo[1], M. Sikora[2], M. Waśniowska[1], M. Dobrzański[2], M. Gyamfi[1], G. Bihlmayer[3], I. Miotkowski[4], A. Kozlowski[2], and R. Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, Jungiusstr. 11, Hamburg, Germany — [2]Department of Solid State Physics, AGH University of Science and Technology, Aleja Mickiewicza 30, Kraków, Poland — [3]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich, Germany — [4]Department of Physics, Purdue University, West Lafayette, USA

The interaction of magnetic impurities adsorbed on topological insulator surfaces causes changes of the electronic properties of the surfaces or the adatoms themselves. In addition the adatoms can present different magnetic properties due to interaction with the host. For this reason we studied the electronic properties and magnetic anisotropy of individual Co atoms adsorbed on Bi_2Se_3 by means of scanning tunneling microscopy/spectroscopy (STM/STS) and x-ray magnetic circular dichroism (XMCD) at low temperatures. After the deposition onto the cold surface STM measurements reveal two different adsorption sites for Co adatoms. Two resonances in the occupied states for both species of adatoms are found using STS. Moreover, XMCD measurements reveal a magnetic anisotropy with the easy axis being aligned out-of-plane. The experimental findings are compared to results of ab-initio calculations.

MA 22.4 Wed 10:15 EB 301

Theoretical study on the reactive chemical doping of the Bi_2Se_3 surface — •Janos Kiss[1,2], Stanislav Chadov[1,2], and Claudia Felser[1,2] — [1]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg University, Mainz — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Recent experimental results have shown that the surface of Bi_2Se_3 exposed to air will become n-type doped. Furthermore, the surface gradually undergoes an oxidation reaction leading to a degradation of the surface transport properties, where the contribution of the topological surface states are consequently decreasing. This is expected to be caused by Se vacancies. However, the formation mechanism of this vacancies and the interaction of moisture -i.e. water- with Bi_2Se_3 is still not clarified. Therefore, we will present the results of our large scale ab-initio calculations and molecular dynamics simulations in order to investigate the effect of Se vacancies and the reactivity of water upon the electronic and atomic structure of the surface.

MA 22.5 Wed 10:30 EB 301

Heusler topological insulators: Electronic structure and transport properties — •C. Shekhar[1], S. Ouardi[2], G. H. Fecher[1,2], A. K. Nayak[1], A. Gloskovskii[2], E. Ikenaga[3], S. Ueda[4], K. Kobayashi[4], and C. Felser[1,2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden — [2]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [3]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan — [4]National Institute for Materials Science, SPring-8, Hyogo, Japan

Topological insulators have a high potential for spintronics devices and quantum computation. Various Heusler compounds crystallize in a fcc structure of the $C1_b$ type and consist of 2 transition metals and a main group element. If the compounds contain heavy metals and a lanthanide element then they exhibit extraordinary physical properties including superconductivity, half-metallic, semiconducting-like behavior, giant magnetoresistivity, heavy fermion state and zero band gap. The density of states of XMZ Heusler compounds (M = Gd, Lu, X= Au, Pt, Pd and Z= Pb, Sb, Bi) were investigated by hard X-ray photoelectron spectroscopy. The comparison of the experimental results to calculations gives evidence for the zero band gap state of the compounds. Further, the temperature dependence of electrical conductivity, magneto resistance, Hall mobility, Seebeck coefficient and thermal conductivity were investigated. The compounds exhibit a high Hall mobility and a linear magnetoresistance (MR). The observed linear MR is a quantum MR and due to the topological insulator state.

MA 22.6 Wed 10:45 EB 301

Topological phase transitions in Bi(111) bilayer by breaking time-reversal symmetry — •Hongbin Zhang, Frank Freimuth, Gustav Bihlmayer, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Time-reversal breaking brings forth many novel phenomena in topological insulators [1]. In this work, using the first principles FLAPW method combined with the Wannier functions technique [2], we investigated topological phase transitions with respect to exchange fields of a two-dimensional topological insulator – Bi(111) bilayer [3]. Numerical evaluation of the spin Chern number [4] for different magnitudes of exchange fields reveals that when the time reversal symmetry is broken by a small exchange field, the system keeps the properties of a topological insulator. After a metallic phase in the intermediate region, the quantum anomalous Hall phase with the non-zero Chern number occurs at sufficiently large enough exchange fields. We analyzed the relation between the spin Chern number, the Z_2 number and the Chern number, and also the phase diagram from the viewpoint of the evolution of the electronic structure, edge states and transport properties in this system. We acknowledge funding under HGF-YIG Programme VH-NG-513.

[1] X. Qi, *et al.*, Phys. Rev. B. **78**, 195424 (2008).
[2] www.flapw.de; F. Freimuth, *et al.*, Phys. Rev. B. **78**, 035120 (2008).
[3] M. Wada, *et al.*, Phys. Rev. B **83**, 121310(R) (2011).
[4] E. Prodan, *et al.*, Phys. Rev. B **80**, 125327 (2009).

MA 22.7 Wed 11:00 EB 301

Predicting surface states from the bulk embedding self-energy — •Daniel Wortmann, Gustav Bihlmayer, and Stefan Blügel — Institute for Advanced Simulation & Peter Grünberg Institut, Forschungszentrum Jülich und JARA, 52425 Jülich, Germany

The protected states localized at surfaces and interfaces of topological insulators are a consequence of the electronic structure of the bulk. Their peculiar features like the typical spin-structure makes them an interesting field of basic research with possible applications in spintronics.

We demonstrate how these states can be efficiently simulated by means of the embedding self-energy as obtained in the Green function embedding technique[1]. The embedding self-energy, which can be understood as a generalized logarithmic derivative, is a property of the bulk crystal only and contains all information required to analyze the consequences of the bulk topology on the surface bandstructure. Using the FLAPW implementation of the embedding method as provided in the FLEUR-code[2], we show how the surface states of prototypical topological insulators like Bi_2Se_3 can be studied efficiently with an easy and direct access to effects for example due to electric fields applied to the surface.

[1] D. Wortmann, H. Ishida, S. Blügel. Phys. Rev. B **66**, 075113(02)
[2] http://www.flapw.de

15 min. break

MA 22.8 Wed 11:30 EB 301

Influence of magnetic impurities on doping and scattering properties of topological surface states: Fe on Bi_2X_3 (X=Te, Se) — •Markus R. Scholz[1], J. Sánchez-Barriga[1], D. Marchenko[1], A. Varykhalov[1], E. Rienks[1], A. Volykhov[2], L. V. Yashina[2], and O. Rader[1] — [1]Helmholtz-Zentrum Berlin — [2]Moscow State University

We study the effect of Fe impurities deposited on the surface of the topological insulators Bi_2Se_3 and Bi_2Te_3 by means of photoelectron spectroscopy. The topological surface state reveals surface electron doping when the Fe is deposited at room temperature and hole doping when deposited at low temperture ($\sim$ 10 K). We show that in both cases the topological surface state remains intact and gapless. We analyze the line broadening for pure Bi_2X_3 (X=Se, Te) and after deposition of Fe. We observe that the constant broadening in the bulk band gap range increases by a factor of 2 upon deposition of Fe. Because we deposit the Fe without electron doping, this result is not due to a gain in warping as was recently suggested. We discuss the results based on different types of scattering mechanisms.

MA 22.9 Wed 11:45 EB 301

Origin of the strong circular dichroism of the topological surface state of Bi_2Te_3 — •Jaime Sánchez-Barriga[1], M. R. Scholz[1], D. Marchenko[1], A. Varykhalov[1], O. Rader[1], A. Volykhov[2], L. V. Yashina[2], J. Braun[3], J. Minár[3], and H. Ebert[3] — [1]Helmholtz-Zentrum Berlin — [2]Moscow State University — [3]Ludwig-Maximilians-Universität München

We have recently reported a strong circular dichroism effect in angle-resolved photoemission of the spin polarized topological surface state of Bi_2Te_3 [1]. The effect has been observed recently also for Bi_2Se_3 and the origin is controversial [2-4]. An initial-state model has been employed to determine the spin orientation directly [3]. We present a series of photoemission measurements and density functional calculations coupled to one-step photoemission theory. Both experiment and theory reveal that the dichroism effect changes sign as a function of photon energy which excludes the initial-state model.

[1] M. R. Scholz, J. Sánchez-Barriga, D. Marchenko, A. Varykhalov, A. Volykhov, L. V. Yashina, O. Rader, submitted to Phys. Rev. Lett. (2010), arXiv:1108.1053
[2] S. R. Park et al., arXiv:1103.0805
[3] Y. H. Wang, D. Hsieh, D. Pilon, L. Fu, D. R. Gardner,Y. S. Lee, N. Gedik, arXiv:1101.5636
[4] Y. Ishida et al., Phys. Rev. Lett. 107, 077601 (2011)

MA 22.10 Wed 12:00 EB 301

Prediction of topological insulators in TlBiSe2 family of chalcogenides — •binghai yan — BCCMS, University of Bremen, Bremen

In this work, we predicted several new topological insulator materials in thallium (Tl) based ternary chalcogenides from first-principles calculations, including TlBiQ2 and TlSbQ2 (Q=Te, Se and S). TlBiSe2 and TlSbSe2 are found to be strong TIs with a large energy gap (~ 0.2 eV), while TlBiTe2 is a topological semimetal. A simple Dirac-type dispersion of topological surface states is observed, similar to the Bi2Se3 type of materials. On the other hand, TlBiS2, TlSbTe2 and TlSbS2 are small gap insulators near the topological trivial-nontrivial transition boundary. Particularly TlBiTe2 can be a good candidate in the seeking of Majorana fermions for its co-existing superconductivity property. The topological feature of TlBiSe2 and TlBiTe2 has already been confirmed by recent experiments. References: 1. B.H. Yan, C.X. Liu, H.J. Zhang, C.Y. Yam, X.L. Qi, Th. Frauenheim and S.C. Zhang, Europhys. Lett. 90, 37002 (2010). 2. Y. L. Chen, Z. K. Liu, J. G. Analytis, J.-H. Chu, H. J. Zhang, B. H. Yan, S.-K. Mo, R. G. Moore, D. H. Lu, I. R. Fisher, S. C. Zhang, Z. Hussain, and Z.-X. Shen, Phys. Rev. Lett. 105, 266401(2011).

MA 22.11 Wed 12:15 EB 301

A recipe for new Topological Insulators based on bonds, bands, symmetry andheavy atoms — •L. Müchler[1], B. Yan[2,3], S. Chadov[1,4], F. Casper[1], S-C. Zhang[2], and C. Felser[1,4] — [1]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [2]Department of Physics, McCullough Building,Stanford University,Stanford, CA 94305-4045, USA — [3]Bremen Center for Computational Materials Science, Universität Bremen, Am Fallturm 1, 28359 Bremen, Germany — [4]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany.

In this work we will present a recipe to find new Topological Insulators (TIs) based on bonds, bands, symmetry and heavy atoms. A big issue concerning the compounds known up to now is the control of the bulk carrier density to produce truly insulating samples in the bulk. Using concepts from chemistry and supported by density-functional calculations, we want to motivate an extended search for new compounds with tunable bulk properties.

MA 22.12 Wed 12:30 EB 301

Graphene nanoribbons with Au induced spin-orbit effects: a DFT study — •Gustav Bihlmayer and Stefan Blügel — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Historically, the prediction of a topological protection of the edge state of a zig-zag graphene nanoribbon (ZGNR) was at the beginning of the field of topological insulators. Unfortunately, a realization of this system is prevented by (i) the extremely small spin-orbit coupling (SOC) in graphene and (ii) the tendency towards formation of antiferromagnetically coupled edge states in ZGNRs.

New experimental and theoretical results show that SOC effects can be enhanced by substrates and/or adatoms with a large atomic number, so that up to 100 meV spin-splitting can be realized in the graphene. Additionally, hybridization with the substrate changes also the localization of the edge state and its tendency towards antiferromagnetic ordering. Density functional theory calculations of Au supported graphene (with and without adatoms) and ZGNRs will illustrate these effects and point the way towards a realization of a ZNGR with a topologically protected edge state.

MA 22.13 Wed 12:45 EB 301

Collision dominated scattering in 3D topological insulators — •Peter Lemmens[1], Vladimir Gnezdilov[2], Dirk Wulferding[1], Yurii Pashkevich[3], Ekaterina Pomjakushina[4], Kazimierz Conder[4], and Helmuth Berger[5] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]ILTPE NAS, Ukraine — [3]DonFTI, Donetsk, Ukraine — [4]PSI, Villigen, Switzerland — [5]EPFL, Lausanne, Switzerland

Despite topological protection in 3D topological insulators there exist scattering processes induced by a resonant excitation from a bulk valence band to Dirac states. This signal in Raman scattering has a Lorentzian lineshape and spin-helical symmetry with a scattering rate of 40 cm^{-1}. A comparison of different compounds (Bi_2Se_3, Bi_2Te_3), substitution experiments as well as first results on BiTeI with giant Rashba spin splitting are presented. Work supported by DFG and NTH.

MA 23: Magnetization / Demagnetization Dynamics II

Time: Wednesday 9:30–13:00 Location: H 1012

Invited Talk MA 23.1 Wed 9:30 H 1012

Uncovering the Ultrafast Angular Momentum Transfer on the Nanoscale in GdFeCo — •A. Scherz[1], C. Graves[1,2], A.H. Reid[1], B. Wu[1,2], T. Wang[1,2], S. de Jong[2], K. Vahaplar[3], I. Radu[3], M. Messerschmidt[4], R. Coffee[4], M. Bionta[4], R. Hartmann[5], N. Kimmel[5], S. Epp[5], A. Tsukamoto[6], J. Turner[4], W.F. Schlotter[4], Y. Acremann[7], A. Kimel[3], A. Kirilyuk[3], J. Stöhr[1,4], T. Rasing[3], and H. Dürr[1] — [1]Stanford Inst. for Material and Energy Science, California — [2]Stanford University, California — [3]Radboud University Nijmegen, Netherlands — [4]LCLS, SLAC Nat. Acc. Lab., California — [5]ASG-MPG, CFEL Hamburg, Germany — [6]Nihon University, Japan — [7]ETH Zürich, Switzerland

The ultrafast control of electron spins is of both fundamental scientific and technological interest. Recent experiments have shown that femtosecond laser excitation can act as a stimulus to switch the direction of the magnetization in ferrimagnetic GdFeCo, called all-optical switching. However, how angular momentum is transferred to result in a switched state remains unknown. To further understand this mechanism, we used the fs x-ray pulses at the x-ray free electron laser facility, LCLS, to study the all-optical magnetization switching of GdFeCo triggered by fs laser excitation using time-, element- and spatially-resolved x-ray resonant magnetic scattering. We present here the first-ever measurement of the fs magnetic response in GdFeCo with spatial resolution down to 10nm. Our results reveal drastically different behaviors on the nanoscale as compared to the bulk and provide insight into the angular momentum transfer channels.

MA 23.2 Wed 10:00 H 1012

Bending spin waves around the corner — •Katrin Vogt[1,2], Helmut Schultheiss[3], Shikha Jain[3], Axel Hoffmann[3], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, D-67663 Kaiserslautern, Germany — [2]Graduate School of Excellence Material Science in Mainz, Staudinger Weg 9, D-55128 Mainz, Germany — [3]Materials Science Division, Argonne National Laboratory, Argonne, IL 60439

The guidance of spin waves in more complicated geometries than simple waveguide strips is a challenge in realizing magnonic devices. Especially in metallic magnetic materials like Permalloy ($Ni_{81}Fe_{19}$), where the length scales are of interest for applications, it will be inevitable to find means how to accomplish truly two-dimensional spin-wave propagation.

Using Brillouin light scattering microscopy, we have studied the propagation of spin waves in Permalloy microstrips exhibiting a smooth bend. We will discuss the use of a direct current flowing through a gold wire underneath the Permalloy to provide a local magnetic field and maintain a transverse magnetization around the bend of the waveguide. We will demonstrate how spin-wave propagation around the bend is improved compared to the case of an externally applied magnetic field which generates strong inhomogeneities in the internal magnetization distribution and prevents any spin-wave propagation around the bend.

Financial support by the Carl-Zeiss-Stiftung is gratefully acknowledged.

MA 23.3 Wed 10:15 H 1012

Mode selective parametric excitation of spin waves in a $Ni_{81}Fe_{19}$ microstripe — •Thomas Braecher[1,2], Philipp Pirro[1], Björn Obry[1], Alexander A. Serga[1], Britta Leven[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Gottlieb-Daimler-Straße 47 67663 Kaiserslautern, Germany

Due to their potential application in logic devices and microwave signal processing spin-wave excitations have been intensively studied. However, experiments in microstructured systems remain a challenge since the spin-wave lifetime in commonly used materials like Permalloy ($Ni_{81}Fe_{19}$) is restricted to a few nanoseconds. We present the experimental observation of parallel parametric amplification of selected thermal spin-wave modes in a transversally magnetized $Ni_{81}Fe_{19}$ microstripe. By employing Brillouin light scattering microscopy we identify the dominant group, i.e. the spin-wave mode that is preferentially amplified. We show that due to the existing spin-wave quantization in the system it is possible to select one specific mode to be parametrically excited by changing the bias magnetic field. This gives access to transversal spin-wave eigenmodes of the stripe, promising the ability to amplify externally excited propagating spin waves that carry information, and also to modes localized at the stripe edges. This work was recently published in Applied Physics Letters (Appl. Phys. Lett. **99**, 162501 (2011)).

Financial support by the DFG and MAINZ is gratefully acknowledged.

MA 23.4 Wed 10:30 H 1012

Micromagnetic study of magnonic band gaps in waveguides with a periodic variation of the saturation magnetization — •Florin Ciubotaru, Andrii V. Chumak, Björn Obry, Alexander A. Serga, and Burkard Hillebrands — FB Physikand Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Spin wave propagation in micro-sized magnonic crystals (MCs) is intensively studied due to their potential technological application for signal processing in spintronic devices. Here we report on micromagnetic simulations [1] of the spin wave propagation in a MC realized as a permalloy waveguide with a periodical variation of its saturation magnetization. In real structures the variation of magnetization can be achieved by using an ion implantation technique. The 2 μm-wide waveguide of 40 nm thickness is magnetized transversal to its long axis. The MC lattice constant is equal to 1 μm. The spin-wave transmission characteristics have been studied as a function of the width of the implanted areas and of the level of the magnetization variation M/M_0. Frequency band gaps were clearly observed. The dependences of the depth, width and the position in frequency and space of the rejection band gaps on the above parameters are referred in our studies. The role of the higher order spin-wave width modes on the MC properties is discussed as well. Support from DFG (grant SE-1771/1-2) is gratefully acknowledged. [1] OOMMF open code, M. J. Donahue, and D. G. Porter, Report NISTIR 6376, NIST, Gaithersburg, MD (1999).

MA 23.5 Wed 10:45 H 1012

Magnon magnetometry of non-linear spin-wave excitations — •Hans G. Bauer[1], Georg Woltersdorf[1], Peter Majchrak[1], Thorsten Kachel[2], and Christian H. Back[1] — [1]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Helmholtz-Zentrum Berlin, Albert-Einstein-Strasse 15, 12489 Berlin, Germany

The understanding of non-linear magnetization dynamics is essential for the operation of many spintronics devices. In particular it is important to understand the flow of angular momentum.

We study experimentally a very simple and relevant system, a thin ferromagnetic film. Time resolved X-ray magnetic circular dichroism experiments allow us to determine precisely the number of magnons in a Permalloy sample. In doing so we show that commonly used models for non-linear resonance are actually not applicable at low bias fields.

A simple non-linear model allows us to find the threshold and associated critical modes that agree well with our experimental findings and with micro-magnetic simulations. Other non-linear properties such as the wave-vector dependent non-linear frequency shift and frequency-locking to half-integer multiples of the driving frequency are also discussed.

Our model is also applicable to 1st and 2nd order Suhl instability processes, demonstrating its general character.

MA 23.6 Wed 11:00 H 1012

Magnetic Anisotropy and Damping of Rare-Earth Doped Permalloy — •Christoph Zollitsch[1], Fredrik Hocke[1], Mathias Weiler[1], Rudolf Gross[1,2], Georg Woltersdorf[3], Jahn-Ulrich Thiele[4], Sebastian T.B. Goennenwein[1], and Hans Huebl[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching — [2]Physik-Department, Technische Universität München, Garching — [3]Physik-Department, Universität Regensburg, Regensburg — [4]Seagate Technology, Fremont, CA, USA

Understanding and engineering the magnetization damping of magnetic materials is of considerable interest both from a fundamental physics perspective and for applications. Of particular importance are low damping materials such as Permalloy ($Ni_{80}Fe_{20}$) and Yttrium Iron Garnet. We study the temperature dependent behavior of the

ferromagnetic resonance (FMR) of $Ni_{80}Fe_{20}$ doped with 1at.% Ho. At room-temperature the FMR dispersion is not altered by the dopant. The latter only leads to an increased damping with respect to the undoped $Ni_{80}Fe_{20}$ as expected in the frame of the slow relaxation mechanism [1]. At around 100 K the FMR is suppressed due to the efficient damping by the Ho dopant. In the temperature regime below 100 K which was previously not studied, the dispersion shifts to higher frequencies by 14 GHz, while the damping reduces to its initial magnitude. This is attributed to an increase in the magnetic moment of Ho in combination with its thermal population.

[1] G. Woltersdorf, et al., Phys. Rev. Lett. **102**, 257602 (2009)

15 min. break

MA 23.7 Wed 11:30 H 1012

Spindynamics of individual permalloy nanowires — •Nathalie Reckers[1], Zheng Duan[2], Ilya Krivorotov[2], Michael Farle[1], and Jürgen Lindner[1] — [1]Fakultät für Physik und Center for Nanointegration Duisburg-Essen, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Department of Physics and Astronomy, University of California, Irvine, USA

Nanostructured single wires (600 nm* 80 μm* 20 nm) composed of Permalloy are investigated by dc electrically detected ferromagnetic resonance in a frequency range of 4-16 GHz at ambient temperature [1]. It is demonstrated that the quasi uniform mode and other localized spinwave modes in a single nanowire can be detected with high sensitivity in different measurement geometries, the external magnetic field being applied along easy and hard direction of the wire. Based on these multi-frequency measurements we observe that in nanostructured finite elements deviations to the widely employed Kittel-resonance equation are present. Examples will be discussed.

Financial support by DFG, SFB 491 is acknowledged.

[1] N. Mecking, Y. Y. Gui and C.-M. Hu, Phys. Rev. B, 224430, (2007)

MA 23.8 Wed 11:45 H 1012

Rotational Doppler Effect in Magnetic Resonance — •Sergi Lendínez[1], Eugene Chudnovsky[2], and Javier Tejada[1] — [1]Departament de Física Fonamental, Facultat de Física, Universitat de Barcelona, Barcelona, Spain — [2]Physics Department, Lehman College, The City University of New York, New York, U.S.A.

The Doppler Effect consists of a shift on the frequency received by an observer which is moving with respect to the source of the radiation. Commonly, linear Doppler is observed. In this case, an observer moving at relative velocity v will perceive a frequency shifted by v/c: $f' = f(1 \pm v/c)$, where the plus (minus) sign is for an observer moving towards (backwards) the source. However, the Doppler Effect can also be observed at rotations of the body. In particular, if a solid rotates with an angular velocity Ω in the field of a circularly polarized electromagnetic wave, in its rotating frame the frequency of the wave will be shifted by $\omega' = \omega \pm \Omega$, where the plus (minus) sign is for a rotation in the opposite (same) direction of the circular polarization.

In the case of a rotating object with a resonant frequency, one would firstly think that the frequency will be shifted by Ω. However, a mechanical rotation of a system of charges is equivalent to a magnetic field, hence it must be checked whether the resonant frequency is affected by this magnetic field. Resonant frequencies of LC circuits are insensitive to magnetic fields, and the frequency will by shifted by Ω as expected. On the contrary, frequencies based upon magnetic resonance will be sensitive to this magnetic field, so the frequency shift may not be Ω.

MA 23.9 Wed 12:00 H 1012

Towards atomistic tight-binding spin dynamics — •S. Rossen[1,2], P. Mavropoulos[1], T. Schena[1], S. Blügel[1], and Th. Rasing[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute for Molecules and Materials, Radboud Universiteit Nijmegen, 6525 AJ Nijmegen, The Netherlands

This work is motivated by the increasing interest in atomistic magnetization dynamics [1]. Until now, the computational approaches are mainly based on model Hamiltonians of the magnetic system. Here we will present a method based on the adiabatic approximation in which the electronic structure is recalculated within the tight-binding approximation during the time evolution, so that the transverse and longitudinal magnetic as well as charge degrees of freedom are coupled [2]. The torques acting on the magnetic moments are obtained self-consistently using constraining fields [3]. It is then possible to describe the magnetization dynamics of a strongly non-equilibrium magnetic state. We will show model calculations of such dynamics where we mainly focus on the integration of the Landau-Lifshitz equation with torques calculated by means of the tight-binding method. The presented results are compared with those of a classical Heisenberg model.

[1] A. Kirilyuk et al., Rev. Mod. Phys. **82**, 2731 (2010).
[2] V. P. Antropov et al., Phys. Rev. B **54**, 1019 (1996).
[3] L. M. Small and V. Heine, J. Phys. F: Met. Phys. **14**, 3041 (1984).

MA 23.10 Wed 12:15 H 1012

Lifting the Degeneracy of Spin Wave Resonances in Three-Dimensional Rolled-Up Microtubes — •Felix Balhorn, Cornelius Bausch, Lennart Moldenhauer, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institut für Angewandte Physik Hamburg, Jungiusstr. 11, 20355 Hamburg

Nowadays, the established methods of nano-sized sensors, integrated circuits or storage devices are mostly based on two-dimensional fabrication technologies. In strong contrast to those planar nanostructures, the concept of self-rolling strained layers [1] holds the opportunity to prepare and study three-dimensional functionalized devices. We recently demonstrated that strained semiconductor/Permalloy layers can be rolled-up into three-dimensional microtubes which exhibit azimuthal spin-wave resonances and act as magnetically tunable filters for the GHz regime [2].

In this talk, the dynamic properties of these structures obtained via broadband-microwave absorption spectroscopy are discussed. We focus here on an experiment where the axis of the rolled-up microtube is oriented parallel to the signal line of our waveguide. The position of the rolling edge is varied with a micromanipulator to optimize the excitation efficiency. A characteristic frequency splitting of resonant modes in external magnetic fields is observed. We gratefully acknowledge support by the DFG via SFB 668, GrK 1286, and by the city of Hamburg via the Cluster of Excellence Nano-Spintronics.

[1] V. Y. Prinz et al., Physica E **6**, 828-831 (2000); [2] F. Balhorn et al., PRL **104**, 037205 (2010)

MA 23.11 Wed 12:30 H 1012

Quasi uniform modes and standing spinwaves in a single Co-Stripe measured by Ferromagnetic Resonance — •Christian Schöppner[1], Sven Stienen[1], Ryszard Narkowicz[2], Dieter Suter[2], Ralf Meckenstock[1], Jürgen Lindner[1], and Michael Farle[1] — [1]University of Duisburg-Essen, CeNIDE, Faculty for Physics, Lotharstr. 1 47057 Duisburg — [2]Technical University Dortmund, Faculty für Physik, Otto-Hahn-Str. 4 44227 Dortmund

Stripe-like magnetic systems of a few micrometer lateral size and few nanometer thickness exhibit quasi-uniform excitations which are influenced by dynamic pinning, modes of standing character and those which are characterized by a pronounced local confinement due to the inhomogeneous demagnetization field. As the sample edges and inhomogeneities in the demagnetization field become important in such systems, it is crucial to rather measure single stripe samples than ensembles. We present results of Ferromagnetic Resonance experiments on one single Co-Stripe of a few micrometer lateral size and 20nm thickness. For the first time measurements were performed using a microresonator [Banholzer et al. Nanotech. 22 (2011)] in an angular dependent way. The angular dependence was conducted over 180 degree with respect to the long axis of the stripe. We used microwave-frequency of 14GHz and external magnetic fields up to 300mT at room temperature. The measured spectra exhibit the mentioned types of spin waves and are in very good agreement with micro magnetic simulations, which will also be discussed. The work is funded by the DFG (LI 1567/3-1)

MA 23.12 Wed 12:45 H 1012

Spin-Wave Interference Patterns: Perfect Imaging with Spin-Waves — •Sebastian Mansfeld, Jesco Topp, Kim Martens, Jan-Niklas Toedt, Daniel Mellem, Wolfgang Hansen, Detlef Heitmann, and Stefan Mendach — Institute of Applied Physics, University of Hamburg, Hamburg, Deutschland

We discuss time resolved scanning Kerr microscopy data showing the diffraction of planar Damon-Eshbach spin waves on a one-dimensional grating, realized by a micrometer sized slit array in a Permalloy film. We observe a unique diffraction pattern behind the grating which pro-

duces images of the spin-wave field at the slits [1]. In accordance to superlensing concepts known from optical metamaterials [2, 3], these images are formed due to the anisotropic shape of the isofrequency line in k-space defined by the dispersion law for spin waves. A consequence is that the resolution of the observed image is not limited by the wavelength of the spin wave, as is the case in isotropic media. Instead, the image resolution is limited by the curvature of the isoline in k-space and by the damping of the spin wave. We show that the images can be tuned by manipulating the isoline in k-space via the excitation frequency and the external magnetic field.

We gratefully acknowledge support by the DFG via SFB 668, SFB 508, GrK 1286, and by the City of Hamburg via the Cluster of Excellence Nano-Spintronics.

[1] Mansfeld et al., Physical Review Letters, in press (2011) - arXiv:1108.5883v1; [2] Liu et al., Science **315**, 1686 (2007); [3] Schwaiger et al., Physical Review Letters **102**, 163903 (2009)

MA 24: Joint Session "Soft X-ray Resonant Scattering for Complex Structural and Magnetic Investigations" (jointly with KR), Organization: Eberhard Goering (MPI-IS Stuttgart)

Time: Wednesday 9:30–12:30 Location: BH 243

Invited Talk MA 24.1 Wed 9:30 BH 243

Soft X-ray Resonant Magnetic Reflectometry of Ferromagnet/Antiferromagnet Interfaces - Probing the Origin of Exchange Bias — •Sebastian Brück[1], Gisela Schütz[2], Kannan M. Krishnan[3], and Eberhard Goering[2] — [1]University of New South Wales and Australian Nuclear Science and Technology Organization, Sydney, Australia — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [3]University of Washington, Seattle, USA

Magnetic interface coupling effects such as exchange bias, the coupling of a ferromagnet to an adjacent antiferromagnet, are very difficult to probe directly by volume integrating techniques due to the small interface to volume ratio. During the last decade, soft x-ray resonant magnetic reflectometry has proven to be a powerful new tool to tackle this problem. Its combination of element selective magnetic sensitivity and high resolution depth profiling capability allows probing even very small magnetic effects at an interface. Investigations by different groups on a broad variety of exchange bias systems based on FeF2, MnPd, CoO, and IrMn have revealed a complex magnetic configuration at the interface. The antiferromagnet shows uncompensated rotatable magnetic moments which are confined to the direct neighborhood of the ferromagnet but also exotic pinned uncompensated magnetic moments. Especially the latter are interesting for our understanding of exchange bias since they should be responsible for the hysteresis loop shift in these systems. We review recent findings in the field and use them to illustrate the capabilities of SXRMR for the investigation of magnetic interface effects.

Topical Talk MA 24.2 Wed 10:00 BH 243

Orbital reflectometry of nickelate heterostructures — •Eva Benckiser — Max Planck Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany

The occupation of d-orbitals has a key influence on the physical properties of transition metal oxides. Heterostructures of these oxides offer the possibility to control the orbital occupations because the electronic structure is very sensitive to changes in the transition-metal-oxygen bond distances induced by strain, dimensional constrains, and the chemical bonding to ions with different electronic configuration. However, atomic-scale modulations of the orbital occupation could thus far not be probed in a quantitative manner. We present results from a polarized soft x-ray resonant reflectivity study on superlattices composed of metallic $LaNiO_3$ and insulating $LaAlO_3$, $LaGaO_3$, or $DyScO_3$. We will demonstrate that it is possible to derive quantitative, spatially resolved orbital polarization profiles with differences of $\sim 3\%$ in the occupation of Ni e_g orbitals in adjacent atomic layers and discuss these results in context with recent theoretical predictions.[1–3] The possibility to quantitatively correlate theory and experiment on the atomic scale opens up new perspectives for orbital physics in oxide heterostructures. [1] Chaloupka, J. and Khaliullin, G., Phys. Rev. Lett. 100, 016404 (2008). [2] Hansmann, P. et al., Phys. Rev. Lett. 103, 016401 (2009) and arXiv:1111.1111 [3] Han, M. J., Marianetti, C. A. & Millis, A. J. Phys. Rev. B **82**, 134408 (2010)

Invited Talk MA 24.3 Wed 10:30 BH 243

Manipulating magnetic and electronic ordering phenomena by electric fields and electromagnetic radiation — •Urs Staub — Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI. Switzlerand

Complex oxides may exhibit very interesting magnetic properties such as the appearance of the colossal magneto-resistance effect, complex charge and orbital ordering phenomena as well as cross-talk of magnetic and electric polarizations in multiferroics. These effects open up the possibility of manipulating magnetism by electric fields or electromagnetic radiation. Here I will give examples, which show how resonant soft x-ray magnetic diffraction can be used to monitor changes to the underlying magnetic structure. I will discuss how the insitu application of an electric field can change the magnetic order or domain population in a multiferroic, how spins can be canted by x-rays or how fast an antiferromagnetic phase transition can be induced by an ultrafast optical excitation, being monitored by ultrafast magnetic x-ray diffraction.

15 min. break

Topical Talk MA 24.4 Wed 11:15 BH 243

Theory of resonant x-ray spectroscopy — •M. W. Haverkort — Max-Planck Institute for Solid State Research, Stuttgart, Germany

Within the first half of this talk I will review the theoretical interpretation of x-ray absorption spectroscopy (XAS), elastic resonant x-ray diffraction (RXD) and resonant inelastic x-ray scattering (RIXS). I will briefly review how XAS can be used to measure the element specific magnetic susceptibility separated to its spin and orbital momentum contributions. Either with the use of sum-rules or by comparison to theory. Next, I will show how with the use of the optical theorem this understanding of XAS can be extended to RXD. This gives access to measure in a quantitative way the element resolved ordered spin and orbital moments. I will then continue to discuss RIXS, an inelastic scattering technique, which due to recent experimental improvements, allows one to measure dispersing magnetic excitations in small samples and thin films. Using the relations between inelastic scattering, elastic scattering and absorption spectroscopy a quantitative theory for RIXS is derived, which allows for an interpretation of the RIXS spectra very similar to Neutron spectroscopy.

In the last half of the talk several experimental results will be presented which show how these techniques can be used to gain understanding in the magnetic interactions in transition metal compounds.

Topical Talk MA 24.5 Wed 11:45 BH 243

Cycloidal Magnetic Order and Ferroelectricity: Manipulation and Imaging with Soft X-Rays — •Eugen Weschke[1], Enrico Schierle[1], Victor Soltwisch[1], Detlef Schmitz[1], Andrej Maljuk[1,2], and Dimitri Argyriou[1,3] — [1]Institut für komplexe magnetische Materialien, Helmholtz-Zentrum Berlin für Materialien und Energie, Germany — [2]Institut für Festkörperforschung, IFW Dresden, Germany — [3]European Spallation Source, Lund, Sweden

Materials with coupled order parameters, such as the magnetoelectric rare-earth manganites, offer interesting means of manipulation, like switching of magnetic order by electric fields. Ordering phenomena in these complex materials can be nicely studied by resonant scattering due to the element-selectivity of the method. In the soft x-ray region, in particular, spatial correlations involving the 3d and 4f electrons and their magnetic moments are directly addressed via dipole transitions. The method is applied to study cycloidal magnetic structures that occur in connection with ferroelectric order in $DyMnO_3$ and $GdMnO_3$, using circularly polarized synchrotron radiation to address the handedness of the structure [1]. The possibility to manipulate ferroelectric domains with the synchrotron beam is also demonstrated, which eventually provides a means to evidence ferroelectric polarization in cases where other methods are not conclusive or difficult to apply.

[1] E. Schierle et al., Phys. Rev. Lett. 105, 167207 (2010).

MA 24.6 Wed 12:15 BH 243

Local Magnetic Structure at the Fe_3O_4/ZnO Interface — •Sebastian Brück[1], Markus Paul[2], He Tian[3], Ozan Kirilmaz[2], Andreas Müller[2], Kai Fauth[1], Eberhard Goering[4], Jo Verbeeck[3], Gustaaf van Tendeloo[3], Michael Sing[2], and Ralph Claessen[2] — [1]University of New South Wales and ANSTO, Sydney, Australia — [2]Physikalisches Institut, Universität Würzburg, Würzburg, Germany — [3]Electron Microscopy for Materials Science, University of Antwerp, Antwerp, Belgium — [4]Max Planck Institute for Intelligent Systems (former Metals Research), Stuttgart, Germany

Magnetite, Fe_3O_4, is a half-metal with 100% spin polarization of the minority band at the Fermi level. This together with its good conductivity match to standard semiconductors makes it a promising candidate for polarized spin injection into semiconductor materials such as Si, GaAs, or ZnO. An important aspect for such applications is the magnetism directly at the interface between Fe_3O_4 and the semiconductor. Soft x-ray resonant magnetic reflectometry (XRMR) is a technique which is capable of providing structural and magnetic depth profiles with 0.1nm resolution. We present a detailed XRMR and electron energy loss spectroscopy (STEM/EELS) study of an epitaxial Fe_3O_4 thin film grown directly on a semiconducting ZnO substrate. Consistent chemical profiles at the interface between ZnO and Fe_3O_4 are found from XRMR and EELS. The magnetic depth profile of tetragonal Fe^{3+} and octahedral Fe^{2+} ions in Fe_3O_4 is derived with monolayer resolution and reveals a change in the Fe stoichiometry directly at the interface.

MA 25: Electron Theory of Magnetism

Time: Wednesday 9:30–10:45 Location: H 0112

MA 25.1 Wed 9:30 H 0112

Magnetic Compton profiles of Fe and Ni corrected by dynamical electron correlations — •Diana Benea[1], Jan Minar[2], Serghey Mankovsky[2], Liviu Chioncel[3,4], and Hubert Ebert[2] — [1]Faculty of Physics, Babes-Bolyai University, Cluj-Napoca, Romania — [2]Chemistry Department, University of Munich, Germany — [3]Augsburg Center for Innovative Technologies, University of Augsburg, Germany — [4]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Germany

Magnetic Compton profiles (MCPs) of Ni and Fe have been calculated using a combined Density Functional and many-body theory approach. At the level of the local spin density approximation the theoretical MCPs does not describe correctly the experimental results around the zero momentum transfer. In this work we demonstrate that inclusion of electronic correlations as captured by Dynamical Mean Field Theory (DMFT) improves significantly the agreement between the theoretical and the experimental MCPs. In particular, an energy decomposition of Ni MCPs gives indication of spin polarization and intrinsic nature of Ni 6 eV satellite, a genuine many-body feature.

MA 25.2 Wed 9:45 H 0112

Magnetic anisotropy energy of disordered and ordered tetragonal FeCo alloys — •Ilja Turek[1,3], Josef Kudrnovsky[2], and Karel Carva[3] — [1]Institute of Physics of Materials ASCR, Brno, Czech Republic — [2]Institute of Physics ASCR, Prague, Czech Republic — [3]Dept. of Condensed Matter Physics, Charles Univ., Prague, Czech Republic

We present results of *ab initio* calculations of the uniaxial magnetic anisotropy energy (MAE) in disordered body-centered tetragonal (bct) FeCo alloys as well as in alloys with a partial $L1_0$ order. The latter systems are simulated by a two-sublattice model with different sublattice compositions. The calculations employ the relativistic TB-LMTO method and the coherent potential approximation (CPA) which enables us to scan the entire intervals of both concentration variables and a broad range of the bct c/a-ratio. For the homogeneous alloys, we have found that the huge maximum MAE of about 800 μeV/atom, obtained previously in a simple virtual crystal approximation, overestimates the MAE of the random alloys in the CPA at least by a factor of four. This effect is due to the strong disorder-induced scattering in the minority spin channel, manifested by a strong broadening of the Bloch spectral functions near the Fermi energy. For the ordered alloys, we have found that the maximum $L1_0$ order compatible with a given Co concentration can bring the MAE up to high values around 500 μeV/atom. However, these high MAEs are significantly reduced by small perturbations of the perfect atomic order. Relation of the MAEs to the orbital magnetic moments will also be presented and discussed.

MA 25.3 Wed 10:00 H 0112

Magnetism without d Electrons from First Principles: Ground State and Spin Dynamics of the Diamond (111) Surface — •Guntram Fischer[1], Pawel Buczek[2], Wolfram Hergert[1], Evgeny Chulkov[3], Victor Tugushev[3], Leonid Sandratskii[2], and Arthur Ernst[2] — [1]University of Halle, Halle, Germany — [2]University of San Sebastian, San Sebastian, Spain — [3]Max Planck Institute for Microstructure Physics, Halle, Germany

The polar (111) surface of diamond has been studied within the framework of density functional theory using a KKR Greens Functions formalism. In agreement with experiment [1], we find an antiferromagnetic ground state driven by a Stoner instability in the manifold of p states. The spin-flip spectrum is determined from time dependent density functional theory [2]. The magnon dispersion is also analyzed in the frozen magnon approach and the Néel temperature is estimated using Monte Carlo simulations [3].

[1] Ramaker *et al.*, Solid State Comm. **63**, 335 (1987)
[2] Buczek *et al.*, PRL **102**, 247206 (2009)
[3] Fischer *et al.*, PRB **80**, 014408 (2009)

MA 25.4 Wed 10:15 H 0112

Electronic structure of ferromagnetic Heusler compounds from meta-GGA density functionals — •Markus Meinert, Jan Schmalhorst, and Günter Reiss — Dünne Schichten und Physik der Nanostrukturen, Fakultät für Physik, Universität Bielefeld, 33501 Bielefeld

Modern meta-GGA density functionals have recently been implemented self-consistently within the GPAW code [1]. We apply the non-empirical revTPSS [2] and the highly parametrized M06-L [3] functionals to the electronic structure problem of ferromagnetic Heusler compounds and other test cases. Changes in the description of the ferromagnetic or half-metallic ground states with respect to LSDA or PBE results will be discussed. [1] J. Enkovaara et al., J. Phys.: Condens. Matter 22, 253202 (2010) [2] J. P. Perdew et al., PRL 103, 026403 (2009) [3] Y. Zhao and D. G. Truhlar, J. Chem. Phys. 125, 194101 (2006)

15 min. break

MA 26: Micromagnetism / Computational Magnetics

Time: Wednesday 10:45–12:15 Location: H 0112

MA 26.1 Wed 10:45 H 0112

Multiscale simulation of micromagnetic singularities — •Christian Andreas[1,2], Attila Kákay[1], Ming Yan[1], and Riccardo Hertel[1,2] — [1]Peter Grünberg Institut, Electronic Properties, Forschungszentrum Jülich GmbH — [2]IPCMS, CNRS UMR 7504, Strasbourg, France

Several fundamental processes like bubble domain reversal and vortex core switching include the formation of Bloch points (BP) [1,2,3]. Such micromagnetic singularities pose limits to the validity of micromagnetic simulations and are usually treated within the realm of micromagnetism by using mesh refinement and extrapolations to zero-mesh size. The problem is the singularity of the exchange energy

density for BPs. A more realistic description is obtained by employing a multiscale model, which removes this singularity. We present a multiscale approach combining our micromagnetic code TetraMag with a Heisenberg model. This allows us to treat the exchange energy around BPs atomistically, by taking into account 10^6 atoms. The multiscale code exploits the computational power of Graphical Processing Units, thereby allowing us to extend the dynamic calculation to several nanoseconds on the micrometer length scale. The results elucidate to which extent BPs can be treated reliably with standard micromagnetic simulations. It is shown that the intrinsic overestimation of the BP energy of the continuum approximation is generally not counterbalanced by discretization effects which systematically underestimate it. [1] Hertel, R. et al., Phys. Rev. Lett. 98, 117201 (2007) [2] Thiaville, A. et al., Phys. Rev. B 67, 094410 (2003) [3] Döring, W. J. Appl. Phys. 39, 1006 (1968)

MA 26.2 Wed 11:00 H 0112

Chiral skyrmions as a new objects for magnetic storage technologies — •Nikolai Kiselev[1,2], Rudolf Schäfer[1], Alex Bogdanov[1], and Ulrich K. Rössler[1] — [1]IFW Dresden, Germany — [2]PGI and IAS, Forschungszentrum Jülich, Germany

Chiral Skyrmions (CS) in magnetic materials are topologically nontrivial, intrinsically stable magnetization configurations with particle-like properties. CS can arise in bulk and nanolayers of magnetic metals with intrinsic [1] or surface/interface [2,3] induced Dzyaloshinskii-Moriya interaction. CS drastically differ from other axisymmetric patterns induced by external dipole-dipole forces (bubble domains in nanolayers [3] and magnetic vortices in magnetic nanodots). They are extremely stable in wide ranges of magnetic field, geometrical and materials parameters (layer thickness, uniaxial anisotropy, magnetization). Our theoretical findings allow us to conclude that CS hold promise for a new paradigm in data storage devices that can be based on stable multidimensional solitons in chiral soft magnetic media.

[1] A. N. Bogdanov, A. D. Yablonsky Sov. Phys. JETP 68, 101 (1989), [2] X. Z. Yu et al. Nature Mat. 465, 901 (2010), [3] S. Heinze et al. Nature Phys. 7, 713 (2011), [4] N.S. Kiselev et al. Phys. Rev. Lett. 107, 179701 (2011); J. Phys. D: Appl. Phys. 44, 392001 (2011).

MA 26.3 Wed 11:15 H 0112

FMR in one-dimensional assemblies of magnetite nanocrystals and anisotropy evolution during growth — •Michalis Charilaou[1], Michael Winklhofer[2], Inés García-Rubio[3], and Andreas U Gehring[1] — [1]Earth and Planetary Magnetism, Department of Earth Sciences, ETH Zurich, 8092 Zurich, Switzerland — [2]Department of Earth and Environmental Science, University of Munich, 80333 Munich, Germany — [3]Laboratory of Physical Chemistry, Department of Chemistry and Applied Biosciences, ETH Zurich, 8093 Zurich, Switzerland

We have simulated FMR spectra of dilute suspensions of linear magnetite chains oriented randomly in space by modeling the chain as a Stoner-Wohlfarth-type rotation ellipsoid whose long axis coincides with an easy [111] axis of the cubic magnetocrystalline anisotropy system. The validity of the model is examined by comparing the results to explicit calculations of the interactions among the particles in the chain. The single ellipsoid model reproduces the experimentally observed FMR traits of such chain assemblies and can be related to the explicit chain model by adjusting the contribution to the uniaxial anisotropy along the chain axis to account for the magnetostatic interactions. Moreover, we investigate the evolution of anisotropy in these systems by fitting FMR signals at different growth-stages of the nanoparticles.

MA 26.4 Wed 11:30 H 0112

Temperature dependence of normal modes of ferrimagnets — •Frank Schlickeiser[1], Unai Atxitia[2], Soenke Wienholdt[1], Denise Hinzke[1], Oksana Chubykalo-Fesenko[2], and Ulrich Nowak[1] — [1]University of Konstanz, Germany — [2]Institute of material science Madrid, Spain

Recently, opto magnetic writing using a circularly polarised laser pulse in the 40 femtosecond range was successfully demonstrated [1-3]. It is assumed that the magnetisation switching is forced by a combination of a heat pulse and a magnetic field created due to the inverse Faraday effect. However, so far this effect has only been found for a special class of materials as the ferrimagnet GdFeCo. The reason for this restriction is not fully understood yet and therefore of great interest. We investigate the dynamics of a ferrimagnet by means of computer simulations as well as analytically, where the behaviour of the precession frequency as well as the effective damping parameter of the ferromagnetic and exchange mode is investigated. Both approaches coincide well for different strengths of an external magnetic field as well as for different strengths of an uni axial anisotropy. Our results, representing a generalisation and improvement of former approximated solutions (e.g.[4]), therefore build a basis for a better theoretical comparison to recent experiments[5]. [1] C.D.Stanciu et al., Phys. Rev. Lett.**99**, 047601 (2007), [2] A.V. Kimel, C. D. et al., Nature **435**, 655 (2010), [3] K.Vahaplar et al., Phys. Rev. Lett. **103**, 117201 (2009), [4] R.Wangsness, Phys. Rev. B **93**, 68 (1954), [5] C.D.Stanciu et al., Phys. Rev. B **73** , 220402 (2006).

MA 26.5 Wed 11:45 H 0112

Temperature-dependent Heisenberg exchange coupling constants from linking electronic-structure calculations and Monte Carlo simulations — •Danny Böttcher[1,2], Arthur Ernst[1], and Jürgen Henk[1,2] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

In various theoretical approximations Heisenberg exchange coupling constants J_{ij} are calculated for zero temperature and, therefore, provide e.g. too small a critical temperature T_C in comparison to the experimental value. In contrast, J_{ij} computed within the disordered local moments (DLM) formalism (i. e. for a paramagnetic sample), overestimate T_C. This mismatch leads to the idea of temperature-dependent exchange parameters.

We propose a method to calculate the temperature dependence of J_{ij} [1]. Within the DLM formalism, the magnetization and the J_{ij} are computed from first principles for any concentration c of the magnetic constituents. The exchange coupling constants are then used in Monte Carlo (MC) simulations to compute the temperature dependence of the magnetization for the given c. By comparing the magnetization from DLM calculations and from MC simulations we obtain a mapping of temperature versus concentration and eventually temperature-dependent J_{ij}. The approach which is applied to bulk Fe and Co can for example improve critical exponents.

[1] D. Böttcher, A. Ernst, and J. Henk, J. Magn. Magn. Mat. **324** (2012) 610.

MA 26.6 Wed 12:00 H 0112

Magnetic Force Microscopy on single crystalline Fe70Pd30 ferromagnetic shape memory films — •Anja Graumann[1], Yanhong Ma[1], Alexander Malwin Jakob[1,2], Frank Frost[1], and Stefan Georg Mayr[1,2] — [1]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstr. 15, 04318 Leipzig, Germany — [2]Translationszentrum für Regenerative Medizin und Fakultät für Physik und Geowissenschaften, Universität Leipzig, 04318 Leipzig, Germany

Fe70Pd30 ferromagnetic shape memory thin films of 500 nm thickness grown on MgO (100) single crystal substrates at approximately 900 °C show a twin-related relief at the sample surface imaged by scanning electron and atomic force microscopy. Using X-ray diffraction measurements with Cu Kα radiation the existance of a martensitic face centered tetragonal phase at room temperature - a necessary condition for the shape memory effect - could be confirmed. To characterize micromagnetic properties, magnetic force microscopy has been performed. Central focus lies on correlations between magnetic and structural properties of the film. The measurements are interpreted with the help of micromagnetic simulations, which reveal a complex magnetic structure governed by shape and crystallographic anisotropies. This work is funded by the German Research Foundation.

MA 27: Half-metals and Oxides (jointly with TT)

Time: Wednesday 9:30–12:15 Location: EB 202

MA 27.1 Wed 9:30 EB 202

Scalable Exchange Bias Effect in $La_{0.66}Sr_{0.33}MnO_{3-x}/SrTiO_3$ thin films — •Daniel Schumacher[1], Alexandra Steffen[1], Jörg Voigt[1], Jürgen Schubert[1], Hailemariam Ambaye[2], Valeria Lauter[2], John Freeland[3], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Spallation Neutron Source, Oak Ridge National Laboratory, Oak Ridge, TN 37831, USA — [3]Advanced Photon Source, Argonne National Laboratory, Argonne, IL 60439, USA

We present an Exchange Bias (EB) effect of controllable size in $La_{0.66}Sr_{0.33}MnO_{3-x}/SrTiO_3$ (LSMO/STO) thin films. Samples have been prepared by Pulsed Laser Deposition and High-Pressure Sputter Deposition in oxygen atmosphere at different oxygen pressures. Increased out-of-plane lattice parameters of the LSMO layers and reduced Curie temperatures indicate oxygen deficiencies in the samples grown at lower oxygen pressures. Whereas the growth at high pressures does not lead to an EB effect, we found an increase of the EB and the coercive fields with decreasing oxygen pressure. Polarized Neutron Reflectometry and X-ray Resonant Magnetic Scattering has been performed to analyze the magnetic depth profile. A layer without net magnetization in LSMO at the interface to STO has been detected in an exchange-biased sample, but not in the non-exchanged-biased one. Hence, an antiferromagnetic structure in this region could be present, which causes the EB effect in this system. A possible explanation is given based on the phase diagram of LSMO.

MA 27.2 Wed 9:45 EB 202

Temperature-dependent magnetic properties of cubic $La_{0.7}Sr_{0.3}MnO_3/SrRuO_3$ from first principles — •Danny Böttcher[1,2], Arthur Ernst[1], Igor Maznichenko[2], and Jürgen Henk[1,2] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

Heterostructures of an antiferromagnetic manganite and an itinerant ferromagnet, e. g. $La_xSr_{1-x}MnO_3$ combined with $SrRuO_3$, exhibit fascinating properties due to the interplay between exchange coupling, magnetocrystalline anisotropy, and interfacial quality [1].

We report on a first-principles study of cubic $La_{0.7}Sr_{0.3}MnO_3$/-$SrRuO_3$ and on Monte Carlo simulations in the framework of a classical Heisenberg model. The exchange parameters of the latter as well as the magnetocrystalline anisotropy constants are calculated from first principles. The spin Hamiltonian includes in addition the dipole-dipole interaction and an external magnetic field.

We focus on the temperature dependency of magnetization and hysteresis loops of this exchange-bias system. In particular, correlation functions reveal atom-resolved magnetic properties at the interfaces.

[1] M. Ziese *et al.*, Phys. Rev. Lett. **104** (2010) 167203.

MA 27.3 Wed 10:00 EB 202

Strained thin films of $LaSrMnO_4$ grown by Pulsed Laser Deposition — •Mehran Vafaee Khanjani, Philipp Komissinskiy, Aldin Radetinac, Thorsten Bitsch, and Lambert Alff — Institute for Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

It is well known that charge and orbital ordering (COO) phenomena occur in a variety of manganese oxide compounds. In the single-layered Ruddlesden-Popper manganite $La_{1-x}Sr_{1+x}MnO_4$, the COO has been observed for $x = 0.5$ which is strongly related to the lattice constants ($a = 3.86$, $c = 12.42$ Å) and Mn-O bond length [1-3]. Strain in thin films affects the structure parameters and consequently the COO. For the first time, we report on the thin film deposition of $LaSrMnO_4$ using pulsed laser deposition. X-ray diffraction reveals the growth of either fully strained or totally relaxed thin films on (110) $NdGaO_3$ and (001) $LaSrAlO_4$ substrates. Such strained thin films with in-plane lattice constants close to the $x = 0.5$ compound ($a = 3.86$, $c = 12.87$) will be the base to study the strain dependence of orbital ordering e.g. by X-ray absorption techniques. The authors would like to thank DPG GK 1035.

[1] D. Senff et al, Phys. Rev. B 71, 024425 (2005). [2] R. Mahesh et al, J. Solid State Chem. 122, 448 (1996) [3] C. S. Hong et al, Chem. Mater. 13, 945 (2001).

MA 27.4 Wed 10:15 EB 202

Magnetic characterization of ferromagnetic LSMO layers on STO grown by different methods — •Martin Wahler[1], Christian Eisenschmidt[1], Nico Homonnay[1], Ionela Vrejoiu[2], Alek Dediu[3], Vasily Moshnyaga[4], and Georg Schmidt[1] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Max Planck Institute of Microstructure Physics, 06120 Halle, Germany — [3]Institute of Nanostructured Materials, ISMN-CNR, 40129 Bologna, Italy — [4]I. Physikalisches Institut, Friedrich-August-Universität Göttingen, 37077 Göttingen, Germany

$La_xSr_{(1-x)}MnO_3$ is widely used as a ferromagnetic electrode for example in organic spintronics. Its epitaxial thin films are well established in oxide heterostructures. For best performance in spintronics applications it is necessary to deposit layers with perfect crystallinity and good control of ferromagnetism and anisotropy. We have investigated LSMO thin films deposited on Strontiumtitanate by various methods namely pulsed laser deposition (PLD), pulsed plasma deposition (PPD) and metalorganic aerosol deposition (MAD). All samples show high crystalline quality as confirmed by X-ray diffractometry and reflectometry. SQUID magnetometry shows that in saturation the layers deposited by PLD and PPD yield similar magnetization values, while the value obtained from MAD samples is higher. Curie temperatures range from 280 K for PPD to $>$ 300 K for PLD and MAD grown samples. The anisotropy as determined by ferromagnetic resonance is uniaxial in plane at room and biaxial at lower temperatures.

MA 27.5 Wed 10:30 EB 202

Fundamental ab-initio studies of $SrRuO_3$, $SrTcO_3$ and $Sr_3Ru_2O_7$ including the observation of [001] surface properties concerning $Sr_3Ru_2O_7$ — •Marcel Hieckel[1,2], Cesare Franchini[3], Jiangang He[3], Florian Mittendorfer[1], Josef Redinger[1], and Raimund Podloucky[2] — [1]Institute of Applied Physics, Vienna University of Technology — [2]Institute for Physical Chemistry, Univ. Vienna — [3]Department for Computational Materials Physics, Univ. Vienna

Oxide perovskite materials attracted enormous attention because of a variety of intriguing physical properties. In this context, we present results of density functional theory (DFT) calculations for the bulk materials $SrRuO_3$, $SrTcO_3$ and $Sr_3Ru_2O_7$ and the [001] surface of $Sr_3Ru_2O_7$. For the exchange-correlation functional the generalized gradient approximation of Perdew-Burke-Ernzerhof [1] was used and further studies were made with post-DFT concepts such as hybrid functional [2] and GW approaches [3]. Structural, electronic and magnetic properties were investigated for all the systems. Furthermore, simulations of scanning tunneling microscopy experiments [4] were performed for the clean as well as the CO-covered Sr3Ru2O7 [001] surface.

Work supported by the Austrian FWF, project Nr. F4511-N16.

[1] J. P. Perdew, K. Burke, and M. Ernzerhof, Phys. Rev. Lett. 77, 3865 (1966). [2] A. V. Krukau et al., J. Chem. Phys. 125, 224106 (2006). [3] L. Hedin, Phys. Rev. 139, A796 (1965). [4] J. Tersoff and D. R. Hamann, Phys. Rev. B 31, 805 (1985).

15 min. break

MA 27.6 Wed 11:00 EB 202

p-Electron Magnetism in anion doped $BaTiO_{3-x}X_x$ (X=C,N,B). — Christoph Gruber[1], •Pedro Osvaldo Bedolla Velazquez[1], Josef Redinger[1], Peter Mohn[1], and Martijn Marsman[2] — [1]Vienna University of Technology, Gusshausstrasse 25-25a/134, 1040 Vienna, Austria — [2]University of Vienna, Sensengasse 8/12 1090 Vienna, Austria

We present VASP calculations using the HSE functional for carbon, nitrogen, and boron doped $BaTiO_{3-x}X_x$ (X=C,N,B). We calculate a 40-atom supercell and replace one oxygen atom by C,N, or B. For all three substituents we find a magnetically ordered groundstate which is insulating for C and N and halfmetallic for B. The changes in the electronic structure between the undoped and the doped case are dominated by the strong crystal field effects together with the large band splitting for the impurity p-bands. Using an MO picture we give an explanation for the pronounced changes in the electronic structure between the insulating non-magnetic state and the as well insulating

magnetic state for doped $BaTiO_3$. p-element doped perovskites could provide a new class of materials for various applications ranging from spin-electronics to magneto-optics.

MA 27.7 Wed 11:15 EB 202

Magnetic and Electrical Properties of the possibly Antiferromagnetic Half-metal Double Perovskite La_2CrWO_6 — •Mehran Vafaee Khanjani, Philipp Komissinskiy, Mehrdad Baghaie Yazdi, Anastasiya Kolchynska, and Lambert Alff — Institute for Materials Science, Technische Universität Darmstadt, 64287 Darmstadt, Germany

The combination of a magnetic ion (B-site) and a non-magnetic ion (B'-site) in double perovskites ($A_2BB'O_6$) can lead to an *induced* magnetic moment at the non-magnetic site [1-3]. Therefore, double perovskites are hot candidates in the search for compensated antiferromagnetic half-metals (AFM-HMs) which are considered to be useful for spintronics, supplying on the one hand, fully spin-polarized electrons, and on the other hand due to the antiferromagnetic configuration, they are magnetically stable. Following band structure calculations [4] and a simple ionic picture, La_2CrWO_6 is an AFM-HM candidate. However, as bulk material this compound is thermodynamically unstable. One way of synthesizing such a material is a thin film approach forcing W into a very unusual W^{3+} state. To our knowledge, we have synthesized for the first time La_2CrWO_6 by pulsed laser deposition. Crystal structure, magnetic and electrical properties are presented. The Authors would like to thank the DFG GK 1035.

[1] K. L. Kobayashi et al, Nature 395, 677 (1998). [2] Y. Krockenberger et al, Phys. Rev. B 75, 020404(R) (2007). [3] A. Winkler et al, New J. Phys. 11, 073047 (2009). [4] V. Pardo et al, Phys Rev B 80, 054415 (2009).

MA 27.8 Wed 11:30 EB 202

Cation distributions and its influence on magnetostrictive properties in inverse spinel ferrites $CoFe_2O_4$ and $NiFe_2O_4$ — •Daniel Fritsch and Claude Ederer — School of Physics, Trinity College Dublin, Ireland

Spinel ferrites $CoFe_2O_4$ (CFO) and $NiFe_2O_4$ (NFO) are both insulating ferrimagnetic oxides with a high magnetic ordering temperature and large saturation magnetisation. Moreover, CFO is a highly magnetostrictive material, i.e., it shows a large length change when exposed to a magnetic field.

The spinel structure consists of two magnetic sublattices, namely A- and B-sublattice, which in the *normal* spinel structure are solely occupied by one of the two cation species. An increasing exchange between the two cation species leads to the *inverse* spinel structure where two cation species are distributed over the B-sublattice. These different possible cation distributions over the B-sublattice strongly influence the total energy of these materials [1].

It has already been shown that density functional theory (DFT) calculations together with the Hubbard "+U" approach provide reliable insight in the structural and magnetic properties of these materials [2]. Here we present DFT total energy calculations for CFO and NFO with different possible cation distributions over the B-sublattice and their influence on the magnetostrictive properties. These results are compared to available experimental data.

[1] D. Fritsch and C. Ederer, Appl. Phys. Lett. **99**, 081916 (2011).
[2] D. Fritsch and C. Ederer, Phys. Rev. B **82**, 104117 (2010).

MA 27.9 Wed 11:45 EB 202

Zinc ferrite - magnetic thin films with highly tunable conductivity — •Kerstin Brachwitz, Katja Mexner, Michael Lorenz, Francis Bern, Michael Ziese, Pablo Esquinazi, and Marius Grundmann — Institut für Experimentelle Physik II, Universität Leipzig, Germany

Zinc ferrite ($ZnFe_2O_4$) has been investigated in several studies, especially because of its promising magnetic properties. However, also the electrical properties are remarkable and important for the application of $ZnFe_2O_4$ in spin filters and magnetic tunnel junctions. In this regard, $ZnFe_2O_4$ thin films were grown by pulsed-laser deposition. The substrate temperature T_S and the oxygen partial pressure $p(O_2)$ were varied for different samples in the range of $430°C \leq T_S \leq 730°C$ and $5 \cdot 10^{-5} \leq p(O_2) \leq 10^{-2}$ mbar, respectively.

The electrical conductivity of the resulting $ZnFe_2O_4$ films can be tuned over 7 orders of magnitude in a range from 10^{-5} to 10^2 S/m by varying T_S [1]. The conductivity of such thin films is thermally activated with activation energies between 70 and 120 meV. The free carrier concentration and their mobility were determined by anomalous Hall effect measurements. Thin films with the largest conductivity exhibit values of about $n = 10^{20}\,cm^{-3}$ and $\mu = 0.07\,cm^2/Vs$.

Furthermore, the structural properties were investigated by X-ray diffraction. These measurements revealed an increasing a-lattice constant with increasing conductivity, indicating a disorder- and vacancy-induced conduction mechanism.

[1] M. Lorenz *et al.*, Phys. Status Solidi RRL **5**, 438 (2011)

MA 27.10 Wed 12:00 EB 202

Giant spontaneous magnetostriction in $FeTiO_3$: effects of repulsive dipole-dipole interactions — •Michalis Charilaou[1,2], Denis Sheptyakov[3], Jörg F Löffler[2], and Andreas U Gehring[1] — [1]Earth and Planetary Magnetism, Department of Earth Sciences, ETH Zurich, 8092 Zurich, Switzerland — [2]Metal Physics and Technology, Department of Materials, ETH Zurich, 8093 Zurich, Switzerland — [3]Laboratory for Neutron Scattering, Paul Scherrer Institute, 5232 Villigen, Switzerland

We present neutron diffraction data and magnetic susceptibility measurements of $FeTiO_3$ ilmenite at temperatures of $1.9\ K < T < 300\ K$. The magnetic susceptibility shows typical antiferromagnetic behavior with a long-range ordering at the Néel temperature $T_N = 58(1)$ K. The magnetic peaks of the neutron diffraction patterns reveal a canted antiparallel spin configuration along the c axis of the R-3 structure. The lattice dimensions decrease with decreasing temperature, but upon the onset of order the c-dimension grows strongly, and at T = 1.9 K exhibits a spontaneous magnetostriction of $2.46(9)\ 10^{-3}$. The observations are interpreted as the result of repulsive dipole-dipole interactions between neighboring Fe-rich layers and the onset of spin-orbit coupling at T_N.

MA 28: Keynote Talk by Ivan Schuller

Time: Wednesday 14:00–14:45 Location: H 0105

Keynote Talk MA 28.1 Wed 14:00 H 0105

A Comprehensive Study of Exchange Bias: Towards a universal explanation. — •Ivan Schuller — Physics Department and Center For Advanced Nanoscience, UCSD, La Jolla, Ca. 92093, USA

Magnetic nanostructures produce interesting new phenomena and novel applications when the physical size becomes comparable to relevant magnetic length scales.

In the *Exchange Biased* configuration in which a ferromagnetic nanostructure is in contact with an antiferromagnet a variety of unusual phenomena arise; the reversal mode of the ferromagnet changes in a substantial fashion, the superparamagnetic transition temperature is strongly affected and there is a noticeable change in the microscopic spin configuration. I will describe a comprehensive study, in which we studied these phenomena in nanostructured ferromagnets prepared by MBE and sputtering combined with lithography and self-assembly. These experiments include magnetotransport, magnetization, Magneto-Optic Kerr effect, neutron and synchrotron scattering, and ultrafast pump-probe measurements. I will present a general explanation of the origin of exchange bias which emerges from many experiments taken together.

Work done in collaboration with R. Morales, M. Velez, O. Petracic, I. V. Roshchin, X. Batlle, J. M. Alameda, M. Kovylina, M. Erekhinsky, J. E. Villegas, A. Labarta, A. Porat, and S. Bar-Ad. Work supported by the US Department of Energy and US Air Force Office of Scientific Research.

MA 29: Poster related to SYXD: "100 Years since the Laue Experiment: Topical Aspects of Diffraction and Scattering" (jointly with KR, BP, CPP, DF, GP, MI, MM)

Time: Wednesday 15:00–17:30 Location: Poster E

MA 29.1 Wed 15:00 Poster E

Clip - The Cologne Laue Indexation Program — •Olaf J. Schumann — Fraunhofer-Institut für Naturwissenschaftlich-Technische Trendanalysen, Euskirchen, Deutschland — II. Physikalisches Institut, Universität zu Köln, Germany

The Cologne Laue Indexation Program is a software for the analysis and simulation of Laue images.

Clip features a modern graphical user interface, could read a large variety of image formats and allows to mark spots *and* zones in a recorded image. These could be used for automatic indexation of the image for arbitrary crystal symmetries and refinement of lattice constants and projection plane parameters. Clip helps with the alignment of the crystal to a desired orientation. It is an open source software (GPL) written in C++ and the cross platform toolkit Qt and runs on Windows, Linux and Mac OS X.

MA 29.2 Wed 15:00 Poster E

A new access to extinction corrections — •Anne K. Hüsecken and Ullrich Pietsch — Naturwissenschaftlich Technische Fakultät, Fachbereich Physik, Universität Siegen, D-57068 Siegen, Germany

In x-ray crystal structure analysis a problem, called extinction, occurs due to multiple scattering in crystals. Over the years several extinction correction theorems have been formulated, but the used parameters have never been proved to be valid for a certain crystal under investigation. Perfect crystals scatter according to the dynamical theory (I~|F|) and imperfect crystals or ideal mosaic crystals due to the kinematical theory (I~|F|*). In most cases, the measured intensities of real crystals are in between both cases and an extinction correction is needed to fulfil the kinematic approach. Present theories dealing with extinction corrections are based on the approach of a mosaic crystal and describe x-ray scattering in terms of the kinematic approach using certain "correction terms" to implement the structure of a real crystal. The mosaic blocs within a real crystal are misorientated to each other and are affected by lattice strain. In addition both 3D shape and size of the blocs are not known. All these parameters can be determined by high-resolution x-ray diffraction techniques performing ω- and ω-2θ-scans through certain reciprocal lattice points. The measured parameters can be used to determine extinction. Our aim for crystallography is to perform these scans only for a few reflections, make a short analysis, to get the size, misorientation and lattice strain of the mosaic blocs. With these parameters it should then be possible to decide which one is the best extinction correction to use.

MA 29.3 Wed 15:00 Poster E

Evaluation of interfacial orientation information from 3D X-Ray diffraction contrast tomography in and its application in a mesoscale grain coasening model — •Melanie Syha, Fabian Sehn, Andreas Trenkle, and Daniel Weygand — Karlsruher Institut für Technologie, IAM

The orientation information from 3D X-Ray diffraction contrast tomography investigations in polycrystalline $SrTiO_3$ ceramics was evaluated before and after annealing. Special emphasis was put on local interface orientations, showing a preference for <100> orientated interfaces that increases during microstructural evolution. Moreover the data was used to investigate orientation dependent relative interface mobilities. The results are discussed in the context of the abnormal growth behavior found in $SrTiO_3$ and used to adapt a mesoscale grain coarsening model to more realistic simulations of microstructure evolution in this material.

MA 29.4 Wed 15:00 Poster E

Inter-layer disorder in sodium cobaltate — •David Jonathan Pryce Morris[1], Alan Tennant[1,2], Klaus Seiffert[1,3], Esther Dudzik[1], Dharmalingam Prabhakaran[4], Jon Goff[5], Michel Roger[6], and Jon Wright[7] — [1]Helmholtz-Zentrum Berlin, Germany — [2]TU-Berlin, Germany — [3]Kiel University, Germany — [4]Oxford University, UK — [5]Royal Holloway, University of London, UK — [6]CEA-Saclay, France — [7]ESRF, France

Sodium Cobaltate is a layered material which has been studied as a potential battery material, has shown good thermoelectric properties and becomes superconducting when hydrated. The physical properties are dependent on sodium content and the ordering of sodium ions. Sodium ordering in NaxCoO2 has previously been observed to have long-range order. Using x-ray diffraction we have observed a phase with long-range in-plane order and inter-layer disorder. Here we will present the data giving a possible structural interpretation.

MA 30: Focus Session "Spin Currents in Magnetic Nanostructures", Organization: Mathias Kläui (Univ. Mainz)

Time: Wednesday 15:00–18:45 Location: EB 301

Invited Talk MA 30.1 Wed 15:00 EB 301

Spin transfer in conducting and insulating magnetic systems — •Yaroslav Tserkovnyak — University of California, Los Angeles

I will review recent developments in the theory of current-induced magnetization dynamics and reciprocal pumping phenomena. Following early realization of the importance of these effects in layered magnetic structures, much attention has been recently paid to continuous ferromagnetic systems with strong magnetic textures (such as domain walls, vortices, skyrmion lattices etc.) as well as magnetic phases with antiferromagnetic or other magnetic order. Magneto-thermoelectric phenomena have furthermore generated a flurry of experimental and theoretical activities, and the field has branched out to encompass new materials, both conducting and (trivially or topologically) insulating. Despite the apparent diversity of underlying magnetic orderings, materials, phases, and nanoscale configurations, it turns out there are very simple guiding principles that allow one to streamline phenomenological and microscopic understanding, put forward insightful experimental predictions, and propose applications, as will be discussed in this talk.

Topical Talk MA 30.2 Wed 15:30 EB 301

Spin pumping with photons and phonons — •Mathias Weiler[1], Franz D. Czeschka[1], Hans Huebl[1], Frederik S. Goerg[1], Matthias Althammer[1], Lukas Dreher[2], Martin S. Brandt[2], Rudolf Gross[1], and Sebastian T. B. Goennenwein[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Walter Schottky Institut, Technische Universität München, Garching, Germany

Spin pumping and the inverse spin Hall effect are key phenomena to generate and detect pure spin currents. In a systematic study of the photon-driven spin pumping effect in a series of ferromagnet/normal metal hybrids, we found that the inverse spin Hall voltage V_{DC} scales with the magnetization precession cone angle, irrespective of the particular properties of the ferromagnet [1]. In a complimentary approach, we show that spin pumping can also be driven by exploiting the purely virtual magnetic driving field caused by coherent phonons in magnetoelastic media [2]. To this end, we excite a Co/Pt thin film bilayer by radio frequency surface acoustic wave pulses and measure V_{DC}. In our time-resolved experiments, we can disentangle photon- and phonon-driven contributions to V_{DC} and find evidence for resonant spin current generation in the exclusive presence of an elastic excitation.

This demonstrates that spin pumping in ferromagnet/normal metal hybrids is a generic phenomenon that can be consistently modeled irrespective of magnetic material and excitation mechanism.

[1] F. D. Czeschka *et al.* Phys. Rev Lett. **107**, 046601 (2011)
[2] M. Weiler *et al.* (2011) arXiv:1110.1187

Invited Talk MA 30.3 Wed 16:00 EB 301

Generation of superdiffusive spin-currents through femtosecond laser excitation of ferromagnetic/non-magnetic hybrid structures — •Peter M. Oppeneer[1], Marco Battiato[1], Karel Carva[1,2], and Pablo Maldonado[1] — [1]Uppsala University, S-751 21 Uppsala, Sweden — [2]Charles University, 12116 Prague, Czech Republic

The process of femtosecond laser excitation in a metallic ferromagnet is analyzed theoretically. Laser excitation creates spin-polarized hot electrons with fast transport characteristics. We develop a semi-classical model for transport of such excited electrons, treating the multiple electronic collisions exactly /1/. The derived transport equation is solved numerically and it is shown that the spin-transport is neither diffusive nor ballistic, it is superdiffusive. Due to distinct lifetimes of majority and minority electrons effectively a spin-polarized current is created. Considering ferromagnetic/non-magnetic layer structures where the ferromagnetic layer is laser excited, and solving the resulting spin-dynamics numerically in the time-domain, we show that injection of a superdiffusive spin-current in the non-magnetic layer is achieved. The injected spin-current consists of hot, mobile majority spin electrons and is nearly 100% spin-polarized. It could be used as a means to accomplish domain wall movement or in spin-based electronics.
/1/ M. Battiato, K. Carva, P.M. Oppeneer, Phys. Rev. Lett. **105**, 027203 (2010).

MA 30.4 Wed 16:30 EB 301

Spin filtering in spinel ferrite $CoFe_2O_4$ — •Michael Foerster, Diego F. Gutierrez, and Josep Fontcuberta — Institut de Ciència de Materials de Barcelona ICMAB-CSIC, Campus de la UAB, 08193 Bellaterra, Catalonia, Spain

Spin filtering promises an effective approach to generate highly spin polarized currents, e.g. for spin injection. Spin filters are realized by tunneling barriers from magnetic insulators, where the exchange split band gap results in spin dependent transmission probabilities. Moodera et al. validated this concept using Europium chalcogenides [1].

However, these compounds have low Curie temperatures and only few magnetic insulators with transitions clearly above room temperature exist. Spinel ferrites, e.g. $CoFe_2O_4$ (T_C = 790 K), are considered most promising candidates. Using point contact spetroscopy, the spin filtering efficiency of $CoFe_2O_4$ thin films on $SrRuO_3$ bottom electrodes has been evaluated [2], but is found to be much below expectations based on calculated band structures. The possible reasons for this low filtering efficiency, which is common for reports on spinel ferrites, are addressed by probing two key properties of ultrathin films: transport, using conducting AFM [3], and magnetic properties when grown on different substrates [4], revealing the points that have to be considered for further optimization.

[1] J.S. Moodera et al., J. Phys.: Condens. Matter 19, 165202 (2007).
[2] F. Rigato et al., Phys. Rev. B 81, 174415 (2010).
[3] M. Foerster et al., Appl. Phys. Lett. 97, 242508 (2010).
[4] M. Foerster et al., Phys Rev. B, published online.

MA 30.5 Wed 16:50 EB 301

Lateral Spin Valves: Transport Measurements and Magnetization Dynamics — •Guido Meier — Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

We study spin-dependent transport in lateral spin-valve devices with tunnel barriers at the interfaces between normal and ferromagnetic metals. Different total conductivities per cross-sectional area are achieved by variation of the oxygen pressure, the oxidation time, and the thickness of the oxidized interface metal layer. We find that with decreasing tunnel conductance the amplitude of the nonlocal spin-valve effect increases by two orders of magnitude up to saturation [1]. Currently the combination of magnetization dynamics and spin transport often addressed as spin-pumping is of great interest [2]. First experimental results including the detection of pure spin currents have been presented [3]. Here we aim at an all-metal lateral spin valve, where the spins are injected into an adjacent normal metal via a ferromagnet with precessing magnetization at resonance. We present a study of the magnetization dynamics of ferromagnetic electrodes. The cone angles of the precessional motion of the magnetization at resonance are determined by measurements of the anisotropic resistance of a single electrode. Large cone angles of up to 13.7 degree are observed [4].

[1] A. Vogel et al., APL 94, 122510 (2009); [2] Y. Tserkovnyak et al., PRL 88, 117601 (2002); [3] M.V. Costache et al., PRB 78, 064423 (2008); [4] N. Kuhlmann et al., PRB submitted (2011).

20 min. break

MA 30.6 Wed 17:30 EB 301

All-electrical spin injection and detection in lateral Co_2FeSi/GaAs devices — •Pawel Bruski, Rouin Farshchi, Oliver Brandt, Jens Herfort, Abbes Tahraoui, and Manfred Ramsteiner — Paul-Drude-Institut Berlin, Hausvogteiplatz 5-7, 10117 Berlin, Germany

The ferromagnetic Heusler alloy Co_2FeSi is closely lattice matched to GaAs and is predicted to be half-metallic, meaning that electrons at the Fermi level are 100% spin-polarized. We demonstrate the successful all-electrical injection and detection of spins in the Co_2FeSi/GaAs hybrid system using a lateral device structure.

The electrical spin detection is achieved through a nonlocal spin-sensitive measurement, which separates the charge and current paths to exclude parasitic effects such as local Hall effects. Evidence for electrical spin injection and detection has been obtained by spinvalve and Hanle measurements, where the latter presents the most robust proof for all-electrical spin injection and detection by revealing the spin precession in an external magnetic field.

A fit based on a one-dimensional spin drift-diffusion model, which takes into account spin relaxation and precession, is in excellent agreement with our experimental Hanle data. A spin lifetime in GaAs of several ns and a spin injection efficiency of 16% are obtained from the fit, with the latter value being close to results acquired from optoelectronic devices consisting of the Co_2FeSi/(Al,Ga)As hybrid system.

MA 30.7 Wed 17:45 EB 301

Optimization of spin injection and detection in lateral nanostructures by geometrical means — •Ondřej Stejskal, Jaroslav Hamrle, and Jaromír Pištora — Department of Physics and Nanotechnology Centre, VSB - Technical University of Ostrava, Czech Republic

Lateral nanostructures are important branch of spintronic devices as they extend possibilities of simpler perpendicular devices. For efficient operation of lateral devices, it is important to maximize spin injection and spin detection efficiency. Several approaches were proposed, such as design of new injector/detector materials (e.g. half metals), or using spin-barried between spin injector/detector and spin conductor (such as MgO barrier).

Here, we suggest alternative optimization of spin injection and detection, by engineering the dimensions of the lateral device. For example, we show that spin injector efficiency can be increased by reduction of cross-sectional area of junction between injector and spin conductor or by increasing the cross-section of the spin-conductor. Furthermore, in lateral spin-valve structures, the detection is provided by second FM element (detector). Depending on purpose of the device, different quantities may need to be optimized, such as spin voltage on detector (in case the purpose is reading of the magnetic state of the detector) or spin current flowing into the detector (in case the spin-manipulation of the detector is important). We discuss how those quantities may be optimized by variation of the cross-sectional area, resistivity and polarization of the junction between detector and spin conductor.

MA 30.8 Wed 18:00 EB 301

Wave-diffusion theory of spin transport in metals after ultrashort-pulse excitation — •Steffen Kaltenborn[1], Yao-Hui Zhu[2], and Hans Christian Schneider[1] — [1]University of Kaiserslautern, Kaiserslautern, Germany — [2]Beijing Technology and Business University, Beijing, China

We present theoretical results for spin and charge-current dynamics after ultrafast spin-polarized excitation in a normal metal. It is first shown analytically how the macroscopic wave-diffusion equations [1] provide a unified description of ballistic and diffusive properties of spin and charge transport including the "intermediate" regime in which transport is characterized by both ballistic and diffusive features. These equations are then applied to a simplified model of ultrafast excitation of spin polarized carriers in gold films of thickness up to several hundred nanometers. If one assumes spin-dependent momentum relaxation times, the computed dynamics of the spin and charge density at the surface of the films of varying thickness qualitatively reproduce recent measurements [2], which were interpreted as arising from the transition from ballistic to diffusive transport. Our calculations support this interpretation, and indicate that the signatures observed in the experiment are quite generic for ultrashort timescales and thin films because they can be traced back to a combination of ballistic and diffusive properties of spin and charge transport.

[1] Y.-H. Zhu, B. Hillebrands, and H. C. Schneider, Phys. Rev. B 78, 054429 (2008)
[2] A. Melnikov et al., Phys. Rev. Lett. 107, 076601 (2011)

MA 30.9 Wed 18:15 EB 301

Direct detection of magnon spin transport by the inverse spin Hall effect — •Andrii Chumak, Benjamin Jungfleisch, Alexander Serga, Roland Neb, and Burkard Hillebrands — Fachbereich Physik and Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany

The combination of the spin pumping effect with the inverse spin Hall effect (ISHE) allows the use of spin waves (or magnons) for the carrying of signals in spintronic devices. In spite of sufficient progress in these studies, no magnon-carried spin transfer has yet been shown directly. We use a spatially separated inductive spin-wave source and an ISHE detector to demonstrate the signal transport by travelling magnons in a time resolved experiment. The setup comprises a 2.1 μm thick YIG waveguide with a 10 nm thick (200 μm x 3 mm) Pt strip deposited on the top. The YIG waveguide is magnetized along its long axis by applying an external bias magnetic field of 1754 Oe. In order to excite short spin-waves packets the 50 μm wide Cu microstrip antenna is placed at a distance of 3 mm from the Pt strip. While propagating under the Pt layer, the spin-wave packet generates a spin current in it due to spin pumping, and the delayed ISHE DC pulse is detected. The delay appears due to the finite spin-wave group velocity and proves the magnon nature of the spin transport. The experiment suggests to utiliza spin waves for the transfer of spin information over macroscopic distances in spintronic devices and circuits. Besides, the contribution of secondary excited magnons to the ISHE voltage is refered in our studies.

MA 30.10 Wed 18:30 EB 301

Light-induced spin pumping in two-dimensional electron systems with random Rashba spin-orbit interaction — •Vitalii Dugaev[1,2], Michal Inglot[2], Evgeny Sherman[3], Jamal Berakdar[1], and Jozef Barnas[4] — [1]Martin-Luther-Universität Halle-Wittenberg, Halle, Deutschland — [2]Rzeszow University of Technology, Rzeszow, Poland — [3]Universidad del Pais Vasco, Bilbao, Spain — [4]Adam Mickiewicz University, Poznan, Poland

Rashba spin-orbit interaction plays an important role in two-dimensional electron systems leading to numerous spin-dependent effects like spin relaxation or anomalous and spin Hall effects. In some cases, the Rashba interaction can be strongly fluctuating in space with zero average value. The most important examples are some symmetric sandwiched structures with semiconductor quantum wells. We consider several different two-dimensional systems with random Rashba interaction. Besides the simple model with a parabolic energy spectrum we also analyze the Dirac model of electrons in graphene. We show that in the case of free-standing graphene the main source of spin-orbit interaction is related to corrugated and rippled surface. Our calculations demonstrate that in all cases the electromagnetic radiation can be used to effectively generate charge and spin densities. The mechanism of spin polarization under electromagnetic radiation is related to fluctuations of Rashba spin-orbit interaction strongly coupled to the electromagnetic field. We believe that this effect of spin pumping can be used in spintronics applications for optically-controlled generation and manipulation of the spin currents.

MA 31: Magnetic Imaging

Time: Wednesday 15:00–16:00 Location: BH 243

MA 31.1 Wed 15:00 BH 243

Fast magnetic imaging using nitrogen-vacancy centers — •Florestan Ziem[1], Steffen Steinert[1], Andrea Zappe[1], Liam Hall[2], Lloyd Hollenberg[2], Nicolas Götze[1], and Jörg Wrachtrup[1] — [1]3rd Physics Institute, University of Stuttgart, 70569 Stuttgart, Germany — [2]School of Physics, University of Melbourne, Victoria 3010, Australia

With the aim to image weak electromagnetic signals at high spatial resolution, e.g. signals of a neuron cell, we investigated the potential of an ensemble of negatively charged nitrogen-vacancy centers (NVs) as a sensor. The NV is a color center in diamond consisting of a substitutional nitrogen and an adjacent vacant lattice site. One of the remarkable features of the NV is, that its magnetic spin state can be optically polarized and read out via its fluorescence at ambient conditions. From Zeeman shifts and coherence lifetimes, the presence of static and fluctuating magnetic fields can be deduced. To detect the fluorescence signal, we employ a wide-field approach, where a CCD camera allows us to capture the fluorescence of a 60 μm x 60 μm area of densely implanted NVs within milliseconds. For samples placed on the diamond surface, this setup thus allows for fast, diffraction limited sensing, while being potentially non-invasive. On the other hand, integrating over the full sensor area allows for the detection of low concentrations of magnetic species in homogenous samples. The capabilities of the NV sensor in the spatially resolving and the integrating measurement mode will be evaluated.

MA 31.2 Wed 15:15 BH 243

Pushing the spatial resolution of X-ray holographic microscopy below 20nm — •Judith Bach[1], Robert Frömter[1], Daniel Stickler[1], Matthias Hille[1], Hans Peter Oepen[1], Leonard Müller[2], Christian Gutt[2], Gerhard Grübel[2], Carsten Tieg[3], and Flora Yakhou-Harris[3] — [1]Universität Hamburg, Germany — [2]DESY, Hamburg, Germany — [3]ESRF, Grenoble, France

Imaging techniques are one of the most direct and intuitive accesses to investigate the magnetic behavior of ferromagnets. On the nanoscale, soft X-ray Fourier-Transform Holography(FTH) [1] is a powerful lensless method that provides element specificity and fast image reconstruction. As one of many improvements over the last years, a new microscope setup was developed extending the method's applicabilty to a broader variety of samples [2]. We present experimental results on resolution achieved at the ID 08 soft X-ray beamline of the ESRF. The results demonstrate a significant improvement of the spatial resolution down to 18 nm. To a large part this was achieved by a smaller sample-camera distance, thus increasing the acceptance in q-space. An additional contribution comes from using so-called HERALDO [3] masks. In contrast to standard FTH masks with circular reference holes, they contain reference slits. We report on the first application of HERALDO to magnetic imaging and compare it to standard FTH.

[1] S. Eisebitt, *et al.*, Nature **432**, 885 (2004).
[2] D. Stickler, *et al.*, Appl. Phys. Lett. **96**, 042501 (2010).
[3] D. Zhu, *et al.*, Phys. Rev. Lett. **105**, 043901 (2010).

MA 31.3 Wed 15:30 BH 243

New approach for the magnetic characterization of isolated nanoparticles with nanometer lateral resolution — •Stephan Block[1] and Christiane A. Helm[2] — [1]ZIK HIKE - Zentrum für Innovationskompetenz Humorale Immunreaktionen bei kardiovaskulären Erkrankungen, Fleischmannstr. 42 - 44, D-17487 Greifswald, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt Universität, Felix-Hausdorff-Str. 6, D-17487 Greifswald, Germany

We present a new atomic force microscopy (AFM) method, which allows the simultaneous measurement of magnetic and geometric properties of nm-sized objects (nanoparticles, e.g. colloids or clusters). Basically, an oscillating magnetic field is applied to the sample and the surface magnetization is probed using a magnetic AFM-tip. Spatial changes of the magnetic flux density affect the vibration amplitude and thus, (dynamic) magnetic properties of the surface can be determined with lateral resolution of few nanometers. We will give a brief introduction of the measurement principles and evaluate the feasibility by characterizing isolated diamagnetic and superparamagnetic nanoparticles on the nm-scale. Hence, it becomes possible to distinguish different materials during AFM measurements by their magnetism (e.g. superparamagnetism or diamagnetism).

MA 31.4 Wed 15:45 BH 243

Monopole-like probes for Magnetic Force Microscopy — •Thomas Mühl, Julia Körner, Albrecht Leonhardt, and Bernd Büchner — Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden

Magnetic force microscopy (MFM) is a powerful method dedicated to

map stray-field distributions, or more precisely, derivatives in space of magnetic field components. Recently we developed a sensor for quantitative MFM based on an iron-filled carbon nanotube (FeCNT). The long Fe nanowire contained in the carbon nanotube can be regarded as an arrangement of two well-separated magnetic monopoles of which only the monopole nearest to the sample surface is involved in the imaging process. The monopole-like character of FeCNT MFM probes allows easy calibration [1]. Moreover, as compared to conventional coated MFM probes, FeCNT sensors show remarkable magnetic stability in external in-plane fields [2].

In this work, we present an improved MFM sensor design again employing FeCNTs. By using higher order flexural vibration modes of the cantilever the new sensor provides both in-plane and perpendicular sensitivity for quantitative MFM measurements. We discuss sensitivity issues related to the dynamic spring constants of the sensor.

[1] F. Wolny, T. Mühl, U. Weissker, K. Lipert, J. Schumann, A. Leonhardt, and B. Büchner, Nanotechnology 21, 435501 (2010).

[2] F. Wolny, T. Mühl, U. Weissker, A. Leonhardt, U. Wolff, D. Givord, and B. Büchner, J. Appl. Phys. 108, 01398 (2010).

MA 32: Joint Session "Surface Magnetism I" (jointly with O)

Time: Wednesday 16:00–19:00 Location: BH 243

MA 32.1 Wed 16:00 BH 243

Observation and quantitative evaluation of superparamagnetic behavior utilizing magnetic exchange force microscopy and spectroscopy — •Schwarz Alexander, Schmidt Rene, and Wiesendanger Roland — Institute of Applied Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

Magnetic exchange force microscopy (MExFM) and spectroscopy (MExFS) can resolve magnetic surfaces and probe the distance dependence of the magnetic exchange interaction with atomic resolution [1,2]. Here we show that the distance dependence of the magnetic exchange interaction can be utilized to modify the barrier height between two magnetization directions in a well-controlled manner. Contrast reversals observed with magnetically coated tips during imaging an antiferromagnetic surface show that tips can switch their magnetization direction by 180°. Since the magnetic exchange interaction is distance dependent, switching rate, lifetimes and the barrier height between the two states are distance dependent as well. Modeling the tip apex as superparamagnetic cluster with uniaxial anisotropy but otherwise independent of the rest of the tip, allows quantifying the energy barrier between both states as well as the zero field anisotropy. Moreover, the influence of a magnetic field via the additional Zeeman energy can be measured. Our study demonstrates the feasibility to observe dynamic magnetic processes utilizing magnetic exchange force microscopy and spectroscopy with atomic resolution.

[1] U. Kaiser et al., Nature 446, 522 (2007).

[2] R. Schmidt et al., Phys. Rev. Lett. 106, 257202 (2011).

MA 32.2 Wed 16:15 BH 243

Possible detection of spin contrast on NiO(001) by AFM using a qPlus sensor with a bulk iron tip — •Florian Pielmeier and Franz J. Giessibl — Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

Magnetic exchange force microscopy was first demonstrated with atomic resolution on the (001) surface of the antiferromagnetic insulator nickel oxide at low temperatures [1]. In order to detect spin contrast on NiO(001), the tips had to be magnetically polarized by an external field of 5 T [1-3].

Here, we observe spin contrast on NiO(001) at 4.3 K without an external field, using a bulk iron tip mounted on a qPlus sensor. However, magnetic contrast is only observed at a distance of about 10 pm further away than the distance where optimal chemical contrast is observed.

[1] U. Kaiser, A. Schwarz, R. Wiesendanger, Nature 446, 522 (2007)

[2] U. Kaiser, A. Schwarz, R. Wiesendanger, Phys. Rev. B 78, 104418 (2008)

[3] A. Schwarz, U. Kaiser, R. Wiesendanger, Nanotechnology 20, 264017 (2009)

MA 32.3 Wed 16:30 BH 243

First-principles study of the magnetic exchange interaction across a vacuum gap — •Cesar Lazo and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany

The miniaturization of spintronic devices towards the limit of single atoms calls for a quantification and understanding of the magnetic exchange interaction in atomic-scale junctions. Such a situation can be realized experimentally using a magnetic tip in an atomic force or scanning tunneling microscope. Here, we apply density functional theory to study the exchange interaction between tip and sample, i.e. across a vacuum gap. In particular, we choose the antiferromagnetic monolayer of Fe on W(001) as the sample system and consider different tips composed of Cr, Fe, and Cr/Fe alloys. We calculate the magnetic exchange energies and forces as a function of tip-sample distance. Our calculations are in good agreement with experiments [1]. We analyze the electronic structure of the tip and sample system and explain the origin and nature of the magnetic exchange interaction in this system [2].

[1] R. Schmidt, C. Lazo, U. Kaiser, A. Schwarz, S. Heinze, and R. Wiesendanger, Phys. Rev. Lett. **106**, 257202 (2011).

[2] C. Lazo and S. Heinze, Phys. Rev. B **84**, 144428 (2011).

MA 32.4 Wed 16:45 BH 243

Micromagnetic simulations of the spin spiral state in bi-atomic Fe chains on Ir(001) — •Matthias Menzel[1], Yuriy Mokrousov[2], Robert Wieser[1], Jessica Bickel[1], Elena Vedmedenko[1], Stefan Blügel[2], Stefan Heinze[3], Kirsten von Bergmann[1], André Kubetzka[1], and Roland Wiesendanger[1] — [1]Institut für Angewandte Physik, Universität Hamburg — [2]Institut für Festkörperforschung, Forschungszentrum Jülich — [3]Institut für Theoretische Physik und Astrophysik, Universität Kiel

Recent spin-polarized scanning tunneling microscopy (SP-STM) measurements in combination with *ab initio* calculations reveal a 120° spin spiral ground state in bi-atomic Fe chains on (5×1)-Ir(001) [1]. Monte-Carlo simulations have shown that thermally induced switching of this magnetic state leads to a time-averaged signal in the SP-STM measurements.

We performed time-resolved and temperature dependent simulations using the Object Oriented MicroMagnetic Framework (OOMMF) [2] to investigate the thermal fluctuations and the stabilization mechanism. Due to their reduced coordination the chain's end atoms are more susceptible to an external magnetic field and the magnetocrystalline anisotropy and play a crucial role for the observability of the spin spiral. The three atom periodicity of the spin spiral leads to three symmetry classes for chains of different lengths, and we show how this affects the stability of the spin spiral.

[1] M. Menzel *et al.*, submitted.

[2] `http://math.nist.gov/oommf/`

15 min. break

MA 32.5 Wed 17:15 BH 243

Dzyaloshinskii-Moriya driven spin spiral in Mn chains on Pt(664) — •Benedikt Schweflinghaus[1], Bernd Zimmermann[1], Marcus Heide[2], Gustav Bihlmayer[1], and Stefan Blügel[1] — [1]Peter Grünberg Institut (PGI-1) & Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Department of Precision Science and Technology, Osaka University, Suita, Osaka 565-0871, Japan

Ferromagnetic Co chains decorating the step edges of Pt(997) are historically the prime example of a one-dimensional metallic magnet [1]. We investigate this system in the light of the recently discovered Dzyaloshinskii-Moriya interaction (DMI) for ultrathin films [2], which can induce spiral magnetic structures of unique rotational sense. Besides Co, the research was extended to Fe and Mn chains.

In this contribution we investigate these structures applying density functional theory (DFT) by means of the full-potential linearized augmented plane-wave (FLAPW) method as implemented in the FLEUR

code [3]. Using a micromagnetic model that includes the spin stiffness, magnetic anisotropy energy (MAE) and the DMI, we study possible magnetic phases such as homogeneous and inhomogeneous spin spirals. While the DMI induces for Mn chains a large-period spiral magnetic state superimposed on an antiferromagnetic order, the MAE prevents such a noncollinear structure for Co and Fe chains, respectively.

[1] P. Gambardella et al., Nature 416, 301 (2002)
[2] M. Bode et al., Nature 447, 190 (2007)
[3] http://www.flapw.de

MA 32.6 Wed 17:30 BH 243

Competing interactions and chiral magnetism in Mn_1/X(111), X = Pd, Pt, Ag and Au — •Manuel dos Santos Dias[1,3], Julie Staunton[1], Andras Deak[2], and Laszlo Szunyogh[2] — [1]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, H-1111 Budapest, Hungary — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

The magnetism of Mn monolayers on X(111), with X = Pd, Pt, Ag and Au, is analysed, using our Relativistic Disordered Local Moment Theory, based on DFT and the KKR Green function method [1]. The substrates control the antiferromagnetism, favouring either a collinear row–by–row state or a triangular Néel state. The latter is shown to possess a well–defined chirality pattern, originating from the Dzyaloshinksy–Moriya interactions. The anisotropic interactions are governed not only by the atomic number of the substrate but also by the extent of its hybridisation with the magnetic monolayer. Comparison with the experimental results for Mn_1/Ag(111) [2] is also given.

We acknowledge funding from Portugal (SFRH/BD/35738/2007) and Hungary (contract OTKA K77771 and project TAMOP-4.2.1/B-09/1/KMR-2010-0002).

[1] M. dos Santos Dias, J. B. Staunton, A. Deak and L. Szunyogh, Phys. Rev. B **83**, 054435 (2011)
[2] C. L. Gao, W. Wulfhekel and J. Kirschner, Phys. Rev. Lett. **101**, 267205 (2008)

MA 32.7 Wed 17:45 BH 243

Tunneling anisotropic magnetoresistance on the atomic scale — •Kirsten von Bergmann[1], Matthias Menzel[1], David Serrate[1], Yasuo Yoshida[1], André Kubetzka[1], Roland Wiesendanger[1], and Stefan Heinze[2] — [1]Institute of Applied Physics, University of Hamburg, Germany — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, Germany

In non-collinear magnetic structures such as spin spirals, which have recently been found to occur at surfaces due to the Dzyaloshinskii-Moriya interaction [1,2], the spin quantization axis changes from atom to atom. In such a magnetic state the electronic structure of adjacent atoms is not equivalent due to spin-orbit coupling. We demonstrate that this effect leads to a tunneling anisotropic magnetoresistance on the atomic scale which can be detected using scanning tunneling microscopy (STM). This allows to image non-collinear magnetic structures at surfaces by STM with non-magnetic tips. We apply a simple model to relate the changes of the local density of states at the atoms with the tunnel current [3]. Thereby, we can explain the experimentally observed STM and spin-polarized STM images for spin-spirals observed for Mn/W [1,2] and for the atomic-scale magnetic skyrmion lattice found for Fe/Ir(111) [4].

[1] M. Bode et al., Nature 447, 190 (2007).
[2] P. Ferriani et al., Phys. Rev. Lett. 101, 27201 (2008).
[3] S. Heinze, Appl. Phys. A 85, 407 (2006).
[4] S. Heinze et al., Nature Phys. 7, 713 (2011).

MA 32.8 Wed 18:00 BH 243

The spin structure of Mn on Co/Cu(001) studied by spin-polarized STM with bulk Cr tips and bulk Fe ring probes — •Chii-Bin Wu, Jiaming Song, and Wolfgang Kuch — Arnimallee 14, 14195 Berlin

Spin-polarized scanning tunneling microscopy with bulk Cr tips and bulk Fe ring probes was used to study the antiferromagnetic (AFM) domains of Mn on Co/Cu(001) at room temperature. Layerwise spin contrast was observed, as well as spin frustration along the overgrown steps of the underlying Co film. Besides, comparison of shape and size of additional small scattered areas with opposite spin contrast on flat terraces to islands at the surface of the Co layer indicates the importance of interface roughness on the spin structure of AFM layers in exchange bias systems.

MA 32.9 Wed 18:15 BH 243

Exchange interactions in Fe clusters on Rh(111) and Ru(0001) from first principles — •Fabian Otte, Paolo Ferriani, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstr. 15, 24098 Kiel, Germany

In the last few years it has been found that a non magnetic substrate can dramatically affect the magnetic properties of an adsorbed magnetic monolayer. For example, the nearest neighbor exchange of a Fe monolayer, which is the prototypical ferromagnetic material, becomes antiferromagnetic on W(001) [1] and Ru(0001) [2], while complex noncollinear magnetic order has been observed on Fe/Ir(111) [3].

Motivated by XMCD experiments [4] that found a surprisingly small dichroism in Fe clusters on Rh(111) and Ru(0001), we studied the magnetic properties of these systems by means of density functional theory calculations, using the projector augmented planewave method as implemented in the VASP-code. We considered collinear magnetic states and cluster sizes up to five atoms with different geometries and mapped total energy calculations onto an effective Heisenberg model. We found a complex trend of the magnetic exchange interaction which alternate between ferro- and antiferromagnetic depending on cluster size, geometry and interatomic distance.

[1] P. Ferriani *et al.*, Phys. Rev. Lett. **94**, 087204 (2005). [2] B. Hardrat *et al.*, Phys. Rev. B, **79**, 094411 (2009). [3] S. Heinze *et al.*, Nature Physics **7**, 524-526 (2011). [4] V. Sessi, S. Krotzky, M. Wasnioska, C. Tieg, J. Honolka and K. Kern, private communication

MA 32.10 Wed 18:30 BH 243

SP-STM study of individual Co atoms on Pd/Co/Ir(111) — •Liudmila Dzemiantsova, André Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Institut für Angewandte Physik, Universität Hamburg, Germany

Magnetic atoms adsorbed on nonmagnetic surfaces have become an active research topic in the last few years due to their importance in the fundamental understanding of magnetism and practical applications for spin-based computing schemes. In particular, the knowledge about the magnetic interactions on the atomic scale is crucial for the tailoring of magnetic devices in reduced dimensions and the tuning of their properties [1].

In this study we designed a system consisting of two atomic-scale magnets decoupled by a metallic layer. Magnetic monolayer Co islands on Ir(111) covered with a single atomic Pd layer were used as a substrate and a decoupling spacer, respectively. Individual Co atoms were deposited on the Pd surface and studied by spin-polarized STM (SP-STM). We observe that Pd grows in two stackings on Co/Ir(111) and gets spin-polarized by the underlying magnetic Co layer. We show that the spin polarization of the Co adatoms at the Fermi level is reversed with respect to Pd. This suggests that the spin moments of Co adatom and Co film are antiferromagnetically coupled [2] or the inversion is unique for single adsorbates on atomically flat surfaces [3].

[1] A. A. Khajetoorians et al., Science, 332, 1062 (2011).
[2] Y. Yayon et al., Phys. Rev. Lett., 99, 067202 (2007).
[3] L. Zhou et al., Phys. Rev. B, 82, 012409 (2010).

MA 32.11 Wed 18:45 BH 243

How the local environment affects the magnetic anisotropy and Kondo Screening of a high-spin atom — •Jenny C. Oberg[1,2], Reyes M. Calvo[1], and Cyrus F. Hirjibehedin[1,2,3] — [1]London Centre for Nanotechnology, UCL, UK — [2]Department of Physics and Astronomy, UCL, UK — [3]Department of Chemistry, UCL, UK

We study the magnetic anisotropy and the Kondo screening of the spin of Co atoms on Cu2N using STM-based tunneling spectroscopy. We find that variations of the surface close to the edges of both small (ca 25nm^2) and large (ca 400 nm^2) Cu_2N islands result in changes in both anisotropy and Kondo screening. For small Cu_2N islands, we find that when the Co atoms are placed very close to the edges the Kondo screening weakens while the anisotropy increases in magnitude and changes its symmetry. Surprisingly, on larger Cu_2N islands formed on supersaturated Cu_2N surfaces, we find that a similar behavior occurs as the Co atoms move away from the edge of the islands: at the center of these large islands, Kondo screening is completely suppressed while the anisotropy energy is twice as large as at the edge of the islands. We examine possible causes for these dramatic changes in the Kondo screening and magnetic anisotropy, including a possible interaction with a quantum-confined surface state below the Cu_2N.

MA 33: Magnetic Coupling Phenomena/ Exchange Bias

Time: Wednesday 15:00–18:00 Location: EB 202

Invited Talk MA 33.1 Wed 15:00 EB 202

Exchange bias and domain evolution at 10 nm scales — •Hans J. Hug[1,2], Miguel A. Marioni[1], Sara Romer[1], Sevil Oezer[2], and Niraj Joshi[1,2] — [1]Empa - Swiss Federal Laboratories for Materials Testing and Research, Ueberlandstrasse 129, CH-8600 Duebendorf, Switzerland — [2]Department of Physics, University of Basel, CH-4056 Basel, Switzerland

An obstacle to understanding the EB effect is that only a subset of the UCS (those pinned and coupled to the F) are responsible for the EB effect. Experimental methods that measure the pinUCS density distribution with spatial resolution comparable to the materials grain size are needed. Here we use quantitative, high-resolution magnetic force microscopy (MFM) to measure the local areal density of pinned uncompensated spins (pinUCS) and to correlate the F-domain structure in a perpendicular anisotropy CoPt multilayer with the pinUCS density [1]. Larger applied fields drive the receding domains to areas of proportionally higher pinUCS aligned antiparallel to F-moments. This confirms our prior results [2] that these antiparallel pinUCS are responsible for the EB effect, while parallel pinUCS coexist. The data confirm that the evolution of the F-domains is determined by the pinUCS in the AF-layer, and also present examples of frustration in the system. Grain-boundary engineering can be used to decouple the AF grains leading to a stronger EB-effect but a smaller coercivity. New types of thin film system showing and exchange bias field of 1T will be discussed. [1] I. Schmid et al. EPL, 81 (2008) 17001 [2] I. Schmid et al. PRL, 105 (2010) 197201

MA 33.2 Wed 15:30 EB 202

XMCD-XRMR studies of Exchange Bias Systems — •Patrick Audehm[1], Mathias Schmidt[1], Sebastian Macke[2], Gisela Schütz[1], and Eberhard Goering[1] — [1]Max Planck Institute for Intelligent Systems, Heisenbergstrasse 3, 70569 Stuttgart, Germany — [2]The University of British Columbia, 2329 West Mall, Vancouver, Canada

Since the discovery of the exchange bias (EB) in 1956 by Meiklejohn and Bean, the effect in all its varieties is not completely understood. We investigated a widely studied EB-system of polycrystalline Co on FeMn. The sputtered samples are investigated with a broad range of different techniques, like as X-ray magnetic circular dichroism (XMCD) and x-ray resonant magnetic reflectivity (XRMR) at the L2,3 edges of the transition metals, simultaneously performed in surface sensitive total electron yield (TEY) and bulk sensitive total fluorescence yield (TFY), all at room and low temperatures. With our state of the art soft-X-ray reflectometer we are able to identify element specifically even smallest amounts of magnetic moment contributions via magnetic reflectivity asymmetry and sum rules. Additionally we are measuring the energy dependent reflection with constant momentum transfer which is the direct combination of XMCD and XRMR. With all these techniques we found uncompensated, non-rotatable magnetic moments in iron. All these moments are located at the interface to the Co-layer. Our results lead to a better understanding of the micro magnetic understanding of the EB.

MA 33.3 Wed 15:45 EB 202

Antiferromagnetic coupling across silicon with Fe3Si magnetic layers — •Rashid Gareev[1], Sergey Makarov[2], Alexey Drovosekov[3], Markus Härtinger[1], Georg Woltersdorf[1], Werner Keune[2], Heiko Wende[2], and Christian Back[1] — [1]University of Regensburg, Universitätstrasse 31, 93040 Regensburg, Germany — [2]University of Duisburg-Essen, Lotharstr. 1, 47048 Duisburg, Germany — [3]Kapitza Institute for Physical Problems, Kosygina st. 2, 117334 Moscow, Russia

Combined ferromagnet/semiconductor Fe/Si/Fe tunneling structures demonstrate strong antiferromagnetic coupling (AFC) [1]. Formation of magnetic silicides at interfaces affects AFC as demonstrated by Co interface *dusting* [2]. Substitution of Fe by magnetic Fe3Si can increase interface spin-polarization, influence AFC and reduce interface diffusion. Epitaxial growth of structures with Si spacers and Fe3Si magnetic layers was controlled by RHEED. We realized AFC in Fe3Si-based structures grown on both GaAs(001) and Si(001) substrates. Formation of interfacial iron-silicides was confirmed by Conversion-electron Mössbauer spectroscopy (CEMS) utilizing 0.5 nm-thick interfacial 57Fe tracing layers. The room temperature AFC for samples grown on GaAs(001) is substantially weaker compared to Fe/Si/Fe and reaches /J/~10 mkJ/m2 for 1.2 nm-thick Si. For structures grown on Si(001) AFC is well above /J/~ 0.1 mJ/m2. The possible reasons for observed AFC behavior are discussed. Support by the Project DFG 9209379 is appreciated. [1]. R.R. Gareev et al, J. Magn. Magn. Mater. 240, 235 (2002). [2]. R.R. Gareev et al, AIP Advances 1, 042155 (2011).

MA 33.4 Wed 16:00 EB 202

Ripple formation in ion bombarded exchange bias systems — •Alexander Gaul[1], Dieter Engel[1], Hans Peter Oepen[2], Sebastian Hankemeier[2], and Arno Ehresmann[1] — [1]Department of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Institute of Applied Physics and Microstructure Advanced Research Center, University of Hamburg, Jungiusstr. 11, D-20355 Hamburg

Artificial magnetic domain patterns with three different magnetization directions in the same layer system have been fabricated by keV-He ion bombardment induced magnetic patterning in IrMn/NiFe exchange biased layers.

High resolution magnetic imaging via scanning electron microscope with polarization analysis (SEMPA) revealed magnetic ripple domains as a fine structure in the artificially fabricated domains. It is shown that the long axes of the ripple domains are always perpendicular to the exchange bias field direction of the respective domain. The magnetic ripple period length has been obtained by fast Fourier transform (FFT) of the SEMPA data. The ripple period length increases with decreasing magnetic anisotropy, which has been varied by applying different fluencies of the ions during bombardment.

MA 33.5 Wed 16:15 EB 202

Structural and magnetic properties of the Fe layers in CoO/Fe/Ag(001) heterostructure — •Rantej Bali[1], Marcio Soares[2], Aline Ramos[2], Helio Tolentino[2], Fikret Yildiz[1], Clemence Boudot[2], Olivier Proux[3], Maurizio De Santis[2], Marek Przybylski[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle, Germany — [2]Institut Néel, CNRS and Université Joseph Fourier, BP 166, F-38042 Grenoble Cedex 9, France — [3]Observatoire des Sciences de l'Univers - OSUG-Grenoble, F-38051 Grenoble, France

We elucidate the influence of interfacial oxidation on the magnetic behaviour of CoO/Fe grown on Ag(001) at 340 K. The Fe layer was in the form of a wedge from 0 to 10 monolayers (ML) thickness. Magneto-optic Kerr Effect (MOKE) and X-ray Absorption Near Edge Spectroscopy (XANES) were employed to obtain the Fe-thickness dependence of the magnetic and structural characteristics respectively. The interfacial region consists of a disordered $Fe_{1-x}O_x$ layer with x varying from 0.6 at the interface to 0 in deeper Fe layers. The depth of $Fe_{1-x}O_x$ formation depends on the Fe thickness prior to CoO coverage; from 0 to 4 ML Fe the whole depth forms the oxide. The depth of $Fe_{1-x}O_x$ decreases linearly from 4 to 2 ML as Fe thickness increases from 4 to 8 ML above which the depth of $Fe_{1-x}O_x$ remains constant. Correspondingly 4 ML of CoO covered Fe show zero magneto-optic signal and at 8 ML the largest exchange bias can be induced by zero field cooling. The results can be explained by considering the growth mode of Fe on Ag(001) and defects from the interfacial $Fe_{1-x}O_x$ layer.

MA 33.6 Wed 16:30 EB 202

Exchange Bias in $IrMn_3$/Co bilayers — •Rocio Yanes[1], Laszlo Szunyogh[2], and Ulrich Nowak[1] — [1]Universität Konstanz, Konstanz, Germany — [2]Budapest University of Technology and Economics, Budapest, Hungary

The exchange bias (EB) effect is a unidirectional anisotropy of a magnetic system, which is characterized by a shift in the hysteresis loop, called exchange bias field H_E. The EB is related to the coupling between a ferromagnet (FM) and an antiferromagnet (AFM) or ferrimagnet (FI), and its stiffness depends on the exchange coupling through the interface.

We studied the magnetic properties of a bilayer of $IrMn_3$/Co using a multiscale modeling, from ab-initio to spin model simulations. The

$IrMn_3$ is an AFM which exhibits a T1 magnetic ground state within a [111] magnetic easy plane [1]. When the $IrMn_3$ is capped by a Co layer, a measurable Dzyaloshinskii-Moriya (DM) interaction arises owing to the breaking of symmetry at the interface [2].

Numerical calculations of the hysteresis loops of $IrMn_3$/Co were carried out for different values of the thickness of the Co capping and the different contributions to the exchange interaction. The results show that $IrMn_3$/Co displays a strong EB effect and its origin is the DM interaction.

[1] L. Szunyogh, et.al., Phys. Rev. B, 79,020403(R) (2009)
[2] L. Szunyogh, et.al., Phys. Rev. B, 83,024401 (2011)

15 min. break

MA 33.7 Wed 17:00 EB 202

Magnetic exchange interactions in perovskites $A\mathbf{TcO_3}$ (A = Ca, Sr, Ba) with high Neel temperature studied from first principles — •Vladislav Borisov[1], Igor Maznichenko[2], Sergey Ostanin[1], Arthur Ernst[1], 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

An extraordinary high Neel temperature (T_N) has been found for the 4d transition metal oxides $A\mathrm{TcO_3}$ (A = Ca, Sr, Ba) with the perovskite structure. The magnetic properties and the exchange interactions in the system were studied from first principles using the KKR-CPA method based on the multiple-scattering theory. For each perovskite, the most preferable magnetic configuration was found to be G-type antiferromagnetic with antiparallel alignment of the neighboring magnetic moments. The observed magnetic ordering is accounted for by the strong superexchange interaction between the Tc cations which is mediated by a pronounced overlap of the technetium 4d orbitals and oxygen p orbitals. We obtained the values of the Neel temperature T_N of 840 K for $CaTcO_3$ and 930 K for $SrTcO_3$ which are in a good agreement with the recent experiments. For $BaTcO_3$ which is not available so far, we predict the fundamental band gap of 0.3 eV and $T_N \approx 1000$ K. In general, an increase in the volume leads to a noticeable enhancement of T_N whereas the presence of vacancies on both the oxygen and Tc sites significantly lowers the critical temperature as well as the magnetic moments of Tc cations.

MA 33.8 Wed 17:15 EB 202

Exchange coupled Sm-Co/Fe thin films — •Martin Kopte, Simon Sawatzki, Christine Mickel, Darius Pohl, Alexander Surrey, Bernd Rellinghaus, Ludwig Schultz, and Volker Neu — Institut für Festkörper- und Werkstoffforschung Dresden

We present hard/soft magnetic tri- and fivelayered thin film stacks grown epitaxially by pulsed laser depostion (PLD), where the Fe layers are sandwiched in between highly uniaxial anisotropic Sm-Co layers [1]. With the total thickness of the Sm-Co layers remaining constant the exchange coupling effect in the fivelayered system is enhanced due to the larger number of Sm-Co/Fe interfaces, i.e. the maximum of the energy density product is shifted to larger Fe contents. Microstructural analysis by TEM/EELS confirms the intended film architecture, but also shows rough and diffused Sm-Co/Fe interfaces. The overall behaviour in the reversible part of the demagnetization can be simulated very well by a simple one-dimensional micromagnetic model [2]. The characteristic behaviour of the polarization, nucleation field and energy density product with varying Fe content is reproduced for both tri- and fivelayers. However, the irreversible switching field remains overestimated. An attempt to account for lateral domain processes in the model, which reduce this field, is made by introducing a defect with a pinning potential assigned to that occuring in single $SmCo_5$ layers.

[1] Sawatzki et al., *Journal of Applied Physics* **109**, 123922 (2011)
[2] Kopte et al., *IEEE Trans. Mag.* **47**, 3736 (2011)

MA 33.9 Wed 17:30 EB 202

Probing antiferromagnetism in NiMn/Ni/(Co)Cu_3Au(001) single-crystalline epitaxial thin films — •Muhammad Yaqoob Khan, Chii-Bin Wu, and Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin, Germany

Antiferromagnetism of equi-atomic single-crystalline NiMn thin film alloys grown on Ni/Cu_3Au(001) is probed by means of magneto-optical Kerr effect (MOKE). Thickness-dependent coercivity (H_c) enhancement of NiMn/Ni/Cu_3Au(001) showed that NiMn thicker than 7 atomic monolayers (ML) order antiferromagnetically at room temperature. It is found that NiMn can couple to out-of-plane (OoP) as well as in-plane (IP) magnetized Ni, the latter stabilized by Co underlayer deposition. The antiferromagnetic (AFM) ordering temperature (T_{AFM}) of NiMn coupled to OoP Ni is found to be much higher (up to 110 K difference) than in the IP case, for otherwise identical interfacial conditions. This is attributed to the *magnetic proximity effect* in which the ferromagnetic (FM) layer substantially influences the T_{AFM} of the adjacent AFM layer and can be explained by either (i) a higher interfacial coupling strength or/and (ii) a thermally more stable NiMn spin structure when coupled to Ni magnetized in OoP direction than in IP. An exchange-bias effect could only be observed for the thickest NiMn film studied (35.7 ML); the exchange-bias field (H_{eb}) is higher in the OoP exchange-coupled system than in the IP one due to the same reason/s.

MA 33.10 Wed 17:45 EB 202

Spin-structure and spin-reorientation transitions in the CoPd/ IrMn exchange bias system. — •Muhammad Bilal Janjua and Gernot Güntherodt — II. Physikalisches Institut A, RWTH Aachen University, 52074 Aachen, Germany.

In MBE grown polycrystalline Co22Pd78/ Ir25Mn75 thin films with [111] texture, a transition in the exchange bias (EB) is observed at low temperatures, where the in-plane EB field becomes greater than the out-of-plane EB field. Despite the out-of-plane magnetization of CoPd at low temperatures, this behavior of EB is an evidence of the change in the spin structure of the antiferromagnet (AFM) IrMn. It is found that with decreasing temperature there is a spin structure transition in IrMn thin films related to the 3Q to 2Q transition in the bulk [1], which implies a change of the AFM spin structure from an out-of-plane component (3Q) to in-plane component (2Q). This transition is responsible for the increase in the in-plane EB at low temperatures. Besides the 3Q-2Q transition of IrMn, a spin reorientation transition from out-of-plane to in-plane (at higher temperatures) is also observed in the thermoremanent magnetization of Co22Pd78(t nm)/Ir25Mn75(15nm) for different thicknesses t. This effect is due to CoPd, but is too weak to perturb the spin structure transition of IrMn, which dominates the temperature dependence of EB.

[1]. A. Sakuma, K. Fukamichi, K. Sasao and R. Y. Umetsu, Phys. Rev. B 67, 024420 (2003).

MA 34: Magnetization / Demagnetization Dynamics III

Time: Wednesday 15:00–18:45 Location: H 1012

MA 34.1 Wed 15:00 H 1012

Magnetic vortex core reversal by excitation of spin waves — •Hermann Stoll[1], Matthias Kammerer[1], Markus Weigand[1], Michael Curcic[1], Matthias Noske[1], Markus Sproll[1], Arne Vansteenkiste[2], Bartel Van Waeyenberge[2], Georg Woltersdorf[3], Christian H. Back[3], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart (formerly MPI for Metals Research) — [2]Department of Solid State Science, Ghent University, Belgium — [3]Department of Physics, Regensburg University

Vortex structures possess azimuthal spin wave modes showing much higher eigenfrequencies than the vortex gyromode. Recently we could image by time-resolved scanning transmission X-ray microscopy vortex core reversal by exciting spin wave eigenmodes with rotating multi-GHz magnetic fields [1], much faster than by excitation of the sub-GHz vortex gyromode as demonstrated before. The vortex core polarization can be switched unidirectionally, either to up or down, as excitation only takes place when the sense of rotation of the external field and the spin wave mode are the same. These experimental results are in good agreement with our micromagnetic simulations [1], which clearly show: (i) the selection rules for this vortex core reversal process, (ii) the creation of a VA pair which is also essential for spin wave mediated

vortex core reversal, (iii) asymmetries in vortex - spin wave interaction, caused by the gyrofield of the moving vortex, when spin waves with opposite rotation senses are excited. Limitations of the switching times for spin wave mediated vortex core reversal will be discussed.

[1] M. Kammerer et al., Nature Communications 2, 279 (2011)

MA 34.2 Wed 15:15 H 1012

Switching the magnetic vortex core by combined gyromode and spin wave excitation. — •Markus Sproll[1], Matthias Kammerer[1], Markus Weigand[1], Matthias Noske[1], Ajay Gangwar[2], Georg Woltersdorf[2], Hermann Stoll[1], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart — [2]Department of Physics, Regensburg University

The vortex core (VC) in micron sized Permalloy platelets can be switched by exciting (i) the sub-GHz vortex gyromode [1] or (ii) multi-GHz azimuthal spin wave modes [2]. We have combined these two excitation schemes at significantly different frequencies and it was found that the switching threshold (i.e., the amplitude of the GHz rotating in-plane magnetic field) needed for spin wave mediated VC reversal is reduced by up to 30 % depending on the amplitude of an additional linear in-plane ac magnetic field at the sub-GHz gyromode eigenfrequency. Experiments have been performed by time-resolved measurements at the MAXYMUS (STXM) endstation at BESSY. Movies have been taken, starting with the excitation of the VC by a gyrotropic vortex gyration before a CW or CCW rotating spin wave mode was excited simultaneously with the gyromode. Finally only the VC gyration is excited again showing in case of polarity switching by the spin wave a reversed sense of rotation. All these experimental findings are in good agreement with micromagnetic simulations. A physical explanation for the reduced switching thresholds will be discussed as well as spintronic applications. [1] B. Van Waeyenberge et al., Nature 444, 461(2006) [2] M. Kammerer et al., Nature Communications 2, 279(2011)

MA 34.3 Wed 15:30 H 1012

Vortex core reversal by pulsed orthogonal magnetic fields of 100 ps duration and below — •Matthias Noske[1], Markus Weigand[1], Matthias Kammerer[1], Markus Sproll[1], Ajay Gangwar[2], Hermann Stoll[1], Georg Woltersdorf[2], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart — [2]Department of Physics, Regensburg University

Recently it was demonstrated that the magnetic vortex core can be unidirectionally switched by exciting azimuthal spin wave modes at frequencies in the multi-GHz range [1]. Compared to core reversal by using the sub-GHz vortex gyromode [2], the increased excitation frequencies allow for shorter switching times. In the present talk we will demonstrate how to speed up spin wave mediated vortex core reversal down to 100 ps by applying pulsed orthogonal magnetic fields. Experiments have been performed by time-resolved scanning transmission X-ray microscopy at the MAXYMUS endstation at BESSY II, Berlin. At micron sized Permalloy discs unidirectional vortex core switching could be achieved at an excitation time of 135 ps. On smaller samples switching was achieved at 105 ps excitation time, but in this case the vortex core reversal was found not to be unidirectional. The experimental findings correspond to our micromagnetic simulations which show a strong dependence on sample geometry. In addition, our simulations indicate that unidirectional vortex core reversal will be feasible at excitation times of less than 100 ps for certain sample geometries.

[1] M. Kammerer et al., Nature Communications 2, 279 (2011)
[2] B. Van Waeyenberge et al., Nature 444, 461 (2006)

MA 34.4 Wed 15:45 H 1012

Ultrafast switching of ferrimagnets — Sönke Wienholdt[1], Denise Hinzke[1], Peter Openeer[2], and •Ulrich Nowak[1] — [1]Universität Konstanz, 78457 Konstanz, Germany — [2]Uppsala University, 75120 Uppsala, Sweden

The ultrafast manipulation of magnetisation by fs laser pulses promises to become a real alternative to conventional techniques based on magnetic fields. It was demonstrated that a 80 fs, circularly polarised laser pulse is able to reverse magnetisation on a ps time scale, as if it acts as a short magnetic field pulse caused by the inverse Faraday effect [1]. In single-shot time-resolved imaging of magnetic structures [2] it has been shown that the magnetisation reverses via a linear pathway [3] without any precession. Even with linearly polarized light switching was demonstrated recently [4], probably on a purely thermal basis. These new types of switching have been demonstrated only in ferrimagnetic materials like GdFeCo, probably because of the antiferromagnetic coupling of the two different sub-lattices in these materials, leading to completely different dynamics as compared to a ferromagnet. To understand this new type of dynamics we perform atomistic spin model simulations of ferrimagnets and investigate their switching mechanisms in detail.

[1] C. D. Stanciu et al., Phys. Rev. Lett. **99**, 047601 (2007). [2] K. Vahaplar et al., Phys. Rev. Lett. **103**, 117201 (2009) [3] N. Kazantseva et al., Europhys. Lett. **86**, 27006 (2009) [4] I. Radu et al., Nature **472**, 205 (2011)

Funded by the EU project FemtoSpin and the CAP in Konstanz.

MA 34.5 Wed 16:00 H 1012

Electron- and phonon-mediated ultrafast magnetization dynamics of Gd — •M. Sultan[1,2,3], A. Melnikov[2,4], U. Atxitia[5], O. C. Fesenko[5], and U. Bovensiepen[1] — [1]Fakult. Phys., Uni. Duisburg-Essen — [2]Fach. Phys., Freie Uni. Berlin — [3]National Cent. Phys., Islamabad — [4]Phys. Chem., FHI, Berlin — [5]Inst. Cienc. Mater., Madrid

Disentangling different microscopic contributions in ultrafast magnetization dynamics is a challenging task. As a potential system to resolve this, Gd exhibits a two step demagnetization with characteristic time scales of 0.75 ps and 40 ps related to the non-equilibrium and a quasi-equilibrium regimes, respectively [1]. Here we report on the temperature dependent ultrafast magnetization dynamics of Gd(0001), which was investigated by employing the fs time-resolved magneto-optical Kerr effect and modelling by the Landau-Lifshitz-Bloch equation. The demagnetization time determined from the experiment increases with temperature from 0.8 ps at 50 K to 1.5 ps at 280 K. A successful theoretical description of this observation was achieved by considering that the localized 4f spin system is affected by two contributions: coupling to the 5d fraction through (a) electronic scattering processes and (b) spin-flip scattering mediated by phonons. We conclude that at temperatures below the Debye temperature a hot electron-mediated process describes the experimentally found demagnetization times well. At higher temperatures phonon-mediated processes have to be included in addition to explain the two times longer demagnetization time.

[1] Wietstruk et al., PRL 106, 127401 (2011)

MA 34.6 Wed 16:15 H 1012

Fs-time and momentum resolved resonant magnetic x-ray scattering on EuTe — •Christoph Trabant[1,2], Niko Pontius[2], Enrico Schierle[2], Eugen Weschke[2], Torsten Kachel[2], Rolf Mitzner[2], Christian Schüssler-Langeheine[2,1], Günther Springholz[3], and Karsten Holldack[2] — [1]II. Physikalisches Institut, Universität zu Köln — [2]G-I2/M-I1, Helmholtz-Zentrum Berlin — [3]Institut für Halbleiterphysik, Johannes Kepler Universität, Linz,Austria

Antiferromagnetic (AFM) materials have been discussed to provide special conditions for ultrafast magnetization dynamics since no macroscopic magnetization exists and dynamics might not be restricted by conservation of angular momentum. EuTe is a prototype AFM semiconductor (2.2eV band-gap). The AFM order results from competing exchange interactions between nearest-neighbors (FM coupling) and next-nearest-neighbors (AFM coupling) Eu^{2+}ions, which sensitively depend on the ion distances. The AFM order is detectable by a $(\frac{1}{2}\frac{1}{2}\frac{1}{2})$ superstructure reflection by resonant soft x-ray diffraction (RSXD).
We investigate the photoinduced magnetic dynamics on the fs- and ps-time-scale for different sample compositions. By recording time resolved q-scans we find that the thin film magnetic profile is modified in a completely different way than for elevated temperatures in thermal equilibrium. The measurements have been performed at the FEMTOSPEX facility at BESSY II.

MA 34.7 Wed 16:30 H 1012

Laser induced heating of thin nickel films investigated by time-resolved electron diffraction — •Carla Streubühr, Thorsten Brazda, Ping Zhou, Dietrich von der Linde, and Uwe Bovensiepen — Universtität Duisburg-Essen, Germany

Recently phonon excitation was reported to play an essential role in the ultrafast demagnetization of ferromagnetic materials [1]. Therefore information on the dynamics of lattice heating in magnetic materials is desired. Here we report on ultrafast lattice heating of thin crystalline nickel films at room temperature which were analyzed by time-resolved electron diffraction after femtosecond laser excitation.

Similar to the experiments on polycrystalline Ni [2], Au, Ag and Cu films [3] we observed an intensity decrease of the various diffraction

spots after laser excitation. The relation of the intensity changes of different orders is interpreted as a rise in lattice temperature according to the Debye-Waller Effect. The heat capacity of nickel can no longer be treated as constant because of its high Debye temperature which leads to differences to the experiments on noble metals. We obtained a lattice temperature increase of about 160 K with a time constant of (1.5 ± 0.4) ps after exciting the sample by a fluence of about 5 $\frac{mJ}{cm^2}$ at a wavelength of 800 nm. In contrast to this the demagnetization of nickel on a silicon substrate is reported to have a time constant of 0.16 ps [1].

[1] B. Koopmans et al, Nature Materials **9**, 259 (2010)
[2] X. Wang et al, PRB **81**, 220301 (2010)
[3] M. Ligges et al, APL **94**, 1019410 (2009)

15 min. break

MA 34.8 Wed 17:00 H 1012

Gilbert damping parameter for transition metals and alloys at finite temperature: first-pinciples calculations — •S. Mankovsky, D. Koedderitzsch, and H. Ebert — Dept. Chemie/Phys. Chemie, Universität München, Butenandtstr. 11, D-81377 München, Germany

We present the results of calculations of the Gilbert damping parameter α for pure 3d transition metals as well as for disordered alloys containing magnetic 3d elements. The calculations of the α parameter were performed within the linear response formalism via the KKR Green's function band structure method. The role of various influences on the Gilbert damping have been investigated: chemical composition, crystal lattice structure, spin-orbit coupling of the elements and temperature. In particular, we focus here on the finite temperature dependence of the Gilbert damping, caused by temperature induced structural and magnetic disorder in the system. These scattering mechanisms have been accounted for by means of the alloy analogy scheme using the coherent potential approximation (CPA) alloy theory. The effects of structural and magnetic disorder are accounted for separately as well as simultaneously, to see their interrelation in pure materials as well as in the presence of impurities. The theoretical results for the Gilbert damping parameters are compared with available experimental data.

MA 34.9 Wed 17:15 H 1012

Accessing the timescale of indirect exchange interaction in GdTb alloy by time-resolved x-ray spectroscopy — •Andrea Eschenlohr[1], Alexey Melnikov[2], Jens Wieczorek[3], Nicolas Bergeard[3], Christian Stamm[1], Torsten Kachel[1], Rolf Mitzner[1], Karsten Holldack[1], Marko Wietstruk[4], Kristian Döbrich[4], Martin Weinelt[4,5], and Uwe Bovensiepen[3] — [1]Helmholtz Zentrum Berlin für Materialien und Energie GmbH — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin — [3]Universität Duisburg-Essen — [4]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin — [5]Freie Universität Berlin

Time-resolved x-ray magnetic circular dichroism measurements on pure Gd and Tb show two-step demagnetization upon laser excitation [1], with different time constants for the second, slower process. In particular, this time constants depend on the strength of spin-lattice coupling, leading to a faster demagnetization in Tb, due to strong direct spin-lattice coupling, than in Gd. Here we investigate GdTb alloy, where the Gd 4f magnetic moments are coupled to the Tb 4f moments via indirect exchange interaction, resulting in an enhanced coupling of the Gd moments to the lattice. Indeed, we find that the Gd magnetic moments in GdTb alloy demagnetize faster than pure Gd. Looking at the element-specific magnetization dynamics on the femtosecond to picosecond timescale, we access the timescale of indirect exchange interaction between Gd and Tb magnetic moments in the alloy.

[1] M. Wietstruk et al., Phys. Rev. Lett. 106, 127401 (2011)

MA 34.10 Wed 17:30 H 1012

Precessional dynamics and damping in Co/Cu/Py spin valves — •Ruslan Salikhov[1], Radu Abrudan[1], Frank Brüssing[1], Stefan Buschhorn[1], Melanie Ewerlin[1], Durga Mishra[1], Florin Radu[2], Ilgiz A. Garifullin[3], and Hartmut Zabel[1] — [1]Ruhr-Universität Bochum, Germany — [2]Helmholtz-Zentrum Berlin, Germany — [3]Zavoisky Physical-Technical Institute, Kazan, Russia

We have studied Co/Cu/Py (where Py = Ni81Fe19) spin valve systems with different thicknesses of Cu-spacer layers (25 and 40 nm) using the Time-Resolved X-ray Resonant Magnetic Scattering at the synchrotron radiation facility BESSY II of the HZB. This method enables the detection of the free precessional decay of the magnetization of ferromagnetic (F) films in response to a field pulse excitation [St. Buschhorn, et. al., J. Phys. D 44, 165001 (2011)]. We have found that the magnetic precessional decay time of Fe magnetic moments in Py layers decreases when changing the mutual orientation of the magnetization direction of Py and Co layers from parallel (P) to antiparallel (AP). Taking into account all possible mechanisms which can cause the observed effect in our samples where the exchange interaction between F-layers is negligible, we suppose that the increase of damping for AP orientation of magnetizations is associated with the spin-pumping-induced damping effect. The observed orientational dependence of the damping of free F-layer in the spin valves due to spin pumping was predicted theoretically by Kim and Chappert [J.-V. Kim, C. Chappert, JMMM 286, 56 (2005)] and until now there was no experimental evidence for this effect in the literature.

MA 34.11 Wed 17:45 H 1012

Small damping constant for Ni/Co multilayers with perpendicular magnetic anisotropy — •Markus Härtinger[1], Christian H. Back[1], See-Hun Yang[2], Stuart S. P. Parkin[2], and Georg Woltersdorf[1] — [1]Department of Physics, Universität Regensburg, 93040 Regensburg, Germany — [2]IBM Almaden, San Jose, U.S.A.

It is known, that perpendicular magnetic anisotropy exists in materials which consist of multilayers comprised of alternating ultrathin layers of Co separated by ultrathin layers especially of Pt, Pd or Ni. In these systems the perpendicular magnetic anisotropy field can be sufficiently large to overcome the shape anisotropy and induces a magnetic easy axis perpendicular to the multilayers.

We study the static and dynamic properties of magnetic multilayers composed of alternating ultrathin layers of Co and Ni. In particular, the evolution of perpendicular magnetic anisotropy and the Gilbert damping parameter is investigated as a function of thickness using ferromagnetic resonance. We find a rather small Gilbert damping constant $\alpha = 0.014$. In addition we recognize only a weak dependence of the magnetic properties of the number of multilayer repetitions.

MA 34.12 Wed 18:00 H 1012

Micromagnetic simulation of spin wave mediated synchronization between two pointcontact spin torque nano-oscillators — •Thomas Kendziorczyk and Tilmann Kuhn — Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

It has been predicted theoretically and observed experimentally that a direct current traversing a magnetic multilayer exerts a spin torque on the magnetic system which can compensate the natural damping and lead to magnetic autooscillations in the GHz range. Due to the easy frequency tunability and the narrow linewidth of the spin torque nano-oscillators (STNOs) this effect has great potential for the construction of nanosized microwave generators. The main problem which has to be solved for future applications is the low output power of a single STNO. In order to construct larger arrays of STNOs a good knowledge about the coupling mechanism between them is indispensable. We have performed micromagnetic simulations based on the Landau-Lifshitz equation including dipolar and exchange interactions with a supplementary spin torque transfer term. We will show that the STNOs can synchronize mutually due to exchange of spin waves and oscillate coherently with the same frequency. The phase difference and spatial coherence of the STNOs depend on the distance between them and differences in their size. These results can be explained by means of a simple model of two coupled differential equations describing nonlinear autooscillators.

MA 34.13 Wed 18:15 H 1012

Quantum mechanical contribution to the magnon dispersion in the Heisenberg model — •Julian Hüser and Tilmann Kuhn — Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

The main contributions to the magnon dispersion in thin magnetic films are provided by the exchange and dipole-dipole interactions. Most fundamental work is based on the Heisenberg model which is able to explain this complex dispersion relation. It has been shown by several authors that by making the transition to classical spins a dispersion relation is obtained which is equal to the result of the harmonic spinwave approximation by applying either the Holstein-Primakoff or the Dyson-Maleev transformation. Because of the nonlinearity of these

boson mappings higher-order terms which are omitted in the harmonic spinwave approximation react on the linear terms and thus modify the dispersion relation. Therefore, this modification is a purely quantum mechanical effect. However, this correction has mostly been neglected so far and barely investigations were made to confirm the validity of the harmonic spinwave approximation. The present work provides an analysis of this quantum mechanical effect and shows in which cases it is negligible or not.

MA 34.14 Wed 18:30 H 1012

Photo-magnonics: Influence of antidot-lattice symmetry on spin-wave Bloch states — •Benjamin Lenk, Nils Abeling, Jelena Panke, and Markus Münzenberg — I. Physikalisches Institut, Georg-August-Universität Göttingen

Femtosecond laser pulses are used to optically excite (pump) and subsequently measure (probe) magnetization dynamics on thin (50 nm) CoFeB films. On timescales as long as nanoseconds spin waves are observed that can be manipulated with periodic structures. In our case, two-dimensional arrays of antidots provide a periodic "potential" to the excited spin waves which then propagate along selected directions of the lattice. On the way towards spin-wave logic devices an understanding of the respective mechanisms for magnonic manipulation is of crucial importance. The structured CoFeB films show magnonic modes with Bloch-like character. Their dispersion $\omega(H_{\text{ext}})$ is used to determine the wave vector which turns out to be π/a, where a is the lattice parameter of the antidot structure. It is shown that the propagation direction remains in nearest-neighbor direction even if the structure's symmetry changes. Moreover, hexagonal lattices yield the possibility to tune the wave vector to $\pi/2a$.

In our contribution, we focus on the influence of the symmetry and prove the population of spin-wave Bloch states at the Brillouin zone boundary. These findings together with the low intrinsic damping of the material under consideration provide the basis for propagation experiments on antidot waveguides, first corresponding results are presented.

MA 35: Magnetic Heusler Compounds I

Time: Wednesday 15:00–18:00 Location: H 0112

Topical Talk MA 35.1 Wed 15:00 H 0112

Heusler compounds: theory and experiments on their electronic structure. — •G. H. Fecher — Max Planck Institute for Chemical Physics of Solids, Dresden

It is well known that Heusler compounds are famous for the occurrence of half-metallic ferromagnetism. Recently they were also suggested to belong to the group of topological insulators. It will be shown that there are some more interesting features in the electronic structure of Heusler compounds between metals and insulators and how they can be designed to exhibit spin gapless semiconductivity and spin gapless antiferromagnetism. Spin gapless semiconductors and halfmetallic antiferromagnets are classes of materials that bridge the gap between the properties of metals and semiconductors. Both exhibit peculiar halfmetallic transport properties and are closely related to halfmetallic ferromagnets. In halfmetallic materials, transport is mediated by electrons having only one kind of spin, i.e., the minority or the majority spin. Spin gapless semiconductors exhibit an additional phenomenon, namely, an open bandgap in one spin channel and a closed bandgap (zero bandgap) in the other. Further, halfmetallic antiferromagnets, also referred to as halfmetallic completely compensated ferrimagnets, exhibit spin order without any macroscopic magnetization. They become spin gapless antiferromagnets when the conducting spin channel exhibits a zero bandgap. The evidence for these phenomena will be exemplified by comparing ab-initio calculations to measurements of the electronic structure by photoemission and electronic transport properties.

MA 35.2 Wed 15:30 H 0112

***Ab initio* investigation of $Co_2FeSi_{1-x}Z_x$ and $Co_2Fe_{1-x}Z_{1+x}$ Heusler alloys: Magnetism and tetragonal instability** — •Heike C. Herper and Peter Entel — Faculty of Physics and CeNIDE, University of Duisburg-Essen, 47048 Duisburg, Germany

Since the magnetic properties of Heusler compounds can be relatively easily controlled by composition these alloys seem to be suitable for different magnetic applications, e.g., in magnetoelectronic and magnetocaloric devices and one can think of multifunctional devices. Here, we present an *ab initio* study of $Co_2FeSi_{1-x}Z_x$ and $Co_2Fe_{1-x}Z_{1+x}$ Heusler alloys with Z = Al, Sb, Sn. Electronic properties have been studied within the density functional theory using the VASP and SPRKKR code. Information about finite temperature properties is obtained from Monte Carlo simulations of the classical Heisenberg model with *ab initio* determined exchange coupling constants.

We have investigated the composition dependence of the magnetic transition temperatures and the spin polarization which are important for spintronic applications as well as the tendencies of martensitic phase transformation. Replacing Si in Co_2FeSi partially by Fe the cubic phase is preferred and spin polarization remains large, whereas, Si excess stabilizes the tetragonal phase, but spin polarization is drastically reduced. However, if fractions of Si are replaced by Sb the system also exhibits a tetragonal instability, but with reasonable large spin polarization.

This work is financially supported through the Deutsche Forschungsgemeinschaft (SFB 491).

MA 35.3 Wed 15:45 H 0112

Optical properties of Co_2FeZ half-metallic Heusler compounds — •Jaroslav Hamrle[1], Dominik Legut[1], Kamil Postava[1], Jaromír Pištora[1], Enrique Vilanova[2], Mirko Emmel[2], and Gerhard Jakob[2] — [1]Department of Physics and Nanotechnology Centre, VSB - Technical University of Ostrava, Czech Republic — [2]Institute of Physics, Mainz University, Germany

Common materials for plasmonic applications are gold and silver, as they provide low damping and negative value of real part of the permittivity. Nowadays, there is a need of new materials, which can provide both plasmonic excitations and magneto-optical activity. Co_2-based half metallic Heusler compounds are promising materials for this purpose, as there are several similarities in electronic band structure for exited states between gold, silver and the majority band of Co_2-based Heusler compounds for photon energies smaller than minority electron gap size (i.e. below 1 eV).

Within this contribution we present complex refractivity index, determined in range from mid-infrared (mid-IR) to near-ultraviolet, of half-metallic Heusler compounds Co_2FeSi, $Co_2FeAl_{0.4}Si_{0.6}$ and $Co_2FeGa_{0.5}Ge_{0.5}$ measured by ellipsometry and IR reflectometry. The optical spectra were computed in the single electron picture within the framework of the DFT. The interband as well as intraband transitions were considered.

MA 35.4 Wed 16:00 H 0112

Electronic, structural, and magnetic properties of the half-metallic ferromagnetic quaternary Heusler compounds CoFeMnZ (Z = Al, Ga, Si, Ge) — •Vajiheh Alijani, Juergen Winterlik, Gerhard Fecher, and Claudia Felser — Institute for Inorganic and analytical Chemistry, Johannes Gutenberg University, 55099 Mainz, Germany

Half-metallic ferromagnets exhibit 100% spin polarization at the Fermi energy and therefore are ideal candidates for spin-injection devices. Several materials besides Heusler compounds have been predicted to exhibit half-metallicity. Several quaternary-or pseudo-ternary Heusler compounds have been designed in order to tailor the middle of the gap exactly to the Fermi energy. For symmetry reasons (T_d), quaternary Heusler compounds with a 1:1:1:1 stoichiometry are substantially different from the $L2_1$ pseudo-ternary Heusler compounds with O_h symmetry and $2:[(1-x):x]:1$ or $2:1:[(1-y):y]$ stoichiometry.

The quaternary intermetallic Heusler compounds CoFeMnZ (Z = Al, Ga, Si, Ge) with 1:1:1:1 stoichiometry were predicted to exhibit half-metallic ferromagnetism by ab-initio electronic structure calculations. The compounds were synthesized using an arc-melting technique and the crystal structures were analyzed using X-ray powder diffraction. The electronic properties were investigated using HAXPES. The low-temperature magnetic moments, as determined from magnetization measurements, follow the Slater-Pauling rule, confirming the proposed high spin-polarizations. All compounds have high Curie-temperatures, allowing for applications at room temperature and above.

MA 35.5 Wed 16:15 H 0112

Curie temperatures of Mn_2CoZ inverse Heusler compounds — •Markus Meinert, Jan Schmalhorst, and Günter Reiss — Dünne Schichten und Physik der Nanostrukturen, Fakultät für Physik, Universität Bielefeld, 33501 Bielefeld

The exchange interactions and Curie temperatures of inverse Heusler compounds Mn_2CoZ (Z = Al, Ga, In, Si, Ge, Sn, Sb) with the Hg_2CuTi structure have been studied by density functional theory. Due to the direct Mn-Mn exchange interaction in Mn_2CoZ, the Curie temperature *decreases*, although the total moment *increases* when the Z valence electron number is increased. The coupling between the nearest-neighbor Mn atoms scales with the magnetic moment of the Mn atom on the C site. A negative pressure dependence of the Curie temperature is predicted, which follows from decreasing magnetic moments under pressure. Curie temperatures of more than 800 K are predicted for Mn_2CoAl (890 K), Mn_2CoGa (886 K), and Mn_2CoIn (845 K), which are in reasonable agreement with experiments.

15 min. break

MA 35.6 Wed 16:45 H 0112

Pressure dependence of Curie temperature and resistivity of complex Heusler alloys — •Vaclav Drchal[1], Shyamal Bose[2], Josef Kudrnovsky[1], and Ilja Turek[3] — [1]Institute of Physiscs AS CR, Praha, Czech Republic — [2]Brock University, St. Catharines, Canada — [3]Institute of Physics of Materials, AS CR, Brno, Czech Republic

Using first-principles electronic structure methods, we have calculated the Curie temperature and resistivity of random quaternary Heusler alloys $(Ni_{1-x}Pd_x)_2MnSn$ and $(Ni_{1-x}Cu_x)_2MnSn$ [1] and studied their dependence on the external hydrostatic pressure [2]. The Curie temperatures were calculated within the random-phase approximation applied to the Heisenberg Hamiltonian, whose parameters were determined using the density functional theory. The Curie temperature increases with pressure in $(Ni_{1-x}Pd_x)_2MnSn$ alloys for all concentrations x while the crossover from the increase to the decrease of the Curie temperature with pressure takes place for $x > 0.7$ in $(Ni_{1-x}Cu_x)_2MnSn$ Heusler alloys. The spin-disorder induced part of the resistivity in $(Ni_{1-x}Pd_x)_2MnSn$ Heusler alloys, calculated by using the disordered local moment model, is presented. Finally, we discuss qualitatively the results on the basis of Anderson's superexchange and Stearn's model of the indirect exchange between localized and itinerant d-electrons.

[1] S.K. Bose et al.: Phys. Rev. B **82** 174402 (2010). [2] S.K. Bose et al.: Phys. Rev. B **84** 174442 (2011).

MA 35.7 Wed 17:00 H 0112

Structural and magnetic properties of $Mn_2Rh_{1-x}Co_xSn$ and $Mn_{2+x}Rh_{1-x}Sn$ Heusler alloys — •Olga Meshcheriakova[1], Juergen Winterlik[1], Gerhard Fecher[1,2], and Claudia Felser[1,2] — [1]Institute for Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Mn_2-based Heusler compounds are promising candidates for spintronic applications as they are known to crystallize with cubic and tetragonal structures or exhibit cubic-tetragonal phase transitions. Sn-containing compounds have only a small lattice mismatch with MgO thus providing higher symmetry correlation between magnetic film and tunneling barrier. Quaternary $Mn_2Rh_{1-x}Co_xSn$ and $Mn_{2+x}Rh_{1-x}Sn$ Heusler alloys have been synthesized with a step of $x = 0.1$ and their magnetic properties were experimentally investigated. In the present work the structural and magnetic properties are discussed depending on the Rh and Co content. The first series undergoes a cubic-tetragonal transition at $x = 0.5$, while the latter one experiences a hexagonal-tetragonal change of structure. The presence of Co increases the Curie temperature keeping the magnetic moment unchanged.

This work is supported by the Graduate School of Excellence Materials Science in Mainz (MAINZ).

MA 35.8 Wed 17:15 H 0112

Electronic properties of $Co_2Fe_xMn_{1-x}Si$ Heusler alloys studied by hard X-ray photoelectron spectroscopy. — •A. Gloskovskii[1], S. Thiess[3], S. Ouardi[1], G. H. Fecher[1,2], W. Drube[3], B. Detlefs[4], T. Kubota[5], Y. Ando[5], and C. Felser[1,2] — [1]Institute of Inorganic Chemistry and Analytical Chemistry, JoGu University, Mainz — [2]Max Planck Institute for Chemical Physics of Solids, Dresden — [3]Deutsches Elektronen-Synchrotron DESY, Hamburg — [4]ESRF, Grenoble — [5]Department of Applied Physics, Graduate School of Engineering, Tohoku University, Sendai

Fully epitaxial magnetic tunnel junctions (MTJs) with a Co_2YZ thin film as a base electrode and a MgO tunnel barrier exhibit high TMR ratios. Quaternary $Co_2Fe_xMn_{1-x}Si$ (CFMS) Heusler alloys are even more promising because the substitution of Mn by Fe increases the number of valence electrons and therefore leads to higher Curie temperatures above 1000 K. The maximum TMR ratio for CFMS-CoFe MTJs was found for Fe fractions of between x=0.4 and 0.6. Half-metallicity disappears for the samples with x$\geq$0.8.

A $B2$ and $L2_1$ site ordered stack of MgO substrate/ Cr [40 nm] buffer layer/$Co_2Fe_xMn_{1-x}Si$ [30 nm]/MgO[2 nm]/AlO_x [1.3 nm] (x = 0, 0.2 ... 1.0) films was studied at beamline P09 at PETRA III and beamline ID32 at the ESRF. The hard X-Ray photoelectron spectroscopy (HAXPES) studies were performed with an excitation energy of 6 keV. It was found that the position of Co 2p core levels and the density of states in the valence band region strongly depend on the Fe/Mn ratio.

MA 35.9 Wed 17:30 H 0112

Symmetry of valence states of Heusler compounds explored by linear dichroism in hard X-ray photoelectron spectroscopy — •S. Ouardi[1], G. H. Fecher[1,2], C. Shekhar[2], B. Balke[1], A. Gloskovskii[1], C. Felser[1,2], E. Ikenaga[3], S. Ueda[4], and K. Kobayashi[4] — [1]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [2]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany. — [3]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan — [4]National Institute for Materials Science, SPring-8, Hyogo, Japan

In the present work, a combination of the the linear dichroism in the angular distribution (LDAD) with the bulk-sensitive hard-x-ray photoelectron spectroscopy (HAXPES) technique was used to investigate the symmetry of the valence states of magnetic, semiconducting and gapless Heusler compounds with $C1_b$ structure. High-resolution photoelectron spectroscopy was performed with an excitation energy of $h\nu$ = 7.938 keV. The linear polarization of the photons was changed using an in-vacuum diamond phase retarder. The valence band spectra exhibit the typical structure expected from first-principles calculations of the electronic structure of these compounds. Noticeable linear dichroism is found in the valence band of the materials and this allows for a symmetry analysis of the contributing states. The differences in the spectra are found to be caused by symmetry-dependent angular asymmetry parameters, and these occur even in polycrystalline samples without preferential crystallographic orientation.

MA 35.10 Wed 17:45 H 0112

Elastic properties and stability of tetragonal Heusler compound — •S. S. Naghavi[1], S.-C. Wu[1,2], G. H. Fecher[1,2], and C. Felser[1,2] — [1]Institute for Inorganic and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [2]Max Planck Institute for Chemical Physics of Solids, Dresden

Cubic-tetragonal phase transition in the Heusler compounds is of particular interest because tetragonally distorted Heusler compounds with a magnetic anisotropy in the perpendicular axis are promising for spin-torque applications. Therefore, theoretical prediction of new tetragonal Heusler compounds is quiet important and also challenging. A different approach to analyze the structural phase transition is to consider the mechanical instability of the stressed lattice, which is a reliable method for a perfect crystal at the zero applied stress. Rather than mechanical instability, determination of elastic constants gives valuable information about the type of bonding, hardness, velocity of sound, Debye temperature, etc. To calculate the elastic constants and related properties highly accurate, one needs an accurate DFT calculator. Therefore, we used FP-LAPW implemented in the Wien2K to calculate the elastic constants of tetragonally distorted structures. This method together with GGA(PPE) exchange-correlation functionals ensure a reliable estimation for electronic structure calculations of Heusler compounds. It is shown that the calculated elastic constants provide a correct estimation for the study of phase transition in the Heusler compounds.

MA 36: Magnetic Heusler Compounds II

Time: Thursday 9:30–12:30 Location: H 1012

Invited Talk MA 36.1 Thu 9:30 H 1012

Tetragonal Heusler-like alloy films with perpendicular magnetic anisotropy for spin torque applications — •Shigemi Mizukami and Terunobu Miyazaki — WPI-Advanced Institute for Materials Research, Tohoku University, Katahira 2-1-1, Sendai, Japan, 980-8577

Some Heusler alloys have half-metallic band structure, exhibiting giant tunnel magnetoresistance (TMR) in magnetic tunnel junctions (MTJs). However, the conventional Heusler alloys, such as Co_2MnSi, have chemically ordered cubic structure, so that these alloys show relatively weak magnetic anisotropy. Magnetic films with a large perpendicular magnetic anisotropy (PMA) are advantageous to the spin torque application, such as magnetic random access memory, because PMA reduces switching current density and increase thermal stability of magnetization directions. Thus, it is interesting to study on Heusler alloy with a large PMA. It has been predicted by the group in Mainz that Heusler-like alloy Mn_3Ga exhibits a large spin polarization as well as a large uniaxial magnetic anisotropy. We have obtained $Mn_{3-x}Ga$ (x=0.5) epitaxial films using a UHV-magnetron sputtering and reported a large uniaxial magnetic anisotropy energy K_u of 12 Merg/cm^3 and also low saturation magnetization of 250 emu/cc, so far. In this talk, we will present structural and magnetic properties and a relatively low Gilbert damping observed in a ultrafast precessional dynamics of magnetization for the $Mn_{3-x}Ga$ alloy films. Furthermore, the TMR effects in MgO-MTJs with $Mn_{3-x}Ga$ electrodes will also be discussed.

Topical Talk MA 36.2 Thu 10:00 H 1012

The role of Heusler alloys in various applications — •Andreas Hütten — Bielefeld Universität

As a consequence of the theoretically predictions of 100% spin polarized half- and full-Heusler compounds over the past decade, Heusler alloys are among the most promising materials class for future applications in magnetoelectronics. The resulting electronic structures as well as their magnetic properties will be used to identify potential areas of applications. Among these areas are magnetic logic, biosensors and granular GMR-sensors. Using Heusler alloyed magnetic electrodes in TMR biosensors will boost their performance in terms of an accessible external field range. This is accompanied by a different noise behavior which in turn can be used so as to characterize the performance of the Heusler alloyed magnetic electrodes. We will cover the development of highly sensitive Heusler TMR-sensors to optimize the magnetic interactions with magnetic markers. A new Concept for the manipulation and controlled guidance of molecules attached to magnetic markers in microfluidic lab-on-a-chip structures will be presented. In addition, printable GMR-sensors based on magnetic Heusler nanoparticles will also be introduced.

MA 36.3 Thu 10:30 H 1012

Magnetic anisotropy and magnetization reversal of Co2MnGe-Heusler nanostripes — •Katherine Gross, Kurt Westerholt, and Hartmut Zabel — Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

We have investigated magnetization reversal and magnetic domain configurations of submicron sized Co2MnGe-Heusler stripes. The magnetic behaviour of this system results from the interplay between the intrinsic magneto-crystalline anisotropy, tuneable growth induced uniaxial anisotropy (1.2x103 J/m3 < KU < 6,1x103 J/m3) and shape anisotropy, as observed by magnetic-force microscopy and longitudinal Kerr hysteresis loop measurements. For sufficiently large KU values, we observe in the remanent state high regular antiparallel domain patterns with the magnetization perpendicular to the long axis of the stripes. By decreasing KU below 4,5x103 J/m3, the demagnetizing energy becomes dominant and the magnetization falls into a flux-closure as well as into dipol structure. A KU=4,5x103 J/m3, which is two orders of magnitude smaller than in Co-nanostripes, seems to be close to a critical lower value for the stabilization of this particular regular domain pattern. The characteristic micromagnetic behaviour, such as coercive, nucleation, and saturation fields can be tailored by varying the aspect ratio length/width, m = 7, 10, 14, 18 of the nanostripes. Weak anisotropy combined with a high degree of spin polarization in Co2MnGe nanostripes is promising for applications related to the control and manipulation of magnetic domain walls by current-driven spin transfer torque.

MA 36.4 Thu 10:45 H 1012

Significant Spin Polarization of Co_2MnGa measured by multichannel spinresolved UPS — •Michaela Kolbe, Gerd Schönhense, Mathias Kläui, and Martin Jourdan — Institut für Physik, Universität Mainz, Staudinger Weg 7, 55128 Mainz

The spin dependent valence band structure of the Heusler compound Co_2MnGa was investigated using spin resolved ultraviolet photoelectron spectroscopy (SRUPS) in a new multichannel detection mode [1]. Special care was taken concerning the preservation of a clean and crystallographically undistorted sample surface by the combination of UHV- thin film preparation and in-situ spectroscopy. Referring to the extreme surface sensitive detection method, Co_2MnGa is a relatively inert Heusler material. Nevertheless, the in-situ investigation proved to be advantageous compared to our previous vacuum-suitcase transport method [2] resulting in a further reduced oxidation.

A high spin polarization of 55% at the Fermi energy was observed which decreases at higher binding energies and shows a sign change at 0.7eV. This experimental result is in good agreement with theoretical predictions for the bulk density of states of this Heusler compound [3]. The possible influence of surface states on the obtained experimental results is discussed.

Financial support by the Stiftung Rheinland-Pfalz für Innovation (project 886) and the DFG (Scho341/9-1, Jo404/4-1) is acknowledged.

[1] M. Kolbe et al., Phys. Rev. Lett. 107, 207601 (2011) [2] M. Hahn et al., Appl. Phys. Lett. 98, 232503 (2011) [3] I. Galanakis et al., J. Phys. D: Appl. Phys. 39, 765 (2006)

15 min. break

MA 36.5 Thu 11:15 H 1012

Tunneling spectroscopy of the Heusler compound Co_2MnGa — •Elena Arbelo Jorge, Mathias Kläui, and Martin Jourdan — Institut für Physik, Johannes Gutenberg Universität Mainz, Staudingerweg 7, 55128 Mainz

Planar tunneling junctions with a Heusler electrode are typically used as tunneling magnetoresistance (TMR) devices. The obtained TMR can be associated with the spin polarization of the Heusler compound applying the Julliere model if amorphous AlO_x is used as a tunneling barrier[1].

Here we use planar tunneling junctions for investigations of the density of states of the Heusler compound Co_2MnGa, which is compared to the results of photoemission spectroscopy (UPS) and band structure calculations.

Planar Co_2MnGa-AlO_x-Au (or CoFe) junctions were prepared by rf-sputtering and photolithographic patterning. With the ferromagnetic counter electrode CoFe used for TMR-devices the bias dependent differential conductivity dI/dV(V) of the junctions shows a pronounced V-shape which we associate with strong contributions of magnon excitations to the tunneling process. These excitations hide the DOS features of the Heusler electrode. However, using Au as the counter electrode characteristic features of the Heusler DOS were identified which are consistent with the results obtained by UPS.

[1] e. g. C. Herbort, E. Arbelo Jorge, and M. Jourdan, Appl. Phys. Lett. 94, 142504 (2009).

Financial support by the DFG-FG559 (Jo404/4-1) is acknowledged.

MA 36.6 Thu 11:30 H 1012

Exchange bias behavior in new tetragonal Heusler compound Mn_2PtIn — •A. K. Nayak[1], J. Winterlik[2], G. H. Fecher[1,2], and C. Felser[1,2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden — [2]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg - University, Mainz

Mn_2YZ based Heusler systems show both stable cubic and tetragonal phases at room temperature with both ferro- and ferrimagnetic ordering. Due to large spin polarization of the conduction electrons, these materials are considered to be one of the most important candidates for spintronics application. It is also suggested that tetragonal alloys are suitable candidates for spin torque transfer (STT) applications. Another stimulating factor related to multi-functionality in tetragonal

Heusler alloys is their potential use for achieving large perpendicular magnetic anisotropy (PMA) required in high density perpendicular magnetic recording media. In this meeting we will present the structural and magnetic properties of the new tetragonal Heusler compound Mn_2PtIn. The low temperature hysteresis loop shows hard-magnetic behavior with low saturation magnetization, which suggests ferrimagnetic ordering in the present system. The shifted field cooled hysteresis loop indicates the presence of unidirectional exchange anisotropy, which is observed in systems showing exchange bias (EB). The observed EB behavior mainly originates from the glassy nature of the low temperature magnetic state, which is confirmed by ac susceptibility and zero field cooled relaxation measurements.

MA 36.7 Thu 11:45 H 1012

Improvement of the spin-transport properties by disorder — •Stanislav Chadov, Gerhard H. Fecher, and Claudia Felser — Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden

In the context of electronic transport characteristics the presence of disorder is often treated as a severe destructive mechanism which must be reduced by any means. On the other hand, partial disorder opens a manifold of ways to affect the system, i.e. additional degrees of freedom to tune the electronic properties. As a constructive example, we will consider the spin-transport characteristics of Mn_3Ga Heusler compound tuned by the random Co-Mn substitution. Based on the first-principle calculations we show that the disorder-induced electron localization occurs only in one of the spin channels, by turning the material from a weakly spin-polarized metal to an almost half-metal in the sense of the spin-transport. In particular, the spin-polarization of the corresponding electron current does not depend neither on the magnetic moment of the compound nor on the spin polarization of the electrons at the Fermi energy. In addition, the proposed model explains the anomalous decrease of the magnetic moment observed experimentally in $Mn_{3-x}Co_xGa$ ($x < 0.5$) alloy series.

MA 36.8 Thu 12:00 H 1012

Rare-earth oxides as interface layer for Co_2FeSi/GaAs heterojunctions — •Thomas Hentschel, Jens Herfort, Oliver Bierwagen, Andre Prössdorf, and Frank Grosse — Paul-Drude-Institut Berlin, Hausvogteiplatz 5-7, 10117 Berlin, Germany

The ferromagnetic Heusler alloy Co_2FeSi is a promising candidate for the spin-polarized injection of charge carriers into a semiconductor. Previous experiments on various GaAs and Si substrates showed a strong in-diffusion of the constituent elements of the layer and interface roughening with increasing growth temperatures T_G, which favor the long-range crystal ordering.

To suppress the intermixing we evaluate rare-earth oxide (REO) layers, with a thickness of a few monolayers only, as diffusion barriers between film and substrate. REOs exhibit high melting points beyond 2000 °C and therefore a strong chemical bonding. We found the (GaAs-)lattice-matched La_2O_3 grown by molecular beam epitaxy to form hexagonal polycrystallites on GaAs(001), while epitaxial growth was observed on GaAs(111)B substrates at $T_G = 350$ °C. Pronounced RHEED-oscillations for the GaAs(111)B case suggest a layer-by-layer growth mode. X-ray diffraction measurements show cubic polycrystallites for the 8%-mismatched Lu_2O_3 on both GaAs substrate orientations.

MA 36.9 Thu 12:15 H 1012

Carbon nanotubes filled with Heusler compounds — •Markus Gellesch, Silke Hampel, Diana Haase, Christian G.F. Blum, Elok Fidiani, Michael Schulze, Christine Täschner, Albrecht Leonhardt, Sabine Wurmehl, and Bernd Büchner — Leibniz Institut für Festkörper- und Werkstoffforschung Dresden

Filling carbon nanotubes with metal compounds is a challenge and limited to few materials so far, despite the prospect of application in e.g. storage technologies or the medical field. Here we present a versatile wet chemical approach that can be used to fill various intermetallic compounds into the inner cavity of multiwalled carbon nanotubes. With this method we synthesize successfully Heusler compounds inside carbon nanotubes. Filled carbon nanotubes are characterized by electron microscopy and x-ray probes as well as by temperature dependent magnetometry. We observe that fillings occur in form of nanoparticles with diameters in the range of 30-60nm. The particles are ferromagnetic and show a saturation magnetic moment comparable to the bulk saturation moment. However, coercive fields are strongly enhanced. We further report that oxidation is suppressed in intermetallic particles in contact with carbon nanotubes. The results of our work may guide the way to the synthesis of numerous other intermetallic systems as nanoparticles.

MA 37: Joint Session "Surface Magnetism II" (jointly with O)

Time: Thursday 9:30–13:00 Location: EB 301

MA 37.1 Thu 9:30 EB 301

Magnetism of Cobalt Nanoclusters on Graphene on Ir(111) — •Stefan Schumacher[1], Chi Vo-Van[2], Johann Coraux[2], Violetta Sessi[3], Olivier Fruchart[2], Nick B. Brookes[3], Philippe Ohresser[4], and Thomas Michely[1] — [1]II. Physikalisches Institut, Universität zu Köln, D-50937 Köln — [2]Institut Néel, CNRS et Université Joseph Fourier, F-38042 Grenoble — [3]European Synchrotron Radiation Facility, F-38043 Grenoble — [4]Synchrotron SOLEIL, F-91192 Gif-sur-Yvette

On the moiré pattern of graphene on Ir(111) a variety of highly perfect cluster superlattices with narrow size distribution can be grown. The magnetic properties of Co clusters comprising from 26 to 2700 atoms, densely self-organized on the graphene/Ir(111) moiré as well as in more sparse arrangements, were studied *in situ* by means of scanning tunneling microscopy (STM) and X-ray magnetic circular dichroism (XMCD). Surprisingly the small clusters show almost no magnetic anisotropy. We find indication for a magnetic coupling between the clusters. Experiments have to be performed carefully as the clusters get readily damaged by soft X-rays.

MA 37.2 Thu 9:45 EB 301

The role of the chemical and van der Waals interactions in defining the spin-polarization at the hybrid graphene-metal interfaces — •Nicolae Atodiresei[1], Vasile Caciuc[1], Predrag Lazić[2], Martin Callsen[1], and Stefan Blügel[1] — [1]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Massachusetts Institute of Technology, Cambridge, 02139 Massachusetts, USA

By performing density functional theory calculations we reveal the bonding mechanism and the adsorption geometry of graphene on Ir(111) and Co/Ir(111) surfaces. Our simulations included the van der Waals interactions by employing a semi-empirical [1] and an *ab initio* [2] approach, as implemented in the JuNoLo code [3]. The binding of the graphene to the metal is dominated by van der Waals interactions although, locally, a polar covalent-like chemical interaction takes place. In turn, this leads to strong variation of the local spin-polarization at the hybrid graphene-Co/Ir(111) interface. [1] S. Grimme, J. Comput. Chem. **27** 1787 (2006); [2] M. Dion *et al.*, Phys. Rev. Lett. **92**, 246401 (2004); [3] P. Lazić *et al.*, Comp. Phys. Commun. **181**, 371 (2010).

MA 37.3 Thu 10:00 EB 301

Magnetic coupling in metal organic networks on surfaces — •Tobias R. Umbach, Christian Felix Hermanns, Matthias Bernien, Alex Krüger, Isabel Ferández-Torrente, Paul Stoll, Katharina J. Franke, Jose I. Pascual, and Wolfgang Kuch — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Metal organic networks offer the possibility to alter the electronic and magnetic functionality of surfaces on a nanometer scale. Here we report on the bilayer metal organic network of Fe atoms and 2,4,6-Tris(4-pyridyl)-1,3,5-triazine (T4PT) on a Au(111) surface. The network is investigated in terms of scanning tunneling microscopy (STM) and X-ray circular dichroism (XMCD). Fe atoms and T4PT molecules form a mixed ordered phase consisting of two distinct layers. The first layer has a triangular structure and every Fe atom is surrounded by three pyridyl groups of three different T4PT molecules. The second layer is exclusively built of T4PT molecules, centered with the triazine ring on top of the Fe atoms of the first layer. XMCD measurements reveal

sizable magnetic moments of the Fe sites and an out of plane magnetic anisotropy. The field dependence of the XMCD signal reveals a finite ferromagnetic coupling of the Fe atoms in the Fe-T4PT network.

MA 37.4 Thu 10:15 EB 301

Electronic and magnetic properties of free and supported transition metal phthalocyanines — •Roberto Robles, Richard Korytar, and Nicolás Lorente — Centre d'Investigacions en Nanociència i Nanotecnologia, CIN2 (CSIC-ICN), Barcelona, Spain

By performing density functional theory calculations we have studied the electronic and magnetic properties of transition metal phthalocyanines (MPc, with M=Fe,Co,Ni,Cu), both in the gas phase and supported on Ag (100) surfaces. First we investigate the properties of the gas-phase MPc's as we change the transition metal and ionize the system. Then we deposit the molecules on the Ag (100) surface, showing how charge transfer and spin moment change by the hybridization with the surface states. We discuss the utility of the anion as a model of the supported situation. We also explore the effect of different exchange-correlation potentials, as well as the influence of van-der-Waals interactions and electronic correlation beyond DFT (GGA+U). Finally, we analyse our results in view of recent STM experiments on the same systems, specially regarding the Kondo effect observed in some of the systems.

- Mugarza, A. et al. Spin coupling and relaxation inside molecule-metal contacts. Nat. Commun. 2:490 doi: 10.1038/ncomms1497 (2011).

MA 37.5 Thu 10:30 EB 301

Spin resolved measurements of magnetic molecules on surfaces — •Jens Brede[1], Régis Decker[1], Jörg Schwöbel[1], Svetlana Klyatskaya[2], Mario Ruben[2,3], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, University of Hamburg, 20355 Hamburg, Germany — [2]Institute of Nanotechnology, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen, Germany — [3]IPCMS, Université de Strasbourg, 67034 Strasbourg, France

The use of magnetic molecules opens a gateway to a flexible design of novel spintronic devices to store, manipulate, and read spin information at nanoscale. 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 interfaces. In particular the role of individual molecular constituents and the impact of the atomic environment on molecular properties, determine device relevant parameters, such as conductance and spin polarization. Here, we applied spin-polarized scanning tunneling microscopy to resolve the physics of the molecule-ferromagnet interface. The analysis focuses on different phthalocyanine molecules. The phthalocyanine constitutes of an organic macrocyclic ligand and can be functionalized with various metal ions in order to modify, e.g. the molecular spin state. We will discuss the spin-dependent transport from magnetic surfaces through such molecules.

MA 37.6 Thu 10:45 EB 301

Controlling the spin and the magnetic coupling of adsorbed molecules by on-surface coordination chemistry — •Christian Wäckerlin[1], Kartick Tarafdar[3], Dorota Chylarecka[1], Jan Girovsky[1], Tatjana Hählen[1], Cristian Iacovita[4], Armin Kleibert[2], Frithjof Nolting[2], Thomas A. Jung[1], Peter M. Oppeneer[3], and Nirmalya Ballav[5] — [1]Laboratory for Micro- and Nanotechnology and — [2]Swiss Light Source, Paul Scherrer Institute, Switzerland — [3]Department of Physics and Astronomy, Uppsala University, Sweden — [4]Department of Physics, University of Basel, Switzerland — [5]Department of Chemistry, Indian Institute of Science Education and Research, India

The chemical and magneto-electronic interaction of metalloporphyrins with axial ligands has been investigated for the specific case where the paramagnetic molecules [1] are supported on ferromagnetic substrates. Specifically, nitric oxide (NO) can coordinate to the porphyrin center and compete with the surface ligand in its influence of the structural and electronic integrity of the porphyrin [2]. The coordination of NO (S=1/2) with Co(II) (S=1/2) [3], Fe(II) (S=1) and Mn(II) (S=5/2) tetraphenyl porphyrins on ferromagnetic Ni or Co thin film substrates is analyzed by combining X-ray magnetic circular dichroism (XMCD), scanning tunneling microscopy (STM) and density functional theory + additional Hubbard U interaction (DFT+U) calculations.

[1] A. Scheybal et al, Chem Phys Lett 411, 214 (2005). [2] W. Hieringer et al, J Am Chem Soc 133, 6206 (2011). [3] C. Wäckerlin et al, Nat Comms 1:61 (2010).

MA 37.7 Thu 11:00 EB 301

Probing individual spin states of Fe-Porphyrins on a superconductor — •Benjamin W. Heinrich, Lukas Z. Braun, José I. Pascual, and Katharina J. Franke — Institut für Experimentalphysik, Freie Universität Berlin, Germany

Scanning Tunneling Microscopy/Spectroscopy (STM/STS) allows for studying the competition between magnetism and superconductivity at a single-impurity level. Commonly, the adsorption of a magnetic atom [1,2], or molecule [3], on a superconductor locally breaks the time-reversal symmetry and gives rise to bound states in the superconducting (SC) gap [4], and/or Kondo quasi-particle states [3]. However, here we can show that decoupling the impurity spin from the SC substrate preserves both the local spin and the SC state.

We use inelastic electron tunneling spectroscopy (IETS) to probe the spin state of single Fe(III)-Octaethylporphyrin-Cloride (FeOEP-Cl) molecules adsorbed on Pb(111). Due to the bulky ligand, the interaction between the central Fe ion, holding the molecular spin, and the substrate is strongly reduced. At 4.5 K, we can observe spin flips on the molecule, while the SC quasi-particle resonances remain unchanged. Reducing the tip-sample distance allows for altering the local anisotropy, while desorbing the chlorine ligand via controlled voltage pulses results in a change of the spin state as revealed by energy shifts of the IETS signal.

[1] A. Yazdani et al., Science 275, 1767 (1997) [2] S.-H. Ji et al., Phys. Rev. Lett. 100, 226801 (2008) [3] K.J. Franke et al., Science 332, 940 (2011) [4] H. Shiba, Prog. Theor. Phys. 40, 435 (1968)

15 min. break

MA 37.8 Thu 11:30 EB 301

Spatially modulated tunnel magnetoresistance on the nanoscale — •Hirofumi Oka, Kun Tao, Sebastian Wedekind, Guillemin Rodary, Valeri Stepanyuk, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

We investigate the tunnel magnetoresistance (TMR) effect within a single Co nano-island by low-temperature spin-polarized scanning tunneling microscopy in magnetic fields. We measure the tunnel current as a function of the bias voltage and extract the TMR. We find a TMR of 290 MΩ for the anti-parallel and 190 MΩ for the parallel state at -0.27 V at the center of a Co island. This gives a TMR ratio of $\sim$50%. The TMR ratio depends on energy and position within the nano-island. We observe a clear spatial modulation of the TMR ratio with an amplitude of $\sim$20% and a spacing of $\sim$1.3 nm between maxima and minima around the Fermi level. This result can be ascribed to a spatially modulated spin-polarization within the Co island due to spin-dependent quantum interference [1]. Our combined experimental and theoretical study reveals that spin-dependent electron confinement affects all transport properties such as differential conductance, conductance and TMR. We demonstrate that the TMR within a nanostructured magnetic tunnel junction can be controlled on a length scale of 1 nm through spin-dependent quantum interference [2].

[1] H. Oka et al., Science 327, 843 (2010).
[2] H. Oka et al., PRL 107, 187201 (2011).

MA 37.9 Thu 11:45 EB 301

First-principles investigation of g-shifts and damping of dynamical magnetic excitations in adatoms on surfaces — •Samir Lounis[1], Antonio T. Costa[2], Bruno Chilian[3], Alexander A. Khajetoorians[3], Jens Wiebe[3], Roland Wiesendanger[3], and Douglas L. Mills[4] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Instituto de Fisica, Universidade Federal Fluminense, 24210-340 Niteroi, Rio de Janeiro, Brazil — [3]Institute of Applied Physics, Hamburg University, Jungiusstrasse 11, D-20355 Hamburg, Germany — [4]Department of Physics and Astronomy, University of California Irvine, California, 92697 USA

Recently, spin excitations in Fe adatoms on Cu(111) and Ag(111) surfaces are probed with magnetic field dependent inelastic scanning tunneling spectroscopy[1]. The calculation of the transverse dynamical magnetic susceptibility allows to analyse the electronic signature of these excitations[2]. We show that an Fe adatom on Ag(111) surface, contrary to other atoms embedded in various lattice configurations, has a surprisingly large g-value of 3 instead of the regular value of 2.

Work supported by the HGF-YIG Programme FunSiLab – Functional Nanoscale Structure Probe and Simulation Laboratory (VH-NG-717).
[1] A. A. Khajetoorians *et al.*, Phys. Rev. Lett. 106, 037205 (2011); B. Chilian *et al.*, Arxiv:1108.2443
[2] S. Lounis *et al.*, Phys, Rev, Lett. 105, 187205 (2010); S. Lounis *et al.*, Phys. Rev. B 83, 035109 (2011)

MA 37.10 Thu 12:00 EB 301

Anomalously large *g*-factor of single atoms adsorbed on a metal substrate — •Jens Wiebe[1], Alexander A. Khajetoorians[1], Samir Lounis[2], Antonio T. Costa[3], Bruno Chilian[1], Douglas L. Mills[4], and Roland Wiesendanger[1] — [1]Institute of Applied Physics, Hamburg University, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, Germany — [3]Instituto de Física, Universidade Federal Fluminense, Rio de Janeiro, Brazil — [4]Department of Physics and Astronomy, University of California Irvine, USA

We performed magnetic field dependent inelastic scanning tunneling spectroscopy (ISTS) on individual Fe atoms adsorbed on different metal surfaces. ISTS reveals a spin excitation which is shifting linearly to higher energies in the magnetic field. The magnetic anisotropies and the *g*-factors of the Fe atoms, as well as the lifetimes of the excitations, are extracted. We find lifetimes of hundreds of fs limited by coupling to electron-hole pairs in the substrate and decreasing linearly in the magnetic field. As expected, the magnetic anisotropy strongly depends on the substrate. Astoundingly, the *g*-factor is $g \approx 3.1$ for Ag(111) [1] instead of the regular value of 2 which is observed for the Cu(111) substrate [2]. This very large *g*-shift can be understood when considering the complete electronic structure of both the Ag(111) surface state and the Fe atom, as shown by *ab initio* calculations of the magnetic susceptibility.

[1] B. Chilian et al., Phys. Rev. B, accepted (2011).
[2] A. A. Khajetoorians et al., Phys. Rev. Lett. **106**, 037205 (2011).

MA 37.11 Thu 12:15 EB 301

Detecting spin excitation of rare-earth atoms and clusters on metallic surfaces — •Toshio Miyamachi[1], Tobias Schuh[1], Stefan Gerstl[1], Arthur Ernst[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Karlsruher Institut für Technologie, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

At the heart of the stability of magnetic bits in information storage is a magnetic anisotropy energy (MAE) and magnetization dynamics. Recent inelastic tunneling spectroscopy (ITS) studies have revealed that the spin states of 3d transition metal atoms and clusters on metallic substrates have extremely short lifetimes of the order of femtosecond due to strong hybridization of 3d states and substrates [1]. To reduce the influence of substrates from atoms and clusters, 4f rare-earth Gd atoms and clusters on Pt(111) and Cu(111) were studied with ITS. Since the 4f states are inner orbitals, the hybridization with substrates could be decreased. In addition, as the relativistic spin orbit interaction plays a crucial role for the MAE, 4f atoms with larger spin and orbital momenta could show larger MAEs than 3d atoms [2]. Obtained results show that the spin excitation of 4f states can be accessed with ITS, and that giant magnetic anisotropies and lifetimes of the excited states of Gd are nearly independent of supporting substrate or size of the cluster, reflecting the strongly localized character of 4f electrons in Gd atoms and clusters.

[1] T. Balashov et al., Phys. Rev. Lett. 102, 257203 (2009)
[2] T. Schuh et al., Phys. Rev. B. 84, 104401 (2011)

MA 37.12 Thu 12:30 EB 301

Spin-transfer torque switching efficiency in SP-STM experiments — •Andreas Sonntag, Stefan Krause, Gabriela Herzog, Anika Schlenhoff, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

The tunnel current generated in spin-polarized scanning tunneling microscopy (SP-STM) experiments can be used to manipulate the switching behavior of superparamagnets [1] or even to reverse the quasistable magnetization of nano-islands [2]. Two main contributions involved in magnetization switching could be identified: Joule heating and the spin-transfer torque.

In our study we investigate the influence of a spin-polarized tunneling current on the switching behavior of superparamagnetic Fe nanoislands on the W(110) surface. Analyzing the lifetimes of the two magnetic states in dependence of the current, Joule heating and spin-torque effects are separated and quantified [3]. While the Joule heating decreases both lifetimes equally, the spin-torque lifts their degeneracy. Both effects are found to scale linearly with the tunneling current. By introducing the so-called spin-transfer torque viscosity and normalizing the torkance with respect to the magnetic moment of the free layer, we compare our findings to experiments performed on lithographically fabricated magneto-tunnel junctions. The results show a comparatively high spin-transfer torque efficiency in our experiments.

[1] S. Krause et al., Science **317**, 1537 (2007).
[2] G. Herzog et al., Appl. Phys. Lett. **96**, 102505 (2010).
[3] S. Krause et al., Phys. Rev. Lett. **107**, 186601 (2011).

MA 37.13 Thu 12:45 EB 301

Spin transfer torque and Joule heating of field-emitted electrons — •Anika Schlenhoff, Andreas Sonntag, Stefan Krause, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg

Since the detection of the spin polarization of field-emitted electrons in the 1970's [1], it is an open question which type of effects a high spin-polarized current of field-emitted electrons has onto a magnetic sample. Though spin-polarized two-photon photoemission has gained first insight into the interaction of hot electrons with an underlying spin system [2], the microscopic details still remain to be discovered.

In our studies, we utilize spin-polarized scanning tunneling microscopy (SP-STM) in the field emission mode [3] for the direct observation of the influence of field-emitted electrons onto atomic-scale superparamagnets [4]. The experiments reveal that the injection of high spin-polarized currents via the first field emission resonance (FER) significantly changes the superparamagnet's switching behavior. Telegraphic noise experiments allow for a detailed current-dependent lifetime analysis, thereby quantifying the spin-transfer torque and Joule heating of the field-emitted electrons. The results are compared to low energy electrons tunneling directly into the nanoisland.

[1] N. Müller *et al.*, Phys. Rev. Lett. **29**, 1651 (1972).
[2] A. B. Schmidt *et al.*, Phys. Rev. Lett **105**, 197401(2010).
[3] A. Kubetzka *et al.*, Appl. Phys: Lett. **91**, 012508 (2007).
[4] S. Krause *et al.*, Phys. Rev. Lett. **103**, 127202 (2009).

MA 38: MagneticThin Films I

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

MA 38.1 Thu 9:30 H 0112

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

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

MA 38.2 Thu 9:45 H 0112

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

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

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

MA 38.3 Thu 10:00 H 0112

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

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

MA 38.4 Thu 10:15 H 0112

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

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

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

MA 38.5 Thu 10:30 H 0112

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

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

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

MA 38.6 Thu 10:45 H 0112

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

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

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

MA 38.7 Thu 11:00 H 0112

Analysis of anisotropy constants for $Co_{50}Fe_{50}$ and Fe films investigated by MOKE — •Timo Kuschel[1], Jaroslav Hamrle[2], Jaromir Pistora[2], Kesami Saito[3], Subrojati Bosu[3], Yuya Sakuraba[3], Koki Takanashi[3], Henrik Wilkens[1], and Joachim Wollschläger[1] — [1]Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49069 Osnabrück, Germany — [2]Department of Physics, VSB - Technical University of Ostrava, 17. listopadu 15, 70833 Ostrava-Poruba, Czech Republic — [3]Institute for Materials Research (IMR), Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai 980-8577, Japan

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

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

15 min. break

MA 38.8 Thu 11:30 H 0112

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

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

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

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

MA 38.9 Thu 11:45 H 0112

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

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

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

MA 38.10 Thu 12:00 H 0112

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

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

MA 38.11 Thu 12:15 H 0112

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

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

MA 38.12 Thu 12:30 H 0112

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

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

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

MA 38.13 Thu 12:45 H 0112

The importance of beyond-Heisenberg interactions in ferromagnetic metal/antiferromagnetic oxides interfaces — •Valerio Bellini[1], Gustav Bihlmayer[2], Franca Manghi[1,3], and Stefan Blügel[1] — [1]CNR - Istituto di Nanoscienze - S3, Modena, Italy — [2]Peter Grünberg Institut (PGI-1) and IAS-1, Forschungszentrum Jülich, Jülich, Germany — [3]Dipartimento di Fisica, Università di Modena and Reggio Emilia, Modena, Italy

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

MA 39: Micro- and Nanostructured Magnetic Materials I

Time: Thursday 9:30–13:00 Location: EB 202

MA 39.1 Thu 9:30 EB 202

Room Temperature Magnetometry of an Individual Iron Filled Carbon Nanotube Acting as Nanocantilever — •Stefan Philippi, Uhland Weissker, Thomas Mühl, Albrecht Leonhardt, and Bernd Büchner — Leibniz Institut für Festkörper- und Werkstoffforschung, Dresden, Deutschland

The influence of external magnetic fields on the bending vibration of a one-side clamped iron filled carbon nanotube (CNT) has been analyzed theoretically and experimentallywith particular consideration to the changes in the resonance frequency. The model involves the application of a modified Euler-Bernoulli-beam to analyze the zero field oscillatory behaviour as well as a magnetostatic approach to determine the influence of any external field distributions. The experiments were conducted in situ in a scanning electron microscope. The measured magnetic moment of the nanowire at room temperature was $\mu = 2.1 \cdot 10^{-14}\,\mathrm{Am}^2$. Due to the favorable geometry of the CNT oscillator, the raw signal using this approach is significantly more favourable than state of the art cantilever magnetometry. The obtained good agreement between model and experiment provides a valuable basis for the development of nanoelectromechanical systems where magnetic interactions are relevant.

MA 39.2 Thu 9:45 EB 202

X-ray microdiffraction studies on complex magnetoelectric composites with defined microstructures — •Stjepan Hrkac[1], Madjid Abes[1], Christian Koops[1], Christina Krywka[1], Martin Müller[1,2], Sören Kaps[3], Rainer Adelung[3], Olaf Magnussen[1], and Bridget Murphy[1] — [1]Institut für experimentelle und angewandte Physik, CAU Kiel, Germany — [2]Strukturforschung an Neuen Werkstoffen, Helmholtz Zentrum Geesthacht, Germany — [3]Institut für Materialwissenschaft, CAU Kiel, Germany

Magnetoelectric (ME) composites, consisting of a piezoelectric (PE) and a magnetostrictive (MS) material, are of great interest for potential applications as highly sensitive ME sensors. A large ME response is only obtained if the lattice deformation induced by an external magnetic field in the MS material can be transferred effeciently to the PE material. The understanding of this mechanical coupling and its dependence on the component's interface structure is still very rudimentary. This study aims at understanding this coupling by directly measuring the strain induced in the PE material in an external magnetic field employing X-ray diffraction methods. We present intrinsic strain maps of ZnO microrods (800 x 30 μm^2), grown by flame transportation synthesis, with a 200 nm MS $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$ (Metglas) coating, measured by the nanofocused X-ray beam provided by the Nanofocus Endstation of the MINAXS-Beamline at Petra III. The studies reveal pronounced compressive strain, which strongly varies across the sample, and a magnetic field induced strain relaxation.

MA 39.3 Thu 10:00 EB 202

Structure, microstructure and magnetic properties of electrodeposited $Fe_{70}Pd_{30}$ nanowires — •Veronika Haehnel[1,2], Christine Mickel[1], Heike Schlörb[1], Sebastian Fähler[1], and Ludwig Schultz[1,2] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]TU Dresden, Faculty of Mechanical Engineering, Institute of Material Science, 01062 Dresden, Germany

Fe-Pd alloys at about 30 at.% Pd show excellent functional properties. The scientific and technological interest is focused on these martensitic transforming alloys as they exhibit the magnetic shape memory effect (MSM). The expected strains of up to several percent make them perfect candidates for nanoactuators or sensors. Due to the reduced dimensions actuation frequencies should increase. Also a double maximum strain compared to thin films is expected for the novel "stray field induced microstructure"-actuation mode, because shape anisotropy favors only one easy axis along the nanowire axis.

In this study we use the cost and time efficient method of electrodeposition within nanoporous aluminum oxide templates to prepare Fe-Pd nanowires. A complexed electrolyte of Fe^{3+} and Pd^{2+} ions and an alternating potential regime is necessary to achieve continuous, almost defect free nanowires exhibiting a composition close to the $Fe_{70}Pd_{30}$ alloy. TEM and structural investigations reveal a bcc Fe-Pd structure and nanocrystalline grain sizes. Magnetic properties are controlled by shape anisotropy as well as magnetostatic interactions between neighboring nanowires. These results represent a promising starting point for future research toward MSM nanoactuators.

MA 39.4 Thu 10:15 EB 202

Magnetic coupling and magnetic anisotropy of iron doped platinum wires — •Lucila Juarez and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Germany

We report a first principles study of the magnetic coupling and magnetic anisotropy in monoatomic freestanding $FePt_n$ wires ($n = 1 - 4$) focusing mainly on the case where iron dopands are equally spaced along the chain. The magnetic coupling between iron dopands was found to change from antiferromagnetic to ferromagnetic depending on the position that impurities occupy with respect to each other. The results can be understood analysing the magnetic polarization of platinum atoms in chains doped with iron at very low concentations. Large anisotropies are present in spin and orbital moments of platinum atoms leading to magnetic anisotropy energies in the order of 10meV /at for some concentrations. The orbital moment of iron atoms couples antiferromagnetically to its spin moment for in chain axis magnetization. However, this does not lead to the destabilization of the easy axis.

MA 39.5 Thu 10:30 EB 202

Directed self-assembly of (sub-)phthalocyanine submonolayers by magnetic stray field landscapes — •Florian Ahrend[1], Ulrich Glebe[1], Tobias Weidner[2], Ulrich Siemeling[1], and Arno Ehresmann[1] — [1]Department of Physics and Chemistry, CINSaT, University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Department of Bioengineering, University of Washington, Seattle

Magnetic stray field landscapes are produced by ion bombardment induced magnetic patterning (IBMP) of exchange-biased magnetic bilayers (A. Ehresmann, Recent Res. Devel. Applied Phys., 7 (2004)) into artificial parallel-stripe magnetic domains. The μm-sized magnetic stripe patterns with antiparallel magnetizations in adjacent domains (head-to-head/tail-to-tail) lead to strong magnetic stray fields above the domain walls. It will be shown that these stray fields influence the self-assembly of submonolayers of chemically modified (sub-)phthalocyanines. Diamagnetic derivatives of these molecules are shown to assemble preferentially in areas offering low magnetic stray field gradients. Characterization of the samples has been performed by X-ray photoelectron emission microscopy (X-PEEM), time-of-flight secondary ion mass spectroscopy (ToF-SIMS) and near-edge x-ray absorption fine structure imaging (NEXAFS-imaging) measurements.

MA 39.6 Thu 10:45 EB 202

Defect-induced ferromagnetism in SiC — •Yutian Wang[1], Lin Li[1], Slawomir Prucnal[1], Kay Potzger[1], Shengqiang Zhou[1], Zhaorong Yang[2], Wolfgang Anwand[3], and Andreas Wagner[3] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, POB 51 01 19, 01314 Dresden, Germany — [2]Key Laboratory of Materials Physics, Institute of Solid State Physics, Chinese Academy of Sciences, Hefei 230031, People's Republic of China — [3]Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, POB 51 01 19, 01314 Dresden, Germany

A controllable method to create defects in SiC is the key requirement for understanding the mechanism of the defect-induced ferromagnetism. Using Ne-ion irradiation, defect-induced ferromagnetism in SiC can be established. Electron-spin resonance and positron annihilation spectroscopy [1] are adopted to determine the location of unpaired electrons and the type of defects. The dependence of magnetic properties on the concentrations of VSi-VC divacancies has been studied. We found that by increasing the irradiation fluence the saturation magnetization has increased initially, then dropped to almost zero since a large irradiation fluence induced too much disorder [2]. Temperature dependent magnetization indicates two ferromagnetic components. One reveals a Curie temperature around 70 K while another one has a Curie temperature above room temperature. Employing electron-spin resonance and SQUID magnetometry leads to the observation of large magnetic anisotropy. Reference: 1.Brauer, G., et al., Phys. Rev. B, 54, 3084 (1996). 2.Li, L. et al., Appl. Phys. Lett., 98, 222508 (2011).

MA 39.7 Thu 11:00 EB 202

Formation of spin-spiral states in Fe zig-zag chains and ladders: A first principles study — •Muhammad Tanveer, Pedro Ruiz-Díaz, and Gustavo Pastor — Institut für Theoretische Physik, Universität Kassel, Heinrich Plett Straße 40, 34132 Kassel, Germany.

A first-principles study of the stability of spiral spin-density wave (SDW) states in free standing Fe wires having linear, zig-zag and ladder geometries is presented. The calculations are based on density-functional theory in the generalised gradient approximation. The spin-spiral magnetic arrangement is described by the wave vector $\mathbf{q} = (0, 0, q)2\pi/a$ along the chains axis. The stability of the spiral structure is quantified in terms of the total energy difference as a function of $\mathbf{q}$ and for different nearest-neighbor (NN) distances. We observed that the zigzag chains have a ferromagnetic (FM) stable ground state whilst the ladders chains tend to favour the formation of a spiral SDW with wave vector $\mathbf{q} \cong (0, 0, 0.2)2\pi/a$. The dependence of the local magnetic moments as a function of $\mathbf{q}$ reflects the itinerant character of magnetism in the Fe chains. The magnetic order and its stability as a function of the NN distances are interpreted in terms of the effective exchange-interaction parameters J_{ij}, which are derived in the framework of a phenomenological classical Heisenberg model.

15 min. break

MA 39.8 Thu 11:30 EB 202

Highly coercive and textured SmCo5 nanoflakes prepared by surfactant assisted high energy ball milling — •Santosh Kumar Pal[1], Juliane Thielsch[1], Ludwig Schultz[1], and Oliver Gutfleisch[1,2] — [1]IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [2]Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 23, 64287 Darmstadt, Germany

Exchange-coupled nanocomposite magnets consisting of a highly coercive and textured hard magnetic phase and a soft magnetic phase with high magnetization have potential to be the next generation of permanent magnets with very high energy products. In this study, we discuss the effects of the type and amount of surfactants on the structural, morphological and magnetic properties of SmCo5 nanoflakes prepared by high energy ball milling. Increase in surfactants concentration result in the decrease of degree of amorphization and reduction in crystallite size with milling time. The coercivity of flakes first increase with milling time up to maximum values of 1.78, 1.96 and 2.07 tesla for 5, 10 and 30 wt.% of PVP respectively, further milling results in decrease of the coercivity and the rate of decrease is lower for higher surfactant concentration. A maximum coercivity of 2.29 tesla was obtained after a milling time of 1.0 and 2.0 h for 10 and 50 wt.% of OA respectively. Degree of texture (DOT) increases with increase in surfactants concentration and decreases monotonically with milling time, 73% of DOT was obtained for 50 wt.% OA after 0.5 h of milling. The pronounced anisotropy and high coercivity of the nanoflakes should prove advantageous for the preparation of exchange spring magnets.

MA 39.9 Thu 11:45 EB 202

Magneto-static interaction of single NiFe nanostructures — •Philipp Staeck, Mahmoud Reza Rahbar Azad, André Kobs, Daniel Stickler, Björn Beyersdorff, Hendrik Spahr, Robert Frömter, and Hans Peter Oepen — Inst. für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

The magneto-static interaction of submicron Ni80Fe20 rectangles (aspect ratio 2:1) has been investigated by means of magnetotransport measurements using anisotropic magneto resistance (AMR). The structures were carved into a Cr(10nm)/Ni80Fe20(20nm)/Pt(2,5nm) trilayer utilizing a focused ion beam (FIB). The material around the rectangles has been rendered via ion milling. Microcircuits are milled by FIB that allow to contact electrically an individual element via a micromanipulator [1]. For this work structure sizes down to 300 nm x 600 nm have been investigated. This one-step structuring approach in combination with a magneto-resistive measuring setup (sensitivity of $\Delta R/R{=}10^{-6}$) was utilized to measure the magnetic energy of micro-magnetic states of single, isolated rectangle obtaining flux closure structures, like Landau state [2]. Recently, it has been shown that rectangles with flux closure structure can magneto statically interact [3]. We have varied the distance between rectangles in an array and measured the energy change of a single element. The strength of the magneto-static interaction between rectangles revealing flux closure domain pattern has been quantified. [1] Daniel Stickler et al., Rev. Sci. Instr. 79, 103901 (2008), [2] André Kobs et al., Phy. Rev. B 80, 134415 (2009), [3] Sebastian Hankemeier et al., PRL 103, 147204 (2009)

MA 39.10 Thu 12:00 EB 202

Temperature dependent switching of single superparamagnetic nanodots — •Alexander Neumann[1], Carsten Thönnissen[1], Simon Hesse[1], Andreas Meyer[2], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Institut für Physikalische Chemie, Universität Hamburg, Germany

We have investigated the temperature dependence of the coercive field and the time dependent switching behavior of single Co/Pt nanodots (<30nm) in the range of 80K to 300K. We used Sharrocks formula to determine from the coercivities the anisotropy constant K and the saturation magnetization M_S [1]. Additionally, the anisotropy constant is determined from the temperature dependent switching behavior [2]. The magnetic volume V of the nanodots is determined directly from images taken by scanning electron microscopy. Both fittings give results that are identical within the error margin and slightly smaller than the film value. The time constant τ_0 is considerably smaller than expected for a macro-spin behavior. The dots were fabricated out of thin Co/Pt film via Ar^+ ion milling at 150eV utilizing SiO_2 particles as a shadow mask. The Co/Pt film is tuned to give perpendicular anisotropy which is preserved in the nanodots [3]. Via a hall cross the state of magnitization is obtained by the anomalous Hall-Effect.

[1]M. P. Sharrock, IEEE Trans. Magn. **26**, p193-197, (1990)
[2]Bean and Livingston, J. Appl. Phys. **30**, 120S, (1959)
[3]H. Stillrich *et al.* Adv. Funct. Mat. **18**, p76-81, (2008).

MA 39.11 Thu 12:15 EB 202

Mesoscopic magnetic structure and competing anisotropies in laterally structured Fe / Cr-layer systems — •Markus Schmitz, Alexander Weber, Emmanuel Kentzinger, Elisabeth Josten, Ulrich Rücker, and Thomas Brückel — JCNS-2, PGI-4: Streumethoden Forschungszentrum Jülich GmbH

Patterned magnetic structures are the basic elements of spintronic devices. The ongoing miniaturization makes the influence of neighboring structures more and more important. Fe/Cr multilayers have been grown epitaxially on GaAs (100) single crystals by Molecular Beam Epitaxy. The Cr interlayers induce an antiferromagnetic coupling between adjacent Fe layers. Thus, the magnetic dipole moment is reduced and a magnetic superstructure is created, which is, due to the contrast of Cr to Fe, easily observable by polarized neutron reflectometry. The lateral structuring was performed by UV-nanoimprint lithography and Reactive Ion Etching. The structural characterization was carried out by Scanning Electron Microscopy, Atomic Force Microscopy and X-ray scattering under grazing incidence. The macroscopic magnetic properties were determined by MOKE and SQUID magnetometry. Polarized neutron reflectometry and off-specular scattering was used to determine the magnetic domain formation within the individual layers. Furthermore, simulations of the neutron data were generated and compared with the measurement in order to improve the simulation model. The work presented gives insight into the interplay of shape and crystalanisotropy within the individual layers and patterns.

MA 39.12 Thu 12:30 EB 202

Magnetic reversal in a laterally structured spin valve system with one tunable magnetic layer — •Frank Brüssing, Melanie Ewerlin, Radu Abrudan, and Hartmut Zabel — Department of Physics, Ruhr-University Bochum, 44780 Bochum, Germany

We investigated the magnetization reversal of interacting Co islands and how their behavior is altered after switching on the interlayer exchange interaction to a second magnetic island with different magnetic domain structure and different coercivity values. We prepared an epitaxial magnetic heterostructure comprising two ferromagnetic layers, one with a high Curie temperature (T_C) (Co) and one with a T_C below room temperature (RT) ($Fe_{1-x}Cr_x$), and a mediating Cr layer in between. After lateral patterning via e-beam lithography and ion beam etching into islands, we investigated elements selectively the magnetization reversal of Co at RT and of the combined system at low temperature, using x-ray resonant magnetic scattering (XRMS). As reference we also investigated the same heterostructure before patterning. The lateral periodic pattern gives raise to new in-plane Bragg reflections, revealing the structural and magnetic intra- and inter-island correlation. For the measurments we have used a CCD camera for investigating the magnetic Bragg peaks and magnetic diffuse scattering as a function of temperature above and below the T_C of $Fe_{1-x}Cr_x$.

MA 39.13 Thu 12:45 EB 202

Fabrication and characterization of patterned exchange-coupled trilayers — •M. Langer[1], J. Osten[1], A. Neudert[1], M. Körner[1], A. Banholzer[1], I. Mönch[2], R. Mattheis[3], J. Fassbender[1], and J. McCord[4] — [1]HZDR, Inst. of Ion Beam Physics and Materials Research, 01314 Dresden — [2]IFW Dresden, Inst. for Integrative Nanosciences, 01069 Dresden — [3]IPHT Jena, Inst. of Photonic Technology, 07702 Jena — [4]Christian-Albrechts-University Kiel, Inst. for Materials Science, 24143 Kiel

Magnetic patterning by means of ion-implantation is an advanced technique to fabricate ferromagnetic micro-/nanostructures. In this case antiferromagnetically exchange coupled trilayers, consisting of two $Co_{90}Fe_{10}$ layers with a Ru interlayer, were used. The ion induced intermixing of the interlayer with its surrounding magnetic layers alters the coupling to a ferromagnetic one. Therefore Co ions with energies of 40-80 keV and a fluence of $5{\cdot}10^{15}$ cm^{-2} were used. Hence, applying masks, ferromagnetically coupled micro-/nanometer sized elements (stripes, squares, circles etc.), embedded in a so-called artificial antiferromagnetic environment, have been fabricated. These structures were characterized by the use of Kerr-microscopy and MOKE-magnetometry to determine the mutual influence of the ferromagnetic elements with the antiferromagnetically coupled environment. Also their magnetic switching behavior was compared to etched single ferromagnetic structures. Domain pinning at the element boundaries was observed.

This work is supported by DFG grant FA314/3-2 and MC9/7-2.

MA 40: PhD Student Symposium: "Spintronics on the Way to modern Storage Technology I", Organization: "Univ. Mainz team"

Time: Thursday 9:50–12:00 Location: BH 243

Thu 9:50 BH 243

Welcome by the AGjDPG and the organizers

Topical Talk MA 40.1 Thu 10:00 BH 243

Magnon Spintronics — •Burkard Hillebrands, Andrii Chumak, Alexandr Serga, and Benjamin Jungfleisch — Fachbereich Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern

Spintronics is concerned with the development of devices which exceed the performance and energy efficiency of charge-based electronics by exploiting the electron's spin degree of freedom. Spin angular momentum, which is the information carrier in spintronics, can be transferred not only by the flow of electrons, but also by magnons: the quanta of spin waves (collective excitations of the spin lattice of a magnetic material). This opens a new research direction: magnon spintronics, a sub-field of spintronics in which information is transferred and processed using magnons. It can be implemented in an electric-isolator environment (yttrium iron garnet, YIG) fully avoiding Ohmic losses. I will give a tutorial style introduction into the main construction blocks of a magnon spintronics device: converters between information carried by the spin and the charge of electrons and magnons, magnon conduits, and physical phenomena allowing information processing by magnons. The most promising convertors for magnon spintronics are based on the spin pumping effect (which transforms spin waves into pure spin currents) and the inverse spin Hall effect (which converts spin currents into charge currents). I will present some selected results addressing magnetic insulator YIG - nonmagnetic Pt structures.

Topical Talk MA 40.2 Thu 10:30 BH 243

Functional materials for spintronics, magnetic devices and magnetization dynamics — •Günter Reiss[1], Andreas Hütten[1], Jan Schmalhorst[1], Markus Meinert[1], Daniel Ebke[1], Andy Thomas[1], Hans-Werner Schumacher[2], Markus Münzenberg[3], and Sergej Demokritov[4] — [1]Physics Department, Bielefeld University, Bielefeld, Germany — [2]PTB Braunschweig, Braunschweig, Germany — [3]Physics Department, Göttingen University, Göttingen, Germany — [4]Physics Department, Münster University, Münster, Germany

Spintronics uses the magnetic moment of electrons to process and store information or to sense magnetic fields. The corresponding devices are usually built from stacks of different thin films such as ferro-, ferri- and antiferromagnets, insulators, seed layers and conductors. The properties of the materials and the various interfaces are the key enablers for the device functionality. Using magnetic tunnel junctions (MTJs) capable of spin torque transfer switching as example we present the challenges of applications and discuss recent advances in using either traditional material combinations such as CoFeB/MgO or new materials such as Heusler alloys and magnetically perpendicular materials. In all stacks, magnetization and damping are key parameters and thus important dynamic properties will be discussed as well. In the last part, new memristive properties will be presented which could enable mimicking brain operations with MTJs.

MA 40.3 Thu 11:00 BH 243

Revealing the significance of heating in the all-optical switching process — •Sabine Alebrand, Daniel Steil, Alexander Hassdenteufel, Mirko Cinchetti, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67653 Kaiserslautern, Germany

It is well known that it is possible to switch the magnetic state of a ferrimagnetic GdFeCo sample all-optically, i.e. just by using one single circularly polarized laser pulse and without any additional external magnetic field [1]. In principle the laser pulse may fulfil two functions: delivering helicity and heating up the sample. Up to now it is still controversially discussed in literature if heating is necessary for the all-optical switching process [2,3].

To shed light on this issue: (i) we consider the dependence of the minimum laser fluence needed to obtain switching on the repetition rate of the laser pulses; and (ii) discuss the results of σ-π experiments using one circularly pulse (acting as angular momentum source) and a linearly polarized pulse (acting as a heating pulse). We show that it is possible to switch all-optically by the combination of both pulses although the fluence of the circularly polarized laser pulse is below the minimum fluence threshold (determined for switching with only one circularly polarized pulse). Both of our experiments clearly favour the fact that heating contributes to the switching process.

[1] Stanciu et al. PRL 99, 047601, 2007 [2] Kirilyuk et al., Rev. of Mod. Phys. 82, 2010 [3] Vahaplar et al., PRL 103, 117201, 2009

MA 40.4 Thu 11:15 BH 243

Large relaxation times in permalloy reprogrammable magnonic crystals — •Rupert Huber, Thomas Schwarze, Georg Duerr, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, James-Franck-Str., D-85748 Garching b. München, Germany

Stimulated by photonic crystals artificial band structures for magnons have attracted growing interest recently. The so called magnonic crystals are expected to have promising impact for nanometer sized spin wave logic elements. We have produced a one-dimensional densely packed ferromagnetic wire array by electron beam lithography and lift-off processing of 30 nm thick permalloy. This is based on a double exposure process, in order to avoid proximity effects at a period of 300 nm. We present data obtained by all electrical spin wave spectroscopy (AESWS). [1] Using a vector network analyzer and two collinear coplanar waveguides we measure spin wave propagation. The signals depend characteristically on an applied in-plane field reflecting the reprogrammable band structure [2]. We present quantitative data on velocities and relaxation times extracted from the phase information of the propagating spin wave.[1] We acknowledge financial support through the Nanoinitiative Munich (NIM) and the European Community*s Seventh Framework Programm (FP7/2007-2013) under Grant Agreement no. 228673 MAGNONICS. [1] Ballieul et al., APL, 83, 5 (2003) [2] J. Topp et al., PRL 104, 207205 (2010)

Topical Talk MA 40.5 Thu 11:30 BH 243

Spin wave propagation and excitation, microwave assisted switching and non-linear magnetic resonance — •Georg Woltersdorf, Hans G. Bauer, and Christian H. Back — Universität Regensburg, Regensburg, Germany

The control of the propagation properties of spin waves is essential for the successful implementation of magnon based logic devices. In

addition since large excitation amplitudes are needed it is desirable to thoroughly understand the non-linear magnetization dynamics in such structures.

We use time resolved Kerr microscopy to study magnetic excitations on a sub-micron length scale. In doing so the spin wave propagation in magnetic wires and microwave assisted switching behavior in magnetic elements is studied. In addition we use X-ray magnetic circular dichroism experiments to determine precisely the number of magnons that are excited in Permalloy films. We show that commonly used models for non-linear resonance are actually not applicable at low bias fields. A simple non-linear model allows us to find the correct threshold field and the associated critical modes. This analysis explains our experimental findings and agrees with micro-magnetic simulations.

MA 41: Joint Session Magnetic Shape Memory Alloys I (jointly with DS, MM)

Time: Thursday 10:15–12:00 Location: H 0106

MA 41.1 Thu 10:15 H 0106

Different types of twin boundaries in 14M modulated Ni-Mn-Ga — •Christian Behler[1,2], Bernd Rellinghaus[1], Anja Backen[1], Sandra Kauffmann-Weiss[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Dresden University of Technology, Institute for Solid State Physics, Department of Physics, 01062 Dresden, Germany

Recent studies [L. Straka et al. Acta Mat. 59 (2011) 7450-7463] have found that various types of twin boundaries, such as type I, type II and modulation twins, with different mobilities can exist in the magnetic shape memory alloy Ni-Mn-Ga. In a 1.5 μm thin epitaxial Ni-Mn-Ga film we observe two types of twin boundaries. This film was investigated by means of scanning electron microscopy (SEM), transmission electron microscopy (TEM) imaging and selected area diffraction (SAED) to clarify the type of the observed boundaries. From the orientations of neighboring variants, determined by SAED, conclusions can be drawn about the type of the interfaces. These analyzed interfaces can be attributed to type I twin boundaries as well as modulation twins. The 14M modulation is generated by nanotwins, which were observed by High Resolution TEM. However, this modulation is not perfect due to the existence of stacking faults.

MA 41.2 Thu 10:30 H 0106

A multi-phase field model to investigate the elastic and magnetic hysteresis behaviour of twinned Ni_2MnGa — •Marcus Jainta[1], Christian Mennerich[1], Frank Wendler[1], and Britta Nestler[1,2] — [1]IMP, Karlsruhe University of Applied Sciences — [2]IAM-ZBS, Karlsruhe Institute of Technology

In the last years, magnetic shape memory alloys became an important matter for material scientists. Due to their fast response time, their large recoverable strain and the good cost efficiency, this material class is well suited to be used as components of actuators or dampers. The microstructure evolution of magnetic shape memory alloys depends on the formation of magnetic domains and on the elastic strains induced by external magnetic fields and mechanical loads. To represent this behaviour, we applied a multi-phase field model of Allen-Cahn type based on a Helmholtz free energy density formulation. It is coupled with a model for linear elasticity and with an implementation of the Landau-Lifshitz-Gilbert equation. The order parameters are related to the different eigenstrains of the twin variants and to the spontaneous magnetization. In this contribution, we describe the model and compare simulation results of our combined micromagnetic phase-field solver with numerical results from the literature. We present simulation results of twinned structures in martensic Ni_2MnGa performing elastic and magnetic hysteresis behaviours under external forces. We also show the applicability of the model to polycrystalline systems.

MA 41.3 Thu 10:45 H 0106

Modulated martensite and its twin boundaries in Ni-Mn-Ga films — •Anja Backen[1,2], Sandra Kauffmann-Weiss[1,2], Anett Diestel[1,2], Ludwig Schultz[1,2], and Sebastian Fähler[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Dresden University of Technology, Institute of Materials Science, 01062 Dresden, Germany

The magnetic shape memory alloy Ni-Mn-Ga has gained much attention due to the high achievable strains of up to 10 % when applying an external magnetic field. The reorientation of martensitic variants is achieved by movement of twin boundaries. An external magnetic field can only overcome a twinning stress of 2 MPa or less, which brings the modulated martensite in the center of research interest. The 14-layer modulated martensite exhibits different generations of twin boundaries. The first generation are nano twin boundaries between non-modulated variants which are formed in order to decrease elastic energy at the austenite-martensite interface. The second generation connects variants of the 14M structure. This second generation is highly mobile and can be moved by an external magnetic field. We analyzed two types of microstructures which represent two cases of the 2nd generation of twinning. Although they appear to be completely different, X-ray diffraction and pole figure measurements reveal that both microstructures are composed of 14M twins. Magnetization measurements show, that only one type of twin boundaries can be moved by a magnetic field which is important for future application in microsystems. This work is funded by DFG via SPP 1239.

MA 41.4 Thu 11:00 H 0106

Freestanding single crystalline Fe-Pd ferromagnetic shape memory membranes: structural, morphological and magnetic characterization — •Yanhong Ma[1], A. Setzer[3], J. W. Gerlach[1], F. Frost[1], P. Esquinazi[3], and S. G. Mayr[1,2] — [1]Leibniz-Institut für Oberflächenmodifizierung e.V., 04318 Leipzig — [2]Translationszentrum für Regenerative Medizin und Fakultät für Physik und Geowissenschaften, Universität Leipzig — [3]Faculty of Physics and Earth Sciences, Institute for Experimental Physics II, Division of Superconductivity and Magnetism, Universität Leipzig

Miniaturized single crystalline $Fe_{70}Pd_{30}$ ferromagnetic shape memory alloy membranes in the correct fct phase are synthesized by employing molecular beam epitaxy on MgO (001) substrates at deposition temperatures of 850°C and higher without post-annealing treatment. Atomic force microscopy images of these martensitic Fe-Pd thin films directly reflect formation of twin structure on the surface and reveal, how martensite variants grow. Martensitic phase transformation in the freestanding thin films is investigated with temperature dependent x-ray diffraction and magnetometry using a superconducting quantum interference device. The XRD patterns measured at various temperatures for freestanding martensitic Fe-Pd thin films show reversible (fct-fcc) and irreversible (bcc/bct-fcc) structural transformations.
This project is funded by the Leipzig Graduate School of Natural Sciences "Building with Molecules and Nano Objects" through the German Science Foundation (DFG), as well as by the German Federal Ministry of Education and Research (BMBF, PTJ-BIO, 0313909).

MA 41.5 Thu 11:15 H 0106

Adaptive nanostructures in Fe-Pd magnetic shape memory alloys — •Markus Ernst Gruner[1], Sandra Kauffmann-Weiss[2], Sebastian Fähler[2], Ludwig Schultz[2], and Peter Entel[1] — [1]Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg — [2]IFW Dresden, P.O. Box 270116, 01171 Dresden

Apart from the prototypical Ni-Mn-Ga Heusler alloy, also Fe-based alloys as $Fe_{70}Pd_{30}$ exhibit significant magnetic field induced strains in moderate magnetic fields. This is bound to a slightly tetragonal fcc structure (fct) which finds no correspondence on the low temperature binding surface which has been determined from density functional theory (DFT) calculations [PRB **83**, 214415 (2011)]. Instead, the energy decreases rather uniformly along the Bain path towards the absolute minimum close to bcc. Recent experiments reveal the possibility of growing $Fe_{70}Pd_{30}$ films with $c/a_{\mathrm{fct}} = 1.09$ extending the Bain path beyond fcc [PRL **107**, 206105 (2011)]. XRD spectroscopy reveals that this is accompanied by a novel relaxation mechanism leading to a nanotwinned pattern consisting of fct building blocks. DFT modelling confirms this process showing a second minimum on the binding surface. This owes to the extremely low formation energy of fct twins causing the autonomous evolution of a twinned superstructure in the simulation cell along [110]. This corresponds to the experimentally observed soft transversal acoustic phonon in this direction, which is

also a central feature of the Ni_2MnGa magnetic shape memory alloy. We demonstrate further that magnetic excitations significantly alter the binding surface and thus potentially influence the transformation.

MA 41.6 Thu 11:30 H 0106

Functional properties of magnetic Heusler alloys from an ab initio point of view — •Peter Entel, Mario Siewert, Markus E. Gruner, Heike C. Herper, and Sanjubala Sahoo — Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany

Magnetic Heusler alloys exhibit complex magnetic phases and multiple intermediate martensitic structures. The strong interplay of magnetic and structural degrees of freedom is decisive for the functional properties associated with the magnetic shape-memory effect and the magneto-, elasto- and barocaloric effect. In this contribution we will discuss how the different functional properties arise from the complex spin interactions between the magnetic ions. We will show that this knowledge can be used to tune and optimize the various functional properties of the Heusler alloys as recently discussed for quaternary magnetic shape memory compounds [1].

[1] M. Siewert *et al.*, Appl. Phys. Lett. **99**, 191904 (2011).

MA 41.7 Thu 11:45 H 0106

Failure of the Maxwell relation for the quantification of caloric effects in ferroic materials — Robert Niemann[1,2], Oleg Heczko[3], Ludwig Schultz[1,2], and •Sebastian Fähler[1,2] — [1]IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany — [2]Department of Physics, Institute for Solid State Physics, Dresden University of Technology, 01062 Dresden, Germany — [3]Institute of Physics, Academy of Science of the Czech Republic, Na Slovance 2, 182 02 Prague, Czech Republic

Giant caloric effects were reported in elasto-, electro- and magnetocaloric materials near phase transformations. Commonly, their entropy change is indirectly evaluated by a Maxwell relation. We report the fundamental failure of this approach. We analyze exemplarily the Ni-Mn-Ga magnetic shape memory alloy. An applied field results in magnetically induced reorientation of martensitic variants, which form during the phase transformation. This results in a spurious magnetocaloric effect, which only disappears when repeating the measurement a second time. This failure is universal as the vector character of the applied field is not considered in the common scalar evaluation of a Maxwell relation.

MA 42: Joint Session "Novel Spincaloritronic Devices: Control of Heat, Charge and Momentum Flow" (jointly with TT), Organization: Markus Münzenberg (Univ. Göttingen), Mathias Weiler (WMI Garching)

Time: Thursday 15:00–17:30 Location: EB 301

Invited Talk MA 42.1 Thu 15:00 EB 301

Spin Seebeck and spin Peltier effects in ferromagnetic-nonmagnetic devices — •Bart van Wees — Zernike Institute of Advanced Materials, Groningen, The Netherlands

I will give an overview of two spincaloritronic effects in ferromagnet-nonmagnetic devices. First, the spin (dependent) Seebeck effect is demonstrated by the injection of a spin current into a non-magnetic metal, using a temperature gradient and an associated heatcurrent [1]. The second example is the recent observation of the spin Peltier effect [2]. In a specially designed device it is shown that a cooling or heating is associated with a spin current which flows in a specially designed permalloy/copper/permalloy structure. The cooling/heating due to the spin Peltier effect is detected as a change in temperature by an on-chip nanoscale thermocouple. Implications for further research will be discussed.

[1]A. Slachter, F. L. Bakker, J.-P. Adam, and B. J. van Wees, "Thermally driven spin injection from a ferromagnet into a non-magnetic metal", Nature Physics 6, 879-882(2010) [2]J. Flipse, F.L. bakker, A. Slachter, F.K. Dejene and B.J. van Wees, "Cooling and heating with electron spins: Observation of the spin Peltier effect", arXiv:1109.6898, subm. to Nature Nanotechnology

Topical Talk MA 42.2 Thu 15:30 EB 301

Magneto Seebeck effect in tunnel junctions — •Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen

The magneto Seebeck effect in magnetic tunnel junctions is the change of the Seebeck coefficient or thermopower caused by switching the relative magnetic orientation of the two ferromagnetic leads. For MgO based tunnel junctions we predict by ab initio calculations that the magneto Seebeck ratio can exceed several 1000% and depends strongly on temperature [1]. I will discuss the role of different magnetic materials and show the importance of the termination of the magnetic layer next to the MgO barrier for ordered FeCo alloys. In particular, the size of the magneto Seebeck ratio can change by two orders of magnitude and even the sign can be changed by changing the termination of the magnetic layer [2]. Further, I analyze the influence of the barrier thickness on the magneto Seebeck ratio. The theoretical results will be compared to recent experimental results [2].

[1] M. Czerner, M. Bachmann, C. Heiliger, Phys. Rev. B 83, 132405 (2011) [2] M. Walter, J. Walowski, V. Zbarsky, M. Münzenberg, M. Schäfers, D. Ebke, G. Reiss, A. Thomas, P. Peretzki, M. Seibt, J. S. Moodera, M. Czerner, M. Bachmann, C. Heiliger, Nature Materials 10, 742 (2011)

Invited Talk MA 42.3 Thu 16:00 EB 301

Seebeck spin tunneling into silicon — •Ron Jansen — National Institute of Advanced Industrial Science and Technology (AIST), Spintronics Research Center, Tsukuba, Ibaraki, 305-8568, Japan.

The combination of thermoelectrics and spintronics offers unique possibilities. On the one hand, it provides a new, spin-based approach to thermoelectric power generation and cooling. On the other hand, it provides a thermal route to create and control the flow of spin in spintronic devices that make functional use of heat and temperature gradients. Here we describe and report the demonstration of Seebeck spin tunneling - a thermally driven spin flow, of purely interfacial nature - generated in a tunnel contact between electrodes of different temperatures. It is shown to be due to the spin dependence of the Seebeck coefficient of a tunnel junction. Thus, Seebeck spin tunneling is the thermoelectric analog of spin-polarized tunneling.

By exploiting this in ferromagnet/oxide/silicon tunnel junctions, we observe a thermal flow of spin angular momentum from the ferromagnet to the silicon without a charge tunnel current. The spin accumulation induced in the silicon scales linearly with heating power and changes sign when the temperature differential is reversed. This thermal spin current can be used by itself, or in combination with electrical spin injection. The results highlight the engineering of heat transport in spintronic devices and enable the (re-)use of heat to increase device efficiency and reduce energy consumption.

J.C. Le Breton, S. Sharma, H. Saito, S. Yuasa and R. Jansen, Nature **475**, 82 (2011).

Topical Talk MA 42.4 Thu 16:30 EB 301

Spin currents in ferromagnetic insulator/normal metal hybrid structures — •Sebastian T.B. Goennenwein[1], Franz D. Czeschka[1], Johannes Lotze[1], Georg Woltersdorf[2], Mathias Weiler[1], Michael Schreier[1], Matthias Althammer[1], Matthias Opel[1], Hans Huebl[1], and Rudolf Gross[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Department of Physics, Universität Regensburg, Germany

In analogy to the well-established charge currents, one can define a *pure spin current* as the directed flow of spin angular momentum. However, in spite of the conceptual analogy, the properties of charge and spin currents are very different: In contrast to electrical currents, spin currents can flow in electrical insulators, since no charge motion is required for the propagation of angular momentum.

We experimentally study pure spin currents in magnetic insulators, using two complementary approaches. The samples comprise an epitaxial yttrium iron garnet (YIG) thin film – a ferrimagnetic insulator – covered in situ with a thin platinum layer. On the one hand, we use spin pumping in combination with the inverse spin Hall effect to generate and detect pure spin currents across the YIG/Pt interface.

The spin mixing conductance derived from these experiments is quantitatively comparable to that of conductive ferromagnet/Pt hybrids. On the other hand, we investigate the local magneto-thermo-galvanic voltages induced in YIG/Pt by a focused, scanning laser beam, and discuss the contribution of spin currents generated by the spin Seebeck effect.

Financial support by DFG SPP 1538 is gratefully acknowledged.

Topical Talk MA 42.5 Thu 17:00 EB 301

Spin waves and spin currents in hybrid magnetic nanostructures — •Sergej O. Demokritov — Institute for Applied Physics, University of Muenster, Muenster, Germany

Unlike the charge current, the spin current, i.e., the flow of angular momentum without the simultaneous transfer of electrical charge, is not a conservative quantity within the conduction carrier system. This is due to the spin orbit interaction that couples the spin of the carriers to angular momentum in the lattice. This coupling usually acts as the source of damping for spin currents; the excess angular momentum in the magnetic subsystem flows into the lattice.

In this talk I will discuss our recent experiments [1] on the YIG/Pt hybrid system, where we show that this flow can be reversed by the three-magnon splitting process and experimentally achieve amplification of spin current due to interaction of spin waves with the lattice.

Finally I will address the interaction of spin current with thermal magnetic fluctuations in a Permalloy microdisk located on top of a Pt microstrip [2]. The spin current in the microdisk is generated by an electric current flowing through the microstrip. We show that the fluctuations in the microdisk can be efficiently suppressed or enhanced by spin currents with different polarizations. The observed phenomenon can be used for controllable reduction of thermal noise in spintronic nanodevices.

[1] H. Kurebayashi et al., Nature Materials, 10 (2011) 660.
[2] V. E. Demidov et al., Phys. Rev. Lett. 107 (2011) 107204

MA 43: Joint Session "Graphen: Spin Transport" (jointly with DS, DY, HL, O, TT)

Time: Thursday 15:00–16:45 Location: H 1012

Topical Talk MA 43.1 Thu 15:00 H 1012

Spin transport in graphene — •Bernd Beschoten — II. Institute of Physics, RWTH Aachen University and JARA: Fundamentals of Future Information Technology, 52074 Aachen

Graphene is considered as promising candidate for spintronics applications. The reason is the weak spin-orbit coupling, the absent hyperfine interaction and the observation of micrometer long spin relaxation lengths [1]. So far most spin transport studies have focused on single layer graphene (SLG). However, bilayer graphene (BLG) has unique electronic properties, which differ greatly from those of SLG by its effective mass of carriers, interlayer hopping and electric-field induced band gap. Our studies of spin transport in BLG as a function of mobility μ, minimum conductivity, charge carrier density and temperature reveal the importance of the D'yakonov - Perel' (DP)-type spin scattering mechanism [2]. In BLG samples, the spin relaxation time τ_s scales inversely with μ both at room temperature and at low temperatures. τ_s times of up to 2 ns are observed in samples with the lowest mobility. We discuss the role of intrinsic and extrinsic factors that could lead to the dominance of the DP-type spin scattering mechanism in BLG. Remarkably, similar spin transport properties are also observed in large area graphene grown by the CVD method on copper foils demonstrating the potential of CVD graphene in spintronics devices [3].

Work supported by DFG/FOR 912.

[1] N. Tombros *et al.*, Nature 448, 571 (2007).
[2] T.-Y. Yang *et al.*, Phys. Rev. Lett. 107, 047206 (2011).
[3] A. Avsar *et al.*, Nano Letters 11, 2363 (2011).

Invited Talk MA 43.2 Thu 15:30 H 1012

Long spin relaxation times in epitaxial graphene on SiC(0001) — •Thomas Maassen[1], Jan Jasper van den Berg[1], Natasja IJbema[1], Felix Fromm[2], Thomas Seyller[2], Rositsa Yakimova[3], and Bart Jan van Wees[1] — [1]Zernike Institute for Advanced Materials, University of Groningen, The Netherlands — [2]Lehrstuhl für Technische Physik, Universität Erlangen-Nürnberg, Germany — [3]Department of Physics, Chemistry and Biology (IFM), Linköping University, Sweden

Spin transport in graphene draws great interest because of recent promising measurements at room temperature (RT). At the same time the limiting factor for spin relaxation seems to be the substrate. By replacing the commonly used SiO_2 substrate we aim to observe improved spin transport. We developed an easy process to prepare lateral spin-valve devices on epitaxial grown monolayer graphene on SiC(0001), that enables us to upscale the production to wafer size. We examine the spin transport properties of this material by performing nonlocal spin-valve and Hanle spin precession measurements. We observe the longest spin relaxation time τ_S in single layer graphene at RT (1.5 ns) and $T = 4.2$ K (2.3 ns), while the spin diffusion coefficient is strongly reduced by nearly 2 orders of magnitude. The increase in τ_S is probably related to the changed substrate, while the small value for D_S is until now unexplained. Nevertheless, the high values for τ_S, combined with the easy production method on a large scale, clear the way for graphene based spintronic devices and applications in the future.

MA 43.3 Thu 16:00 H 1012

Manipulation of spin transport properties in graphene — •Frank Volmer[1,2], Tsung-Yeh Yang[1,2], Eva Maynicke[1,2], Marc Drögeler[1,2], Sebastian Bläser[1,2], Gernot Güntherodt[1,2], and Bernd Beschoten[1,2] — [1]II. Institute of Physics, RWTH Aachen University, 52074 Aachen, Germany — [2]JARA: Fundamentals of Future Information Technology, 52074 Aachen, Germany

It has been shown that the dominant spin relaxation mechanism in bilayer graphene is of the D'yakonov-Perel' type [1]. In this case the spin dephasing time increases with decreasing momentum scattering time or, respectively, with decreasing charge carrier mobility.

Therefore, it is desirable to control and to manipulate the mobility of a single device in order to get a further insight into the dephasing mechanisms. As the charge transport through the two-dimensional graphene is known to be strongly affected by adatoms, it is furthermore interesting to explore their influence on the spin transport. Hence we use current annealing, chemical solvents and electron beam induced deposition to add or to remove impurities on the graphene surface and study their influence on the spin transport properties.

First results indicate that even in single-layer graphene devices (nonlocal spin valves with Co/MgO injectors) a D'yakonov-Perel'-type dephasing mechanism is dominating.

This work has been supported by DFG through FOR 912.

[1] T.-Y. Yang *et al.*, Phys. Rev. Lett. 107, 047206 (2011)

MA 43.4 Thu 16:15 H 1012

Anisotropic super-spin at the end of a carbon nanotube — •Manuel J. Schmidt — RWTH-Aachen, Deutschland

The interplay of edge magnetism and spin-orbit interactions is studied theoretically on the basis of zigzag ends of carbon nanotubes. Spin-orbit coupling, generally weak in ordinary graphene, is strongly enhanced in nanotubes and thus cannot be neglected at low energies. In the present case it leads to a magnetic anisotropy on the order of 10 mK. Also the relation to correlated topological edge states is shortly discussed.

Carbon nanotubes with zigzag ends have localized electronic states at those ends. These localized states correspond to the edge states in graphene and are equally susceptible to Coulomb interactions. The latter drive a transition, known as edge magnetism in graphene. However, due to the very limited spatial size of this magnetic state, it should not be considered as a symmetry broken state but rather as a super-spin, composed of a few individual electron spins. Without spin-orbit interaction, the ground state of this super-spin would be 2S+1 fold degenerate. Finite spin-orbit coupling, however, breaks this degeneracy in such a way that the true ground state is unique and time-reversal invariant. Furthermore, it turns out that the magnitude of this effect may be tuned by a partial suppression of the magnetism (tunable edge magnetism).

15 min. break

MA 44: Joint Session "Spins in Organic Materials" (jointly with DS)

Time: Thursday 16:45–19:00 Location: H 1012

MA 44.1 Thu 16:45 H 1012

Tunneling anisotropic magnetoresistance in organic spin valves — •M. Grünewald[1,3], M. Wahler[1,3], F. Schumann[3], C. Gould[1], R. Schmidt[2], F. Würthner[2], L.W. Molenkamp[1], and G. Schmidt[1,3] — [1]Physikalisches Institut (EP3) Universität Würzburg, Am Hubland, 97074 Würzburg — [2]Institut für Organische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg — [3]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, von-Danckelmann-Platz 3, 06120 Halle

Over the past years a number of spin valves (SV) based on various organic semiconductors (OSCs) and contact materials have been demonstrated. Although some experiments indicate injection of spinpolarized carriers and some clearly show tunneling, it is still unclear for a number of other results whether their data show tunneling magnetoresistance (TMR) or actual spin injection and consequently giant magnetoresistance (GMR). We report the observation of tunneling anisotropic magnetoresistance (TAMR) in an organic SV-like structure with only one ferromagnetic electrode. The device is based on a new perylene diimide-based n-type OSC. The effect originates from the tunneling injection from the bottom contact ($La_{0.7}Sr_{0.3}MnO_3$). Magnetoresistance measurements show a clear SV signal, with the typical two-step switching pattern caused by the magnetocrystalline anisotropy of the epitaxial magnetic electrode. TAMR so far has not been considered when interpreting the results of organic SVs. Our results imply that careful measurements on any organic SV are necessary in order to distinguish between TAMR and true SV-operation (TMR/GMR).

MA 44.2 Thu 17:00 H 1012

Spin properties of the Alq_3-cobalt oxide (CoO) interface — •Norman Haag, Sabine Steil, Nicolas Grossmann, Mirko Cinchetti, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Stra. 46, D-67663 Kaiserslautern

The effect of cobalt oxidation is crucial for the understanding of the performance of organic spin valves with Co electrodes [1], as it is expected that cobalt will partly oxidize during sample production. For this reason, we analyzed the spin properties of the interface formed between tris(8-hydroxyquinoline)aluminium (III) (Alq_3) and cobalt oxide. We deposited 30 ML of Co(100) and exposed the sample to an oxygen atmosphere with varying pressure. The degree of oxidation is extracted by evaluating the changes in the work function according to *Wang et al* [2]. Subsequently, Alq_3 was grown on the oxidized cobalt. The resulting interface was characterized by means of spin-resolved ultraviolet photoemission spectroscopy. We detected the energy level alignment and the spin polarization in the region of a few eV below E_F, both as a function of degree of oxidation. The most striking result is the shift of the Alq3 molecular orbitals of up to 1 eV (for strong oxidation) away from the Fermi level. This behavior could change the character of spin and carrier conduction (from holes to electrons) in spintronics devices.

[1] Dediu *et al.*, Nature Materials **8**, 707 (2009)
[2] Wang *et al.*, Surface Science **124**, 51 (1983)

MA 44.3 Thu 17:15 H 1012

Spin-filtering at hybrid organic-inorganic interfaces — •Sabine Steil, Nicolas Grossmann, Norman Haag, Mirko Cinchetti, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany.

Organic semiconductors have demonstrated their potential as a new class of materials for spintronics applications [1]. They are expected to constitute a new building block for advanced spintronics devices. One of their most intriguing properties is that they form hybrid interfaces with ferromagnetic metals [2]. As an example, we have recently shown that the spin-injection efficiency at the cobalt-copper phthalocyanine interface can be tailored by electron doping [3]. Here, we will show our recent experiments on the interface between cobalt(001) and tris(8-hydroxyquinoline)aluminium(III) (Alq3). Interface formation was studied by means of spin-resolved ultraviolet photoemission spectroscopy, while the spin- and time-resolved two-photon photoemission spectroscopy was used to measure the spin-dependent lifetime of hot charge carriers excited in an unoccupied hybrid interface state. The magnitude of the lifetime, gives information about the degree of hybridization of the considered state. More importantly, we found that the lifetime in such state is spin-dependent, providing direct evidence that hybrid organic-inorganic interfaces can be employed as a novel kind of spin-filter.

[1] V. A. Dediu, et al., Nat. Mater. 8, 707(2009) [2] S. Sanvito, Nat. Phys. 6, 562-564(2010) [3] M. Cinchetti et al., PRL 104, 217602(2010)

MA 44.4 Thu 17:30 H 1012

Theoretical study of dynamical switching of a single spin by exchange forces — •Robert Wieser[1], Vasile Caciuc[2], Cesar Lazo[3], Hendrik Hölscher[4], Elena Y. Vedmedenko[1], Roland Wiesendanger[1], and Stefan Heinze[3] — [1]Institut für Angewandte Physik, Universität Hamburg, D-20355 Hamburg, Germany — [2]Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [3]Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, D-24098 Kiel, Germany — [4]Institut für Mikrostrukturtechnik, Forschungszentrum Karlsruhe, P.O. Box 36 70, D-76021 Karlsruhe, Germany

We demonstrate the possibility to dynamically switch the spin of a single atom or molecule with the magnetic tip of an atomic force microscope due to the acting exchange forces. We choose a single transition metal benzene molecule as model system and calculate the exchange interaction with an Fe tip using density functional theory. The exchange energy displays a Bethe-Slater type behavior with ferromagnetic coupling at large tip-sample distance and antiferromagnetic coupling at closer proximity. The exchange energies reach maximum values of a few 10 meV which allows to switch single spins by overcoming the energy barrier due to the magneto-crystalline anisotropy. The spin dynamics of the system was explored by solving the time dependent Schrödinger equation with additional relaxation term. We discuss six possible scenarios, defined by the occurrence of quantum tunneling, relaxation, and tip-sample distance.

MA 44.5 Thu 17:45 H 1012

Nanoscale assembly and order of paramagnetic organic radicals — Sabine-Antonia Savu[1], Indro Biswas[1], Mathias Glaser[1], Lorenzo Sorace[2], Matteo Mannini[2], Andrea Caneschi[2], Thomas Chassé[1], and •Maria Benedetta Casu[1] — [1]IPTC, University of Tübingen, Tübingen, Germany — [2]LAMM, University of Florence, Florence, Italy

Nitronyl nitroxide radicals are a class of paramagnetic compounds that are of interest not only because of their magnetic properties but also because of their use as a building block in more complex magnetic structures. A crucial aspect is the possibility to grow thin films, down to the submonolayer regime, investigating their chemical, physical, and morphological properties. In this work we present X-ray photoelectron spectroscopy (XPS), near edge X-ray absorption fine structure (NEXAFS), atomic force microscopy (AFM), and electron paramagnetic resonance (EPR) investigations of thin films of a pyrene derivative of the nitronyl nitroxide radical (nitpyrene). Nitpyrene was deposited on Au(111) single crystals, using strictly controlled evaporation conditions. The electronic structure and the interaction with the surface are discussed, as well as the growth mode. The persistence of the paramagnetic character of the molecules has been proved by EPR measurements.

MA 44.6 Thu 18:00 H 1012

Electronic structure and magnetic properties of metallocene multiple-decker sandwich nanowires — Cristian Morari[1], Florian Beiuseanu[2], and •Liviu Chioncel[3] — [1]National Institute for Research and Development of Isotopic and Molecular Technologies, 65-103 Donath, RO-400293 Cluj Napoca, Romania — [2]Department of Physics, University of Oradea, RO-410087 Oradea, Romania — [3]Augsburg Center for Innovative Technologies, University of Augsburg, D-86135 Augsburg, Germany

We present a study of the electronic and magnetic properties of the multiple-decker sandwich nanowires (CP-M) composed of cyclopentadienyl (CP) rings and 3d transition metal atoms (M=Ti to Ni) using Density Functional Theory first-principles techniques. We demonstrate that structural relaxation is an important effect in determin-

ing the magnetic ground-state of the system. Notably, the computed magnetic moment is zero in CP-Mn, while in CP-V a significant turn-up in magnetic moment is evidenced. CP-Fe/Cr show a half-metallic ferromagnetic ground state with a gap within minority/majority spin channel. In order to study the effect of electronic correlations upon the half-metallic ground states in CP-Cr, we introduce a simplified three-bands Hubbard model which is solved within the Variational Cluster Approach. We discuss the results as a function of size of the reference cluster and the strength of average Coulomb U and J exchange parameters. For range of studied parameters U=2-4eV and J=0.6-1.2eV the half-metallic character is not maintained in the presence of local Coulomb interactions.

MA 44.7 Thu 18:15 H 1012

Metal-organic hybrid interface states of a ferromagnet/organic semiconductor hybrid junction as basis for engineering spin injection in organic spintronics — Stefan Lach[1], •Anna Altenhof[1], Kartik Tarafder[2], Felix Schmitt[1], Md. Ehesan Ali[2,3], Michael Vogel[1], Jens Sauther[1], Peter Oppeneer[2], and Christiane Ziegler[1] — [1]Dep. of Physics and Research Center OPTIMAS, University of Kaiserslautern, D-67663 Kaiserslautern — [2]Dep. of Physics and Astronomy, Uppsala University, S-75120 Uppsala — [3]Center for Theoretical Chemistry, Ruhr-University Bochum, D-44801 Bochum

Hybrid spintronic devices that combine organic semiconductors (OSC) with ferromagnetic (FM) substrates are expected to provide a route to devices with improved and new functionalities. A crucial role is played by the FM-OSC interface. State-of-the-art DFT+U calculations in combination with UPS and XPS as well as spin-resolved UPS directly demonstrate the formation of new hybrid interface states (HIS), induced by chemisorption of CuPc, CoPc, and FePc at Co [1]. Whereas FePc and CoPc have only weakly spin-polarized levels at the Fermi level, CuPc shows strong spin-polarization directly at EF. On the other hand, the interaction leads to a vanishing magnetic moment in case of CuPc and a strong ferromagnetic coupling in case of CoPc and FePc. The difference is explained by the symmetry of the d-orbitals which are massively involved in the hybridization. [1] S. Lach, A. Altenhof, K. Tarafder, F. Schmitt, Md. E. Ali, M. Vogel, J. Sauther, P. M. Oppeneer, Ch. Ziegler, Adv. Funct. Mat., in press

MA 44.8 Thu 18:30 H 1012

Theoretical modelling of electronic structure and exchange interactions for metal-phthalocyanines — •Wei Wu[1,2], Andrew Fisher[2], Nic Harrison[3], Sandrine Heutz[1], Tim Jones[4], and Gabriel Aeppli[2] — [1]Department of Materials and London Centre for Nanotechnology, Imperial College London — [2]UCL Department of Physics and Astronomy and London Centre for Nanotechnology, University College London — [3]Department of Chemistry, Imperial College — [4]Department of Chemistry, Warwick University

The theoretical understanding of exchange interactions in organics provides a key foundation for quantum molecular magnetism. Recent SQUID magnetometry of a well know organic semiconductor, copperphthalocyanine [1,2] (CuPc) shows that it forms quasi-one-dimensional spin chains. Green's function perturbation theory and density functional theory simulations [3,4] are used to calculate exchange interactions and electronic structure for CuPc, CobaltPc, LithiumPc, and ChromiumPc. The exchange interactions depend strongly on stacking angles, but weakly on sliding angles. Our results qualitatively agree with the experiments and can guide experimentalists to synthesis novel materials.

[1] S. Heutz, et. al., Adv. Mat., 19, 3618 (2007) [2] Hai Wang, et. al., ACS Nano, 4, 3921 (2010) [3] Wei Wu, et. al., Phys. Rev. B 77, 184403 (2008) [4] Wei Wu, et. al., Phys. Rev. B 84, 024427 (2011)

MA 44.9 Thu 18:45 H 1012

Uncovering the electronic structure of manganese phthalocyanine — •Rico Friedrich[1], Torsten Hahn[1], Jens Kortus[1], Francisc Haidu[2], Michael Fronk[2], Georgeta Salvan[2], Benjamin Mahns[3], and Martin Knupfer[3] — [1]Institut für Theoretische Physik, TU Bergakademie Freiberg, 09596 Freiberg — [2]Institut für Physik, TU Chemnitz, 09107 Chemnitz — [3]Institut für Festkörper- und Werkstoffforschung, IFW Dresden, 01171 Dresden

Manganese phthalocyanine is a magnetic transition metal complex, that exhibits organic semiconducting behavior in the bulk. Because of its high thermal and chemical stability it is a promising candidate for molecular spintronics applications. However this compound shows extraordinary electronic structure properties which can be investigated by various spectroscopic techniques as for instance EELS, PES and Ellipsometry. Here we want to present the results of our ab initio density functional calculations on this system and show how they can help to understand the significant influences on the experimentally observed electronic properties. For this purpose also environmental influences as air exposure need to be considered since they will be of decisive character in view of real applications. In particular the change of magnetic properties is crucial as this directly affects spin transport phenomena.

MA 45: Joint Session "Magnetic Shape Memory Alloys II" (jointly with DS, MM)

Time: Thursday 15:00–18:45 Location: H 0112

MA 45.1 Thu 15:00 H 0112

Stress accomodation in polytwinned NiTi nanograins studied with the phase-field method — •Christian Mennerich[1], Frank Wendler[1], Marcus Jainta[1], Anna Weisshaar[1], and Britta Nestler[1,2] — [1]Karlsruhe University of Applied Sciences — [2]Karlsruhe Institute of Technology

During the martensitic transformation in NiTi shape memory alloys, grains of a critical radius below about 50 nm do not transform into martensite. A multi-phase field model of Allen-Cahn type is used to analyse the accomodation of a spherical nanograin inclusion embedded in the austenite phase at room temperature. The model is based on a Helmholtz free energy density formulation and includes elastic and eigenstrain energy contributions. The model is implemented using finite differences, assuming staggered grids for the components of the elastic displacements. We present the techniques used to describe the time-spatial evolution of the system oppose this to the simulation of a mechanical equilibrium. The model is successfully applied to Eshelby's inclusion problem to verify the correctness of the implementation. With this model, we study the stress accomodation of polytwinned spherical NiTi nanograins that are embedded in an austenite matrix. The results are compared to analytical solutions and numerical results from the literature.

MA 45.2 Thu 15:15 H 0112

Structure and magnetic properties of epitaxial Fe-Pd-Cu films — •Sandra Kauffmann-Weiss[1], Sven Hamann[2], Markus E. Gruner[3], Peter Entel[3], Ludwig Schultz[1], Alfred Ludwig[2], and Sebastian Fähler[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden — [2]Ruhr-Universität Bochum, Institut für Werkstoffe, Universitätsstraße 150, 44780 Bochum — [3]University of Duisburg-Essen, Theoretical Physics, Lotharstraße 1, 47048 Duisburg

Epitaxial films are promising candidates for magnetic shape memory (MSM) applications on the microscale. We investigated the magnetic properties of $Fe_{70}Pd_{30-x}Cu_x$ ferromagnetic shape memory alloys with different Cu contents (x = 0, 3, 7) in strained epitaxial films. For the MSM alloy $Fe_{70}Pd_{30}$ we recently demonstrated, that a tetragonal distortion up to 54 % can be induced into the crystal lattice by strained epitaxial film growth [S. Kauffmann-Weiss et al., Phys. Rev. Lett. 107, 2011, 206105]. Due to the tetragonal distortion intrinsic magnetic properties like Curie temperature, saturation magnetisation and magnetocrystalline anisotropy can be controlled. Epitaxial $Fe_{70}Pd_{27}Cu_3$ and $Fe_{70}Pd_{23}Cu_7$ films show slightly lowered values for spontaneous polarisation and Curie temperature, but strongly increased magnetocrystalline anisotropy constants compared to the binary $Fe_{70}Pd_{30}$ alloy and the Ni-Mn-Ga prototype system. These results indicate that alloying of $Fe_{70}Pd_{30}$ with Cu is a promising route to fabricate films with excellent magnetic properties to be used for the MSM effect.

This work is supported by DFG through SPP1239.

MA 45.3 Thu 15:30 H 0112

Dynamic simulation of the giant magnetocaloric effect in Ni-Mn-based Heusler alloys — •Tino Gottschall[1], Jian Liu[1], Konstantin Skokov[1], James David Moore[1], and Oliver

Gutfleisch[1,2] — [1]IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany — [2]2Technische Universität Darmstadt, Institut für Materialwissenschaft, Petersenstr. 23, 64287 Darmstadt, Germany

The origin for the inverse magnetocaloric effect in Ni-Mn-based Heusler alloys is a first-order magnetostructural transition between a low temperature paramagnetic/antiferromagnetic martensite and a high temperature ferromagnetic austenite phase. Performing direct measurements, we report a large adiabatic temperature change ΔT_{ad} exceeding -6 K at a field change of 2 T in a novel Ni-Mn-In-(Co) alloy. Such a giant magnetocaloric effect makes them potential candidates for energy efficient magnetic refrigeration. Far from an ideal first-order transition material, a wide transition temperature range was observed in this sample probably due to the existence of a local inhomogeneity over the sample. The transition distribution has the shape of a Gaussian function. Based on these considerations we were able to simulate the temperature change under adiabatic conditions, which agrees very well with the experimental data. Three parameters to manipulate the dynamic cooling process, namely field dependency, transition width and potential temperature change, are discussed for an in-depth understanding of the underlying physics behind the observed giant magnetocaloric effect.

MA 45.4 Thu 15:45 H 0112

Element-specific temperature dependence of the Ni and Mn magnetization in $Ni_{51.6}Mn_{32.9}Sn_{15.5}$ — •Bernhard Krumme[1], Alexander Auge[2], David Klar[1], Frank Stromberg[1], Andreas Hütten[2], and Heiko Wende[1] — [1]Faculty of Physics and CeNIDE, University of Duisburg-Essen, D-47048 Duisburg, Germany — [2]Thin Films and Nanostructures, Department of Physics, University of Bielefeld, D-44801 Bielefeld, Germany

Off-stochiometric compositions of the Heusler compound Ni_2MnSn with an increased content of Mn are known to be ferromagnetic shape memory alloys (FSMA). This class of materials shows a structural phase transition influencing the magnetization as well as the electric resistivity. Therefore, such materials are of interest for applications, e.g. as actuators. We investigated the influence of the structural phase transition on the element-specific magnetization and electronic structure of Ni and Mn in $Ni_{51.6}Mn_{32.9}Sn_{15.5}$ by means of X-ray absorption spectroscopy (XAS) and X-ray magnetic circular dichroism (XMCD). Due to the element-specificity we were able to reveal a different temperature dependence of the ratio of orbital to spin magnetic moment of Mn compared to Ni. In parallel a change of the electronic structure of Mn is observed, whereas for Ni almost no modifications occur. By applying a magnetic field of 3T in the martensite phase it is possible to reduce the ratio of orbital to spin magnetic moments indicating a field induced reverse martensitic transition (FIRMT).

– Supported by DFG (SFB 491) and SOLEIL, Paris.

MA 45.5 Thu 16:00 H 0112

Effect of the film thickness on the martensitic transformation in Ni-Mn-Sn ultra-thin films — •Niclas Teichert, Alexander Auge, and Andreas Hütten — Department of Physics, Thin Films and Physics of Nanostructures, Bielefeld University, Universitätsstraße 25, 33615 Bielefeld

Off-stoichiometric Ni-Mn-Sn is a ferromagnetic shape memory alloy (FSMA) in certain Mn-rich compositions. The studied alloy shows a phase transformation during cooling from a cubic high temperature austenite phase to a martensite phase with lower symmetry. Subsequent heating leads to the inverse transformation back to austenite. We have produced highly epitaxial $Ni_{51.6}Mn_{32.9}Sn_{15.5}$ thin films of thicknesses between 200 nm and 20 nm on MgO substrates via co-sputtering. The dependency of the martensitic transition on the film thickness was determined by conductivity and anomalous Hall effect (AHE) measurements in the temperature range between 20 K and 340 K. These measurements give us information about the transformation characteristics such as transition temperatures, temperature dependent saturation magnetization and the amount of transforming material for the different films. The AHE is used to analyze the scattering mechanisms during the transformation.

MA 45.6 Thu 16:15 H 0112

Hysteretic aspects of the inverse magnetocaloric effect in martensitic alloys. — Mehmet Acet[1], •Ivan Titov[1], Antoni Planes[2], Lluis Mañosa[2], David Gonźalez-Alonso[2], and Thorsten Krenke[3] — [1]Fachbereich Physik, Experimentalphysik, Universität Duisburg-Essen, D-47048 Duisburg, Germany — [2]Facultat de Fisica, Departament d'Estructura i Constituents de la Matéria, Universitat de Barcelona, Diagonal 647, E-08028 Barcelona, Catalonia, Spain — [3]Thyssen Krupp Electrical Steel GmbH, D-4588 1 Gelsenkirchen, Germany

The presence of a large positive entropy change around the martensitic transformation in $Ni_{50}Mn_{35}Sn_{15}$ and in $Ni_{50}Mn_{33.5}In_{16.5}$ is expected to lead to substantial cooling on applying a magnetic field. However, unlike in Ni-Mn-In, the relatively low temperature-shift of the hysteresis with applied field in Ni-Mn-Sn could limit cooling. In both cases we measure direct temperature-change on applying a magnetic field around the reverse and forward branches of the martensitic transition. In Ni-Mn-Sn we initially detect cooling on applying a magnetic field (inverse MCE) and again further cooling on removing the field (conventional MCE). When the field is reapplied once more we detect only warming due to the irreversibility of the metallurgical state of the alloy. In Ni-Mn-In, the temperature change is largely reversible due to the strong shift in the martensitic transformation temperature with applied field. In this case the metallurgical state of the sample can be partially recovered. The results are discussed in relation to the form of the hysteresis and its thermal shift with applied magnetic field.

MA 45.7 Thu 16:30 H 0112

Twin boundaries in trained 10M Ni-Mn-Ga single crystals — •Robert Chulist[1], Alexei Sozinov[2], Ladislav Straka[2,3], Thomas Lippmann[4], Carl-George Oertel[1], and Werner Skrotzki[1] — [1]Institut für Strukturphysik, Technische Universität Dresden, D-01062 Dresden, Germany — [2]AdaptaMat Ltd., Yrityspiha 5, Helsinki, FIN-00390, Finland — [3]Laboratory of Engineering Materials, Aalto University, PL 14200, FIN-00076 AALTO, Finland — [4]Institut für Werkstoffforschung, Helmholtz-Zentrum Geesthacht, D-21502 Geesthacht, Germany

The arrangement of twin boundaries in trained 10M Ni-Mn-Ga single crystals was investigated by electron backscatter diffraction (EBSD) in the scanning electron microscope. Precise monoclinic structure data including direction of modulation were used to determine all possible boundaries. Besides type I, II and compound twins typical for monoclinic symmetry a boundary between two directions of modulation was also detected. Compared to EBSD analysis done with simple tetragonal structure for 10M Ni-Mn-Ga alloys, a more complex microstructure with new boundaries is revealed. The crystallographic results have also been confirmed by diffraction of high-energy synchrotron radiation.

15 min. break

MA 45.8 Thu 17:00 H 0112

Blocking effects of twinning microstructure in Ni_2MnGa thin films — •Tobias Eichhorn, Richard Hausmanns, Peter Klaer, Hans-Joachim Elmers, and Gerhard Jakob — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz

The Heusler compound Ni_2MnGa is one of the rare materials showing a shape memory effect that can be controlled by an external magnetic field. Huge magnetic-field-induced strains (MFIS) of almost 10 % have been demonstrated for bulk single crystals, which makes the compound interesting for actuator applications. Freestanding epitaxial films, as prepared in this work, open up possibilities for miniaturized devices. So far the absence of MFIS in thin film samples at ambient temperature hinders technical implementation. We identify the twinning microstructure, as induced by the film-substrate interaction, to be responsible for blocking effects. The detailed variant configuration and twinning structure for different crystallographic orientation is studied by means of X-ray diffraction and microscopy methods. While (100) oriented samples show an entangled twinning structure, films of (110) orientation possess a promising martensite structure.

Complementary to magnetometry we employ X-ray magnetic circular dichroism measurements to uncover the origin of the magnetocrystalline anisotropy in the system.

This work is part of the DFG priority program SPP 1239.

MA 45.9 Thu 17:15 H 0112

Vibrational properties of Ni-Mn-Ga ferromagnetic shape memory alloys in the austenite phase — •Semih Ener[1], Jürgen Neuhaus[1,2], and Winfried Petry[1,2] — [1]Technische Universität München, Lehrstuhl für Funktionelle Materialien, Garching, Germany — [2]Technische Universität München, Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), Garching, Germany

In the ferromagnetic shape memory Ni-Mn-Ga alloys the structural transition can be driven either by an external magnetic field or tem-

perature. In this work we investigate the effect of temperature on the vibrational properties of Ni_2MnGa and $Ni_{49}Mn_{32}Ga_{19}$ in the austenite phase by using mainly inelastic neutron scattering. The measurements were done at the Forschungsneutronenquelle Heinz Maier-Leibnitz (FRM II), Garching. The Born-von Kármán model is applied to the Ni_2MnGa full phonon dispersion in the austenite phase and macroscopic properties are calculated from this model. The effect of temperature on the phonon softening in TA_2[110] phonon branch is investigated in detail in a wide temperature range for both Ni_2MnGa and $Ni_{49}Mn_{32}Ga_{19}$. The relations between the phonon softening and the structural transition are well understood for both compositions but the effect of magnetic ordering is not comprehended especially for the off-stoichiometric composition.

MA 45.10 Thu 17:30 H 0112

Correlation Between Microstructure and Magnetic Properties in Epitaxial Ni-Mn-Ga Thin Films — •Gesa Welker[1], Aleksej Laptev[1], Mikhail Fonin[1], Yuansu Luo[2], and Konrad Samwer[2] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen

Ni-Mn-Ga and related alloys exhibit a magnetic shape memory effect and have been subject to research due to their large magnetic field induced strain of up to 10% [1]. So far, only few investigation of their magnetic domain structure has been done on thin films [2].

Here we investigate the morphology and magnetic domain configurations in epitaxial Ni-Mn-Ga thin films grown on MgO(001) substrates by dc-magnetron sputtering [3] as well as in free-standing microstructures released from the rigid substrate by etching. We investigated Ni-Mn-Ga films of different compositions and thicknesses at varying temperatures by means of atomic force microscopy (AFM) and magnetic force microscopy (MFM) in remanence. In the martensitic state we found large domains with out-of-plane magnetization. The domain walls are oriented perpendicular to the martensitic twin boundaries direction. On a smaller scale, the magnetic domain structure is governed by the orientation of the easy axis of the martensitic variants.

Our results could be helpful for the construction of microscale actuators or sensors based on Ni-Mn-Ga thin films.[1] K. Ulakko et al.,Scripta Mater. 36, 1133-1138 (1997)[2] Q. Pan et al., J. Appl. Phys. 91, 7812-7814 (2002)[3] Y. Luo et al., J. Phys. 13, 013042 (2011)

MA 45.11 Thu 17:45 H 0112

Influence of the addition of platinum on the magnetic shape memory alloy Ni_2MnGa — •Mario Siewert, Markus E. Gruner, Heike C. Herper, and Peter Entel — University of Duisburg-Essen, Faculty of Physics

We have studied the influence of the addition of platinum on the magnetic shape memory alloy Ni_2MnGa by means of *ab initio* calculations. In particular, the quaternary system $Ni_{2-x}Pt_xMnGa$ was studied for $0 \leq x \leq 2$. As a main result, the preference of a tetragonal distortion increases with the amount of Pt that is added to the system. The increased preference of the tetragonal $L1_0$-structure goes hand in hand with the onset of antiferromagnetic tendencies in the Pt-rich alloys. The martensitic trends which are observed in the phase diagram of Ni-Mn-Ga are also observed for the alloy systems containing platinum. In particular, the transformation temperature can be further increased when substituting Ga by Mn which introduces additional antiferromagnetic tendencies. The modulated 14M structure which is responsible for the magnetic shape memory effect in Ni_2MnGa, also appears in systems with excess Pt. It turns out that the shape memory effect is about 14% and therefore larger than in Ni_2MnGa.

MA 45.12 Thu 18:00 H 0112

Mapping local elasticity of twinned martensitic NiMnGa films using atomic force acoustic microscopy — •Yuansu Luo[1], Walter Arnold[1,2], and Konrad Samwer[1] — [1]I.Physikalisches Institut, Universität Göttingen — [2]Fachbereich Werkstoffwissenschaften der Universität des Saarlandes, Saarbrücken

Local elasticity of magnetic shape memory films NiMnGa was mapped qualitatively and quantitatively on nanometer scale by means of atomic force acoustic microscopy (AFAM). The films (100nm) used were prepared on MgO substrates by magnetron sputtering. The first bending resonance vibrations of the AFM cantilever were measured by sweeping the frequency from 0.5 to 3MHz. Different contact stiffness was measured in this way for martenstic twin variants due to their anisotropic crystallography. Broad and multi-resonance behavior was observed, reflecting the damping and multi-variant properties of 7-layer modulated martensite. The stiffness image mapped by the measured resonance frequency exhibits however a contrast opposite to the height image mapped by conventional AFM. The result can be associated with the mobility of twin boundaries, namely they are mobile at the top and immobile at bottom of twin lamellas. The load dependent contact indentation was measured. A softening emerges at a critic force and can be contributed to moving of twin boundaries under the local mechanical load. The local elastic moduli were calibrated by a standard sample (SrTiO3). The values evaluated are in the range from 170 to 230 GPa, enlarged by a factor of about 10 compared to stress-free bulk samples. (Supported by BMBF-13N10061)

MA 45.13 Thu 18:15 H 0112

Martensitic and magnetic microstructure of epitaxial Ni-Mn-Ga films — •Anett Diestel[1,2], Anja Backen[1,2], Volker Neu[1], Sandra Kauffmann-Weiss[1,2], Ludwig Schultz[1,2], and Sebastian Fähler[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Dresden University of Technology, Department of Mechanical Engineering, Institute of Materials Science, 01062 Dresden, Germany

The modulated 14M martensite phase of the magnetic shape memory (MSM) alloy Ni-Mn-Ga shows huge strains up to 10 % by magnetically-induced reorientation of martensitic variants. The interaction between the crystallographic short and the magnetic easy axis is an essential requirement for the MSM effect. For Ni-Mn-a bulk materials a staircase-like domain pattern with 90°- and 180°-domain walls is already known. To understand this interaction in thin films we analyzed the martensitic and magnetic microstructures of epitaxial Ni-Mn-Ga films of different thicknesses by atomic and magnetic force microscopy. The observed domain pattern of thin epitaxial films differs considerably from the bulk concept. Due to the reduced variant width magnetic exchange coupling has to be considered. An interaction between the martensitic microstructure and the magnetic out-of-plane stripe domain pattern was established and a correlation between the domain width periodicity Λ_{DW} and the film thickness d according to $\Lambda_{DW} \sim d^{1/2}$ was identified in good agreement with the theoretical band domain model of Kittel. This work was funded by DFG through SPP 1239.

MA 45.14 Thu 18:30 H 0112

High resolution surface study of modulation in martensites. — •Aleksej Laptev[1], Mikhail Fonin[1], Yuansu Luo[2], Konrad Samwer[2], Emmanouel Pagounis[3], and Markus Laufenberg[3] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen — [3]ETO MAGNETIC GmbH, 78333 Stockach, Germany

In our work we address the preparation of high-quality surfaces of Ni-Mn-Ga single crystals with different stoichiometries as well as of epitaxial Ni-Mn-Ga films [1] and the investigation of their surface structure down to the atomic scale by variable temperature scanning tunneling microscopy (VT-STM) in ultra-high vacuum (UHV) conditions. The (001)-oriented sample surface was studied at different temperatures in both austenitic and martensitic phase. The samples reveal on the nanometer scale in the martensitic state a pronounced surface corrugation which was shown to arise from the modulation in martensites [2]. For off-stoichiometric samples seven- (films) and ten-layered (single crystal) modulation periodicities were found. Atomically resolved pictures reveal atomic rows stacked in sequences with varying periods and occasional stacking faults. On the other hand the stoichiometric single crystal with the 5M modulation shows a very regular modulation periodicity and a different shape of the modulation corrugation. This work was supported by the BMBF-Projects MSM-Sens 13N10061 and 13N10062.

[1] Y. Luo et al., *New J. Phys.* **13**, 013042 (2011).
[2] P. Leicht et al., *New J. Phys.* **13**, 033021 (2011).

MA 46: MagneticThin Films II

Time: Thursday 15:00–17:15 Location: EB 202

MA 46.1 Thu 15:00 EB 202

Local pinning in Co ferromagnetic nanowires induced by ion irradiation — •Luis Serrano-Ramón[1,2], Amalio Fernández-Pacheco[3], Rosa Córdoba[2], Tolek Tyliszczak[4], Ricardo Ibarra[1,2], and José M. de Teresa[1,2] — [1]Instituto de Ciencias Materiales de Aragón, Zaragoza, Spain — [2]Laboratorio de Microscopías Avanzadas, Zaragoza, Spain — [3]Cavendish Laboratory, Cambridge, UK — [4]Lawrence Berkeley National Laboratory, Berkeley, USA

The control of the movement of a domain wall in a ferromagnetic nanowire has been systematicaly studied with the aim of building ultrafast spintronic logic or storing devices [1,2]. Geometric constrictions are widely used to create local confining potentials that act as pinning sites for individual domain walls. As an alternative, the local modification of magnetic propierties by ion irradiation is suitable to induce pinning sites [3]. In this work high purity Co nanowires grown by Focused Electron Beam Induced Deposition [4, 5] have been irradiated with Ga+ in order to study the change induced by this proccess in their magnetic propierties. A systematic increase in the nucleation field of the wires has been observed by Magneto-Optical Kerr Effect. Local pinning sites induced by the irradiation have been succesfully created on 250 nm wide wires. The pinning force has been studied by Scanning Transmission X-Ray Microscopy and MOKE. [1] Parkin et al, Science, 320,190-194,(2008); [2] D. A. Allwood et al, Science, 309, 1688-1692, (2005);[3] Andreas Vogel et al, APL, 98, 202501, (2011); [4] A. Fernandez-Pacheco et al, J. Phys D, 42, 055005, (2009); [5] L. Serrano-Ramón et al, ACSnano, 5, 7781,(2011).

MA 46.2 Thu 15:15 EB 202

Magnetic tunnel junctions based on zinc ferrite and cobalt — •Michael Bonholzer, Kerstin Brachwitz, Katja Mexner, Jan Zippel, Michael Lorenz, and Marius Grundmann — Universität Leipzig, Institut für Experimentelle Physik II, Linnéstraße 5, 04103 Leipzig, Germany

Magnetic tunnel junctions (MTJs) could play an important role in future computer architecture and spintronic systems. The oxide zinc ferrite shows a good tunability in magnetic and electric properties and is a promising candidate for oxide MTJ structures. We present magnetic tunnel junctions built from zinc ferrite, magnesium oxide and cobalt. Zinc ferrite, acting as soft magnetic bottom electrode, was grown by pulsed laser deposition (PLD) on MgO substrates. The thin films ($d \approx 200\,\mathrm{nm}$) were characterized by atomic force microscopy (AFM), X-ray diffraction (XRD), SQUID- and Hall-effect measurements and optimized in their conductivity ($\sigma \approx 50\,\mathrm{S/m}$) and surface roughness ($\mathrm{rms} \approx 0.2\,\mathrm{nm}$). The thickness of the barrier material magnesium oxide was varied between 5 and 60 nm. It was also grown by PLD and the surface and stuctural properties were measured by AFM and RHEED. The cobalt top-electrode, which serves as hard magnetic electrode, was fabricated by thermal evaporation. The MTJ-structure was defined by multi-step photolitography with wet-chemical etching, using crossed-over masks in order to limit the contact area to $50 \times 50\,\mu\mathrm{m}^2$. Current-voltage measurements in dependence of an external magnetic field were performed and a tunnel-magnetoresistance (TMR) up to 65% was found.

MA 46.3 Thu 15:30 EB 202

Stretchable Magnetoelectronics — •Michael Melzer[1], Daniil Karnaushenko[1,2], Gungun Lin[1,2], Denys Makarov[1], Ingolf J. Mönch[1], and Oliver G. Schmidt[1,2] — [1]Institut für Integrative Nanowissenschaften, IFW Dresden, Helmholtzstraße 20, 01169 Dresden — [2]Materialsysteme der Nanoelektronik, Technische Universität Chemnitz, Reichenhainer Straße 70, 90107 Chemnitz

Currently, magnetic sensors are fabricated on rigid substrates like silicon wafers. However, successful operation of such devices on stretchable and flexible substrates can open up a variety of new applications due to arbitrary surface geometries possible after fabrication. Here, we exploit the surface wrinkling effect of thin metal layers on PDMS rubber membranes to create stretchable magnetoresistive (GMR) sensors [1]. The investigated systems include GMR multilayers as well as top pinned spin valves. Magneto-electric measurements reveal similar characteristics for such sensor elements on free-standing rubber membranes as on conventional silicon wafers, despite the different surface structures. The thermally induced wrinkling of the GMR layer along with the free-standing rubber membrane underneath allows for a totally elastic stretchability of the sensor element preventing the GMR film from cracking. In this respect the world's first elastically stretchable magnetic sensors are introduced and a new strategy for biosensors with intriguing advantages is outlined as an example for their application. The work was supported in part by the German federal ministry of education and research (project Nanett; FKZ: 03IS2011).

[1] M. Melzer et al., Nano Letters, 11, 2522 (2011).

MA 46.4 Thu 15:45 EB 202

Simulations of magneto-optical surface plasmon resonance (MOSPR) effects in Au/Co/Au trilayers for biosensing — •Sebastian Kübler, Kerstin Kämpf, Friedrich Wilhelm Herberg, and Arno Ehresmann — Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

In the past years it has been shown that it is possible to improve the sensitivity of biosensors based on the surface plasmon resonance (SPR) effect by the combination of the SPR effect with the transverse magneto-optic Kerr effect (tMOKE). The magneto-optic SPR (MOSPR) of Au/Co/Au trilayer systems in transverse configuration for the dielectric layers air ($n = 1$) and water ($n = 1.33$) was simulated. The normalized difference of the reflectivity $R(H+)$ and $R(H-)$ (δ-signal) shows a strong thickness dependence. The magnitude of the δ-signal changes with the refractive index n of the dielectric layer. In order to mimic realistic biosensor conditions the δ-signal of a Au(10.75 nm)/Co(6 nm)/Au(20.25 nm) trilayer was calculated and compared with the reflectivity of a 50 nm Au layer within the typical refractive index range ($n = 1.33 - 1.4$) of commercial SPR sensors. In this range the amplitude of the resulting δ-signal decreased by a factor of ~ 64. For a refractive index change of 10^{-2} the δ-signal stays in the same order of magnitude. This finding demonstrates the essential need of defined metal layer thicknesses for distinct refractive index regions to exploit the sensitivity of an MOSPR based biosensor.

MA 46.5 Thu 16:00 EB 202

Spectroscopic observation of strain-assisted T_C enhancement in EuO upon Gd doping — •S. G. Altendorf[1,2], N. Hollmann[2], R. Sutarto[1,3], C. Caspers[1], R. C. Wicks[3], Y.-Y. Chin[1,2], Z. Hu[1,2], H. Kierspel[1], I. S. Elfimov[3], H. H. Hsieh[4], H.-J. Lin[5], C. T. Chen[5], and L. H. Tjeng[1,2] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Max Planck Institute for Chemical Physics of Solids, Dresden — [3]Department of Physics and Astronomy, University of British Columbia, Canada — [4]Chung Cheng Institute of Technology, Taoyuan, Taiwan — [5]National Synchrotron Radiation Research Center, Hsinchu, Taiwan

EuO is a ferromagnetic semiconductor which, upon electron doping, shows a wealth of spectacular phenomena including insulator-to-metal transition and colossal magnetoresistance. Moreover, the doped charge carriers are propagating in an almost 100% spin polarized band, making EuO to be an attractive candidate for spintronics. To facilitate the use of EuO in device applications, it is important to increase the relatively low Curie temperature. The origin of the T_C enhancement of EuO upon Gd doping is studied using soft x-ray absorption spectroscopy on pure and Gd-doped EuO thin films. Temperature and doping dependent changes in the oxygen K edge spectra provide information about the correlation of magnetism and lattice. Band structure calculations reveal that these spectral changes and the increase of T_C to 125 K for Gd-doped EuO cannot be explained by electron doping alone. The compression of the crystal lattice due to the incorporation of the smaller Gd^{3+} ions plays also an important role.

MA 46.6 Thu 16:15 EB 202

Novel orbital ordering and Raman modes in 2p magnetic CsO2 — •baomin zhang[1], s. riyadi[2], t. t. m. palstra[2], g. a. de wijs[1], r. a. de groot[1], and g. r. blake[2] — [1]Electronic Structure of Materials, Institute of Molecules and Materials, Radboud University Nijmegen — [2]Solid State Materials for Electronics, Zernike Institute for Advanced Materials, Rijksuniversity Groningen

Aniogenic magnetism is a relatively new area recently. Antiferromagnetic CsO2 has a tetragonal stucture above 190 K, and the symmetry is reduced (accompanied by the tilting of oxygen dimers) at lower

temperatures. Based on density functional calculation, we report a novel orbital ordering here, which is new in 2p magnetic materials. The highest occupied orbitals show ordered py and px characters, and the strong super exhange interaction between px and py orbitals realizes the one dimensional spin chain character found in experiments. Also, the calculated Raman frequencies 1118 cm-1 (streching of oxygen dimer), 195—200cm-1 (libration of dimer) and 66–75 cm-1 (exclusive movement of Cs along lattice c direction) agree well with experiments. The interpretation for latter two cases is given for the first time.

MA 46.7 Thu 16:30 EB 202

All-Electron Hybrid-Functional Calculations of the Europium Chalcogenides — •Martin Schlipf, Markus Betzinger, Marjana Ležaić, Christoph Friedrich, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

High spin polarization in the Eu chalcogenides offers the prospect of efficient spin filters in semiconductors. EuO is particularly suited as it exhibits the highest Curie temperature among these materials and can be grown epitaxially on Si, GaN, and GaAs. Throughout the EuX (X = O, S, Se, Te) series, as the chalcogenide atoms become bigger, the band gaps increase whereas the magnetic coupling constants decrease, giving rise to a FM to AFM transition. For our theoretical investigation, we employ the hybrid exchange-correlation functionals PBE0 and HSE, which incorporate a fraction of nonlocal Hartree-Fock exchange and thus extend the realm of density functional theory (DFT) to strongly correlated materials. We present the electronic, structural, and magnetic ground state as predicted from first-principle calculations using the FLAPW method `FLEUR`, in which recently hybrid functionals were implemented [1,2]. The results show an excellent agreement with experimental observations from the literature. We investigate trends across the series and focus in particular on how the material properties are modified when the chalcogenide atom is changed.
We acknowledge funding by HGF-YIG, contract VH-NG-409.
[1] M. Betzinger, *et al.*, Phys. Rev. B **81**, 195117 (2010).
[2] M. Schlipf, *et al.*, Phys. Rev. B **84**, 125142 (2011).

MA 46.8 Thu 16:45 EB 202

Angular depedence of XMCD/XMLD of MnNi at Mn $L_{2,3}$ and $M_{2,3}$ edges — •Dominik Legut[1], Jan Rusz[2], and Peter Oppeneer[2] — [1]Nanotechnology Centre, Ostrava, Czech Republic — [2]Department of Physics and Astronomy, Uppsala, Sweden

The full angular dependence of the x-ray magnetic circular/linear dichroism (XMCD/XMLD) spectra on the crystalline orientation of the magnetization was investigated for MnNi. The anisotropic XMCD and XMLD spectra were computed in the single electron picture within the framework of the DFT. The excitation stemming from core 2p levels as well as from semicore 3p levels (edges) were considered. The calculated results show different behavior between $L_{2,3}$ and $M_{2,3}$ edges, because of hybridization of two $3p_{1/2}$ sub-levels and four $3p_{3/2}$ sub-levels (m_j levels).[1] The XMLD signal is strongly dependent on the magnetization direction with respect to the crystal axes. Furthermore, the influence of lattice distortion and the exchange-correlation approximation was studied. In experiments, the samples are usually thin over-layers, often possessing lower symmetry, thus the corresponding distortion affects the spectral shape. The non-cubic symmetry of the studied structures gives rise to x-ray natural linear dichroism contributions. Their magnitude with respect to the magnetic dichroism contribution is discussed.

References:
1. S. Valencia *et al.*,Phys. Rev. Lett. **104**, 187401 (2010).

15 min. break

MA 47: Micro- and Nanostructured Magnetic Materials II

Time: Thursday 17:15–19:00 Location: EB 202

MA 47.1 Thu 17:15 EB 202

Magnetism on Curved Surfaces — •Robert Streubel[1,2], Denys Makarov[1], Florian Kronast[3], and Oliver G. Schmidt[1,2] — [1]Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany — [2]Material Systems for Nanoelectronics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin, Germany

An elegant way to alter the fundamental magnetic interactions at the nanoscale is to introduce a curvature that leads to local thickness variation. In this respect, we investigated magnetic properties in permalloy (Py, $Ni_{80}Fe_{20}$) caps on both SiO_2 spherical particles with diameters from 100 to 800 nm and tubular non-magnetic rolled-up tubes with diameters from 250 to 1,700 nm. Both equilibrium and remanent states of individual caps and close-packed cap arrays were visualized by means of X-ray magnetic circular dichroism photoemission electron microscopy (XMCD-PEEM). The weak magnetostatic coupling leads to a chirality coupling with specific space-filling patterns. Vortex nucleation and annihilation fields of cap arrays are 5 times *smaller* than of equivalent individual planar disks and more than 3 times *larger* than of close-packed arrays of planar disks. Both temperature-dependent hysteresis measurements and relaxation measurements were performed to estimate the energy barrier for vortex nucleation and annihilation.

MA 47.2 Thu 17:30 EB 202

Energy Landscapes and magnetization dynamics of nanostructured magnetic materials — •David Gallina, Peter Jensen, and Gustavo M. Pastor — Institut für Theoretische Physik, Universität Kassel, 34132 Kassel, Germany

The magnetic relaxation processes in disordered two-dimensional ensembles of dipole-coupled magnetic nanoparticles are theoretically investigated. The energy landscape of the system is explored numerically by calculating saddle points, adjacent local minima and the associated minimum energy paths (MEPs) as functions of the structural disorder and external magnetic field. Representative MEPs between fully-polarized states having opposite magnetization directions $\vec{M}$ and $-\vec{M}$ are illustrated. The changes in energy and magnetization along the reaction coordinate are discussed. A connected (ergodic) network of the thermodynamic-relevant low-energy local minima and the corresponding transition rates between them are determined. As a result, we follow the time evolution of the system for different initial configurations and manipulations of the external magnetic field in order to simulate different experiments on these magnetic systems.

MA 47.3 Thu 17:45 EB 202

Anisotropic magnetoresistance in self-assembled antidot arrays — •Felix Häring, Ulf Wiedwald, Lorenz Lechner, and Paul Ziemann — Institute for Solid State Physics, Ulm University, Germany

Magnetic antidot arrays are prepared by colloidal lithography using size-reduced self-assembled polystyrene (PS) colloids as templates for the subsequent deposition of magnetic thin films. After removal of PS spheres including magnetic caps we obtain hexagonally ordered Fe and FeNi antidot films (thickness typically 20 nm). Based on initially 200 nm PS spheres the antidot diameter is varied in the range 30-180 nm and changes of the hysteresis are examined and compared to a continuous film. We observe strongly increased coercive fields due to huge local shape anisotropy. In-plane anisotropic magnetoresistance (AMR) proofs that magnetization reversal and AMR amplitude heavily depend on the antidot diameter. Averaging over large areas of the array leads to loss of the expected 6-fold anisotropy. Constricting, however, the AMR measurements to highly ordered areas of antidots (about 2μm x 15 μm) by applying focused ion beam (FIB), we locally can study the magnetization reversal in next and next but one neighbor directions. In this way, observation of anisotropy with respect to the antidot lattice becomes feasible. Results are supported by micromagnetic simulations.

MA 47.4 Thu 18:00 EB 202

Magnetization reversal processes in $Fe_{1-x}Tb_x$ nanodot arrays — •C. Schubert[1], P. K. Arekapudi[1], B. Hebler[1], H. Schletter[1], A. Liebig[1], F. Radu[2], and M. Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany — [2]Department Magnetization Dynamics, Helmholtz Zentrum Berlin, 12489 Berlin, Germany

For spintronic and storage applications rare earth-transition metal alloy films like amorphous ferrimagnetic $Fe_{1-x}Tb_x$ are suitable materials owing to their high perpendicular magnetic anisotropy (7 - 10 Merg/cm^3) and low net magnetization (<300 emu/cm^3) [1]. In particular, arrays of Fe-Tb nanodots can exhibit manifold magnetic properties interesting for future sensor applications.

We present an investigation of the structural properties and the magnetization reversal process of amorphous $Fe_{1-x}Tb_x$ nanodots with a diameter of 30 nm, a height of 20 nm, and a period of 60 nm in the composition range from x = 0.19 to 0.23. All depositions were realized by magnetron (co-)sputtering on pre-patterned SiO_2/Si(100) substrates, which were fabricated by nano imprint lithography. The magnetization reversal of the nanodots occurs largely via coherent rotation as observed from angular dependent MOKE measurements in a polar geometry and by MFM imaging which shows single domain states.

[1] Y. Mimura et al., *J. Appl. Phys.* **49**, 3 (1978)

MA 47.5 Thu 18:15 EB 202

Hard magnetic (001)-textured FePtCu bit patterned media — •Patrick Matthes[1], Torbjörn Eriksson[2], Thomas Werner[3], Beate Mainz[1], and Manfred Albrecht[1] — [1]Inst. of Physics, Chemnitz University of Technology, DE-09107 Chemnitz — [2]Obducat Technologies AB, SE-20125 Malmö — [3]Center for Microtechnology, Chemnitz University of Technology, DE-09126 Chemnitz

To overcome the areal density limit of conventional magnetic materials for hard disk drives due to thermal instability problems, new materials with high K_u and new concepts for magnetic recording will be necessary [1]. In order to resolve the „recording trilemma“ the recording principle of bit patterned media has been proposed [2] and in combination with FePt based alloys an areal density beyond 1 Tb/in.^{2} is possible [1]. In this study hard magnetic 6 nm thick FePtCu films were prepared by sputtering at room temperature and post annealing. A dot array with a dot size of 20 nm and a period of 60 nm was then fabricated by post patterning using nanoimprint lithography. The fabricated dots are in a single domain state and reveal a rather sharp switching field distribution. The latter can be explained by the post-patterning process which induces damage to the side walls of the dots affecting their switching field. [3].

[1] S.N. Piramanayagam et al., J. Magn. Magn. Mater. **321**, 485 (2009)
[2] R.M.H. New et al., J. Vac. Sci. Technol., B **12**, 3196 (1994)
[3] J. Lee et al., Appl. Phys. Lett. **99**, 062505 (2011)

MA 47.6 Thu 18:30 EB 202

Magnetization reversal in dipolarly coupled PdFe nanodot arrays — •Melanie Ewerlin, Derya Demirbas, Frank Brüssing, Oleg Petracic, and Hartmut Zabel — Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, 44780 Bochum, Germany

We have studied a 2-dimensional XY macrospin model system by fabricating nanodot arrays from Pd1-xFex with low Fe-concentrations as magnetic material. Pd1-xFex films of 10 nm thickness and various Fe concentrations x were deposited by ion beam sputtering. Structural as well as magnetic characterizations were performed using superconducting quantum interference device (SQUID) magnetometry, magneto-optic Kerr effect (MOKE), atomic force microscopy (AFM) and x-ray diffraction (XRD). For the nanostructuring we used films with x=13 at% showing a Curie temperature of 290 K to ensure that the system can be cooled from a completely paramagnetic state into the macrospin state. We have fabricated circular dots with a diameter of 150 nm showing a single domain state. The dots are arranged on a square lattice with various inter-dot distances. The magnetization reversal of the entire system was studied using a low-temperature MOKE setup and compared to model expectations of a XY system with dipolar interactions. The results indicate a two step ordering process from intra-island to inter-island with decreasing temperature. To this end micromagnetic simulations are performed to determine the magnetization configuration of the dots depending on their thickness, diameter and distances.

MA 47.7 Thu 18:45 EB 202

Co/Pd multilayers on SiO_x pillar arrays at ultra-high density — •Fabian Ganss[1], Birgit Hebler[1], Andrea Cattoni[2], Anne-Marie Haghiri-Gosnet[2], and Manfred Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Laboratory for Photonics and Nanostructures, CNRS, 91460 Marcoussis, France

In order to demonstrate the preparation of ultra-high density bit patterned media, Co/Pd multilayers with perpendicular magnetic anisotropy were sputter deposited onto arrays of SiO_x pillars. These substrates were prepared by electron beam lithography and high temperature post-baking of HSQ resist [1] and provide pillars of various diameters at different pitches down to 26 nm, the latter corresponding to a potential storage density of 1.1 Tbit/in^2. The deposition was carried out under different deposition angles up to 60° to investigate the benefit of the shadowing effect while keeping a constant layer thickness by compensating the lower effective deposition rate by an increased process time. SQUID-VSM measurements of these films on planar substrates confirm comparable magnetic properties. The coated pillar arrays were investigated by MFM to prove exchange decoupling between the magnetic dots and estimate the switching field distributions. The exchange decoupling was proven successfully at densities up to 0.95 Tbit/in^2.

[1] A. Cattoni et al., Microelectron. Eng. 87, 1015-1018 (2010)

MA 48: PhD Student Symposium: "Spintronics on the Way to modern Storage Technology II", Organization: "Univ. Mainz team"

Time: Thursday 13:00–15:00 Location: BH 243

Invited Talk MA 48.1 Thu 13:00 BH 243

Ultrafast manipulation of magnetic order — •Theo Rasing — Radboud University Nijmegen

The interaction of sub-picosecond laser pulses with magnetically ordered materials has developed into an extremely exciting research topic in modern magnetism and spintronics. From the discovery of subpicosecond demagnetization to the recent demonstration of magnetization reversal by a single 40 femtosecond laser pulse, the manipulation of spins by ultra short laser pulses has become a fundamentally challenging topic with a potentially high impact for future spintronics, data storage and manipulation and quantum computation. In addition, when the time-scale of the perturbation approaches the characteristic time of the exchange interaction (˜10-100 fs), the soin dynamics enters a novel, highly non-equilibrium, regime where the exchange interaction might even become time dependent. Using ultrashort excitations, we may be able to manipulate the exchange interaction itself. Such studies require the excitation and probing of the spin and angular momentum contributions to the magnetic order at timescales of 10fs and below, a challenge to be met by future fs X-ray FEL*s.

References A.V.Kimel, et al, Nature 435 (2005), 655-657 C.D.Stanciu, et al, Phys.Rev.Lett.99, 047601 (2007) A.V.Kimel, et al, Nature Physics 10, 727-731 (2009) K.Vahaplar, et al, Phys.Rev.Lett.103, 117201 (2009) A.Kirilyuk, et al, Rev. Mod. Phys. 82, 2731-2784 (2010) I.Radu et al, Nature 472, 205 (2011)

Topical Talk MA 48.2 Thu 13:30 BH 243

Spin-transfer processes: Magnetic coupling, spin-transfer torque, and pure spin currents — •Daniel E. Bürgler — Peter Grünberg Institute, Electronic Properties (PGI-6) and Jülich-Aachen Research Alliance, Fundamentals of Future Information Technology (JARA-FIT), Forschungszentrum Jülich, D-52425 Jülich, Germany

Modern magnetic storage technology relies on manipulating and detecting magnetization states of nanometer-sized ferromagnetic (FM) entities. Spin-transfer processes in FM/non-FM/FM structures give rise to spintronic concepts featuring such functionalities. Equilibrium spin-transfer without net spin or charge transport is the origin of (anti)ferromagnetic interlayer coupling, which played a key role for the discovery of giant magnetoresistance. A spin-polarized current, i.e. flow spin momentum and charge, exerts a torque on the magnetization when entering a FM material by transferring spin angular

momentum from the current to the magnetization. These spin-transfer torques give rise to current-driven magnetization dynamics with unprecedented properties like magnetization reversal without applying an external field or the excitation of persistent large-angle magnetization precessions with frequencies in the GHz range, which are the basis for spin-transfer nano-oscillators. Pure spin currents, finally, transport spin momentum without net motion of charge. This situation results for instance from spin accumulation in a non-magnetic metal. Non-local transport measurements in lateral spin valve exploit spin accumulation to generate and detect pure spin currents. Devices based on pure spin currents potentially operate with significantly reduced dissipation.

MA 48.3 Thu 14:00 BH 243

Improved reliability of magnetic field programmable gate arrays through the use of memristive tunnel junctions — •Jana Münchenberger, Patryk Krzysteczko, Günter Reiss, and Andy Thomas — Bielefeld University, Thin Films and Physics of Nanostructures, 33615 Bielefeld

Since the recent, successful implementation of the long-hypothesized memristor, its use in neuronal computing and in the reproduction of biological neural networks has gained increasing attention. In addition to the development of these new applications, the growing number of devices with memristive properties is promising to improve already established technologies. We use the recently reported memristance in magnesium-oxide-based magnetic tunnel junctions (MTJs) to improve the error tolerance in magnetic random access memory and magnetic field programmable logic. The MTJs have a thin barrier of 1.3 nm and were structured by e-beam lithography and ion beam etching. They show a tunnel-magnetoresistance (TMR) ratio of 100% and a memristive effect of about 6%. Using this effect, we can show that it is possible to tailor the resistance of the MTJs and thus compensate for resistance fluctuations that occur as a result of the fabrication process. Furthermore, the MTJs maintain stable resistances and do not need to be periodically refreshed.

MA 48.4 Thu 14:15 BH 243

Manipulation of Skyrmions created by opto-magnetic switching — •Stefan Gerlach, Denise Hinzke, and Ulrich Nowak — University of Konstanz, 78457 Konstanz, Germany

Magnetic bubbles are spots of opposite magnetization and can be observed in ferromagnetic thin films and nanoelements with high perpendicular anisotropy[1]. Their dynamics is determined by a topological number called the Skyrmion number which relates them to the well-known and similiar Skyrmions[2].

Opto-magnetic switching is known to reverse the magnetization of small spots in thin films within picoseconds[3]. We use Landau-Lifshitz-Bloch (LLB)-based simulations which allow for the linear reversal mechanism[4] combined with a two temperature model to describe the opto-magnetic switching. We will show how bubble domains can be created and discuss their dynamics when manipulated with external magnetic fields.

[1] C. Moutafis, et al., Phys. Rev. B 79, 224429 (2009)
[2] N. S. Kiselev et al., J. Phys. D: Appl. Phys. 44, 392001 (2011)
[3] K. Vahaplar et al., Phys. Rev. Lett. 103, 117201 (2009)
[4] N. Kazantseva et al., Phys. Rev. B 77, 184428 (2008)

Topical Talk MA 48.5 Thu 14:30 BH 243

Magnetoelastic Magnetization Control and Magnetization Dynamics at Low Temperatures — •Hans Huebl[1], Andreas Brandlmaier[1], Christoph Zollitsch[1], Johannes Lotze[1], Mathias Weiler[1], Fredrik Hocke[1], Georg Woltersdorf[2], Ruldof Gross[1], and Sebastian T.B. Goennenwein[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Universität Regensburg, Regensburg, Germany

In magnetic storage applications magnetization direction manipulation and magnetization switching speed are two key parameters. While magnetization orientation is usually controlled by means of Oersted fields, magnetization control via elastic strain fields represents an alternative approach. Here, we implement such a "spin-mechanics" concept in a hybrid structure consisting of a ferromagnetic thin-film deposited onto a piezoelectric actuator. The combination of piezoelectric and magnetoelastic effects allows to change the magnetization orientation by up to 90° solely via the voltage applied to the actuator. In a second set of experiments, we investigate magnetization damping, which directly relates to the magnetization switching speed. We discuss broadband ferromagnetic resonance as a tool to investigate magnetization damping as a function of temperature between 300 K and 50 mK, and address the impact of photon-magnon coupling.

This work is supported by the Excellence Cluster "Nanosystems Initiative Munich (NIM)" and DFG SFB 631.

MA 49: Joint Session "Surface Magnetism III" (jointly with O)

Time: Thursday 15:15–19:15 Location: BH 243

MA 49.1 Thu 15:15 BH 243

Ultimate limit of electron-spin precession upon reflection in ferromagnetic films — A. Hallal[1], T. Berdot[1], P. Dey[1], L. Tati Bismaths[1], L. Joly[1], A. Bourzami[2], F. Scheurer[1], H. Bulou[1], •J. Henk[3], M. Alouani[1], and W. Weber[1] — [1]Institut de Physique et Chimie des Matériaux de Strasbourg, France — [2]Université Ferhat-Abbas, Sétif, Algeria — [3]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

We report the discovery of 180° electron-spin precession in spin-polarized electron-reflection experiments on Fe films on Ag(001) [1], the largest possible precession angle in a single electron reflection. Both experiments as a function of Fe film thickness and *ab initio* calculations show that the appearance of this ultimate spin precession depends with utmost sensitivity on the relaxation of the Fe surface layers during growth. Similar spin precession is also predicted for other ferromagnetic films.

[1] A.Hallal *et al.*, Phys. Rev. Lett. **107** (2011) 087203.

MA 49.2 Thu 15:30 BH 243

High resolution electron energy loss spectroscopic studies of surface spin waves in ultrathin Co films on Cu(001) — •Rajeswari Jayaraman[1], Harald Ibach[1], Antonio Tonino Costa[2], and Claus Michael Schneider[1] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Departamento de Ciências Exatas, Universidade Federal de Lavras, 37200-000 Lavras, Minas Gerais, Brazil

Electron energy loss spectroscopy has become a valuable tool for studies of the dispersion of spin waves at ferromagnetic surfaces. Using our recently developed high resolution spectrometer [1] we have extended a previous study [2] of the surface spin waves of fcc cobalt films deposited on Cu(001) along the [011] direction to lower wave vectors $k_{\|}$ and lower spin wave energies. Spin waves are resolved down to $k_{\|} = 0.2\text{Å}^{-1}$ and spin wave energies of 15meV. For $k_{\|} = 0.2-0.35\text{Å}^{-1}$ spectra with resolution of 7meV exhibit a noticeable contribution of bulk spin waves, in agreement with theoretical calculations. We have furthermore studied the dispersion along the [001] direction. In agreement with theory [3] we find that the spin wave dispersion is nearly isotropic in this system even at higher wave vectors.

[1] H. Ibach et al., to be published.
[2] R. Vollmer et al., Phys. Rev. Lett. 91, 147201 (2003).
[3] A.T. Costa et al., Phys. Rev. B 69, 64413 (2004); A.T. Costa et al., Phys. Rev. B 70, 054406 (2004).

MA 49.3 Thu 15:45 BH 243

Ultrafast Magnetization Dynamics of Gadolinium and Terbium Studied by XUV Photoelectron Spectroscopy — •Martin Teichmann[1,2], Kristian Döbrich[1,2], Björn Frietsch[1,2], Cornelius Gahl[1,2], Robert Carley[1,2], Olaf Schwarzkopf[3], Philippe Wernet[3], and Martin Weinelt[1,2] — [1]Max-Born-Institut, Max-Born-Straße 2a, 12489 Berlin — [2]Freie Universität Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin — [3]Helmholtz-Zentrum für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin

Recent results from IR-pump-XUV-probe angle-resolved photoelectron spectroscopy (ARPES) experiments on the ultrafast demagnetization of thin films of Gd(0001) and Tb(0001) on W(110) will be presented.

Following excitation by an intense IR pulse, ARPES with 35 eV photons allows us to directly probe the response of the exchange-split valance band. As a signature of ultrafast demagnetization by the IR pulse, we see a rapid reduction of the exchange-splitting in the valence band of both metals. However, due to its larger spin-lattice coupling, the response of terbium to laser excitation is far stronger than gadolinium. We also observe significant differences between the responses of the minority and majority bands in the first picosecond, both within and between the two metals. This ultrafast response is in contrast to quasi-equilibrium thermal demagnetization, and reveals a spin dependence to the exchange coupling between the valence and 4f states responsible for magnetic ordering. Laser excitation drives the system out of magnetic equilibrium on the picosecond timescale.

MA 49.4 Thu 16:00 BH 243

Structural aspects of magnetic coupling in a bilayer CoO(111) on Ir(100) — Florian Mittendorfer[1], Raimund Podloucky[2], and •Josef Redinger[1] — [1]Inst. of Applied Physics, Vienna University of Technology, Vienna, Austria — [2]Inst. of Physical Chemistry, University of Vienna, Vienna, Austria

Experimentally, stoichiometric CoO is found to form a (111)-like hexagonal c(10x2) bilayer on the square fcc Ir(100) surface [1]. Besides lateral displacements and vertical bucklings two distinct local building blocks can be detected: hexagonal BN-like almost co-planar Co-O fragments and NaCl-type O atoms above Co triangles. Consequently, different magnetic couplings for the different arrangements should be expected, which will be further modified by the coupling to the non-magnetic substrate. We have performed DFT and DFT+U calculations for the proposed c(10x2) CoO(111)/Ir(100) structure and structural variants and also for the NaCl (RS) and Wurtzite (WZ) type bulk phases. Quite interestingly for the bulk phases PBE and even HSE predict the WZ to be the stable one, a trend which could only be reversed in PBE+U calculations for high values of U. Furthermore ferromagnetic coupling for bulk WZ CoO is found to be energetically much closer to the antiferromagnetic groundstate as compared to RS CoO. For the bilayer CoO(111)/Ir(100) systems this translates into a rather complex magnetic arrangement of ferro and antiferromagnetc couplings, which could be easily modified by small changes to the geometrical structures as determined by the CoO/Ir interface.
[1] C. Ebensperger et al., Phys Rev. B81, 235405 (2010).

MA 49.5 Thu 16:15 BH 243

Interfacial uniaxial anisotropy and magnetization reversal of Fe/$BaTiO_3$(001) layers — •Vasili Hari Babu[1], Remya Kunjuveettil Govind[2], Joachim Gräfe[1], Martin Welke[1], Karl-Michael Schindler[2], and Reinhard Denecke[1] — [1]Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie, Universität Leipzig, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany

Multiferroics, consisting of both ferroelectric and ferromagnetic phases, have attracted scientific and technological interest due to the magnetoelectric coupling between the phases. In these heterostructures, the growth and magnetic anisotropy of the ferromagnetic phase are to be known to exploit the sizeable magnetoelectric effects. In the present work, Fe films were grown up to 24 *ML* thickness on a ferroelectric $BaTiO_3$(001) substrate by electron beam evaporation in an ultra high vacuum chamber and the determination of the magnetic properties was carried out by using *in-situ* magneto-optic Kerr effect. The layers were seen to have onset of ferromagnetic ordering at 6 *ML* thickness and the layers up to 12 *ML* thick were seen to exhibit uniaxial magnetic anisotropy (UMA) in the Fe[110] direction. However, the magnetization reversal of layers above 16 *ML* thick was seen to exhibit a growing cubic anisotropy along with the UMA from the fact that the growth of Fe(10) unit cell is 45° rotated to the $BaTiO_3$(10) direction in order to reduce the lattice mismatch. The competition between the uniaxial (aided by the interface) and cubic anisotropies of these layers is explained by accounting the quadratic magneto-optic Kerr effects.

MA 49.6 Thu 16:30 BH 243

Electric-field induced phase transition in Fe/Ni(111) — •Lukas Gerhard, Moritz Peter, and Wulf Wulfhekel — Physikalisches Institut, Karlsruher Institut für Technologie (KIT), Germany

It is known that both the crystallographic and the magnetic structure of Fe thin films exhibit a rich phase diagram. As has been found recently, this can be exploited to trigger a phase transition in 2 ML thick Fe films by magento electric coupling (MEC) [1]. In order to show that the phenomenon is not limited to this particular system, we studied 1 ML Fe films on a Ni(111) substrate. In atomically resolved scanning tunneling microscopy (STM) images two different crystallographic structures were revealed: Fcc and hcp domains coexist and show slightly different local densities of states. Indeed these domains can be switched by the application of very high electric fields. The induced crystallographic phase transition is studied with atomic resolution showing the lateral displacement of every Fe atom. The dynamic behaviour of the observed transition shows the same characteristics as the MEC in Fe/Cu(111) and can be explained by electric field induced lattice relaxations. A full understanding of the magnetism in this system requires additional theoretical efforts. [1] L. Gerhard et al. Magnetoelectric coupling at metal surfaces. Nat. Nano 5, 792-797 (2010)

MA 49.7 Thu 16:45 BH 243

Enhanced magnetoelastic coupling of Fe layers on the NiO/Ag(001) — •Anita Dhaka, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle, Germany

Magnetoelastic (ME) coupling is the driving force for magnetostriction of bulk samples. The ME coupling coefficients B_1 and B_2 determine the magnetostriction λ_{100} and λ_{111}, respectively, of cubic systems. They also determine the impact of lattice strain on the magnetic anisotropy. Therefore their experimental determination is of utmost importance for the understanding of magnetic anisotropy of epitaxially strained monolayers [1]. We have performed *in-situ* ME stress measurements on Fe monolayers on epitaxially grown NiO/Ag(001) to investigate the effect of an antiferromagnetic (AFM) buffer layer on the magnetoelasticity of ferromagnetic (FM) monolayers. Here, we measured the ME coupling coefficient B_2 of 6 monolayer (ML) Fe, which is unexpectedly large. We find $B_2 = -19.6 \pm 1.6$ MJ/m^3, which differs in both magnitude and sign from the bulk value of +7.83 MJ/m^3 [1]. For the deposition of 6 ML Fe on Ag(001) we measure $B_2 = +2 \pm 0.6$ MJ/m^3, which is almost a factor of four smaller than the bulk value. Notably, the induced strain in the Fe film on both substrates is comparable. This suggests that the FM-AFM interface plays an important role for the enhanced B_2 of Fe on NiO.
[1] D. Sander, Rep. Prog. Phys. 62, 809 (1999).

MA 49.8 Thu 17:00 BH 243

Growth mode and atomic structure of MnSi thin films on the Si(111) surface — •Benjamin Geisler[1], Peter Kratzer[1], Takayuki Suzuki[2,3], Theresa Lutz[2], Giovanni Costantini[2,4], and Klaus Kern[2,5] — [1]Fakultät für Physik and Center for Nanointegration, Universität Duisburg-Essen, 47048 Duisburg, Germany — [2]Max-Planck-Institut für Festkörperforschung, D-70569 Stuttgart, Germany — [3]Department of Electronics Engineering and Computer Science, Fukuoka University, Fukuoka 814-0180, Japan — [4]Department of Chemistry, University of Warwick, Coventry, CV4 7AL, United Kingdom — [5]Institut de Physique de la Matière Condensée, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

Thin films of MnSi, epitaxially grown on Si(111), are interesting in the field of spin injection into semiconductors. However, due to the complexity of the material, little is known about the film atomic structure and its dependence on the growth conditions. We performed DFT calculations for thin films of MnSi on Si(111) in their ground state crystal structure (B20) to analyze experimental STM images which recently revealed the coexistence of different surface terminations. We give an explanation for the atomic structure behind this observation and present evidence that the film structure depends on the growth protocol (codeposition vs. reactive epitaxy). Furthermore, our calculations indicate an increased magnetic moment of the films due to the biaxial strain induced by the substrate and a preference of ferromagnetic alignment over antiferromagnetic orderings. This makes the material promising for applications in Si-based spintronics.

15 min. break

MA 49.9 Thu 17:30 BH 243

Surface morphology and atomic structure of Fe_3Si on GaAs(001) and GaAs(110) and magnetic correlations — •Sani Noor[1], Igor Barsukov[2], M. Samet Özkan[1], Lina Elbers[1], Nikita Melnichak[2], Benjamin Geisler[3], Jürgen Lindner[2], Peter Kratzer[3], and Ulrich Köhler[1] — [1]Experimentalphysik IV, AG Oberflächen, Ruhr-Universität Bochum — [2]Experimentalphysik - AG Farle, Universität Duisburg-Essen — [3]Fakultät für Physik and

Center for Nanointegration (CeNIDE), Universität Duisburg-Essen

The system Fe_3Si/GaAs is a FM/SC combination that possesses properties such as a low lattice mismatch, high thermal stability and half-metallic behaviour that make it an interesting candidate for spintronic devices.

In this contribution we present STM studies of stoichiometric Fe_3Si layers grown epitaxially on GaAs(001) and GaAs(110) and compare the structural findings with the magnetic behaviour. From MOKE, SQUID and FMR measurements the magnetic moments as well as the magnetic anisotropies could be determined as a function of the layer thicknesses. Furthermore, we find a transition from superparamagnetic behaviour to ferromagnetic behaviour at a thickness of 3 ML. In accordance with theoretical calculations an enhanced magnetic moment can be observed for thicknesses below 20 ML. We also compare STM simulations of the Fe_3Si surface with the experimental filled and empty state images.

MA 49.10 Thu 17:45 BH 243

Interplay between magnetic anisotropy and quantum-well states in thin magnetic films — •Tamene Dasa, Pavel Ignatiev, and Valeriy Stepanyuk — Max-Planck-Institut für Mikrostrukturphysik Weinberg 2, D-06120 Halle, Germany

In this work the magnetic properties of thin magnetic films on non magnetic substrate have been investigated. The main focus is on the interplay between the magnetic anisotropy (MA) and the spin-polarized qauntum-well states arising in such films. The study is performed in the framework of the Density Functional Theory (DFT) by means of the VASP code and the LSDA for the exchange-correlation. We consider Co and Fe films, with vertical size varying from 1 to 6 monolayers, on Pt(001) surface. The Pt substrate is expected to provide high MA.[1] Our results demonstrate that the magnetic anisotropy energy (MAE) and the easy axis direction can be altered by changing the thickness of the film. This effect is explained in terms of the spin-polarized quantum-well states within the film. We also show the possibility to tune the MAE by means of capping the magnetic film by non-magnetic material.

[1] P. Gambardella, S. Rusponi, M. Veronese, S. S Dhesi, C. Grazioli, A. Dallmeyer, I. Cabiria, R. Zeller, P. H. Dederichs, K. Kern, C. Carbone, and H. Brune, Science **300**, 1130 (2003).

[2] M. Tsujikawa, A. Hosokaw and Tatsuki Oda, Phys. Rev. B **77**, 054413 (2008).

MA 49.11 Thu 18:00 BH 243

Effect of the external electric field on surface states — •Pavel Ignatiev, Oleg Brovko, and Valeri Stepanyuk — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

We present an *ab initio* study of surface states exposed to the external electric field (EEF). We consider two examples: the Shockley-type surface state on Cu(111) and spin-polarized surface states arising on Co nanoislands. Using the KKR method supplemented with a possibility to account for the EEF, we demonstrate that the EEF affects both energetics and intensities of surface states. Our results on Cu(111) are compared with recent STS studies on the Stark shift of the Cu(111) Shockley surface state.[1] For spin-polarized surface states on a Co bilayer on Cu(111), we show that the spin-selective screening of the EEF by evanescent vacuum surface states tails leads to a possibility of reversing the sign of the surface states spin polarization.[2] Field-induced variations of the majority and the minority surface states band structures change significantly standing-wave patterns [3] of the spin-polarized electrons opening, thus, another way to locally switch spin-polarization of confined surface states. The effect of the electric field on magnetism of the Co bilayer is characterized also in terms of the effective magnetoelectric coefficient.[4]

[1] L. Limot *et al.*, Phys. Rev. Lett. **91**, 196801 (2003); J. Kröger *et al.*, Phys. Rev. B **70**, 033401 (2004).

[2] P. A. Ignatiev, V. S. Stepanyuk, Phys. Rev. B **84**, 075421 (2011).

[3] H. Oka *et al*, Science **327**, 843 (2010).

[4] C.-G. Duan *et al.*, Phys. Rev. Lett. **101**, 137201 (2008).

MA 49.12 Thu 18:15 BH 243

Quantum Spin Holography with Surface State Electrons — •Oleg O. Brovko[1,2] and Valeri S. Stepanyuk[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

Recently Moon and coworkers have shown that information can be stored in a fermionic state of a two-dimensional electron gas and have dubbed the proposed concept quantum holographic encoding [1]. They have constructed molecular holograms of CO molecules on a Cu(111) surface, hosting a Shockley-type surface state (SS) [2]. Interference of electron waves scattered at the molecules led to the formation of an electron density pattern representing an information page [1]. This page has then been read out with an STM. It has been also shown that using the innate energy dispersion of SS electrons one can not only project the hologram in two spatial degrees of freedom but also stack them one on top the other in the energy dimension.

In our contribution we expand the concept and show that the spin of the electron can also act as a new dimension for information storage. If the molecules or atoms used in creation of a hologram are magnetic, then the scattering of surface state electrons becomes spin-dependent, allowing one to store different information pages in different spin channels. As an example we demonstrate the possibility of simultaneous encoding of two different information pages with electrons of the same energy but opposite spins.

[1] C.R. Moon et al., Nature Nano. 4, 167 (2009)

[2] W. Shockley, Phys. Rev. 56, 317 (1939)

MA 49.13 Thu 18:30 BH 243

First-principles investigation of energy– and impurity–dependent electron focusing effect — •Mohammed Bouhassoune, Peter H. Dederichs, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

It has been shown recently that the electronic signature of subsurface impurities can be revealed using Scanning Tunneling Spectroscopy (STS) [1,2]. A single impurity buried below the surface induces anisotropic spatial oscillations of the charge density due to a focused coherent interference of scattered electrons. These oscillations whose strength is determined by the shape of the host Fermi surface can be observed at the surface even if the impurity is far below the substrate. Using the full-potential Korringa-Kohn-Rostoker Green-function (KKR-GF) method, we investigate the energy dependent scattering of electrons at several magnetic and non-magnetic buried impurities below the Cu(100) surface. This allows a real-space mapping of the constant energy surfaces of the host material and a possible characterization of the impurity through the analysis of the induced phase shifts of the electron-density oscillations.

This work is supported by the HGF-YIG Programme FunSiLab – Functional Nanoscale Structure Probe and Simulation Laboratory (VH-NG-717).

[1] A. Weismann et al., Science **323**, 1190 (2009).

[2] S. Lounis *et al.*, Phys. Rev. B **83**, 035427 (2011) and references therein.

MA 49.14 Thu 18:45 BH 243

Spin-dependent two-electron emission from ferromagnetic Fe(001) — •Jürgen Kirschner[1], Frank O. Schumann[1], Carsten Winkler[1], Franz Giebels[2], Herbert Gollisch[2], and Roland Feder[2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle — [2]Theoretische Festkörperphysik, Universität Duisburg-Essen, 47048 Duisburg

We present a joint experimental and theoretical study of correlated electron pair emission from a ferromagnetic Fe(001) surface induced by spin-polarized low-energy electrons [1]. Spin-dependent angular and energy distributions of the emitted pairs have been measured and calculated. They are analyzed with the aid of the spin-, momentum-, symmetry-, and layer-resolved valence electron density of states, which we obtained by an ab-initio density functional theory calculation. The observed spectra are found to arise almost completely from only three surface parallel atomic layers. Momentum distributions for parallel spins of the emitted electrons exhibit an exchange-correlation hole, which is larger than the correlation hole in the antiparallel spin case. By comparing experimental antiparallel-spin pair spectra with their theoretical counterparts we determine an effective screening strength of the Coulomb interaction in the surface region.

[1] F. Giebels, H. Gollisch, R. Feder, F.O. Schumann, C. Winkler, and J. Kirschner, Phys. Rev. B 84, 165421 (2011).

MA 49.15 Thu 19:00 BH 243

Extending the two-dimensional electron spin-filter to a larger range of scattering energies and angles — •D. Kutnyakhov[1], K. Medjanik[1], S.A. Nepijko[1], H.J. Elmers[1], G. Schönhense[1],

C. Tusche[2], J. Kirschner[2], F. Giebels[3], H. Gollisch[3], and R. Feder[3] — [1]Inst. f. Physik, Univ. Mainz — [2]MPI f. Mikrostrukturphysik, Halle — [3]Theor. Festkörperphysik, Univ. Duisburg-Essen

In continuation of recent work on the novel imaging spin-filter technique based on electron diffraction from W(001) in the specular (00)-LEED spot [1,2], we studied the scattering energy (E) and angle of incidence (theta)-landscape of the spin sensitivity S, and reflectivity I/I_0. The setup includes a spin-polarized GaAs electron source and a delayline detector for spatially-resolving detection. Intensities, spin-orbit-induced asymmetries and figures of merit have been calculated by means of a relativistic layer KKR SPLEED code [3]. We assumed a 6 % inward relaxation of the topmost layer. The quasi-particle potential input for the SPLEED calculations was obtained by computing the ab-initio ground state electronic structure (FLAPW) and secondly augmenting the resulting potential by a complex self-energy correction. E-theta-behaviour studies open a path to an increased angular acceptance and energy range of the approach, thus increasing the performance of the multichannel spin-filter for electron spectroscopy [2].

Funded by DFG (Scho341/9 and TR 49), graduate school MAINZ.

[1] C. Tusche et al., APL 99 (2011) 032505; [2] M. Kolbe et al., PRL 107 (2011) 207601; [3] R. Feder in Polarized Electrons in Surface Physics, ed. by R. Feder (World Scientific, Singapore, 1985).

MA 50: Joint Session "Spincaloric Transport" (jointly with TT)

Time: Friday 9:30–11:30 Location: EB 301

MA 50.1 Fri 9:30 EB 301

Magneto-Seebeck Effect in Magnetic Tunnel Junctions — •Marvin Walter[1], Jakob Walowski[1], Vladyslav Zbarsky[1], Markus Münzenberg[1], Markus Schäfers[2], Daniel Ebke[2], Günter Reiss[2], Andy Thomas[2], Patrick Peretzki[3], Michael Seibt[3], Michael Czerner[4], Michael Bachmann[4], and Christian Heiliger[4] — [1]I. Phys. Inst., Uni Göttingen, Germany — [2]Dept. of Physics, Bielefeld University, Germany — [3]IV. Phys. Inst., Uni Göttingen, Germany — [4]I. Phys. Inst., Uni Giessen, Germany

We present the observation of a magneto Seebeck effect in CoFeB/MgO/CoFeB magnetic tunnel junctions (MTJs). The effects could be used for thermal spin-injection and thermally driven spin-transfer torque. The samples presented in this work consist of a minimal pseudo-spin-valve stack with sputtered Ta and CoFeB layers and an e-beam evaporated MgO barrier. The MTJs are heated by either a diode laser or a Ti:Sa femtosecond laser for higher powers. The laser is focused onto the sample in a confocal microscope setup. The heating is simulated by finite element methods and the experimental results are compared with ab-initio calculations of the magneto-thermoelectric power and of the spin-Seebeck coefficient. A magneto-Seebeck effect of up to 40% is found for higher laser powers and a theoretically predicted sign change of the thermal voltage is observed. The experimental data and the temperature simulations are in good agreement with the ab-initio calculations. In addition, time-resolved reflectivity and autocorrelation measurements in a pump-probe setup are carried out.

MA 50.2 Fri 9:45 EB 301

Anisotropy of the Seebeck effect and anomalous Nernst effect from Kubo linear response formalism — •S Wimmer, D Ködderitzsch, and H Ebert — Universität München, Department Chemie, Butenandtstr. 5-13, D-81377 München, Germany

Employing the linear response Kubo formalism [1] implemented using the relativistic multiple scattering Korringa-Kohn-Rostoker technique we study the anisotropy of the Seebeck effect (ASE) and the anomalous Nernst effect (ANE) in ferromagnetic cubic transition-metal alloys. The diagonal and off-diagonal elements of the thermoelectric tensor, Seebeck and Nernst coefficients, respectively, are derived from Kubo-Greenwood transport calculations by use of Mott's formula for the thermopower [2]. Results for the ASE are discussed in comparison to the corresponding electric field-driven effect, the anisotropic magneto-resistance (AMR). The ANE is analogously compared to calculations of its galvanomagnetic counterpart, the anomalous Hall effect (AHE). The chemical disorder of the investigated alloys is treated on the level of the coherent potential approximation (CPA). As will be shown, a corresponding description of the Spin Seebeck effect can be achieved by making use of a relativistic spin projection scheme [3].
[1] S. Lowitzer, D. Ködderitzsch and H. Ebert, PRL **105**, 266604 (2010). [2] N.F. Mott and H. Jones, *The Theory of the Porperties of Metals and Alloys*, (Oxford University Press, Oxford, 1936), chap. 7. [3] S. Lowitzer, D. Ködderitzsch and H. Ebert, PRB **82**, 140402(R) (2010).

MA 50.3 Fri 10:00 EB 301

Evidence for thermal spin transfer torque — •Haiming Yu[1,2,3], Simon Granville[1], Dapeng Yu[3], and Jean-Philippe Ansermet[1] — [1]Ecole Polytechnique Fédérale de Lausanne, Lausanne, Switzerland — [2]Technische Universität München, Garching b. München, Germany — [3]Peking University, Beijing, China

Spin caloritronics, i.e., the addition of thermal effects to the electrical and magnetic properties of nanostructures, has recently seen a rapid development. It has been predicted that a heat current can exert a spin torque on the magnetization in a nanostructure, analogous to the well-known spin-transfer torque induced by an electrical current. We provided the experimental evidence for this effect in spin valves, showing the switching field change with heat current.

We present measurements of the second harmonic voltage response of Co-Cu-Co pseudo-spin-valves deposited in the middle of Cu nanowires. We exploit the quasi-1D nature of the nanostructures to generate a heat current by asymmetric Joule heating in the Co layers. Both the magnitude of the second harmonic response of the spin valve and the field value of the maximum response are found to depend on the heat current. Both effects show that the magnetization dynamics of the pseudo-spin-valves is influenced by the heat current. The data provide a quantitative estimate of the thermal spin torque exerted on the magnetization of the Co layers.

MA 50.4 Fri 10:15 EB 301

Spin-wave propagation and transformation in a thermal gradient — •Björn Obry, Vitaliy I. Vasyuchka, Andrii V. Chumak, Alexander A. Serga, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We study the influence of a thermal gradient on the propagation behavior of spin waves in an yttrium iron garnet (YIG) waveguide. It is shown that the propagation of externally excited spin waves in regions of varying temperature results in a modification of the spin-wave wavelength. In a special case also the reflection of spin waves in a thermal gradient is observed. These observations can be attributed to a continuous change of saturation magnetization depending on the local temperature. The presented results reveal the potential of thermal gradients for the controlled manipulation of spin-wave propagation in waveguides. Financial support by the Deutsche Forschungsgemeinschaft (DFG, VA 735/1-1) within Priority Program 1538 "Spin Caloric Transport" is gratefully acknowledged.

MA 50.5 Fri 10:30 EB 301

Spin dependent electronic-transport calculations of Co_2FeAl and Co_2FeSi — •Denis Comtesse[1], László Szunyogh[2], Heike C. Herper[1], and Peter Entel[1] — [1]Faculty of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany — [2]Institute of Physics, Budapest University of Technology and Economics, Budafoki út 8, H1111 Budapest

We present *ab initio* calculations of the electronic-transport properties perpendicular to the planes of Co_2FeAl and Co_2FeSi with Pt contacts. We use a fully relativistic description of the electronic structure within the screened Korringa-Kohn-Rostoker (SKKR) [1] formalism. The Kubo-Greenwood formalism is employed to calculate the electronic-transport and the spin projection operator introduced by Lowitzer *et al.* [2] is used to evaluate the spin dependent contributions to the total current. In addition we investigate which regions of the two dimensional Brillouin zone give the main contributions to the transport of the two spin channels. It is found that only small characteristically distributed regions of the Brillouin zone contribute significantly to the current in Co_2FeAl and Co_2FeSi. Furthermore, we investigate how the transport properties change with increasing system size. Therefore, systems with different numbers of layers between the leads have been

taken into account. Financial support by Deutsche Forschungsgemeinschaft within the priority program SPP 1538 is greatfully acknowleged.

MA 50.6 Fri 10:45 EB 301

Magnon mediated heat transport in a magnetic insulator — •Vitaliy I. Vasyuchka, Alexander A. Serga, Andrii V. Chumak, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

In a magnetic system thermal gradients can appear as a natural result of thermalization of artificially excited magnons. Detection and measurement of such gradients provides information about the heat transport by magnon currents. In our experiments, the temperature gradient created by coherent surface and volume magnons excited in a tangentially magnetized yttrium iron garnet (YIG) film was detected using an infrared thermography technique. In the case of volume magnons the temperature distribution along the YIG film was found symmetrical relative to the antenna, while the thermalization of the surface magnons results in an unsymmetrical distribution. Moreover, the shift of the temperature maximum apart from the antenna was registered in the case of surface magnons. The difference in the temperature profiles is understood as a result of a nonreciprocal propagation of surface magnons. The time dynamics of the magnon-induced thermal gradients was studied.

Financial support by the Deutsche Forschungsgemeinschaft (DFG, VA 735/1-1) within Priority Program 1538 "Spin Caloric Transport" is gratefully acknowledged.

MA 50.7 Fri 11:00 EB 301

Large scale *ab initio* calculations of Konbu phases using KKR*nano* — •Elias Rabel[1], Alexander Thiess[1], Tetsuya Fukushima[2], Nguyen D. Vu[2], Kazunori Sato[2], Hiroshi Katayama-Yoshida[2], Phivos Mavropoulos[1], Rudolf Zeller[1], Peter H. Dederichs[1], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich — [2]Department of Materials Engineering Science, Graduate School of Engineering Science, Osaka University, 1-3 Machikaneyama, Toyonaka, Osaka 560-8531, Japan

Konbu phases are column-like structures grown by 2-dimensional spinodal nanodecomposition in various materials. Recent experiments have shown interesting effects such as giant Peltier cooling in a submicron-sized CuNi/Au junction, which are possibly related to the presence of these phases [1]. From a theoretical perspective an *ab initio* treatment of a few thousand atoms is the minimal requirement, which we are able to meet with the recently developed Korringa-Kohn-Rostoker Green-function program KKR*nano*. Motivated by the experimentally found spin-thermoelectric properties, we investigate the electronic and magnetic structure of Konbu phases in (Zn,Cr)Te and CuNi. Kinetic Monte-Carlo simulation results provide valuable insight into the spatial structure of these phases and serve as input for our *ab initio* calculations.

Funding by the DFG Priority Programme 1538 "Spin Caloric Transport" is gratefully acknowledged.

[1] A. Sugihara et al., Appl. Phys. Express **3**, 065204 (2010).

MA 50.8 Fri 11:15 EB 301

Domain Wall Motion by the Magnonic Spin Seebeck Effect — •Ulrike Ritzmann, Denise Hinzke, and Ulrich Nowak — Universität Konstanz

In the last years it was demonstrated that in ferromagnetic materials spatial temperature grandients can lead to spin accumulation [1], even in magnetic insulators [2]. In this context, it is important to note that in addition to a spin polarized charge current also a chargeless angular momentum current driven by spin waves can exist.

Here, we propose the existence of domain wall (DW) dynamics driven by magnonic spin currents due to temperature gradients. To get some insight into this effect we introduce two different approaches: the stochastic Landau-Lifshitz-Gilbert equation, applied to spin models, and the Landau-Lifshitz-Bloch equation describing the dynamics of the thermally averaged spin polarization on micromagnetic length scales. We show that these approaches describe this new type of DW motion, where chargeless spin currents following from a temperature gradient drag a DW into the hotter region [3]. Furthermore, for a better understanding of the relevant length scales, we investigate the propagation and frequency range of thermally induced magnons.

We acknowledge financial support by the Deutsche Forschungsgemeinschaft through Schwerpunktprogramm SpinCaT.

[1] K. Uchida et al., Nature **455**, 778 (2008).
[2] K. Uchida et al., Nat. Mater. **9**, 894(2010).
[3] D. Hinzke and U. Nowak, Phys. Rev. Lett. **107**, 027205(2011)

MA 51: Spin Excitations/ Spin Torque

Time: Friday 9:30–11:45 Location: H 1012

MA 51.1 Fri 9:30 H 1012

Ab initio investigation of the influence of the magnetic material in magnetic tunnel junctions on the bias dependence of the spin-transfer torque — •Christian Franz, Michael Czerner, and Christian Heiliger — I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Deutschland

We perform an investigation of the material dependence of the bias dependent spin-transfer torque (STT) in magnetic tunnel junctions using *ab initio* methods. In particular, we investigate Fe, Co and FeCo alloys.

We calculate the STT using a non-equilibrium Green's function method based on the Keldysh formalism which was implemented in a KKR method. The FeCo alloy is described both by a stacking of Fe and Co layers (ordered alloy) and by the coherent potential approximation (CPA). In the CPA calculations we incorporate non-equilibrium vertex corrections.

Our results show that for an ordered alloy the material of the ferromagnetic layer closest to the barrier has a strong influence on the bias dependence of the STT. Although the size of the STT is nearly independent of the material the qualitative bias dependence changes substantially. When we use the CPA to describe the FeCo alloy different terminations at the interface are mixed. Consequently, the features of the bias dependence of the different pure materials or ordered alloys are washed out. We compare our results to recently presented experimental ones.

MA 51.2 Fri 9:45 H 1012

Electronic transport and magnetization dynamics in realistic devices: a multiscale approach — •Simone Borlenghi[1,2], Valentin Rychkov[2], Cyril Petitjean[3], Grégoire De Loubens[2], Olivier Klein[2], and Xavier Waintal[3] — [1]Department of Material Science and Engineering, KTH-Stockholm, Sweden — [2]Nanoelectronic group, SPEC, CEA-Saclay, France — [3]Theory group SPSMS, CEA-Grenoble, France

We report on a theoretical model, based on Continuous Random Matrix Theory (CRMT) [1] and non equilibrium Green functions, that describes on an equal footing transport and magnetic degrees of freedom in realistic devices. Our approach offers a systematic way to perform multiscale simulations of spin transport [2] in mesoscopic systems with arbitrary geometry, connected to an arbitrary number of electron reservoirs. The model can be parametrized both with experimentally accessible parameters and ab initio calculations, and it is suitable for a large variety of materials (normal metals, ferromagnets, superconductors, semiconductors).

As an application of our model, we have coupled CRMT to a micromagnetic simulation code, in order to model a spectroscopic experiment performed on a spin torque nano oscillator. Our simulations predict correctly the selection rules for spin wave modes excited by spin torque, and give a description of the complex dynamics of the magnetization in qualitative agreement with experiments.

[1] V. Rychkov et al., Phys. Rev. Lett. 103 (2009), 066602.
[2] S. Borlenghi et al., Phys. Rev. B 84 (2011), 035412.

MA 51.3 Fri 10:00 H 1012

Extrinsically controlled spin relaxation in NiFe thin films induced by a periodic scattering potential — •Michael Körner[1], Kilian Lenz[1], Anja Banholzer[1], Jochen Grebing[1],

Igor Barsukov[2], Florian M. Römer[2], Jürgen Lindner[2], Michael Farle[2], and Jürgen Fassbender[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf (HZDR), P.O. Box 510119, 01314 Dresden, Germany — [2]Fakultät für Physik and Center for Nanointegration Duisburg-Essen (CeNIDE), Universität Duisburg-Essen, D-47048 Duisburg, Germany

The spin relaxation process of thin $Ni_{80}Fe_{20}$ (Py) films is influenced by introducing a periodic scattering potential using ion beam techniques. These potentials can be created in two ways: (i) by Cr^+ implantation into the surface of the Py film, using a lithographically defined mask. (ii) by using nanometer scale periodically modulated substrates (ripple) that change the morphology of the Py film grown on top [2]. The magnetic damping contributions are determined by frequency-dependent ferromagnetic resonance measurements using a vector network analyzer. For both sample systems we find several strongly enhanced linewidth peaks over a wide frequency range. By varying the scattering potential, the frequency positions of the damping peaks are preselectable.

This work is supported by DFG grant FA 314/6-1 and SFB 491.

[1] I. Barsukov et al., Phys. Rev. B 84, 140410(R) (2011).
[2] J. Fassbender et al., New Journal of Physics 11, 125002 (2009).

MA 51.4 Fri 10:15 H 1012

Domain Wall Torques from First Principles — •Frank Freimuth, Yuriy Mokrousov, and Stefan Blügel — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We present first-principles calculations of the adiabatic and non-adiabatic (NA) torques on domain-walls (DW) in bulk Fe, Co, Ni, FePd and FePt. Our calculations take into account both disorder and the spin-orbit interaction (SOI). The relation between the Gilbert damping and the NA torque is discussed. It has been shown experimentally [1] that additional SOI-mediated torques occur in asymetrically interfaced magnetic layers and suppress the Walker breakdown. The underlying mechanisms of these SOI-driven torques are investigated for Co/Pt slabs. It is shown that – in analogy to anomalous Hall and spin Hall effects – intrinsic [2,3] and extrinsic [4] contributions to the various torques can be distinguished and sometimes are of similar size. Additionally, we briefly describe our computational method [5,6], discussing particularly the use of the Wannier interpolation technique and the treatment of disorder. This work is supported by the HGF-YIG grant VH-NG-513.

[1] I. M. Miron et al., Nature Materials **10**, 419-423 (2011)
[2] H. Zhang et al., Phys. Rev. Lett. **106**, 117202 (2011)
[3] F. Freimuth et al., Phys. Rev. Lett. **105**, 246602 (2010)
[4] J. Weischenberg et al., Phys. Rev. Lett. **107**, 106601 (2011)
[5] F. Freimuth et al., Phys. Rev. B **78**, 035120 (2008)
[6] www.flapw.de

MA 51.5 Fri 10:30 H 1012

Determination of the nonadiabatic spin transfer torque parameter via SEMPA investigations — •Stefan Rössler[1], Sebastian Hankemeier[1], Robert Frömter[1], Hans Peter Oepen[1], and Benjamin Krüger[2] — [1]Institute of Applied Physics, Hamburg, Germany — [2]I. Institute of Theoretical Physics, Hamburg, Germany

The displacement of a magnetic vortex core in a permalloy rectangle due to an ultrahigh DC current density has been measured utilizing Scanning Electron Microscopy with Polarization Analysis (SEMPA).

A permalloy square of 6 μm x 6 μm x 10 nm size has been prepared on a single crystalline diamond substrate. The ground state for structures of this size is the Landau structure where the magnetization is curling around a sharp vortex core in the middle of the structure. In the center of the core the magnetizaion points out of plane to reduce exchange energy. Thus, each Landau state can be characterized by its sense of rotation c and the direction of the out of plane magnetization p allowing four different states of magnetization. The displacement of the vortex core for three of these different cp-states has been measured up to a DC current density of 7×10^{11}A/m^2. As shown in [1] the measurement of three different cp-states allows to separate the effects caused by the oerstedt field, the nonadiabatic, and the adiabatic spin transfer torque. From these measurements the parameter of nonadiabaticity has been determined.

This work is supported by DFG via SFB 668.

References: [1] Krüger et al., Phys. Rev. Lett. **104**, 077201 (2010)

MA 51.6 Fri 10:45 H 1012

Life times and chirality of spin-waves in antiferromagnetic and ferromagnetic FeRh: time depedent density functional theory perspective — •Leonid Sandratskii and Pawel Buczek — Max-Planck-Institut für Mikrostrukturphysik, Halle

The first-principles study of the spin excitations in antiferromagnetic (AFM) and ferromagnetic (FM) phases of FeRh is reported. The study is based on the calculation of the transversal dynamic spin susceptibility. We demonstrate that although the Fe atomic moments are well defined there is a number of important phenomena absent in the Heisenberg description: Landau damping of spin waves, large Rh moments induced by the AFM magnons, the formation of the optical magnons terminated by Stoner excitations. We relate the properties of the spin-wave damping to the features of the Stoner continuum and compare the chirality of the spin excitations in AFM, FM and param agnetic systems.

MA 51.7 Fri 11:00 H 1012

Magnon Excitations in Epitaxial Fe Films on Ir(001) — •Tzu-Hung Chuang, Yu Zhang, Huajun Qin, Khalil Zakeri, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

Fe(001) films with a thickness of up to 10 monolayers (ML) grow pseudomorphically on Ir(001) with a constant in-plane film strain [1]. The room temperature ferromagnetic hysteresis loop is observed only above 5 ML. The Fe films with a thickness of 6 ML show a very small magnetic anisotropy. Here we report the experimental results of high wavevector magnon excitations probed on a 6 ML Fe film by spin-polarized electron energy loss spectroscopy (SPEELS). The magnon dispersion relation is measured along the [100]- and [110]- directions of the Fe film. It is found that the magnon dispersion relation is anisotropic. The results cannot be explained by the classical Heisenberg spin Hamiltonian taking only the isotropic Heisenberg exchange interaction into account.

[1] V. Martin, W. Meyer, C. Giovanardi, L. Hammer, K. Heinz, Z. Tian, D. Sander, and J. Kirschner, Phys. Rev. B **76**, 205418 (2007).

MA 51.8 Fri 11:15 H 1012

Time-dependent spin-wave theory — •Andreas Rückriegel, Andreas Kreisel, and Peter Kopietz — Institut für Theoretische Physik, Universität Frankfurt

We generalize the spin-wave expansion in powers of the inverse spin to time-dependent quantum spin models describing rotating magnets or magnets in time-dependent external fields. We show that in these cases the spin operators should be projected onto properly defined rotating reference frames before the spin components are bosonized using the Holstein-Primakoff transformation. As a first application of our approach, we calculate the re-organization of the magnetic state due to Bose-Einstein condensation of magnons in the magnetic insulator yttrium-iron garnet; we predict a characteristic dip in the magnetization which should be measurable in experiments.

MA 51.9 Fri 11:30 H 1012

Charge ordering and charge accumulation in magnetic spin-ice lattices — •Elena Y. Vedmedenko — Institute of Applied Physics, University of Hamburg Jungiusstr. 11, 20355 Hamburg, Germany

Dipolar spin ice has attracted much attention because of their intriguing ground state ordering and elementary excitation properties. We present the theoretical investigation of magnetic dipolar spin ice on periodic and aperiodic lattices. Especial attention is paid to the evolution and the distribution of excitations with magnetic charges as a function of magnetic field and magnetic potential. It is demonstrated that depending on the micromagnetic reversal mechanism in individual particles charge ordered states or charge accumulation can be observed.

MA 52: Poster II - Magnetic Heusler compounds, Magnetic shape memory alloys, Thin Films, Micro-/Nano-structured magnetic materials, Graphene, Spins in organics, Magnetic imaging, Surface Magnetism, Spin excitations/Torque, Spincaloric transport

Time: Friday 11:00–14:00 Location: Poster A

MA 52.1 Fri 11:00 Poster A

Inverse tunnel magnetoresistance with Mn_2VGa based magnetic tunnel junctions — •Christoph Klewe, Markus Meinert, Jan Schmalhorst, and Günter Reiss — Department of Physics, Thin Films and Physics of Nanostructures, Bielefeld University, 33501 Bielefeld, Germany

The ferrimagnetic Heusler compound Mn_2VGa is predicted to have a pseudo-gap in the majority carriers [1], which should lead to inverse tunnel magnetoresistance. We synthesized epitaxial Mn_2VGa thin films on MgO(001) substrates by dc magnetron co-sputtering, resulting in nearly stoichiometric films. XRD analysis revealed a mostly B2-ordered structure for the films deposited at substrate temperatures of 350°C, 450°C, and 550°C.

Magnetic tunnel junctions with MgO barrier and CoFe counterelectrodes were fabricated. After post-annealing at up to $T_a = 400°C$ negative TMR was obtained around zero bias, providing evidence for the inverted spin-polarization. Band structures of both electrodes were computed within the coherent potential approximation [2] and used to calculate the TMR vs. U characteristics, which are in good agreement with our experimental findings.

In addition, measurements on GMR-devices fabricated with Cu spacer layers were carried out. The current-in-plane GMR was negative as well, consistent with our TMR results.

[1] K. Özdogan, I. Galanakis, E. Sasioglu, B, Aktas, J. Phys.: Condens. Matter **18**, 2905 (2006). [2] H. Ebert, D. Ködderitzsch, J. Minar, Rep. Prog. Phys. **74**, 096501 (2011).

MA 52.2 Fri 11:00 Poster A

Magnetic properties of the full Heusler compounds $Mn_{2+x}V_{1-x}Si$ — •Christian Sterwerf, Markus Meinert, Jan-Michael Schmalhorst, and Günter Reiss — Dünne Schichten und Physik der Nanostrukturen, Fakultät für Physik, Universität Bielefeld, 33501 Bielefeld, Deutschland

Half-metallic Heusler compounds have attracted much interest in the recent years because of their possible applications in spintronic devices. They provide a high spin polarization of the electrons at the Fermi level. A fully compensated half metallic ferrimagnet is ideal for spintronic devices since a vanishing magnetization leads to low stray fields and a lower energy consumption.

Thin films of the ternary full Heusler compound $Mn_{2+x}V_{1-x}Si$ were prepared by DC and RF magnetron co-sputtering on MgO (001) substrates. At $x = 0.5$ the compound has 24 valence electrons per formula unit, resulting in complete magnetic compensation according to the Slater Pauling rule $m = N - 24$.

In this work we investigate the films by means of x-ray diffraction, x-ray reflectometry, magnetometry techniques and transport measurements, especially of the anomalous Hall effect.

MA 52.3 Fri 11:00 Poster A

Magneto-optical characterization of single crystalline $Co_2FeAl_{0.4}Si_{0.6}$ thin films on MgO substrates — •Ana Ruiz Calaforra[1], Andres Conca[1], Britta Leven[1], Tanja Graf[2,3], Frederick Casper[2], Claudia Felser[2,4], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [3]Graduate School of Excellence - Material Science in Mainz, 55099 Mainz, Germany — [4]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

The full Heusler compound $Co_2FeAl_{0.4}Si_{0.6}$ (CFAS) has been predicted to provide a 100% spin polarization with an enhanced temperature stability due to the fact that the Fermi level lies in the middle of the energy gap. Therefore, this material is a promising candidate for TMR- and GMR-devices. For this, the understanding of the magnetic properties of these compounds is of great importance. We present magneto-optical investigations on epitaxial thin CFAS films deposited on MgO (100) substrates with different seed layer materials. A magneto-optical Kerr effect setup with a rotational stage was used to study the magnetocrystalline anisotropy of the sample. An overall uniaxial anisotropy with a biaxial contribution strongly depending on the nature of the used seed layer was observed.

Support by the BMBF project MultiMag (VDI-TZ 13N9913) is acknowledged.

MA 52.4 Fri 11:00 Poster A

Evolution of atomic order upon annealing in Co_2MnSi thin films probed by ^{59}Co and ^{55}Mn NMR — •Steven Rodan[1], Alexey Alfonsov[1], Sabine Wurmehl[1], Filippo Ferraro[2], Jürgen Kohlhepp[2], Bert Koopmans[2], Yuya Sakuraba[3], Bosu Subrojati[3], Koki Takanashi[3], and Bernd Büchner[1] — [1]Leibniz Institute for Solid State and Materials Research (IFW), 01171 Dresden, Germany — [2]Eindhoven University of Technology, 5600 MB Eindhoven, Netherlands — [3]Institute for Materials Research, Tohoku University, 980-8577 Sendai, Japan

Materials with high spin polarization at the Fermi level are highly desirable for spintronics applications. Many intermetallic Heusler compounds, such as Co_2MnSi, exhibit half-metallic ferromagnetism with such large spin polarization, but this tends to depend strongly on the ordering of the atoms in the crystal lattice. Pulsed nuclear magnetic resonance (NMR) proves to be essential for identifying the type(s) of disorder present by investigating the structure locally. We performed ^{59}Co and ^{55}Mn NMR experiments on several annealed and as-cast Co_2MnSi thin films, the results of which together reveal that the atomic ordering evolves with different annealing temperatures. We compare our results with previous structural analysis which used x-ray diffraction.

MA 52.5 Fri 11:00 Poster A

Direct investigation of the Co_2MnSi/MgO interface by spin-resolved photoemission — •R. Fetzer[1], J.-P. Wüstenberg[1], T. Taira[2], M. Yamamoto[2], M. Aeschlimann[1], and M. Cinchetti[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Str. 46, D-67663 Kaiserslautern — [2]Graduate School of Information Science and Technology, Hokkaido University, Kita 14 Nishi 9, Sapporo 060-0814, Japan

State-of-the-art tunnelling magnetoresistance (TMR) devices based on magnetic full Heusler compounds (e.g. Co_2MnSi) as electrodes and insulating MgO as tunnelling barrier are very promising as advanced spintronic devices [1]. Understanding the spin-dependent electronic properties of Heusler/insulator interfaces is hereby of great importance for further improvement of these multilayer systems. We have studied the Co_2MnSi/MgO (100) interface by means of spin-resolved near-threshold photoemission spectroscopy. The excitation source was laser light with photon energy lower than the MgO band gap width. This allows to investigate directly the spin-dependent electronic properties of the interface as a function of the MgO thickness. We found that the interface spin polarization is positive and can be detected through MgO layers up to 20 ML. Furthermore distinct changes in crystal structure and chemical composition of the epitaxial MgO layer were observed by means of LEED and Auger electron spectroscopy when varying its thickness. We will discuss the connection between the quality of the MgO layer and the detected interface spin polarization.

[1] T.Ishikawa et al., J. Appl. Phys 103, 07A919 (2008)

MA 52.6 Fri 11:00 Poster A

Spin-wave propagation in a $Co_2Mn_{0.6}Fe_{0.4}Si$ Heusler waveguide — Thomas Sebastian[1,2], •Philipp Pirro[1], Thomas Brächer[1,2], Alexander A. Serga[1], Burkard Hillebrands[1], Yusuke Ohdaira[3], Hiroshi Naganuma[3], Mikihiko Oogane[3], and Yasuo Ando[3] — [1]FB Physik und Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Material Science in Mainz, Staudinger Weg 9, 55128 Mainz, Germany — [3]Departement of Applied Physics, Tohoku University, Sendai, Japan

The class of Cobalt-based full Heusler compounds combines high Curie temperatures and spin polarizations with a lower Gilbert damping than most conventional 3d-ferromagnets [1]. These material parame-

ters make them promising candidates in the emerging field of *magnon spintronics*. In this concept, information is transferred and processed via magnons - the excitations of the magnetic system - without flow of electronic currents. Here we present the first observation of spin dynamics in a microstructured Heusler waveguide using Brillouin light scattering microscopy. The low magnetic losses estimated by FMR measurements [2] have been confirmed by the increase of the observed propagation distances (up to 80 μm, with an exponential decay length of at least 10 μm) compared to the commonly used $Ni_{81}Fe_{19}$.

We acknowledge financial support by the *DFG Research Unit 1464: ASPIMATT*.

[1] S. Trudel, J. Phys. D: Appl. Phys. **43**, 1930001 (2010).
[2] T. Kubota, Appl. Phys. Lett. **94**, 122504 (2009).

MA 52.7 Fri 11:00 Poster A

Electronic structure, magnetic and transport properties of Heusler compounds $Fe_{3-x}Mn_xSi(x = 0,..,3)$ — •Y. Shapiro[1], G. H. Fecher[1,2], S. Ouardi[1], A. Gloskovskii[1], B. Balke[1], S. Ueda[3], and C. Felser[1,2] — [1]Institute of Inorganic and Analytical Chemistry,Johannes Gutenberg - University, Mainz — [2]Max Planck Institute for Chemical Physics of Solids, Dresden — [3]NIMS Beamline Station at SPring-8, National Institute for Materials Science, Japan.

Heusler compounds are promising materials in many fields of contemporary research. The spectrum of their possible applications ranges from magnetic and magneto-mechanical materials from semiconductors, thermoelectrics to superconductors. The properties of these intermetallic compounds can be altered by changing the degree and kind of chemical order as well as by substituting one element by another.

The substitutional series of polycrystalline Heusler compounds $Fe_{3-x}Mn_xSi(x = 0,...,3)$ were synthesized and experimentally investigated with respect to their electronic and crystalline structure as well as magnetic and transport properties. The crystal structure was determined by means of x-ray diffraction. The temperature dependence of electrical resistivity, Seebeck coefficient, and thermal conductivity were investigated. Hard and soft X-ray photoelectron spectroscopy (HAXPES and MgK_α XPS) was carried out to study the details of the electronic structure and relate it to the transport properties.

MA 52.8 Fri 11:00 Poster A

Transport investigations on Mn_3Si — •Frank Steckel, Regina Hermann, Christian G. F. Blum, Steven Rodan, Sabine Wurmehl, Christian Hess, and Bernd Büchner — Leibniz-Institute for Solid State and Materials Research, Dresden, Germany

We investigate the electronic and thermal transport phenomena of the itinerant antiferromagnet Mn_3Si, which has been suggested to be a prototype material for realizing half-metallic ferromagnetism with a spin density wave below 26 K. We measured the resistivity, the Hall-effect as well as the thermal conductivity and the thermopower in the temperature range from 10 K up to 300 K using single crystals. In the vicinity of the antiferromagnetic transition temperature we found clear anomalies in the transport coefficients and a large fluctuation regime which extends to temperatures much higher (up to about 150 K) than the antiferromagnetic ordering temperature.

MA 52.9 Fri 11:00 Poster A

Spin calorics in ferromagnetic Heusler alloys on semiconductors — •Yori Manzke, Farshchi Rouin, Ramsteiner Manfred, and Jens Herfort — Paul-Drude-Institut für Festkörperelektronik, Hausvogteiplatz 5-7, 10117 Berlin, Germany

Recently, a spin-based counterpart to the Seebeck effect (SE) has been discovered in various ferromagnetic systems, which can potentially serve to generate spins from waste heat in future spintronic devices. In contrast to the SE, where a temperature gradient leads to a charge potential difference across a material, in the spin-based version (or SSE) a thermal gradient induces a "spin voltage", i.e. a chemical potential difference due to a spin imbalance in the material. However, the SSE is difficult to isolate due to other magnetothermal effects, and special experimental criteria must be met to eliminate such artifacts. Here, we report clear evidence of spin-induced voltages across Pt strips deposited on epitaxially grown Fe_3Si/GaAs hybrid structures. The Pt strips are intended to convert spin currents from the Fe_3Si layer into measurable voltages via the inverse spin Hall effect, while also eliminating magnetothermal artifacts. These voltages depend on the magnetization of the Fe_3Si layer and appear as a consequence of thermal gradients across the sample. Nonetheless, the spatial and temperature dependences of the spin voltages observed in our samples fundamentally differ from those of other materials systems for which the SSE has been reported. Therefore, these findings may be crucial for the understanding of the SSE.

MA 52.10 Fri 11:00 Poster A

Pulsed laser deposition of thin film Heusler compounds — •Mirko Emmel, Christian Mix, and Gerhard Jakob — Institut für Physik, Johannes Gutenberg-Universität Mainz, Deutschland

Pulsed laser deposition (PLD) is a versatile technique to deposit thin films of one or more targets illuminated by a focused pulsed-laser beam. Since the energy source is located outside the chamber, the use of ultra-high vacuum is possible. Due to a stoichiometric transfer between target and substrate, PLD allows depositing all kinds of multicomponent materials. We optimized the optical elements, which resulted in higher transmission of the laser energy and a more defined laser spot on the target. At a base pressure of about 10^{-9} mbar we successfully deposited thin films of different Heusler compounds. A further advantage of a PLD system is the capability to use relatively small targets, which are not suitable for other deposition methods like sputtering. The minimum diameter of a PLD-target is defined by the spot size of the laser on the target in order to avoid ablating other material. Hysteresis loops of Co_2FeSi and Rh_2MnGe thin film showed the expected magnetic saturation values. Ellipsometry measurements of Co_2FeSi thin films were performed to determine the permittivity. This work is supported by the DFG research group ASPIMATT and the Stiftung Rheinland-Pfalz für Innovation.

MA 52.11 Fri 11:00 Poster A

Magnetic resonance study of highly spin polarized compounds — •A. Alfonsov[1], S. Rodan[1], M. E. Belesi[1], S. Wurmehl[1], V. Kataev[1], F. Ferraro[2], J. T. Kohlhepp[2], H. J. M. Swagten[2], B. Koopmans[2], K. Takanashi[3], B. Subrojati[3], Y. Sakuraba[3], and B. Büchner[1] — [1]IFW Dresden, D-01169 Dresden, Germany — [2]Eindhoven University of Technology, 5600 MB Eindhoven, Netherlands — [3]Institute for Materials Research, Tohoku University, 980-8577 Sendai, Japan

Heusler alloys have attracted a considerable attention in recent years since these compounds can be halfmetallic ferromagnets. Such materials have a theoretical 100% spin polarization at the Fermi level at low temperatures, which gives them a significant potential for spintronics applications. The halfmetallicity strongly depends on the local atomic ordering. Therefore, a precise knowledge of the structural and magnetic ordering also on a local scale is crucial to control the macroscopic physical properties. To obtain this knowledge one has to call for local probe techniques. In this work we present recent nuclear magnetic resonance and electron spin resonance study of various Co-, Mn- and Fe-based Heusler compounds exhibiting different structural disorders and different magnetic ground states.

MA 52.12 Fri 11:00 Poster A

Elastic properties and stability of Heusler compounds — •S. -C. Wu[1,2], S. S. Naghavi[1], G. H. Fecher[1,2], and C. Felser[1,2] — [1]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [2]Max Planck Institute for Chemical Physics of Solids, Dresden

The properties of Heusler compounds which are the promising thermoelectric materials are important. Various Heusler compounds are investigated with respect to their malleability and stability. By applying isotropic strain in different ways to the cubic crystal could calculate the elastic constants. The result of the cubic elastic anisotropy can be used to decide the structural stability. The behavior that Young's modulus is largest in the $\langle 111\rangle$-type directions whereas the rigidity modulus is largest in the $\langle 100\rangle$-type directions shows a direct consequence of $A_e > 1$. Zener's ratios of the most stable compounds are in the range of $1.9 < A_e < 2.7$. $A_e < 0$ is not stable and $A_e = 0$ is isotropic. More physical properties could be derived from the calculated elastic constants.

MA 52.13 Fri 11:00 Poster A

Antisite disordering in new Fe-based tetragonal Heusler compounds characterised by 57Fe-Mössbauer spectroscopy — •Teuta Gasi, Vadim Ksenofontov, Jürgen Winterlik, and Claudia Felser — Institut für Anorganische und Analytische Chemie, Johannes Gutenberg Universität, Staudinger Weg 9, 55099 Mainz, Germany

We report on magnetic properties and antisite disordering in tetragonal Heusler Compounds investigated by 57Fe-Mössbauer Spectroscopy.

These materials are important because of their potential application in spintronic especially for STT (spin-transfer torque) technology, magnetocaloric or STO etc. New tetragonal Heusler compounds based on Fe and Mn were synthesized by arc-melting and characterized. 57Fe transmission and conversion electron Mössbauer spectroscopy (CEMS) was applied to explore magnetism and local surrounding of Fe atoms in bulk samples. Measurements reveal that the magnetic moments of Fe atoms in these compounds are almost vanishing, whereas in the cubic ones magnetic moments are much higher. Taking into account magnetic susceptibility measurements of Mn based compounds, one can conclude that magnetic moments of Mn atoms are mainly responsible for the bulk magnetization. The Mössbauer data support this observation.

MA 52.14 Fri 11:00 Poster A

A General Phase-field Model for the Martensite Rearrangement in Ni_2MnGa — •Christian Mennerich[1], Frank Wendler[1], Marcus Jainta[1], Anna Weisshaar[1], and Britta Nestler[1,2] — [1]Karlsruhe University of Applied Sciences — [2]Karlsruhe Institute of Technology

Ferromagnetic shape memory alloys have gained major interest in the last 15 years as components in actuators and dampers, as they provide large recoverable strains at low operation cost. A multi-phase field model of Allen-Cahn type has been successfully applied to describe the microstructure rearrangement in Ni_2MnGa in the martensitic state, induced by external magnetic or strain fields. The model is based on a Helmholtz free energy density formulation and includes magnetic and elastic energy contributions. With order parameters that are related to the different eigenstrains of the twin variants and the spontaneous magnetization, the time-spatial evolution of the system is described by a set of partial differential equations. The evolution of the order parameters depends on energy contributions for twin interfaces and bulk phase states. To make the complex boundary value problem treatable, different techniques (staggered grids, geometric integration methods, Fast Fourier methods etc) are combined. In this contribution we describe the model, the discretization and numerical implementation. We present simulation results to show the general applicability of the model to the magnetic shape memory effect and stress induced martensite microstructure rearrangement.

MA 52.15 Fri 11:00 Poster A

Structural and magnetic properties of zinc ferrite thin films grown by pulsed-laser deposition — •Kerstin Brachwitz[1], Marcus Jenderka[1], Andrey Timopheev[2], Alexandre Azevedo[2], Nikolai Sobolev[2], Annette Setzer[1], Pablo Esquinazi[1], Michael Lorenz[1], and Marius Grundmann[1] — [1]Institut für Experimentelle Physik II, Universität Leipzig, Germany — [2]Departamento de Fisíca and I3N, Universidade de Aveiro, Portugal

Zinc ferrite ($ZnFe_2O_4$) is a promising candidate for the application in magnetic tunnel junctions due to its ferrimagnetic properties. In this regard, we investigated the structural and magnetic properties of $ZnFe_2O_4$ thin films grown by pulsed-laser deposition on different substrates at various substrate temperatures (T_S).

X-ray diffraction measurements reveal an increasing crystalline quality of the films with increasing T_S. Epitaxial single phase $ZnFe_2O_4$ (100) thin films were observed on $SrTiO_3$ (100) substrates, whereas no symmetric $ZnFe_2O_4$ reflexes were observed for thin films deposited on r-plane sapphire independent of T_S.

Magnetic properties were studied by static magnetization and ferromagnetic resonance (FMR) measurements. All films show a strong magnetic ordering, even if the zinc ferrite spinel phase has not been detected. However, energy dispersive X-ray spectroscopy studies reveal a stoichiometric Zn/Fe ratio. FMR measurements revealed fourfold cubic magnetic anisotropy of $ZnFe_2O_4$ thin films grown on $SrTiO_3$. The values of effective magnetization and cubic anisotropy have been determined from a detailed study of the FMR spectra.

MA 52.16 Fri 11:00 Poster A

Theoretical and experimental investigation of ultrathin iron fcc films — •Michael Vogel, Matthias Kronseder, Florian Freund, Georg Woltersdorf, and Christian Back — Universität Regensburg

The magnetic properties of ultrathin films are determined in essence by the magnetic anisotropy constant, magnetic moment and the exchange interaction integral. Due to the challenging experimental accessibility of these parameters and the fact that none of these parameters can be obtained separately, the combination of experimental and theoretical methods can be used [1]. Optical (MOKE) and photoemission (MCD) measurements combined with ab initio calculations (DFT-VASP) [2] leads to a full understanding of the magnetic behavior of this system. For the theoretical investigation of the interatomic exchange interactions and the magnetic moment we have modeled those as a function of the involved strain in thin films. Assuming a ferromagnetic state of thin films as demonstrated experimentally in [3], we have calculated the exchange interaction from first principles by rotating moments within specially constructed supercells, based on structural data achieved by I(V)-LEED measurements also done in [3]. In addition the exchange interactions have also been determined using a "spin-spiral" technique [4].

[1] H. L. Meyerheim et al., PRL 103, 267202 (2009) [2] G. Kresse et al., Comp. Mater. Sci. 6, 15 (1996). [3] S. Müller et al., Phys. Rev. Lett. 74, 765 (1995). [4] L.M. Sandratskii, J. Phys. Condens. Matter 3, 8565 (1993); J. Phys. Condens. Matter 3, 8587 (1993).

MA 52.17 Fri 11:00 Poster A

Magnetic properties of thin iron films on strontium titanate substrates — •Armin Haase, Kay Potzger, Oskar Maciej Liedke, and Rantej Bali — Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf

In this study, the magnetic moment of thin iron films will be investigated. The methods of preparing the strontium titanate substrate surfaces for layer growth, creating near-surface defects, and growing thin iron films will be described. A procedure for surface preparation using a sequence of etching and annealing steps in an oxygen-rich environment will be introduced. The defects were created using ion implantation, and the samples were tested for defect magnetism. A magnetic moment was determined for hydrogen with the fluency of $2 \times 10^{17}\ \frac{1}{\mathrm{cm}^2}$ and the energy of 1,2 keV. Nitrogen implantation did not produce defect magnetism. In a separate process, iron layers of varying thicknesses were grown and investigated for their groth modes and magnetic properties. Finally, the steps described above were combined and repeated.

MA 52.18 Fri 11:00 Poster A

Magnetic and structural properties of $Fe_{1-x}Tb_x$ and $Fe_{0.82-x}Co_{0.18}Tb_x$ thin films — •Birgit Hebler[1], Christian Schubert[1], Herbert Schletter[1], Florin Radu[2], Andreas Liebig[1], and Manfred Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Hemholtz-Zentrum Berlin für Materialen und Energie, Albert-Einstein-Str.15, D-12489 Berlin, Germany

Amorphous rare earth-transition metal alloys with perpendicular magnetic anisotropy exhibit a versatile magnetic configuration making them interesting materials for exchange coupled heterostructures used in spintronic devices. We present an investigation of $Fe_{1-x}Tb_x$ and $Fe_{0.82-x}Co_{0.18}Tb_x$ thin films with a varying content of terbium (16 at. % $<$ x $<$ 30 at. %). The 20 nm thin films were prepared by magnetron co-sputtering in a UHV-chamber at room temperature. X-ray diffraction measurements and transmission electron microscopy imaging in cross-section geometry show an interdiffusion of the platinum protecting layers into the amorphous films at the interface. The temperature dependence of the magnetization reversal process was obtained by SQUID-VSM measurements in a maximum applied field of 7 T from 4 K to 400 K. Around the compensation temperature an anomalous reversal behavior was observed at higher fields, which may be assigned to a spin flop transition in the sperimagnetic configuration.

MA 52.19 Fri 11:00 Poster A

Investigations of magnetism in multiferroic layer systems — •Martin Welke[1], Joachim Gräfe[1], Vasili Hari Babu[1], Remya Kunjuveettil Govind[2], Martin Trautmann[2], Francis Bern[3], Michael Ziese[3], Karl-Michael Schindler[2], and Reinhard Denecke[1] — [1]Wilhelm-Ostwald-Institut für Physikalische und Theoretische Chemie, Universität Leipzig — [2]Institut für Physik, Universität Halle — [3]Institut für Physik, Universität Leipzig

Systems with multiferroic properties are of interest for research since the 60s of the 20th century. In the starting time single crystal multiferroics were in the focus of research. Nowadays layer systems with ferroelectric and ferromagnetic components are also studied.

The work presented deals with different ferrite layers - namely Nickelferrite and Cobaltferrite - on Bariumtitanate (001). Preparation of the ferrite films was done by PLD in UHV. Subsequently they were measured by SQUID in order to obtain magnetization loops. From temperature-dependend data, there seems to be an influence of the

phase transitions of Bariumtitanate on the magnetic response of the ferrite films. Altogether Nickelferrite and Cobaltferrite appear to have a small remanent magnetization.

In order to additionally characterize these materials XPS measurements were carried out. Especially the Iron to Oxygen ratio is of interest.

Furthermore XAS measurements of thick ferrite layers were taken into account.

MA 52.20 Fri 11:00 Poster A

Magnetic anisotropy of strained $La_{0.7}Sr_{0.3}CoO_3$ thin films probed by XMCD — •Felix Eilers[1,2], Michael Merz[1], Dirk Fuchs[1], Hilbert von Löhneysen[1,3], Peter Nagel[1], and Stefan Schuppler[1] — [1]KIT, Institut für Festkörperphysik — [2]KIT, Fakultät für Physik — [3]KIT, Physikalisches Institut, Karlsruhe, Germany

The magnetic properties of perovskite-type $La_{1-x}Sr_xCoO_3$ have their origin in the variety of possible valence and spin states of the Co ion and in strong electronic correlations. Bulk $La_{0.7}Sr_{0.3}CoO_3$ is known to be a ferromagnetic metal below $T_C \approx 240\,\mathrm{K}$ and to exhibit large Joule magnetostriction. This motivated us to investigate a complementary magnetoelastic effect: the effect of biaxial strain on the magnetization.

$La_{0.7}Sr_{0.3}CoO_3$ thin films were grown on lattice-mismatched substrates ($LaAlO_3$ and LSAT) by pulsed laser deposition. X-ray diffraction confirmed the films to be subjected to compressive or tensile strain, respectively. Near-edge x-ray absorption fine structure (NEXAFS) and x-ray magnetic circular dichroism (XMCD) at the Co $L_{2,3}$ edge and the O K edge provided spectroscopic information on the electronic and magnetic structure. Sum rules were used to extract magnetic moments from the XMCD spectra. The difference between in-plane and out-of-plane magnetic moments was found to vary with the biaxial strain.

We gratefully acknowledge the Max Planck Institute for Intelligent Systems (E. Goering, T. Tietze, G. Schütz) for the use of their XMCD end station and the synchrotron light source ANKA for the provision of beam time.

MA 52.21 Fri 11:00 Poster A

Temperature and thickness dependent sign change of the Anomalous Hall Effect in Co/Pd multilayers — •Vedat Keskin[1,2], Bekir Aktas[2], Zoe Kugler[1], Jan-Michael Schmalhorst[1], and Günter Reiss[1] — [1]Thin Films & Physics of Nanostructures, Bielefeld University, Germany — [2]Gebze Institute of Technology, Izmit, Turkey

The anomalous Hall effect (AHE) [1] was studied on ultra-thin Co/Pd multilayers, which might be a promising material for AHE based perpendicular magnetic recording technology [2]. The Co/Pd multilayers were grown on Si wafers by using conventional dc magnetron sputtering techniques. We focused on the Co thickness and temperature dependence of the AHE and the longitudinal resistivity, whereas the Pd thickness was kept constant at 1.8nm. The Co thickness was incrementally increased from 0.20nm to 0.55 nm. The AHE measurements were carried out in the temperature range of 14-330 K.Uniquely, we have observed that for a fixed temperature the polarity of the AHE changes at a certain Co thickness, the critical Co thickness decreases with increasing temperature. This behavior will be discussed with respect to the influence of extrinsic skew scattering [3]. [1] E. H. Hall, Philos. Mag. 10, 301 (1880) [2] D. Rosenblatt, M. Karpovski, and A. Gerber, Appl. Phys. Lett. 96, 022512 (2010) [3] J. Smit, Physica (Amsterdam) 24, 39 (1958).

MA 52.22 Fri 11:00 Poster A

X-ray absorption and magnetic circular dichroism of perpendicular $Mn_{3-x}Ga$ thin films — •Daniel Ebke, Manuel Glas, Jan Schmalhorst, Markus Meinert, Patrick Thomas, and Günter Reiss — Thin Films and Physic of Nanostructures, Bielefeld University, 33615 Bielefeld, Germany

Recently, the integration of materials with perpendicular magnetic anisotropy into magnetic tunnel junctions (MTJs) has found a lot of attraction due to the predicted lower current densities for spin torque switching and higher thermal stability. Especially, the interface of the electrodes to the tunnel barrier play a key role for the realization of MTJs with high tunneling magneto resistance (TMR) ratios. In this work, we have investigated the chemical and magnetic interface properties of perpendicular magnetized $Mn_{3-x}Ga$ (x=0-1) thin films for MgO based MTJs as a function of deposition temperature and stoichiometry. The results will be compared to the corresponding magnetic bulk properties and the crystallographic ordering.

MA 52.23 Fri 11:00 Poster A

Hall effect studies in ultrathin LSMO/SRO superlattices — •Francis Bern[1], Michael Ziese[1], and Ionela Vrejoiu[2] — [1]Division of Superconductivity and Magnetism, University of Leipzig, 04103 Leipzig, Germany — [2]Max Planck Institute of Microstructure Physics, 06120 Halle, Germany

A variety of ultrathin multilayer films have been produced by pulsed laser deposition. The itinerant ferromagnet $SrRuO_3$ (SRO) and the double-exchange ferromagnet $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) were grown on $SrTiO_3$ (STO), both in single layers as well as in superlattices. Characterization by magnetotransport measurements indicate a structural transition due to strain in the ultrathin layers. The complex temperature dependence of the anomalous Hall coefficient suggests changes in the electronic structure and/or a conducting interfacial layer at the LSMO/SRO interface.

MA 52.24 Fri 11:00 Poster A

CPP – GMR using the Heusler alloy $Co_2FeAl_{0.4}Si_{0.6}$. — •F. Casper[1], K. Rott[2], G. Reiss[2], and C. Felser[1,3] — [1]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg - University, Mainz, Germany — [2]Department of Physics, Bielefeld University, Bielefeld, Germany — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Large tunneling magneto resistance (TMR) values were reported from magnetic tunneling junctions (MTJs) using Heusler alloys, which indicates a high spin polarization of the electrode materials. These high spin polarized materials should also enhance current-perpendicular-to-plane giant magneto resistance (CPP GMR). Most of these experiments were performed on small MgO-substrates which are not suitable for an industrial application. We implemented the Heusler compound $Co_2FeAl_{0.4}Si_{0.6}$ (CFAS) into an industrial production. A twelve inch target is used to sputter a Cr(10)/Ag(50)/CFAS(10)/Ag(5)/CFAS(10)/Ru(8) spin valve structure on silicon and MgO wafers. The structure of the films was determined by x-ray diffraction. The film was microfabricated to form a pillars with the size of 0.2 X 0.1 μm^2 up to 1.0 X 0.4 μm^2 for the measurement of CPP-GMR. Depending on the annealing temperature the TMR ratio reaches values of 7% on MgO and 1.2% on Si wafers at room temperature. This work is supported by the Federal Ministry for Education and Research BMBF, project "'Multimag"'.

MA 52.25 Fri 11:00 Poster A

Slow Relaxation Effects in CMR Manganite Films and Superlattices — •Markus Jungbauer, Felix Koeth, Sebastian Hühn, Markus Michelmann, and Vasily Moshnyaga — I. Physikalisches Institut, Universität Göttingen

Colossal magnetoresistance (CMR) and complex magnetic/electric state close to the I. order phase (metal-insulator) transition in ferromagnetic perovskite manganites are still puzzling phenomena. We studied epitaxial films of $(La_{1-y}Pr_y)_{0.7}\,Ca_{0.3}MnO_3$/MgO(100) (y=0.4-0.6) with respect to their magnetotransport and magnetooptic properties with special focus on the relaxation effects. Close to the metal-to-insulator transition temperature, T_{MI}, application of magnetic field, $B = 0 - 1\,\mathrm{T}$, leads to a relaxation of the electrical resistivity on a timescale, $\tau \approx 100\,\mathrm{s}$. Considering the observed temperature hysteresis of resistance and magnetization close to T_C as well as an anomalous increase of coercive field and low-field CMR in the vicinity of T_{MI} a following semi-quantitative picture of the complex magnetic state close to the phase transition was developed: the nanoscopic single-domain ferromagnetic clusters are coupled antiferromagnetically by a short-range-ordered correlated polaronic phase with a thickness of few monolayers. By growing digital $(FMM/AFMCOI)_N$ superlattices with $FMM = La_{0.7}(Ca,Sr)_{0.3}MnO_3$ and $AFMCOI = Pr_{1-x}Ca_xMnO_3$ (x=0.3-0.7) we try to reproduce and to tune this unique magnetic state with the main aim to obtain the enhanced low-field CMR close to room temperature. A financial support from EU FP7 via the Project IFOX (interfacing oxides) is acknowledged.

MA 52.26 Fri 11:00 Poster A

Tailoring perpendicular anisotropy in Co/Pd multilayers by ion irradiation — •Julia Osten[1], Peter Greene[2], Tamio Endo[3], Nobuyuki Iwata[4], Kilian Lenz[1], Kai Liu[2], and Jürgen Fassbender[1] — [1]Institute of Ion Beam Physics and Materials Research HZDR, Dresden, Germany — [2]U.C. Davis Physics Department, Davis, CA, USA — [3]Mie University, Tsu, Mie, Japan — [4]Nihon University, Funabashi, Chiba, Japan

A major obstacle towards the increase in areal magnetic recording density and the decrease in bit size is the retention of thermal stability while maintaining reasonable write fields. Materials with graded magnetic anisotropy are promising candidates to solve this problem. Here we demonstrate the approach of using post-deposition Ar-ion irradiation to tailor the perpendicular anisotropy in Co/Pd multilayer thin films. The films, with uniform as well as graded perpendicular anisotropy, were synthesized by magnetron sputtering. Based on TRIDYN simulations, different primary ion energies (1-25 keV) are chosen to achieve varying penetration depths of the ions creating a depth dependent anisotropy grading. Before and after ion irradiation, MOKE as well as magnetometry measurements were employed to detect the changes of the magnetic properties. Upon ion irradiation, the Co/Pd films exhibit reduced coercivity and remanence with increasing fluence. Higher ion energies have a more pronounced effect on reducing the perpendicular anisotropy.

The work at UCD was supported by the US NSF (DMR-1008791 & ECCS-0925626).

MA 52.27 Fri 11:00 Poster A

Method to separate the anomalous Hall signal of different Co/Pt nanodots — •Carsten Thönnissen[1], Alexander Neumann[1], Simon Hesse[1], Andreas Meyer[2], and Hans Peter Oepen[1] — [1]Institut für Angewandte Physik, Universität Hamburg, Germany — [2]Institut für Physikalische Chemie, Universität Hamburg, Germany

On nanosized Hall crosses (<100nm) made via electron beam lithography (EBL) nanodots are created, which can be magnetically investigated with single dot sensitivity via anomalous Hall effect (AHE). The nanodots were fabricated from thin Co/Pt films using SiO_2 particles as shadow mask for Ar^+ ion milling at 150eV [1]. Due to the fact that the number of nanodots in the sensitive area of the cross varies between one and five it is necessary to separate the signals of the different nanodots. For that purpose we use a measurement setup similar to the van der Pauw method. The DC current is sent through adjoining legs of the Hall cross and a voltage drop is measured across the other legs. The obtained signal is proportional to the current through the dot and depends on the local current direction at the position of the dot. By cyclic permutation we obtain different signal ratios which allow us to identify the individual particles. By means of micrographs taken by scanning electron microscopy we identify the position and arrangement of the dots, which is used to simulate the voltage that has to be expected for the different geometries.

[1] H. Stillrich *et al.* Adv. Funct. Mat. **18**, p76-81, (2008).

MA 52.28 Fri 11:00 Poster A

Single wire and ensemble measurements on NixCo1-x nanowires for the determination of switching field distributions — •Philip Sergelius[1], Tim Böhnert[1], Stephan Martens[1], Victor Vega Martinez[2], Kornelius Nielsch[1], and Detlef Görlitz[1] — [1]Institute of Applied Physics, University of Hamburg, Hamburg, Germany. — [2]Depto. Física, Universidad de Oviedo, Oviedo, Spain.

NixCo1-x nanowires with x varying between 0.05 and 0.77 have been synthesized by potentiostatic electrodeposition into self ordered Al2O3 Membranes (AAO) by hard anodization. The variation of the Ni:Co composition in the alloyed nanowires of appr. 20μm length, 150nm diameter and 305 nm spacing allows for a tuning of the switching field along the wire axes between 190 Oe and 400 Oe.

We performed First Order Reversal Curve (FORC) measurements on the nanowire ensembles in a VSM (Quantum Design VersaLab). The FORC analysis yields the distribution of the coercive fields for all nanowires in the membrane and the distribution of their interaction fields. Additionally, MOKE analyses utilizing a NanoMOKE2TM (Durham Magneto Optics Ltd) were performed on up to 100 singular wires of each ensamble in order to have adequate statistics for the distribution of coercivities ranging from 150 Oe to 450 Oe. The obtained coercivity distributions with widths of appr. 18 % from the FORC and MOKE measurements are discussed and compared revealing the impact of different interaction fields in the investigated templates.

MA 52.29 Fri 11:00 Poster A

Investigation of the influence of dipolar interactions on the magnetic behavior of Ni nanorods — •Florian Krämer, Philipp Bender, Andreas Tschöpe, and Rainer Birringer — Universität des Saarlandes, Saarbrücken

Ni nanorods with diameters < 42nm are expected to be uniaxial ferromagnetic single domain particles. In recent years, the magnetic properties of Ni nanorods in porous alumina templates were extensively studied. However, the investigation of characteristic magnetic properties was hampered by the large dipolar interactions (DI) due to the dense packing of the rods in the template. We synthesized Ni nanorods (D =19 nm) by current-pulsed electrodeposition of Ni into ordered porous alumina templates. The filled templates were characterized by static magnetization measurements (SMM) as a modelsystem of uniaxial ferromagnets with significant DI. Then, the nanorods were released from the templates by dissolution of the alumina in aqueous NaOH, dispersed in 20 wt% gelatine solutions @60°C and aligned paralell by an external homogenous magnetic field during gelation. These gels were also characterized by SMM as an corresponding system of uniaxial ferromagnets with negligible DI. The objective of this work was to study the influence of DI on the magnetic properties of such uniaxial ferromagnetic particles. We measured the remanence and the coercivity as a function of the angle between the rodaxis and the external field, the switching field distribution, the shape anisotropy constant and the activation volume.

MA 52.30 Fri 11:00 Poster A

Magnonic modes in rectangular antidot lattices — •Jelena Panke, Benjamin Lenk, Nils Abeling, and Markus Münzenberg — I. Physikalisches Institut, Georg-August-Universität Göttingen

On the way towards spin-wave logic devices an understanding of mechanisms for the manipulation and guiding of spin waves is of crucial importance. Femtosecond laser pulses are used to optically excite (pump) and subsequently measure (probe) magnetization dynamics on timescales as long as nanoseconds. Two-dimensional arrays of antidots in a ferromagnetic film provide a periodic "potential" to the excited spin waves and induce drastic changes in the magnetization dynamics.

In the spin wave spectra of rectangular CoFeB antidot lattices different modes are observed which are influenced by the variation of material parameters (filling fraction, antidot diameter, lattice parameter). We focus on these Bloch-like modes and investigate the spin-wave population for different directions of the external field. By applying the external field along the long or short axis $a_{1,2}$ of the rectangular lattice a magnonic mode appears with a wave vector $k = \pi/a_{1,2}$ at the boundary of the first Brillouin zone for each respective direction. Therefore it is possible to tune the Bloch modes only by rotating the external field. Furthermore, band structure calculations are used to investigate the changed dispersion on the patterned media as compared to the continuous film. The periodic lattice structure induces band gaps at the zone boundary that are also sensitive to the field direction and can explain the prefered population of the magnonic modes.

MA 52.31 Fri 11:00 Poster A

Influence of the dipolar interaction on the quasi-static magnetic properties of elliptical microstructures in dense packed arrays — •Andres Conca, Thomas Sebastian, Georg Wolf, Britta Leven, and Burkard Hillebrands — FB Physik und Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Elliptical magnetic structures with dimensions of a few micrometers play a crucial role in the design of magnetic field sensors and in data storage applications such as MRAM cells. The magnetic properties of such structures are mostly controlled via the shape anisotropy. In many cases, a high packing density is required. However the effect of dipolar interaction between the individual elements within the array due to stray fields can be very strong when the distances are of only a few micrometers.

We present measurements of the influence of the packing density on the coercive field H_C of elliptical elements in arrays. For this purpose, 5×5 arrays of elliptical elements were prepared with varying interelement distances. The arrays were structured using e-beam lithography from a 5 nm thick polycrystalline CoFeB thin film deposited on a Si substrate. The measurements were performed with a μMOKE setup equipped with a micro-focused HeNe-laser beam with a spotsize of 1 μm.

MA 52.32 Fri 11:00 Poster A

Magnetic Films on Nanoperforated Substrates — •Carsten Schulze[1], Marco Faustini[2], Michael Grobis[3], Denys Makarov[4], David Grosso[2], and Manfred Albrecht[1] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Laboratoire de Chimie de la Matière Condensée de Paris, Université Pierre et Marie Curie-Paris 6, CNRS, 75252 Paris Cedex

05, France — [3]San Jose Research Center, Hitachi GST, San Jose, CA 95135, USA — [4]IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany

A study of the magnetization reversal in ferromagnetic thin films with perpendicular magnetic anisotropy deposited onto substrates with densely distributed nanoperforations is presented. The nanoperforated substrates are fabricated by a wet-chemical evaporation induced self-assembly process of block-copolymer micelles, Co/Pt multilayers are used as ferromagnetic thin films. The pinning of magnetic domain walls on the substrate-induced defects has been shown earlier [1, 2], as well as the possible application of such a system as a percolated perpendicular recording medium [3, 4].

Here, the dependence of the pinning strength on the interplay between saturation magnetization, anisotropy, domain wall width and perforation size will be discussed.

[1] D. Makarov *et al.*, *IEEE Trans. Magn.* **45** (2009) 3515.
[2] C. Schulze *et al.*, *Nanotechnology* **21** (2010) 495701.
[3] D. Suess *et al.*, *J. Appl. Phys.* **99** (2006) 08G905.
[4] M. Grobis *et al.*, *Appl. Phys. Lett.* **98** (2011) 192504.

MA 52.33 Fri 11:00 Poster A

Ion beam irradiation of interlayer exchange coupled trilayers in the sub-micron regime — •Roland Neb[1], Thomas Sebastian[1], Philipp Pirro[1], Stefan Pofahl[2], Rudolf Schäfer[2], Bernhard Reuscher[3], and Burkard Hillebrands[1] — [1]TU Kaiserslautern, Landesforschungszentrum Optimas, 67663 Kaiserslautern, Germany — [2]IFW Dresden, 01069 Dresden, Germany — [3]IFOS Kaiserslautern, 67663 Kaiserslautern, Germany

Focused ion beam irradiation is a well known tool for patterning thin film media. We use this tool to pattern an antiferromagnetically coupled Fe/Cr/Fe trilayer in the micron and sub-micron regime. The irradiated areas become ferromagnetic, allowing for the creation of well-defined ferromagnetic areas in an antiferromagnetically coupled environment. The suitability of such irradiated elements for information storage was investigated. We found that if certain conditions for the patterning process are met, sub-micron elements are able not only to store information but also to be overwritten by a sufficiently high magnetic field. The resulting bit density is strongly dependent on the applied ion dose, changing by a factor of 100 in the regime of 10^{14} to 10^{16} ions/cm^2.

Financial support by the Deutsche Forschungsgemeinschaft, the Graduate School *Material Science in Mainz* and the Graduiertenkolleg 792 is gratefully acknowledged.

MA 52.34 Fri 11:00 Poster A

Mechanical deformation of Dy nanocontacts in magnetic field — Marc Müller[1], •Oliver Berg[1], Christoph Sürgers[1], and Hilbert v. Löhneysen[1,2] — [1]Karlsruhe Institute of Technology, Physikalisches Institut and Center for Functional Nanostructures, D-76049 Karlsruhe — [2]Karlsruhe Institute of Technology, Institut für Festkörperphysik, D-76021 Karlsruhe

Recently, we demonstrated the reproducible tuning of the electrical conductance of Dy nanocontacts in a magnetic field by exploiting the large magnetostriction of Dy [1]. Here we report on the dependence of the contact shape on an applied magnetic field. The nanocontacts were obtained from Dy wires by the mechanically controlled break-junction technique. In zero magnetic field we find the usual variation of the conductance G vs. electrode distance x while breaking the wire mechanically, with a sequence of steps and more or less prominent conductance plateaus. From the behavior $G(x)$ we estimate the shape of the nanocontact after several cycles of mechanical deformation of the wire. We find that the final shape of the nanocontact depends on the strength and orientation of an applied magnetic field. This shaping under alternating tensile and compressive stress is attributed to the rearrangement of magnetic domains in magnetic field during formation of the nanocontact by magnetoelastic coupling.

[1] M. Müller et al., Nano Letters **11**, 547 (2011)

MA 52.35 Fri 11:00 Poster A

Rolled-up tubes and cantilevers from magnetic $SrRuO_3$-$Pr_{0.7}Ca_{0.3}MnO_3$ films — Christoph Deneke[1,4], •Kathrin Dörr[2], Elisabeth Wild[3], Stefan Baunack[3], Angelo Malachias[4], and Oliver Schmidt[3] — [1]Laboratorio Nacional de Nanotecnologia, Caixa Postal 6192, Campinas, S.P., Brazil — [2]MLU Halle-Wittenberg, Halle, Germany — [3]Institute for Integrative Nanosciences, IFW Dresden, Dresden, Germany — [4]Laboratorio Nacional de Luz Sincrotron, Caixa Postal 6192, Campinas, S.P., Brazil

Three-dimensional microobjects are fabricated by the controlled release of inherently strained $SrRuO_3/Pr_{0.7}Ca_{0.3}MnO_3/SrRuO_3$ trilayers from $SrTiO_3(001)$ substrates. Cantilevers and rolled-up microtubes with a diameter of 6-8 μm are demonstrated. The etching behavior of the $SrRuO_3$ film is investigated and a selectivity of 1:9100 with respect to the $SrTiO_3$ substrate is found. The initial and final strain states of the rolled-up oxide layers are studied by x-ray diffraction on an ensemble of tubes. Relaxation of the sandwiched $Pr_{0.7}Ca_{0.3}MnO_3$ layer towards its bulk lattice parameter is observed as the major driving force for the roll-up of the trilayers. Finally, microdiffraction experiments reveal that a single object can represent the ensemble proving a good homogeneity of the rolled-up tubes.

MA 52.36 Fri 11:00 Poster A

Interaction of Josephson and magnetic oscillations in Josephson tunnel junctions with a ferromagnetic layer — •Sebastian Mai, Ervand Kandelaki, Anatoly Volkov, and Konstantin Efetov — Theoretische Physik III, Ruhr-Universität Bochum, 44780 Bochum, Deutschland

We studied the dynamics of Josephson junctions with a thin ferromagnetic layer F (SFIFS junctions). In such junctions, the phase difference ϕ of the superconductors and magnetization M in the F layer are two dynamic parameters coupled to each other. We derived equations describing the dynamics of these two parameters and calculated the modified current-voltage (I-V) characteristics in the presence of a weak magnetic field (Fiske steps). We showed that the magnetic degree of freedom not only changes the form of the Fiske steps but also the overall view of the I-V curve (new peaks related to the magnetic resonance appear). We also calculated the power P absorbed in the system if a microwave radiation with an ac in-plane magnetic field is applied (magnetic resonance). The obtained formula for the power P essentially differs from the one which describes the power absorption in an isolated ferromagnetic film. In particular, this formula describes the peaks related to the excitation of standing plasma waves as well as the peak associated with the magnetic resonance.

MA 52.37 Fri 11:00 Poster A

Molecular Dynamic Simulation of atomic deposition between MnAs cluster — •Andreas Rühl and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University Giessen, D-35392, Germany

MnAs is a promising ferromagnetic material for magnetoelectronic devices, in particular as nano-scaled clusters, providing a great tunability concerning the shape and position. We investigate hexagonal MnAs clusters which are separated by a metal. Such structures could be produced by using a FIB (focused ion beam) two disconnect two touching MnAs clusters and to deposit a metal between them. We succesfully implemented a molecular dynamic program to simulate the atomic deposition of the metal atoms on the surface of the MnAs cluster. The necessary effective interaction potentials between the simulation participants are gained by means of a force matching method, where the effective potentials are fitted to ab initio data.

MA 52.38 Fri 11:00 Poster A

Spin-resolved photoemission study of Bis(phthalocyaninato) terbium(III) ($TbPc_2$) deposited on Co/Cu(001) — •Nicolas Grossmann[1], Sabine Steil[1], Norman Haag[1], Mirko Cinchetti[1], Mario Ruben[2], and Martin Aeschlimann[1] — [1]Department of Physics and Resarch Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institut of Nanotechnology, Karlsruhe Institute of Technology, 76344 Eggenstein-Leopoldshafen

We have studied the formation of the electronic structure of the interface between an epitaxially grown Co(001) thin film and the single molecular magnet Bis(phthalocyaninato)terbium(III) ($TbPc_2$). The organic semiconductor was progressively grown on the cobalt substrate. The grown interfaces have been characterized by means of spin-resolved ultraviolet photoemission. For every growth step we have monitored the changes in the work function, the energetic position of the occupied molecular orbitals and interface states, and the changes in the cobalt spin polarization induced by interface formation. The most striking result is the presence of an occupied spin polarized hybrid interface state with a negative spin polarization, lying 0,7 eV below the Fermi level. The spin polarization of this state shows a pronounced temperature dependency. Our results agree with the recent observation of an antiferromagnetic coupling between $TbPc_2$ and a ferromagnetic metal substrate reported in [1].

[1] Gambardella et al., Phys. Rev. Lett. 107, 177205 (2011)

MA 52.39 Fri 11:00 Poster A

Organic molecular beam deposition of a paramagnetic organic magnet — Sabine-Antonia Savu[1], •Reza Kakavandi[1], Indro Biswas[1], Mathias Glaser[1], Lorenzo Sorace[2], Matteo Mannini[2], Andrea Caneschi[2], Thomas Chassé[1], and Maria Benedetta Casu[1] — [1]IPTC, University of Tübingen, Tübingen, Germany — [2]LAMM, University of Florence, Florence, Italy

Nitronyl nitroxide radicals are an interesting class of organic compounds because of their magnetic properties. In this work we present a soft X-ray investigation of thin films of a pyrene derivative of the nitronyl nitroxide radical (nitpyrene), deposited onto well characterized single crystals surfaces, using strictly controlled evaporation conditions. We approach the deposition of nitpyrene using the knowledge obtained during the last years on thin film processes of organic molecules. The electronic structure and the interaction with the surface are discussed. By analyzing the attenuation of the XPS substrate signal, we find indications for island plus layer growth mode, supported by AFM measurements. We have also investigated the molecular orientation of the pyrene part versus film thickness, identifying the strength of molecule-molecule interactions versus molecule-substrate interactions by using X-ray absorption and photoemission spectroscopies.

MA 52.40 Fri 11:00 Poster A

Electron Localization in a Charge Transfer Salt on Au(111) — Tobias R. Umbach[1], Isabel Fernandez-Torrente[1], •Michael H. Kleinert[1], Ricardo Rurali[2], Mats Persson[3], Jose I. Pascual[1], and Katharina J. Franke[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Institut de Ciencia de Materials de Barcelona, Campus de Bellaterra, 08193 Bellaterra (Barcelona), Spain — [3]The Surface Science Research Center, The University of Liverpool, L69 3BX, United Kingdom

Alkali metals are perfect candidates for varying the electronic structure in molecular environments. Acting as electron donors with a low ionization potential, they easily build charge transfer complexes under the presence of an acceptor molecule. We investigated such a charge transfer process in a monolayer of the acceptor molecule 7,7,8,8,-tetracyanoquinodimethane (TCNQ) doped with Na on a Au(111) surface, using low-temperature scanning tunneling microscopy and spectroscopy. The self-assembled Na-TCNQ phase shows a Kondo resonance centered on the cyano-terminations of the TCNQ molecules, which proves the presence of an unpaired electron in the complex. Ab initio calculations corroborate the transfer of the Na's 3s electron to the organic acceptor and reveal its localization at the cyano groups.

MA 52.41 Fri 11:00 Poster A

Transport properties of novel Anthraquinone based molecular switches — •Simon Liebing[1], Torsten Hahn[1], Nadine Seidel[2], Tim Ludwig[3], and Jens Kortus[1] — [1]Institut for Theoretical Physics, TU Bergakademie Freiberg, 09596 Freiberg, Germany — [2]Institut for Organic Chemistry, TU Bergakademie Freiberg, 09596 Freiberg, Germany — [3]Institute for Theoretical Physics, TU Dresden, 01062 Dresden, Germany

Anthraquinone derivatives were recently reported to be good candidates for application as molecular switches [1]. We present a novel molecular system based on the anthraquinone-core π conjugated spacers and linkers units. The influence on the transport properties of model junctions by chemical modifications of the anthraqunine-core as well as the impact of difficult linker units is discussed. The authors show how chemical modifications can be used for Fermi level and band gap engineering. The theoretical results based on DFT [2] and NEGF [3] calculations are used to suggest further optimizations of the molecular system.

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MA 52.42 Fri 11:00 Poster A

Simulation of STM images and STS spectra of Metal-Phthalocyanine molecules on different substrates - comparing the DFT/NEGF and QME approach — •Torsten Hahn[1] and Tim Ludwig[2] — [1]Institute of Theoretical Physics, TU Bergakademie Freiberg, Freiberg, Germany — [2]Institute of Theoretical Physics, TU Dresden, Dresden, Germany

STM (scanning tunneling microscopy) and STS (scanning tunneling spectroscopy) experiments are the methods of choice to study the transport characteristics of single molecules in an well defined environment [1]. Metal Phthalocyanines are known to be promising candidates for applications in molecular spintronics. The interpretation of measured STM/STS data is crucial for the understanding of material properties. We compare theoretical results obtained from DFT - NEGF (density functional theory - non equilibrium green functions formalism) [2] and QME (quantum master equation) [3] investigations and discuss their impact on the interpretation of experimental data.

[1] C. Iacovita et. al., Phys. Rev. Lett. 101, 116602 (2008)
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[3] Timm, Phys. Rev. B 77, 195416 (2008)

MA 52.43 Fri 11:00 Poster A

Quantitative MFM on superconducting thin films — •Henry Stopfel[1], Silvia Vock[1], Tetyana Shapoval[1], Volker Neu[1], Ulrike Wolff[1], Dmytro S. Inosov[2], Silvia Haindl[1], Jan Engelmann[1], Rudolf Schäfer[1], Bernhard Holzapfel[1], and Ludwig Schultz[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Max Planck Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany

Quantitative interpretation of magnetic force microscopy (MFM) data is a challenge, because the measured signal is a convolution between the magnetization of the tip and the stray field emanated by the sample. It was established theoretically that the field distribution just above the surface of the superconductor can be well approximated by the stray field of a magnetic monopole [1]. The description of the MFM tip, however, needs a second approximation. The temperature-dependent vortex-distribution images on a NbN thin film were fitted using two different tip models. Firstly, the magnetic tip was assumed to be a monopole that leads to the simple monopole-monopole model for the tip-sample interaction force. Performing a 2D fitting of the data with this model, we extracted λ, Δ and the vortex pinning force [2]. Secondly, a geometrical model was applied to calculate the tip-transfer-function of the MFM tip using the numerical BEM method [3].

[1] G. Carneiro and E. H. Brandt, PRB 61, 6370 (2000)
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[3] Vock S. et al., IEEE Transactions on Magnetics 47, 2352 (2011)

MA 52.44 Fri 11:00 Poster A

Observation of antiferromagnetic domains using magneto-optical microscopy. — •Anna Möhn, Ingolf Mönch, Denys Makarov, Rudolf Schäfer, Oliver G. Schmidt, and Ludwig Schultz — IFW Dresden, Institute for Metallic Materials Dresden, Germany

Two different exchange biased systems were studied. Both antiferromagnetic/ferromagnetic-bilayer systems contain Py as ferromagnetic material, but one with IrMn and the other one with CoO as antiferromagnetic layer. Through the different Néel-temperatures of the antiferromagntic materials the systems show the exchange bias effect under different temperature conditions. The exchange bias effect can be used to imprint a well-defined domain pattern into the antiferromagnetic layer. To observe those imprinted antiferromagnetic domains directly we will use the Voigt effect. This quadratic magneto-optical effect is a birefringence of linearly polarized light which we observe in reflection with a wide-field Kerr microscope. Using the Voigt effect on a ferromagnet, we can see domains which differ by 90° in the axis of the magnetic moments independent of their net magnetization. The same effect is expected to be seen in an antiferromagnet if the antiferromagnetic domains are magnetized along orthogonal easy axes [1]. The required 90° domains are firstly generated as a Landau pattern in the (structured) ferromagnetic film of our bilayer systems and then imprinted to the antiferromagnetic film by cooling below the blocking temperature.

[1] Peter Oppeneer, University Uppsalla, private communication

MA 52.45 Fri 11:00 Poster A

Direct Imaging of Precessional Domain Wall Propagation in Ferromagnetic Rings Induced by Circular Magnetic Fields — A. Bisig[1,2,3], •M. A. Mawass[1,4], M. Stärk[1,3], C. Moutafis[1,3], J. Rhensius[3,5], J. Heidler[2], M. Curcic[2], E. Prabu[2], M. Noske[2], M. Weigand[2], T. Tyliszczak[5], B. Van Waeyenberge[6], H. Stoll[2], G. Schütz[2], and M. Kläui[1,3,4] — [1]Paul Scherrer Institut, Villigen, Switzerland — [2]Max-Planck-Institut für Intelligente Systeme,

Stuttgart, Germany — [3]Universität Konstanz, Konstanz, Germany — [4]Johannes Gutenberg-Universität Mainz, Mainz, Germany — [5]Advanced Light Source, LBNL, Berkeley, USA — [6]Ghent University, Ghent, Belgium

The controlled displacement of magnetic domain walls (DW) along magnetic nanostructures is a key prerequisite to memory storage or DW logic devices. Depending on the strength of the driving force (magnetic field or spin-polarized currents), the propagation of DW changes from simple translation to more complex precessional modes, i.e. periodic transformations of vortex DWs into transverse DWs and back during propagation. We present direct experimental visualization of the precessional motion of vortex DWs in permalloy nanorings controlled by circular fields. Employing scanning transmission x-ray microscopy (STXM) we image the propagation of a pair of vortex DWs in a stroboscopic measurement scheme. We find that the DW velocity strongly varies during the transformation processes and that the propagation and DW spin structures are highly reproducible indicating the direct observation of the Walker breakdown.

MA 52.46 Fri 11:00 Poster A

Magnetic resonant scattering with Laser generated higher harmonic radiation — •Christian Weier[1], Dennis Rudolf[1], Roman Adam[1], Claus M. Schneider[1], André Kobs[2], Gerrit Winkler[2], Robert Frömter[2], Hans P. Oepen[2], Margaret M. Murnane[3], and Henry C. Kapteyn[3] — [1]Peter Grünberg Institut, Research Center Jülich, 52425, Jülich, Germany — [2]Institut für Angewandte Physik, University of Hamburg, 20355, Hamburg, Germany — [3]JILA, University of Colorado, Boulder, CO 80309-0440, USA

Laser driven higher harmonic generation has recently been used to generate extreme ultraviolet (EUV) radiation for probing magnetization dynamics of ferromagnets, element selectively, with a time resolution of few femtoseconds. EUV photons with energies of 52 eV, 61 eV and 67 eV can reach M-absorption edges of Fe, Co and Ni, respectively, what leads to a resonantly enhanced magneto-optical signal. On the other hand, there is a strong progress in imaging techniques using laser generated EUV radiation due to its low divergence and high coherence. In our experiment, we resonantly scatter EUV light from Co/Pt-multilayers forming a magnetic domain pattern. As a consequence of the magnetization dependent scattering, the amplitude of the resulting image in k-space is directly related to the average domain size. Exploring advantage of the femtosecond coherent EUV radiation, our scattering experiment gives the possibility to probe magnetization dynamics with a high temporal and spatial resolution.

MA 52.47 Fri 11:00 Poster A

Switching the magnetization of nanomagnets using SP-STM — •Benjamin Ehlers, Gabriela Herzog, Johannes Friedlein, Stefan Krause, and Roland Wiesendanger — University of Hamburg, Institute of Applied Physics, Jungiusstraße 11A, 20355 Hamburg, Germany

With spin-polarized scanning tunneling microscopy (SP-STM) it is possible to manipulate the switching behavior of atomic-scale superparamagnets, using a high spin current generated between a magnetic tip and a magnetic sample. [1]

Here, current-induced magnetization switching of thermally quasistable magnetic nanoislands with a state lifetime on the order of several hours is demonstrated using SP-STM. The magnetization of an individual Fe nanoisland consisting of about 40 atoms on a W(110) surface is reversibly switched between two states by the application of short spin-polarized tunnel current pulses in the μA regime [2]. The combined action of Joule heating and spin-transfer torque during the pulse leads to a controlled reversal of the magnetization. The switching efficiency is evaluated as a function of different current pulse parameters, i.e. pulse length and amplitude, bias polarity and bias value.

[1] S. Krause, L. Berbil-Bautista, G. Herzog, M. Bode, and R. Wiesendanger, Science **317**, 1537 (2007).
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MA 52.48 Fri 11:00 Poster A

Complex magnetic ground states observed in Fe nanostructures on different Ir surfaces — •Matthias Menzel[1], Kirsten von Bergmann[1], Stefan Heinze[2], Yuriy Mokrousov[3], Gustav Bihlmayer[3], Jessica Bickel[1], Jens Brede[1], Robert Wieser[1], Elena Vedmedenko[1], Stefan Blügel[3], André Kubetzka[1], 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

The reduced symmetry and large spin-orbit interaction can give rise to complex magnetic ground states in 3*d*-transition metal nanostructures on heavy element surfaces, e.g. [1]. Especially, Fe nanostructures on an Ir surface are promising candidates for non-collinear magnetic states, due to an extremely weak Heisenberg exchange [2].

Here, we present SP-STM measurements of Fe chains on the (5×1)-Ir(001) surface as well as the Fe monolayer on Ir(111) which reveal atomic-scale, non-collinear magnetic ground states in both systems [3,4]. Density functional theory calculations show that the weak Heisenberg exchange allows other interactions, as the Dzyaloshinskii-Moriya exchange or higher-order interactions, to dominate the energy landscape.

[1] M. Bode *et al.*, Nature **447**, 190 (2007).
[2] B. Hardrat *et al.*, PRB **79**, 094411 (2009).
[3] S. Heinze *et al.*, Nature Physics **7**, 713 (2011).
[4] M. Menzel *et al.*, submitted.

MA 52.49 Fri 11:00 Poster A

Quantum-Mechanical Model of Spin Polarized STM — •Kolja Them, Thim Stapelfeldt, Elena Y. Vedmedenko, and Roland Wiesendanger — Institute for Applied Physics University of Hamburg Jungiusstr. 11 20355 Hamburg

Spin sensitive studies of individual magnetic ad-atoms and atomic ensembles on surfaces with spin-polarized scanning tunneling microscopy (SP-STM) have raised the necessity of a quantum-mechanical description of spin dynamics during SP-STM experiments. The quantum-mechanical treatments of STM experiments typically deal with the expectation values of observables using Gibbs ensemble averages. An SP-STM measurement, however, is a time-average of the expectation values. The lack of the time-averaging might be a reason for the fact that the theoretically predicted relaxation time on the nanosecond scale for a single spin of a magnetic adatom is at odd with the femtosecond rates measured for Fe adatoms on semiconductor surfaces. Another still unexplained finding is the extremely high switching frequency of Co atoms on Pt(111) at zero magnetic field. In the present paper we use the algebraic formulation of quantum statistical mechanics to clearly separate the thermal equilibrium Gibbs states and the time evolution of the system during SP-STM experiments. Using elaborated techniques we calculate dynamics of single quantum spins as well as magnetic ensembles at finite temperatures. We demonstrate that the relaxation times of those quantum objects on different substrates lie in the femto- or pico-second regime.

MA 52.50 Fri 11:00 Poster A

Spin-transfer torque experiments on Co2MnSi/Ag/Co2MnSi (001) nanopillars — •Şaban Tırpancı[1,2], Daniel E. Bürgler[1], Yuya Sakuraba[3], Subrojati Bosu[3], Koki Takanashi[3], and Claus M. Schneider[1] — [1]Electronic Properties (PGI-6) and JARA-FIT, Forschungszentrum Jülich, Jülich, Germany — [2]GIT, Gebze, Turkey — [3]IMR, Tohoku University, Sendai, Japan

The Heusler alloy Co2MnSi (CMS) is a half-metallic ferromagnet with a Curie temperature above room temperature (RT) and high spin polarization, which in combination with Ag spacer layers yields large GMR ratios of up to 36 percent at RT [1]. Therefore, CMS is a very promising material for new spintronic devices. Fully epitaxial CMS/Ag /CMS(001) thin films are prepared by UHV magnetron sputtering [1]. Ellipsoidal nanopillars with diameters between 120 nm to 300 nm are fabricated by e-beam lithography and ion-beam etching for spin-torque measurements in current-perpendicular-plane (CPP) geometry. The two CMS layers of 20 and 5 nm thickness act as fixed and free layer, respectively, and are separated by 8 nm Ag. Previous work [1,2] is extended by performing DC and HF measurements at low temperatures in order to study the influence of the increased polarization on critical currents for current-induced switching and magnetic excitation as well as the efficiency of injection locking [3] as a prerequisite for synchronization of several spin-torque oscillators.

[1] Y. Sakuraba et al.,. Phys. Rev. B 82, 094444 (2010)
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MA 52.51 Fri 11:00 Poster A

Determination and characterization of spin torque in perpendicular magnetized multilayer materials — •Tomek Schulz[1], Jan Heinen[1,2], Mathias Kläui[1,2,7], Olivier Boulle[3], Gregory

Malinowsky[4], Christian Ulysse[6], Giancarlo Faini[6], Denise Hinzke[2], Henk Swagten[5], Bert Koopmans[5], and Berthold Ocker[8] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany — [2]Fachbereich für Physik, Universität Konstanz, Germany — [3]Spintec, UMR CEA/CNRS/UJF-Grenoble 1/Grenoble-INP, France — [4]Laboratoire de physique des solides, Universite Paris-sud, France — [5]Department of Applied Physics, Eindhoven University of Technology, The Netherlands — [6]CNRS, Phynano team, Laboratoire de Phtonique et de Nanostructures, Marcoussis, France — [7]SwissFEL, Paul Scherrer Institut, Villigen PSI, Switzerland — [8]Singulus Technologies AG, Kahl am Main, Germany

We report on measurements to deduce the spin torque contribution of current induced domain wall motion in out-of-plane magnetized multilayer materials. Using complementary measurement techniques such as the current-field equivalency and thermally activated domain wall hopping allow us not only to separate the torque terms on the same material, but also to gauge their accuracy and validity. The extension of these techniques to characterize novel materials reveals not only the predicted dominant non-adiabatic spin torque as in the Co/Pt multilayer nanowires, but also a dominant adiabatic torque in Co/Ni multilayer nanowires highlighting the importance of the materials composition for the acting torques.

MA 52.52 Fri 11:00 Poster A

Dynamical magnetic susceptibility of nanostructures with spin–orbit coupling — •Manuel dos Santos Dias, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

We outline a real–space linear response theory of the dynamical spin susceptibility of nanostructures, accounting for the spin–orbit interaction. The starting point is the existing formalism of time–dependent Density Functional Theory, in the Korringa–Kohn–Rostoker Green function method [1,2]. The linear response to an external time-dependent applied magnetic field transverse to the orientation of the magnetisation generates both transverse and longitudinal time-dependent spin susceptibilities, while the induced charge fluctuations introduce the screened Coulomb interaction in the problem. The breaking of the spin rotational invariance due to the spin–orbit interaction is explored, and the roles of the familiar magnetocrystalline anisotropy and the coupled spin–charge fluctuations are compared, and some examples for adatoms on simple non–magnetic surfaces are given.

Work supported by the HGF-YIG Programme FunSiLab – Functional Nanoscale Structure Probe and Simulation Laboratory (VH-NG-717).

[1] S. Lounis, A. T. Costa, R. B. Muniz and D. L. Mills, Phys. Rev. Lett. **105**, 187205 (2010)
[2] S. Lounis, A. T. Costa, R. B. Muniz and D. L. Mills, Phys. Rev. B **83**, 035109 (2011)

MA 52.53 Fri 11:00 Poster A

Imaging of magnetization reversal by spin transfer torque — •Matthias Buhl[1], Artur Erbe[1], Sebastian Wintz[1], Jörg Raabe[2], Jochen Grebing[1], Kay Potzger[1], and Jürgen Fassbender[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Swiss Light Source, Paul-Scherrer Institut

The magnetic moment of nanosized magnets is widely used for data storage in modern electronics. Integration of such magnets into larger circuits can be possible, if the read-out and the storage of data can be performed electrically. This can, for example, be achieved by using spin transfer torque for the definition of magnetic moment of a nanomagnet. Here, we demonstrate switching of a single magnetic pillar in a so-called current in plane geometry. The pillar structures are fabricated from CoFe layers using electron beam lithography on SiN membranes. The magnetization direction of the pillar is imaged using scanning transmission x-ray microscopy (STXM).

MA 52.54 Fri 11:00 Poster A

Magnon dispersion relation in adiabatic spin approximation — •Christian Franz and Christian Heiliger — I. Physikalisches Institut, Justus-Liebig-Universität, Gießen, Deutschland

The adiabatic approximation is used to separate the fast electronic degrees of freedom from the slow magnetic ones. A single magnetic moment is assigned to each atom in an itinerant ferromagnet. The interaction of these moments can be described by an effective Heisenberg model.

$$H = -\sum_{i,j} J_{i,j}\vec{S}_i \cdot \vec{S}_j - \frac{g\mu_b B_0}{\hbar}\sum_{i,j} S_i^z \qquad (1)$$

The exchange parameters of this model are obtained from *ab initio* calculations by applying the magnetic force theorem. The magnon dispersion and various physical parameters as the spin-wave stiffness and the Curie temperature can be determined within this model. We perform this calculations several systems and find result in good agreement with experimental and other theoretical results. This is the first step in including magnons and the electron-magnon interaction in transport calculations.

MA 52.55 Fri 11:00 Poster A

Influence of pure diffusive spin currents on magnetic switching in non-local spin valves — •Björn Burkhardt[1], Helmut Körner[2,3], Piotr Laczkowski[4], Laurent Vila[4], and Mathias Kläui[1,2,3] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, 50099 Mainz, Germany — [2]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [3]SwissFEL, Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [4]Laboratoire Nanostructure et Magnetisme, CEA/INAC, 38054 Grenoble, France

We analyzed magnetic switching processes in Permalloy stripes during injection of pure diffusive spin currents. These spin currents are created via a non-local spin valve design with aluminium as the non-magnetic spin conduit between the stripes. By measuring the non-local spin signals as a function of temperature we find a non-montonous behavior. To determine the spin diffusion length in the aluminium conduit the distance between injection and detection stripe was varied. The depinning of domain walls assisted by pulsed pure spin currents is further studied and the spin-torque and the Joule heating effect are separated, by using the underlying symmetries of the effect.

MA 52.56 Fri 11:00 Poster A

Domain Wall Manipulation with a Magnetic Tip — •Thim Stapelfeldt, Robert Wieser, Elena Y. Vedmedenko, and Roland Wiesendanger — Institute of Applied Physics and Microstructure Advanced Research Center

A theoretical concept of local manipulation of magnetic domain walls is introduced. In the proposed procedure, a domain wall is driven by a spin-polarized current induced by a magnetic tip, as used in a scanning tunneling microscope, placed above a magnetic nanostripe and then moved along its long axis with a current flowing through the vacuum barrier. The angular momentum from the spin-polarized current exerts a torque on the magnetic moments underneath the tip and leads to a displacement of the domain wall. Particularly, the manipulation of a ferromagnetic 180° transverse domain wall has been studied by means of Monte Carlo simulations. The coercivity created by defects as well as tailord pinning centers is presented as a function of the change of the exchange constant and the pinning center size, respectively.

MA 52.57 Fri 11:00 Poster A

Spin caloric transport: Investigation of out-of-plane thermal gradient effects in thin film geometries — •Andreas Kehlberger, Enrique Vilanova Vidal, Gerhard Jakob, and Mathias Kläui — Johannes Gutenberg University of Mainz, Institute of Physics, Mainz

Spin caloric transport is expected to open new avenues towards low energy nanoscale spin sources. The measurement of the spin-Seebeck effect has drawn much attention to the research of thermally induced spin currents in thin film structures. In order to explain the observed amplification of signal due to the temperature of the environment, phonon enhancement of the spin caloric effect has been suggested. This magnon-phonon interaction calls for an understanding of the underlying effects of the thermal behavior of the used substrates in thin film experiments. Many thin film studies assume in-plane thermal gradients along the substrate neglecting perpendicular thermal gradients. We present studies of different measurement geometries revealing the importance of out-plane gradients, which can often not be avoided. These unexpected temperature differences lead to asymmetric thermally induced effects such as the anomalous Nernst effect, which have to be taken into account. Measurements of these effects are compared to measurements in a new optimized setup, which focuses on the minimization of the out-of-plane gradient to reveal the spin-Seebeck contribution to the signal. This work is supported by the DFG priority program SPP 1538 Spin Caloric Transport.

MA 52.58 Fri 11:00 Poster A

Experimental Study of the Anisotropic Magneto-Thermopower in (113) oriented (Ga,Mn)As Thin Films — •Sibylle Meyer[1], Matthias Althammer[1], Lukas Dreher[2], Wladimir Schoch[3], Sebastian T. B. Goennenwein[1], and Rudolf Gross[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Walter Schottky Institut, Technische Universität München, Garching, Germany — [3]Institut für Quantenmaterie, Universität Ulm, Ulm, Germany

In analogy to the anisotropic magnetoresistance (AMR), the thermopower of ferromagnetic materials also characteristically depends on the orientation of the magnetization vector. This anisotropic magnetothermopower (AMTP) has only scarcely been studied to date. Taking the ferromagnetic semiconductor (Ga,Mn)As with its large magneto-resistive effects as a prototype example, we have measured the evolution of both the AMR and the AMTP effects at liquid He temperatures as a function of both the orientation and the magnitude of an externally applied magnetic field. Our data show that the AMTP effect can be adequately modeled only if the symmetry of the (Ga,Mn)As crystal is explicitly taken into account. We will quantitatively compare AMR and AMTP data taken on the same (113) - oriented (Ga,Mn)As thin film with corresponding model calculations, and address the differences between the magneto-resistance and the magneto-thermopower coefficients. Financial support by DFG via SPP 1538 is gratefully acknowledged.

MA 52.59 Fri 11:00 Poster A

Experimental determination of the spin mixing conductance in YIG/Pt bilayers — •Philipp Ross[1], Johannes Lotze[1], Franz D. Czeschka[1], Matthias W. Althammer[1], Mathias Weiler[1], Thomas Brenninger[1], Rudolf Gross[1,2], and Sebastian T. B. Goennenwein[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany

A spin current is a directed flow of angular momentum. Since spin currents are independent of charge motion, they can also propagate in electrical insulators. One elegant way to generate a spin current is the process of spin pumping: the magnetization of a ferromagnet is driven into resonant precession, and relaxes by emitting a spin current into an adjacent normal metal. The efficiency of the spin pumping process is dependent on the spin-mixing conductance which is in the order of 1×10^{19} m^{-2} in a variety of conducting ferromagnets [1]. We have grown insulating yttrium iron garnet (YIG) thin films on gadolinium gallium garnet substrates by pulsed laser deposition, and covered them in situ with a Pt layer. On these samples, we simulaneously recorded ferromagnetic resonance and the DC voltage generated by the inverse spin Hall effect, at different fixed temperatures between room temperature and 3 K. We find the spin-mixing conductance to be in the range from 1.2×10^{18} m^{-2} to 8×10^{19} m^{-2}, which is consistent with values measured on conductive ferromagnet/Pt interfaces. Financial support by DFG SPP 1538 is gratefully acknowledged.

[1] F. D. Czeschka *et al.*, Phys. Rev. Lett. **107**, 046601 (2011)

MA 52.60 Fri 11:00 Poster A

Local charge and spin currents in magnetothermal landscapes — •Michael Schreier, Mathias Weiler, Hans Huebl, Matthias Althammer, Martin S. Wagner, Rudolf Gross, and Sebastian T. B. Goennenwein — Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany

The interplay of spin currents and phonons is currently vigorously investigated, e.g., in spin Seebeck effect measurements. In such spin caloritronic experiments, homogenous temperature gradients were used to date for spin current generation. However, for a detailed understanding of the magnon-phonon interaction, a spatially resolved study of spin currents in magnetothermal landscapes appears mandatory.

We use a focused, scannable laser beam to generate a local thermal gradient along the surface normal of a thin insulating $Y_3Fe_5O_{12}$ (YIG) film grown on $Gd_3Ga_5O_{12}$. This thermal gradient gives rise to a local spin current that we electrically detect by means of the inverse spin Hall effect in a Pt thin film deposited on top of the YIG. In our room temperature experiments, we demonstrate all-electrical detection [1] and thermal manipulation of the YIG magnetic texture. We furthermore discuss the interplay of local temperature gradients, charge currents and magnetic domains also in conductive ferromagnetic thin films. Taken together, our findings open the path for local magnetothermal generation and control of spin and charge currents in ferromagnetic thin films.

This work is supported by DFG via SPP1538.

[1] M. Weiler *et al.* (2011) arXiv:1110.3981v1

MA 52.61 Fri 11:00 Poster A

Realization of an experimental setup for temperature dependent measurements of the Spin Seebeck Effect — •Daniel Meier, Hanno Meyer zu Theenhausen, Jan-Michael Schmalhorst, and Günter Reiss — Thin Films and Physics of Nanostructures, Physics Department, Bielefeld University, Germany

Spin caloritronics is a growing field of research in the branch of spintronics, which combines spin, charge and heat currents. The discovery of the spin Seebeck effect (SSE) [1] gives a method for a thermal spin generator. The effect was first studied in Permalloy (Py) thin films on Sapphire substrates [1], which were partly covered by thin Pt stripes. When an in-plane temperature gradient is applied perpendicular to the Pt stripes a spin current into the Pt can be generated, which can be converted into an electromotive force via the inverse spin Hall effect. As a consequence one can measure a voltage between the ends of the Pt stripe in a range of a few μV. The voltage size and sign depends on the position of the Pt stripe on the Py film and on the size of the temperature gradient [1].

This work presents a setup for SSE measurements at variable temperatures. It was tested on various Py/Pt samples grown on MgO and Sapphire substrates utilizing conventional photo lithography or shadow mask techniques. A high resolution of about 50nV was achieved when measuring the planar Nernst effect in the different samples.

[1] K. Uchida et al., Nature Vol. 455, 2008, 778–781

MA 52.62 Fri 11:00 Poster A

Dependence of the magneto-Seebeck effect on the CoFe distribution in MgO tunnel junctions — •Jakob Walowski[1], Marvin Walter[1], Vladyslav Zbarsky[1], Anissa Zeghuzi[1], Christian Leutenantsmeyer[1], Mirco Marahrens[1], Markus Münzenberg[1], Markus Schäfers[2], Daniel Ebke[2], Günter Reiss[2], Andy Thomas[2], Patrick Peretzki[3], Michael Seibt[3], Michael Czerner[4], Michael Bachmann[4], and Christian Heiliger[4] — [1]I. Phys. Inst., Universität Göttingen — [2]Dept. of Physics, Bielefeld University — [3]IV. Phys. Inst., Universität Göttingen — [4]I. Phys. Inst., Universität Gießen

Thermally driven techniques gain more importance, as ever smaller element sizes in electronics reach exorbitantly high current densities, threatening with a breakdown of Moore's Law. Currently magnetic tunnel junctions attract a lot of attention, because they are interesting from the spinelectronic and the spincaloritronic point of view. Spin-transfer torque magnetic RAM, as well as thermal-spin-transfer torque elements are in the current discussion as future technologies.

The magneto-thermal effects in CoFeB|MgO|CoFeB tunnel junctions strongly depend on the distribution of the Co and Fe atoms within layers at the interface to the MgO barrier. Supported by theoretical calculations using the energy dependent transmission function, we present the temperature dependent Seebeck coefficients in parallel and antiparallel magnetization alignment, and the magneto-Seebeck ratio for tunnel junctions with different Co and Fe distributions.

We acknowledge the funding by the DFG through the SFB 602.

MA 52.63 Fri 11:00 Poster A

Barrier thickness dependence of the Magneto Seebeck effect in magnetic tunnel junctions: Ab initio studies — •Michael Czerner and Christian Heiliger — I. Physikalisches Institut, Justus Liebig Universität Giessen, D-35392, Germany

The magneto Seebeck effect is the dependence of the thermopower in a magnetic tunnel junction on the relative orientation of both magnetic layers [1]. First calculations show that there is a non-trivial barrier thickness dependence of this effect [1]. Therefore, we systematically investigate the thermopower for parallel and antiparallel alignment of the magnetic leads in MgO based tunnel junctions. We show that the actual dependence on the MgO thickness also depends on the magnetic material of the leads. Our theoretical investigations are ab initio calculations based on density functional theory. In particular, we used the Korringa-Kohn-Rostoker and the non-equilibrium Green's function method to obtain the transmission function T(E). Using T(E), we calculated in linear response the transport coefficients, e.g. conductance, Seebeck coefficient, thermal conductance (electronic contribution) [2]. Additionally we study the thermopower as a function of the tilting angle between the magnetization of the two ferromagnetic leads.

[1] M. Walter, J. Walowski, V. Zbarsky, M. Münzenberg, M. Schäfers, D. Ebke, G. Reiss, A. Thomas, P. Peretzki, M. Seibt, J. S. Moodera, M. Czerner, M. Bachmann, C. Heiliger, Nature Materials

10, 742 (2011)
[2] M. Czerner, M. Bachmann, C. Heiliger, Phys. Rev. B 83, 132405 (2011)

MA 52.64 Fri 11:00 Poster A

Scanning laser setup for local heat gradients in ferromagnetic micro- and nanostructures — •Florian Brandl, Haiming Yu, Thomas Rapp, and Dirk Grundler — Lehrstuhl für Physik funktionaler Schichtsysteme, Technische Universität München, Physik Department, James-Franck-Straße 1, 85748 Garching b. München, Germany

We report on the development of a scanning laser setup that allows us to generate temperature gradients locally in ferromagnetic devices. With our system we position a focused laser beam on a sample with a translation stage offering nm resolution. A pair of crossed coils provides magnetic fields in the plane of the sample of up to 100 mT. The local heating will be tested using magnetoresistance measurements on ferromagnetic micro- and nanostructures. We also plan to combine the setup with ferromagnetic resonance measurements. We acknowledge financial support through the German priority program SPP 1538 "spin caloric transport" and the German excellence cluster "Nanosystems Initiative Munich".

MA 52.65 Fri 11:00 Poster A

Thermomagnetic properties improved by self-organized flower-like phase separation of ferromagnetic $Co_2Dy_{0.5}Mn_{0.5}Sn$. — •Michael Schwall[1], Peter Klaer[2], Hans-Joachim Elmers[2], and Benjamin Balke[1] — [1]Institute of Inorganic Chemistry and Analytical Chemistry, Johannes Gutenberg - University, Mainz — [2]Institute of Physics, Johannes Gutenberg - University, Mainz

A thermodynamically stable phase separation of $Co_2Dy_{0.5}Mn_{0.5}Sn$ into the Heusler compound Co_2MnSn and $Co_8Dy_3Sn_4$ is induced by rapid cooling from the liquid phase. The phase separation forms an ordered flower-like structure on the microscale. The increased scattering of phonons at the phase boundaries reduces thermal conductivity and thus improves thermoelectric and spincaloric properties.

MA 52.66 Fri 11:00 Poster A

Extrinsic Spin Nernst effect from first principles — •Katarina Tauber[1,2], Martin Gradhand[3], Dmitry Fedorov[1,2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [2]Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [3]H.H. Wills Physics Laboratory, University of Bristol, United Kingdom

Recently, a new field *"Spin Caloritronics"* [1] arose, which relates the spin degree of freedom to a temperature gradient. Within an *ab initio* approach we present a study of the *spin Nernst effect*, which describes the creation of a transversal spin current or spin accumulation due to a longitudinal temperature gradient ∇T. This effect is similar to the intensively studied spin Hall effect, where instead of ∇T an electric field is applied. Here we investigate the extrinsic skew scattering mechanism, which is dominant in the limit of dilute concentrations of substitutional alloys. Our calculations are based on a fully relativistic Korringa-Kohn-Rostoker method and a solution of the linearized Boltzmann equation. As a first application, we consider a Cu host with different impurities.

[1] G.E. Bauer, A.H. MacDonald, and S. Maekawa, Solid State Commun. 150, 459 (2010).

MA 52.67 Fri 11:00 Poster A

Observation of Spin Seebeck Effect in Magnetic Semiconductor — •Ivan Soldatov, Christian Hess, Ludwig Schultz, and Rudolf Schaefer — IFW Dresden, Helmholtzstraße 20, 01069 Dresden

If a temperature gradient is applied along or perpendicular to a ferromagnetic /nonmagnetic metal interface, one can observe a pure spin current injected into the normal metal in direction perpendicular to the interface. This effect, called Spin Seebeck Effect (SSE), occupies a central role in the field of spin caloritronics, which explores the possibility of controlling spin currents by means of heat currents. In this work we investigate the SSE in a semiconducting ferromagnetic layer in Pt/GaMnAs/GaAs structures in conventional setup, purposed in pioneering work by Uchida (K. Uchida et al. Nature 455, 778 (2008)). The results include the absolute temperature dependence of the SSE dependence on the applied temperature gradient and the direction of applied magnetic field. The work is supported by the DFG-priority program Spin Caloric Transport