Magnetism Division
Fachverband Magnetismus (MA)

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Overview of Invited Talks and Sessions

(Lecture rooms: H 1012, H 0112, H 1012, EB 202, EB 301; Posters: A)

Thyssen-Krupp Electrical Steel Dissertationspreis

Monday 09:30–11:30 EB 202
Four candidates will compete for the prize. Please attend!

Tutorial: Density Functional Theory: A computational path to interesting spin-textures and novel skyrmions

MA 1.1	Sun	16:05–16:50	H 1012	**Introduction to Spin-Density-Functional Theory** — •Nicole Helbig
MA 1.2	Sun	16:50–17:35	H 1012	**Determining chiral magnetism from density functional theory** — •Stefan Blügel
MA 1.3	Sun	17:45–18:30	H 1012	**Magneto-transport properties in spiralling spin textures** — •Yuriy Mokrousov

PhD-Student Symposium "Quantum Phase Transitions: Emergent Phenomena beyond elementary excitations": Invited Talks (jointly with jDPG)

MA 18.1	Tue	9:30–10:15	EB 301	**Experimental Studies of Quantum Phase Transitions** — •Andrew Mackenzie
MA 18.2	Tue	10:15–10:45	EB 301	**Metallic Quantum Ferromagnets** — •Manuel Brando
MA 18.4	Tue	11:30–12:15	EB 301	**Theoretical Concepts of Quantum Phase Transitions** — •Matthias Vojta
MA 18.5	Tue	12:15–12:45	EB 301	**Quantum criticality and beyond** — •Andrew Schofield
MA 18.7	Tue	14:00–14:30	EB 301	**Quantum Criticality in Quantum Magnets** — •Christian Rüegg
MA 18.9	Tue	14:45–15:15	EB 301	**Beyond quantum phase transitions** — •Wilhelm Zwerger

Invited Talks

MA 4.1	Mon	9:30–10:00	H 1012	**Fabrication of individual nano-magnets and nano-magnet arrays by Focused Electron Beam Induced Deposition (FEBID)** — •Andreas Berger
MA 9.1	Mon	15:00–15:30	H 0112	**Ultra-fast three terminal perpendicular Spin-Orbit MRAM** — •Gilles Gaudin
MA 28.1	Wed	11:30–12:00	H 0110	**The Future of Magnetoreception Research in Animals** — •Erich Pascal Malkemper
MA 53.1	Fri	9:30–10:00	EB 202	**Antiferromagnetic spintronics** — •Tomas Jungwirth

Focus Session "Progress in Spin-Polarized Electron Spectroscopies"

MA 11.1	Mon	15:00–15:45	EB 301	**Acoustic und standing spin wave modes in ultra-thin 3d metal films** — •Harald Ibach
MA 11.2	Mon	15:45–16:15	EB 301	**Magnetic structure and magnetic anisotropy on the atomic scale** — •Chunlei Gao
MA 11.3	Mon	16:30–17:00	EB 301	**Spin-resolved photoelectron spectroscopy with high efficiency and potential of full momentum analysis** — •Shigemasa Suga
MA 11.4	Mon	17:00–17:30	EB 301	**High-efficiency spin-resolved ARPES with a TOF-based exchange polarimeter** — •Chris Jozwiak
MA 11.5	Mon	17:30–18:00	EB 301	**Prospects of Multichannel Spin Detection** — •Gerd Schönhense

Focus Session "Towards quantitative magnetic measurements at ultimate spatial resolution with electrons"

MA 26.1	Wed	9:30–10:00	EB 202	**Magnetic measurements at high resolution in an electron microscope: a review.** — •Josef Zweck
MA 26.2	Wed	10:00–10:30	EB 202	**Observation and Manipulation of Magnetic Skyrmions** — •Shinichiro Seki
MA 26.3	Wed	10:45–11:15	EB 202	**Visualization Of Three Dimensional Magnetization Of Magnetic Nanostructures** — •Charudatta Phatak
MA 26.4	Wed	11:15–11:45	EB 202	**Utilizing chirality to explore local magnetic moments** — •Peter Schattschneider
MA 26.5	Wed	11:45–12:15	EB 202	**Linking magnetic properties to nanoscale spectral and spatial features** — •Thomas Thersleff

Focus Session "Ultra-fast magnetism under electronic nonequilibrium conditions"

MA 31.1	Wed	15:00–15:30	H 1012	**Ultrafast optical tuning of ferromagnetism in EuO via the carrier density** — •Manfred Fiebig
MA 31.2	Wed	15:30–16:00	H 1012	**Intra-atomic exchange in ultrafast magnetism** — •Martin Weinelt
MA 31.3	Wed	16:15–16:45	H 1012	**Laser induced ultrafast demagnetization in solids: a time-dependent density functional theory perspective** — •Sangeeta Sharma
MA 31.4	Wed	16:45–17:15	H 1012	**Ultrafast control of the exchange interaction with electric fields** — •Johan H. Mentink
MA 31.5	Wed	17:15–17:45	H 1012	**Controlling, probing and harnessing the strongest force in magnetism** — •Alexey Kimel

Focus Session "All-optical magnetic switching"

MA 41.1	Thu	9:30–10:15	H 1012	**Optically-induced magnetisation switching: Experiments and models** — •Hans Christian Schneider
MA 41.2	Thu	10:15–10:45	H 1012	**All optical control of magnetic thin films and nanostructures** — •Eric Fullerton
MA 41.3	Thu	11:00–11:30	H 1012	**All-optical switching: a challenge for its theoretical description** — •Ulrich Nowak
MA 41.4	Thu	11:30–12:00	H 1012	**All-optical helicity-dependent magnetic switching in Tb-Fe** — •Rudolf Bratschitsch
MA 41.5	Thu	12:00–12:30	H 1012	**Ultrafast magnetization dynamics of thin films showing helicity dependent magnetization switching** — •Grégory Malinowski

Invited talks of the joint symposium SYDW

See SYDW for the full program of the symposium.

SYDW 1.1	Mon	9:30–10:00	H 0105	**Domain walls: from conductive paths to technology roadmaps** — •Gustau Catalan
SYDW 1.2	Mon	10:00–10:30	H 0105	**Domain walls and oxygen vacancies - towards reversible control of domain wall conductance** — •Patrycja Paruch
SYDW 1.3	Mon	10:30–11:00	H 0105	**Novel mechanisms of domain-wall formation** — •Andres Cano
SYDW 1.4	Mon	11:30–12:00	H 0105	**Novel materials at domain walls** — •Beatriz Noheda
SYDW 1.5	Mon	12:00–12:30	H 0105	**Controlling and mapping domain wall behaviour in ferroelectrics** — •John Martin Gregg, Jonathan Whyte, Raymond McQuaid, Michael Campbell, Amit Kumar, Roger Whatmore

Invited talks of the joint symposium SYNP

See SYNP for the full program of the symposium.

SYNP 1.1	Tue	9:30–10:00	H 0105	**Connectomics: The dense reconstruction of neuronal circuits** — •Moritz Helmstädter
SYNP 1.2	Tue	10:00–10:30	H 0105	**Whole-brain imaging and analysis of network activity in behaving zebrafish** — •Misha Ahrens
SYNP 1.3	Tue	10:30–11:00	H 0105	**Circuit neurophysics: Theory and biophysics of information-flow through large-scale neuronal systems** — •Fred Wolf
SYNP 1.4	Tue	11:15–11:45	H 0105	**Cognitive devices based on ion currents in oxide thin films** — •Stuart Parkin
SYNP 1.5	Tue	11:45–12:15	H 0105	**Distributed neuro-physical interfaces: technology and "exciting" biophysics** — •Shy Shoham

Invited talks of the joint symposium SYHM

See SYHM for the full program of the symposium.

SYHM 1.1	Wed	15:00–15:30	H 0105	**Amplitude or Higgs Modes in Condensed Matter** — •Chandra Varma
SYHM 1.2	Wed	15:30–16:00	H 0105	**Higgs Particles for Systems with U(1) Symmetry in Two Dimensions** — •Lode Pollet
SYHM 1.3	Wed	16:00–16:30	H 0105	**Massive Photons and the Anderson-Higgs Mechanism in Superconductors** — •Dirk van der Marel
SYHM 1.4	Wed	16:45–17:15	H 0105	**Amplitude Higgs Mode in 2H-$NbSe_2$ Superconductor** — •Marie-Aude Méasson, Romain Grasset, Yann Gallais, Max Cazayous, Alain Sacuto, Pierre Rodière, Laurent Cario
SYHM 1.5	Wed	17:15–17:45	H 0105	**The Higgs Mode in Disordered Superconductors Close to a Quantum Phase Transition** — •Aviad Frydman, Daniel Sherman, Uwe S. Pracht, Boris Gorshunov, Martin Dressel

Invited talks of the joint symposium SYMM

See SYMM for the full program of the symposium.

SYMM 1.1	Thu	9:30–10:15	H 0105	**From MAX to MXene - From 3D to 2D** — •Michel Barsoum
SYMM 1.2	Thu	10:15–10:45	H 0105	**Structure evolution during low temperature growth of nanolaminate thin films** — •J.M. Schneider, L. Shang, H. Bolvardi, Y. Jiang, A. Al Gaban, D. Music, M. to Baben
SYMM 1.3	Thu	11:00–11:30	H 0105	**Autonomous healing of crack damage in MAX phase ceramics** — •Willem G. Sloof
SYMM 1.4	Thu	11:30–12:00	H 0105	**Magnetic MAX phases from first principles and thin film synthesis** — •Johanna Rosen
SYMM 1.5	Thu	12:00–12:30	H 0105	**Weak Field Magneto-Transport Properties of Mn+1AXn Phases** — •Thierry Ouisse, Lu Shi, Benoit Hackens, Benjamin Piot, Didier Chaussende

Sessions

MA 1.1–1.3	Sun	16:00–18:30	H 1012	**Tutorial: Density Functional Theory: A computational path to interesting spin-textures and novel skyrmions**
MA 2.1–2.3	Sun	16:00–18:30	H 0107	**Tutorial on Ferroics (DF with MA/TT)**
MA 3.1–3.12	Mon	9:30–12:45	H 0112	**Magnetic Heuslers, Half-metals and Oxides (jointly with TT)**
MA 4.1–4.9	Mon	9:30–12:00	H 1012	**Micro- and Nanostructured Materials**
MA 5	Mon	9:30–11:30	EB 202	**Thyssen-Krupp Electrical Steel Dissertationspreis**
MA 6.1–6.12	Mon	9:30–12:45	EB 301	**Surface Magnetism (Joint Session with O,TT) - Skyrmions**
MA 7.1–7.7	Mon	11:30–13:15	EB 202	**Magnetic Semiconductors**
MA 8.1–8.8	Mon	15:00–18:30	EB 107	**Focused Session on Ferroic Domain Walls I (DF with MA)**
MA 9.1–9.12	Mon	15:00–18:45	H 0112	**Spin Excitations/Spin Torque**
MA 10.1–10.14	Mon	15:00–18:45	H 1012	**Magnetic Heuslers, Half-metals, Semiconductors and Oxides**
MA 11.1–11.5	Mon	15:00–18:00	EB 301	**Focus: Progress in Spin-Polarized Electron Spectroscopies**
MA 12.1–12.30	Mon	19:00–21:00	Poster C	**Poster Session on Ferroic Domain Walls - Multiferroics (DF with KR/MA/TT)**
MA 13.1–13.8	Tue	9:30–13:00	EB 107	**Focused Session on Ferroic Domain Walls II (DF with MA)**
MA 14.1–14.11	Tue	9:30–12:30	H 0112	**Electronic Structure of Magnetism, Computational Magnetism**
MA 15.1–15.11	Tue	9:30–12:15	H 1012	**Magnetic measurement methods**
MA 16.1–16.11	Tue	9:30–12:30	EB 202	**Bio- and Molecular magnetism**
MA 17.1–17.8	Tue	9:30–11:30	ER 270	**Spintronics: Excitons and local spins (HL with MA/TT)**
MA 18.1–18.16	Tue	9:30–16:30	EB 301	**PhD symposium of the Division of Magnetism and the jDPG 2015: Quantum Phase Transitions: Emergent phenomena beyond elementary excitations**
MA 19.1–19.70	Tue	9:30–13:00	Poster A	**POSTER Ia**
MA 20.1–20.47	Tue	9:30–13:00	Poster A	**POSTER Ib**
MA 21.1–21.6	Tue	14:00–16:00	EB 107	**Focused Session on Ferroic Domain Walls III (DF with MA)**
MA 22.1–22.13	Wed	9:30–13:00	EB 107	**Multiferroics I (DF with DS/KR/MA/TT)**
MA 23.1–23.8	Wed	9:30–11:30	H 0110	**Spincaloric Transport I (jointly with TT)**
MA 24.1–24.11	Wed	9:30–12:30	H 0112	**Magnetic Materials I**
MA 25.1–25.9	Wed	9:30–11:45	H 1012	**Magnetic Imaging**
MA 26.1–26.6	Wed	9:30–12:30	EB 202	**Focus: Towards quantitative magnetic measurements at ultimate spatial resolution with electrons**
MA 27.1–27.13	Wed	9:30–13:00	EB 301	**Magnetization / Demagnetization Dynamics I**
MA 28.1–28.2	Wed	11:30–12:15	H 0110	**Bio-Magnetism (Magnetoreception)**
MA 29.1–29.8	Wed	15:00–17:00	H 0110	**Spincaloric Transport II (jointly with TT)**
MA 30.1–30.8	Wed	15:00–17:00	H 0112	**Magnetic Materials II**
MA 31.1–31.5	Wed	15:00–17:45	H 1012	**Focus: Ultra-fast magnetism under electronic nonequilibrium conditions**
MA 32.1–32.10	Wed	15:00–17:45	EB 202	**Spin Structures and Magnetic Phase Transitions**
MA 33.1–33.13	Wed	15:00–18:50	EB 107	**Multiferroics II (DF with DS/KR/MA/TT)**
MA 34.1–34.8	Wed	9:30–11:30	ER 270	**Topological insulators: Theory (HL with DS/MA/O/TT)**
MA 35.1–35.14	Wed	15:00–18:45	EB 301	**Magnetization / Demagnetization Dynamics II**
MA 36.1–36.5	Wed	11:45–13:00	ER 270	**Topological insulators: Transport (HL with DS/MA/O/TT)**
MA 37.1–37.6	Wed	15:00–16:30	ER 270	**Topological insulators: Structure and electronic structure (HL with DS/MA/O/TT)**
MA 38.1–38.12	Thu	9:30–12:45	H 0110	**Magnetic Nanoparticles**
MA 39.1–39.8	Thu	9:30–11:30	H 0112	**Spin-dependent Transport Phenomena I**
MA 40.1–40.9	Thu	10:00–12:30	ER 164	**Spintronics: Mobile electrons and holes (HL with MA/TT)**
MA 41.1–41.5	Thu	9:30–12:30	H 1012	**Focus: All-optical magnetic switching**
MA 42.1–42.10	Thu	9:30–12:00	EB 202	**Topological Insulators I (jointly with DS, HL, O, TT)**
MA 43.1–43.9	Thu	9:30–12:00	EB 301	**Magnetization / Demagnetization Dynamics III**
MA 44.1–44.9	Thu	15:00–17:30	H 0110	**Surface Magnetism (Joint Session with O) - Adatoms on surfaces**
MA 45.1–45.11	Thu	15:00–18:00	H 0112	**Spin-dependent Transport Phenomena II**
MA 46.1–46.13	Thu	15:00–18:30	H 1012	**Magnetic Thin Films I**
MA 47.1–47.11	Thu	15:00–17:45	EB 202	**Topological Insulators II (jointly with DS, HL, O, TT)**
MA 48.1–48.9	Thu	15:00–17:15	EB 301	**Magnetization / Demagnetization Dynamics IV**
MA 49.1–49.35	Thu	15:00–18:00	Poster A	**POSTER II**
MA 50	Thu	18:00–19:00	H 0110	**Mitgliederversammlung des Fachverbandes Magnetismus**
MA 51.1–51.12	Fri	9:30–12:30	H 0112	**Magnetic Shape Memory Alloys (Joint Session with MM)**

MA 52.1–52.12	Fri	9:30–12:45	H 1012	**Magnetic Thin Films II**
MA 53.1–53.9	Fri	9:30–12:00	EB 202	**Spintronics (incl. Quantum Dynamics) (jointly with HL, TT)**
MA 54.1–54.7	Fri	9:30–11:15	EB 301	**Magnetic Coupling Phenomena**

General Meeting of the Magnetism Division (Fachverband Magnetismus)

Thursday 18:00–19:00 H 0110
All members of the Magnetism Section are invited to participate!

MA 1: Tutorial: Density Functional Theory: A computational path to interesting spin-textures and novel skyrmions

Organizer: St. Blügel (FZ Jülich)

Ferromagnetic materials are important constituents of many modern hi-tech devices. In the last years one became however aware that non-collinear spin-textures could revolutionize spintronics. The focus of attention is on the spin-orbit interaction in magnetic solids with lack of inversion symmetry, that give rise to magnetic structures of particular winding sense and can lead to the formation of topological magnetization solitons, so-called magnetic skyrmions. These are then new functional magnetic units with interesting dynamical and novel spin-dependent transport properties. Density functional theory is the most powerful theoretical approach providing microscopic inside into the various magnetic interactions and spin-dependent transport properties, which is an important requisite for the design of materials and the analysis of experiments. While density function theory is practised widely, in this field new concepts and tools are coming into play. These will be introduced with the motivation that experimentalists can follow what we really calculate, what we can do, which assumption are made and how theory papers in this field can be interpreted and theory students might get some insight into this modern methodology, widening their scope or applying them to their own problems. After a brief introduction, the first tutorial focusses on the conceptual foundation of the relativistic, spin-dependent density functional theory, the second on the formation of new magnetic ground states and the third on spin-dependent transport properties.

Time: Sunday 16:00–18:30 Location: H 1012

Introductory Remarks

Tutorial MA 1.1 Sun 16:05 H 1012

Introduction to Spin-Density-Functional Theory — •Nicole Helbig — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, D-52425 Jülich, Germany

Density functional theory is the most powerful framework for a microscopic analysis of electronic properties of real solids. Spin-density-functional theory (spin-DFT) extends the density functional theory framework to allow for the description of magnetic systems, possibly in the presence of an external magnetic field. In this tutorial we introduce this subject from an elementary point of view and discuss the theoretical background of spin-DFT in both its collinear and non-collinear versions. Approximations for the exchange-correlation energy, which are necessary for practical applications, are also introduced. We give examples for calculations of different magnetic structures within spin-DFT and discuss how the theoretical results compare to experiments.

Tutorial MA 1.2 Sun 16:50 H 1012

Determining chiral magnetism from density functional theory — •Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Spin-orbit interaction in magnetic solids with bulk or structure inversion-asymmetry leads to the Dzyaloshinskii-Moriya interaction [1]. This magnetic interaction is a source of chiral magnetism and can subsequently lead to magnetic skyrmions – topological magnetization solitons – that may open a completely new vista to spintronics. A crucial issue is to find magnetic materials and ultra-thin films that combine the right properties such that these skyrmions can be formed. Density functional theory is a theoretical framework that permits the calculation of magnetic properties of materials from first-principles and is as such a tool for the analysis of experiments, for providing understanding of the magnetic interaction and for the design of the proper materials. In this endeavor your help is requested, many more *ab initio* calculations and experiments are needed. In this tutorial I explain concepts used to find these complex magnetic phases. The tutorial is conceptualized such that experimentalists can follow what we really calculate and what we can do and which assumptions are made, and theory students might get some insight into our methodology [2]. Examples are discussed mostly from the field of thin films [3].

[1] M. Bode *et al.*, Nature **447**, 190 (2007).
[2] see for example `www.juDFT.de`
[3] S. Heinze *et al.*, Nature Physics **7**, 713 (2011).

10 min. break

Tutorial MA 1.3 Sun 17:45 H 1012

Magneto-transport properties in spiralling spin textures — •Yuriy Mokrousov — Institute for Advanced Simulation, Forschungszentrum Jülich, 52425 Jülich, Germany

Spin-dependent transport properties in chiral magnets are currently of great interest both experimentally and theoretically. In this respect the skyrmion lattices comprised of topologically non-trivial whirls of magnetization which are typically stabilized at small magnetic field in the vicinity of the magnetic transition temperature are particularly intensively studied in B20 compounds. The Hall signal measured in these systems contains two topology-driven contributions due to the topological Hall effect (THE) and the anomalous Hall effect (AHE). It can be shown that the THE and AHE are a consequence of the Berry phases which electrons pick up in real and reciprocal spaces, respectively, while the so-called mixed Berry phases due to coupled dynamics in real and reciprocal space would give rise to a magnetic interaction which favors the chirality of the magnetization and gives rise to the skyrmion lattice - the Dzyaloshinskii-Moriya interaction (DMI). In my talk I will show how first principles methods can be used to justify the validity of the Berry phase concepts, as well as estimate and understand the physics of transport properties and DMI in skyrmion phase of complex materials. Moreover, I will try to convey a point that advanced material-specific modelling is a unique tool, which can be used to explore the emergent field of magneto-transport in nanometer-scale non-collinear textures.

MA 2: Tutorial on Ferroics (DF with MA/TT)

This tutorial introduces the field of domain and domain-wall engineering, key concepts and materials, and launches our 3-days focus on ferroic domain walls. The tutorial will provide a forum for non-specialists to get informed / involved and, at the same time, aims at inspiring topical discussions to stimulate a vivid scientific exchange during the following Sypmosium (SYDW), the three Focus Sessions and a Poster Session.

Organizers: Elisabeth Soergel (Universität Bonn) and Dennis Meier (ETH Zürich)

Time: Sunday 16:00–18:30 Location: H 0107

Tutorial MA 2.1 Sun 16:00 H 0107
Fundamentals of ferroelectric materials — •Susan Trolier-McKinstry — Penn State University, University Park, PA, USA

This tutorial will cover the fundamental phenomena that underpin the field of ferroelectricity, with an emphasis on the relationship between crystal structure and the allowed domain states. An introduction will be made to ferroelectricity, pyroelectricity, piezoelectricity, and the origins of the dielectric response. The crystal structures of key materials, including perovskites, $LiNbO_3$, the tungsten bronzes, and polymer ferroelectrics will be introduced, along with the link between the loss of symmetry elements and the allowed domain states. The tutorial will conclude with an introduction to the movement of domain walls, and the influence that this has on the properties of ferroelectric materials.

Tutorial MA 2.2 Sun 16:50 H 0107
Domain walls in multiferroics as functional oxide interfaces — •Manfred Fiebig — Department of Materials, ETH Zürich, Vladimir-Prelog-Weg 4, 8093 Zurich, Switzerland

The functionality of any ferroic material depends on its domains. Consequently, their shape and manipulation in external fields are of major research interest. In compounds uniting magnetic and electric order in the same phase, the magnetoelectric coupling on the level of the domains is, however, largely unexplored. For such so-called multiferroics it is therefore not known how exactly electric or magnetic fields affect the multiferroic domains and their walls. In my talk I will discuss this issue and focus on the influence of the multiferroic order on the ferroelectric state and its domain walls. Examples I will include are: (i) multiferroics with geometric ferroelectricity such as hexagonal $YMnO_3$ where the domain walls exhibit anisotropic conductance and can therefore be regarded as "tunable oxide interfaces"; (ii) multiferroics with magnetically induced ferroelectricity such as $MnWO_4$ or $TbMnO_3$ where the electric polarization within the wall is expected to rotate instead of passing through zero, as in conventional displacive ferroelectrics; (iii) multiferroics with strain-induced ferroelectricity like $SrMnO_3$ where the interplay of strain and oxygen vacancies leads to polar state in which domain walls act as insulating boundaries to the conducting domains.

Tutorial MA 2.3 Sun 17:40 H 0107
Ferroelastic templates for multiferroic domain boundaries — •Ekhard Salje — University of Cambridge, Cambridge, UK

The field of Domain Boundary Engineering is introduced. Ferroelastic domain pattern are derived and their dynamical behaviour is deducted from experimental observations and computer simulations. It is then shown that twin boundaries are particularly easily modified to possess functional properties that do not exist in the bulk. Such functional properties include (super-) conductivity, ferroelectricity, and ferromagnetism. In addition, chemical mixing inside domain walls can generate novel chemical compounds. This effect is refereed to as 'Chemical Mixing in Confined Spaces'. Functionalities often generate chiralities and vortex structures in domain boundaries. It is shown that chirality (in order parameter space) leads to Bloch lines and vortex points as one- and zero-dimensional domain walls embedded in two-dimensional ferroelastic domain walls and are hence walls in walls. Examples in $CaTiO_3$ and $SrTiO_3$ are discussed.

[1] E.K.H. Salje, Ferroelastic Materials, Annual Review of Materials Research, 42, 265-283 (2012)
[2] E.K.H. Salje and K.A. Dahmen, Crackling Noise in Disordered Materials, Annual Review of Condensed Matter Physics, 5, 233-254 (2014)
[3] E.K.H. Salje, Multiferroic Domain Boundaries as Active Memory Devices: Trajectories Towards Domain Boundary Engineering, Chem. Phys. Chem., 11, 940-950 (2010)
[4] D.D. Viehland and E.K.H. Salje, Domain boundary-dominated systems: adaptive structures and functional twin boundaries, Advances in Physics, 63, 267-326 (2014)

MA 3: Magnetic Heuslers, Half-metals and Oxides (jointly with TT)

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

MA 3.1 Mon 9:30 H 0112
Half-metallic compensated ferrimagnetic behaviour of $Mn_{1.5}V_{0.5}$FeAl Heusler compound — •Rolf Stinshoff, Peter Adler, Gerhard Fecher, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Half-metals, i.e. materials exhibiting 100 % spin polarization, naturally attract much interest in spintronics [1]. Some of them have already shown their potential in applications such as magnetic tunneling junctions. Despite the very high TMR ratios achieved at low temperatures using half-metallic materials, further technological requirements, such as low stray fields, temperature stability etc., still have to be improved. In this context, some advantages are provided by the group of completely compensated ferrimagnets which still keep the half-metallicity. Several of them were predicted theoretically within the Heusler family. Here we will discuss the experimentally measured characteristics (structural, magnetic and transport properties) of the newly synthesized $Mn_{1.5}V_{0.5}$FeAl Heusler material, which is suggested to be a fully compensated half-metallic ferromagnet by the first principle calculations [2].

[1] R. A. de Groot, F. M. Müller, P. G. van Engen, K. H. J. Buschow, Phys. Rev. Lett. **50**, 2024-2027 (1983)
[2] S. Wurmehl, H. C. Kandpal, G. H. Fecher, C. Felser, J. Phys. Condens. Matter **18**, 6171-6181 (2006)

MA 3.2 Mon 9:45 H 0112
High-throughput screening for antiferromagnetic Heusler compounds using density functional theory — •Jan Balluff, Markus Meinert, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Due to the exchange bias effect, antiferromagnetic compounds are of particular interest for the field of spintronics. Since Heusler compounds are a very versatile family of alloys, we attempt to find promising antiferromagnetic compounds unknown by now. We report on a high-throughput screening among the Heusler compounds for stable antiferromagnetic systems. Starting from a detailed evaluation of raw magnetic data for Heusler compounds extracted from the AFLOWLib [1], we extend the data by explicitly checking for stable antiferromagnetic ground states. [1] S. Curtarolo et al., Comp. Mat. Sci. 58 , 218 (2012)

MA 3.3 Mon 10:00 H 0112
Spin-selective electron localization induced by disorder in Mn-Co-Al Heusler alloys — •Sunil Wilfred D'Souza, Siham Ouardi, Lukas Wollmann, Stanislav Chadov, and Claudia Felser — Max-Planck-Institut für Chemische Physik fester Stoffe

Understanding the role of disorder opens new alternatives in the state-of-the-art design of the multicomponent materials. First proposals to improve the electron transport characteristics by constructive chemical disorder were already suggested for the tetragonal non-halfmetallic ferrimagnetic Mn_3Ga-based Heusler alloys, where the possibility of the spin-selective electron localization was demonstrated by the first-principles. Here we consider the spin-selective electron localization within the cubic $Mn_{2-x}Co_{1+x}Al$ ($0 \leq x \leq 1$) Heusler series. In contrast to the strongly anisotropic tetragonal case, the isotropic cubic geometry allows for an easier experimental check of the proposed spin-selective electron localization. The residual transport properties, i.e. spin-projected resistivities were calculated within the Kubo-Greenwood linear response formalism, using Coherent Potential Approximation (CPA) description for the electron localization, within the framework of the fully-relativistic SPR-KKR Green's function method. Here we also give the comparison with the first experimental data.

MA 3.4 Mon 10:15 H 0112

Advantages of constructive disorder: design of the spin-selective electron localization in Mn_3Ga-derivatives — •Stanislav Chadov, Sunil Wilfred D'Souza, Lukas Wollmann, and Claudia Felser — Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden

Understanding the role of disorder opens new alternatives in the state-of-the-art design of the multicomponent materials. Theoretically we will try to design a situation in which the constructive disorder serves as a mechanism preventing the propagation of certain quasiparticles, namely the spin-down electrons – the so-called *spin-selective* electron localization. Here we make use of chemical disorder induced by the small stoichiometric variations. As a suitable example, we take a non-halfmetallic Mn_3Ga Heusler, and subsequently develop the appropriate constructive disorder scheme justifyed by the first-principles calculations based on the Coherent Potential Approximation (CPA) and Kubo-Greenwood linear response formalsim within the framework of the SPR-KKR Green's function method. As it follows from our results, almost any relatively small substitution of Mn by other $3d$ transition element (except of Cu) leads to a dramatic increase of the spin-polarization along the tetragonal crystalline axis.

MA 3.5 Mon 10:30 H 0112

Superconducting TiN seed layer for Heusler compounds — •Alessia Niesen[1], Manuel Glas[1], Daniel Ebke[2], Jan Schmalhorst[1], and Günter Reiss[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany

TiN thin films were prepared by DC and RF magnetron sputtering in an UHV sputtering system. Epitaxial growth was achieved on MgO (001) and $SrTiO_3$ (001) substrates at deposition temperatures above 450°C. The crystallographic and surface properties of TiN were determined by X-ray diffraction (XRD) and reflection (XRR) measurements. In addition, atomic force microskopy (AFM) was performed to verify the low roughness ($< 1\,nm$) measured by the XRR. The out-of-plane lattice constant and the resistivity of TiN reached the theoretical predicted values of 4.24 Å and nearly $20\,\mu\Omega cm$ (bulk value). 4-terminal transport measurements in a closed cycled helium cryostat showed a phase transition to the superconducting state at temperatures below 5 K for TiN deposited at 450°C on MgO and $SrTiO_3$ substrate. The suitability of TiN as seed layer for ferromagnetic materials like Iron and Heusler compounds, e. g. Co_2FeAl and $Mn_{3-x}Ga$, was investigated by analysing the crystallographic and magnetic properties. Epitaxial growth of both Heusler compounds (Co_2FeAl and $Mn_{3-x}Ga$) on a TiN seed layer has been proven for various deposition temperatures. Hall-measurements additionally showed a higher coercitivity and squareness ratio for Mn-Ga thin films when prepared on a TiN buffer.

MA 3.6 Mon 10:45 H 0112

Mn-based candidates for rare earth free permanent magnet — •Adel Kalache, Bayardulam Jamiyansuren, Siham Ouardi, Guido Kreiner, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Permanent magnets are used in a wide range of applications from hybrid cars and wind turbines to computer hard-disk drives. Rare earth (RE) magnets such as Nd-Fe-B and Sm-Co show unique hard magnetic performance but are subject to both price and supply issues. New RE free permanent magnets are also needed to fill the gap between the low cost hexagonal ferrites and the expensive RE magnets. Some Mn-based intermetallic compounds are promising candidates because of their high Curie temperature and their tetragonal structure of the $L1_0$ type or distorted Heusler $D0_{22}$ type. The resulting intrinsic uniaxial magnetic anisotropy leads to appreciable hard magnetic properties. The synthesis of Mn-based RE free magnets with melt spinning technique improves some extrinsic properties such as microstructure and grain size. These features allow an increase of the coercivity of material, leading to higher figure of merit BH_{max}. Structural characterization and magnetic properties of some tetragonal Mn-based compounds such as Mn-Ga and Mn-Ge will be presented. Neutron diffraction is reported for $Mn_{60}Ga_{40}$. Substitution of Mn with other transition metals will also be discussed in order to improve the magnetic hardness.

15 min. break

MA 3.7 Mon 11:15 H 0112

Calculation of electronic structure and field-induced magnetic collapse in ferroic materials — •Peter Entel — Faculty of Physics, University Duisburg-Essen, D-47048 Duisburg, Germany

We have performed ab initio electronic structure calculations and Monte Carlo simulations of Fe-Rh, Mn-Ga-C and Heusler intermetallics alloys such as Ni-Co-Cr-Mn-(Ga, In, Sn) which are of interest for magnetic shape-memory devices, solid-state refrigeration and energy systems, an emerging technology involving solid systems. The calculations reveal that the important magnetic phase diagrams of these alloys which show the magnetic collapse and allow predictions of the related magnetocaloric effect which they exhibit at finite temperatures, can be obtained by the ab initio computations alone. This is a one-step procedure from theory to alloy desigan of ferroic functional devices.

MA 3.8 Mon 11:30 H 0112

Ab initio study of tetragonal Heusler alloys for magnetic applications with high anisotropies — •Heike C. Herper, Yaroslav O. Kvashnin, and Olle Eriksson — Department of Physics and Astronomy, Uppsala University, Sweden

Materials with high magnetic anisotropy (MAE) are of broad technological interest whereby typical magnets with high MAE are based on expensive materials such as Pt or Nd. Therefore, cheap and abundant replacements are demanded. Heusler alloys are of special interest because their magnetic and structural properties can be quite easily designed by composition. Here we present an ab initio study for a series of tetragonal Ni-based Heusler alloys Ni_2YZ with (Y = Mn, Fe, Co) and Z varying from B to Sn. Combined VASP and RSPt investigations reveal MAE values for $L2_1$ ordered Co containing alloys which are comparable to the Mn-Ga based alloys found in literature. However, for e/a values larger than 32 they tend to inverse order which is accompanied by a significant reduction of the MAE. Even though the MAE values for alloys with Y = Fe are found to be smaller compared to the Ni_2CoZ alloys, the maximum energy products are similar. In contrast to the $L2_1$ ordered Ni_2CoZ systems out of plane MAE has been observed for several Ni_2FeZ alloys.

MA 3.9 Mon 11:45 H 0112

Magnetism in tetragonal Heusler compounds — •Lukas Wollmann[1], Stanislav Chadov[1], Jürgen Kübler[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany. — [2]Institut für Festkörperphysik, Technische Universität Darmstadt, Darmstadt, Germany

Compounds with uniaxial anisotropy are of general interest in the field of magnetism, and in particular within the emerging field of spintronics. Uniaxial anisotropy is an inherent property of many tetragonal Heusler compounds. Here we report on a comprehensive study on tetragonal Manganese-based Heusler compounds, by starting from a set of cubic parent systems and continuing with the mechanisms of their tetragonal distortion, in particular focusing on the magnetic properties, and explaining the microscopic origin of the observed properties, as for example, for the magnetocrystalline anisotropy. Rather high anisotropy values were obtained for those systems containing heavy transition metals, which suggests them as candidate materials for spin transfer torque magnetization switching applications.

MA 3.10 Mon 12:00 H 0112

Phase separation in NiSn- and CoSb-based Half-Hesleur alloys — Joaquin Miranda Mena, •Heiko G. Schoberth, Thomas

Gruhn, and Heike Emmerich — Material- und Prozesssimulation, Bayreuth University. Universitätsstraße 30 D-95448 Bayreuth, Germany

We combine DFT calculations, Monte Carlo simulations and mean field models to study the thermodynamic conditions for phase separation in two families of quaternary-Half-Heusler alloys. In the first family, γNiSn (γ =TiHf, TiZr), we found that phase separation is achieved in the range 500-700 K, but no phase separation is present when alloying with γ=ZrHf. For CoTi(1-x)ZxSb (Z=Sc, Cr, Mn, Fe, Cu) we found transition temperatures in the range 800-3000 K. The transition temperature is favored at nearly one third of concentration (x). However, at large x some materials do not present phase separation, but rather a type of crystal order. We discuss these results in the view of thermoelectrics, where apparently induced phase separation enhances the figure of merit.

MA 3.11 Mon 12:15 H 0112

Highest Curie temperature in Co-Fe based Heusler compounds — •Julia Erika Fischer[1], Siham Ouardi[1], Gerhard Fecher[1], Guido Kreiner[1], Peter Adler[1], Claudia Felser[1], Simone Fabbrici[2], and Franca Albertini[2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Institute of Materials for Electronics and Magnetism CNR, Parma, Italy

Half-metallic ferromagnetic Co-based Heusler compounds are one of the most promising class of materials for high performance spintronic devices due to the recently experimentally demonstrated strong spin polarization and their reported high Curie temperatures [1, 2].
We have prepared a series of polycrystalline Co-Fe based Heusler alloys and studied the structural and magnetic properties. From thermomagnetic analysis measurements we found Curie temperatures of more than 1200 K, which are the highest values in Heusler alloys so far. Therefore, a higher thermal stability of magnetization is expected even for moderate device temperatures. In particular, the Co-Fe disorder was investigated by Mößbauer spectroscopy to study the influence on the magnetic properties.

[1] B. Balke et al., Sci. *Technol. Adv. Mater.* 9, 014102 (2008).
[2] M. Jourdan et al., *Nat. Commun.*, 5 (3974), 1 (2014).

MA 3.12 Mon 12:30 H 0112

Antiferromagnetic order in CuMnSb crystal and its stability — •Frantisek Maca, Vaclav Drchal, and Josef Kudrnovsky — Institute of Physics ASCR, Praha, Czech Republic

It is well known that the ground state of the CuMnSb is antiferromagnetic with alternating ferromagnetic layers in the <111> direction - the AFM(111) structure. The first ab initio calculations comparing nonmagnetic, ferromagnetic and AFM(111) structures [1] also have shown that the antiferromagnetic state has the lowest total energy. However, we found by using FLAPW and TB-LMTO calculations that the ideal AFM(001) structure has always lower total energy than the AF(111).

Experimental measurements show a high resistivity of CuMnSb samples which indicates the presence of disordered impurities. We compare formation energies for various defects in order to find the type of disorder which favors the AFM arrangement. Calculations indicate as the most probable candidate the Mn-Cu swapping. We show that presence of disorder and electron correlations are needed for realistic theoretical description. The total energy results are supported by discussion of magnetic exchange interactions.

[1] T. Jeong, Ruben Weht, and W. E. Pickett, Phys. Rev. B 71, 184103 (2005).

MA 4: Micro- and Nanostructured Materials

Time: Monday 9:30–12:00 Location: H 1012

Invited Talk MA 4.1 Mon 9:30 H 1012

Fabrication of individual nano-magnets and nano-magnet arrays by Focused Electron Beam Induced Deposition (FEBID) — •Andreas Berger — CIC nanoGUNE Consolider, Tolosa Hiribidea 76, Donostia - San Sebastian, Spain

During the past decade, FEBID has been established as a one-step technique for the fabrication of 1-, 2- and even 3-dimensional nanostructures. Specifically, there has been a growing interest in the development of FEBID processes for magnetic materials in the last few years, namely for Fe, Co and Ni, which may provide new routes for the fabrication of magnetic nano-devices as well as complex nano-magnet designs. Among these ferromagnetic metals, Co attracts the most attention because an exceptionally high purity can be obtained under the correct deposition conditions [1]. Here, we present a systematic investigation of the deposition parameters and the characterization of the structure and physical properties of our FEBID cobalt deposits, including the effect of unintended parasitic deposits as well as strategies for their removal [2]. The magnetic properties of our deposits were characterized by magneto-optical microscopy. Specifically, we investigated individual nano-scale wires down to diameter sizes of 30 nm [3], magnetic dot-arrays with periods as low as 13 nm, as well as the fabrication of non-trivial 3-dimensional magnetic nano-structures via FEBID.

References: [1] O. Idigoras et al., Nanofabrication 1, 23 (2014); [2] E. Nikulina et al., Appl. Phys. Lett. 103, 123112 (2013); [3] E. Nikulina et al., Appl. Phys. Lett. 100, 142401 (2012)

MA 4.2 Mon 10:00 H 1012

Magnetization reversal in fourfold ferromagnetic nanostructures of different dimensions — •Andrea Ehrmann[1], Tomasz Blachowicz[2], Sara Komraus[2], Marie-Kristin Nees[3], Peter-Jürgen Jakobs[3], Harald Leiste[3], Michael Mathes[4], and Marie Scharschmidt[4] — [1]Niederrhein University of Applied Sciences, Faculty of Textile and Clothing Technology, Germany — [2]Silesian University of Technology, Institute of Physics, Poland — [3]Karlsruhe Nano Micro Facility (KNMF), Karlsruhe Institute of Technology (KIT), Germany — [4]ACCESS e. V., Aachen, Germany

Ferromagnetic nanostructures with lateral dimensions between 160 nm and 400 nm have been created in a lithographic process. The fourfold particles produced from permalloy have rectangular-shaped walls around a square open area. Their magnetic properties have been measured angle-dependent using the Magneto-Optical Kerr Effect (MOKE). The oral presentation reports on the angle-dependence and the influence of the lithography radiation dose on magnetization reversal mechanisms. While the nanostructure size changes the angle-dependence of the coercivities quantitatively and qualitatively, the magnetic properties are quite stable against variations of the radiation dose, i.e. the wall width, enabling reliable creation of nanostructures with the desired properties [1].

[1] A. Ehrmann, T. Blachowicz, S. Komraus, M.-K. Nees, P.-J. Jakobs, H. Leiste, M. Mathes, M. Schaarschmidt: Directional-dependent MOKE measurements on fourfold ferromagnetic nanostructures of different dimensions, submitted

MA 4.3 Mon 10:15 H 1012

The role of vortex-antivortex pairs and cluster knots of domain walls in magnetization reversal — •Sukhvinder Singh, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P O. Box 151150, D66041, Saarbrücken, Germany

Magnetic force microscopy was employed to investigate the role of domain wall substructures in the magnetization reversal in patterned Permalloy thin films in an in-plane magnetic field. This study reveals that the magnetic reversal mechanism proceeds through periodic subdivisions of domain walls connected between cluster knots. The magnetic flux transfer across domain walls was observed to be assisted by nucleation and annihilation of vortex-antivortex pairs in the domain wall. The nucleation of vortex-antivortex pairs creates channels to transfer the magnetic flux across the domain wall. The change in the magnetic energy landscape along the long and short axes was linked to the different evolutions of the domain wall clusters at the edges of the samples. Furthermore, the experimental findings were interpreted and evaluated by comparing and analyzing the results obtained by micromagnetic simulations. By considering the magnetic energies over the whole sweep range of the applied field, it was observed that demagnetization and exchange energies dominate the Zeeman energy only near remnant state. This restricts the transformations of the domain wall substructures to the near zero field range.

MA 4.4 Mon 10:30 H 1012

Magnetic hardening of FeCo nanowires — Sara Liébana-Viñas[1], •Ruslan Salikhov[1], Cristina Bran[2], Marina Spasova[1], Ulf Wiedwald[1], Manuel Vazquez[2], and Michael Farle[1] — [1]University Duisburg-Essen, Duisburg and CENIDE, Germany — [2]Institute of Material Science of Madrid (CSIC), Madrid, Spain

We report on the magnetic hardening of FeCo nanowires (NW) by forming few nm thick oxides at both NW tips. FeCo NWs with 20 and 40 nm diameter were synthesized in porous alumina templates. We found that the formation of a 3 nm thick FeCo oxide layer at the NW tips results in an increase of the coercive field by 20% at T = 10 K. Our finding experimentally confirms that magnetic NWs even with large aspect ratios (up to 300) are demagnetized via nucleation of domain walls (DWs) at the NW tips. The magnetic hardening suggests the possibility to improve the performance of FeCo NWs for applications in magnetic field sensors, recording heads and rare-earth free permanent magnets. The importance of DW pinning at both ends of magnetic NWs will be discussed. We acknowledge funding of EU through FP7-REFREEPERMAG.

MA 4.5 Mon 10:45 H 1012

Surface crystallization and magnetic properties of FeCuSiBP soft magnetic ribbons — •Elena Lopatina[1,2], Ivan Soldatov[1,2], Christian Becker[1,2], Viktoria Budinsky[3], Mie Marsilius[3], Ludwig Schultz[1,2], Giselher Herzer[3], and Rudolf Schaefer[1,2] — [1]IFW Dresden, Dresden, Germany — [2]Institute for Materials Science, TU Dresden, Dresden, Germany — [3]VACUUMSCHMELZE GmbH & Co. KG, Hanau, Germany

Surface crystallization in soft magnetic alloys has been the subject of many studies that were mainly performed by Mossbauer spectroscopy, atomic force microscopy, transmission- and scanning electron microscopy. However, there are only few studies of surface crystallization by means of magneto-optical Kerr microscopy, which allows a direct visualization of the changes in magnetic microstructure that arise from surface crystallization. In this work we report on the influence of surface crystallization on the magnetic properties and magnetic microstructures of FeCuSiBP ribbons by Kerr imaging. The as cast ribbon has been annealed at temperatures in the interval of 370-550 °C, by pulling the ribbon through a furnace, thus applying some tensile stress along the ribbon axis that causes a creep-induced transverse anisotropy into the ribbon. Furthermore, since the vast majority of applications of soft magnetic materials operate under AC conditions, we show by time-resolved Kerr microscopy how the surface domain structure react to ac magnetic fields up to the kHz regime and how the dynamic surface hysteresis loops compare to the inductively measured bulk loops with rising frequency, both on original and etched ribbons.

MA 4.6 Mon 11:00 H 1012

Magnetic nanostructure patterns via hierarchical self-assembly: An in-situ study combining GISAXS and NRS — •Denise Erb, Kai Schlage, Hans-Christian Wille, and Ralf Röhlsberger — Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany

Nanopatterning via self-assembly has gained considerable interest as an alternative to lithography-based techniques for nanostructure fabrication. We propose a routine for preparing highly ordered metallic nanostructure arrays based exclusively on self-assembly processes: crystal surface reconstruction, copolymer microphase separation, metal diffusion on heterogeneous surfaces. The versatile routine allows fabricating nanostructures in a variety of shapes and sizes. We present results of in-situ structural and magnetic investigations of Fe nanodot arrays during formation by Grazing Incidence Small Angle X-ray Scattering (GISAXS)[1] and Nuclear Resonant Scattering of synchrotron radiation (NRS) [2], examining the dependence of nanodot morphology on deposition conditions and the evolution of magnetic moment dynamics during nanodot growth [3].

[1] G. Renaud, R. Lazzari, and F. Leroy, Surface Science Reports 64 (2009) 255

[2] R. Röhlsberger, Nuclear Condensed Matter Physics with Synchrotron Radiation, Springer Tracts in Modern Physics 208 (2004)

[3] D. Erb, Ph.D. thesis, University of Hamburg, submitted (2014)

MA 4.7 Mon 11:15 H 1012

Building Blocks of Artificial Square Spin Ice: Stray-Field Studies of Thermal Dynamics and Tuned Interactions. — •Merlin Pohlit, Fabrizio Porrati, Michael Huth, and Jens Müller — Physikalisches Institut Goethe-University, Frankfurt a. M., Germany

Over the last decade, spin ice systems with their intricate interplay between disorder, frustration and degeneracy giving rise to fundamentally new phenomena like the occurrence of monopole excitations, came to the fore of intensive research interest. Due to the ability to tune the geometric shape and the possibility to access spatially-resolved magnetic properties, artificial spin ice systems, i.e. nanostructured arrays of macroscopic spins, were succesfully employed as 2D model systems for their 3D equivalent. Here we present magnetic measurements performed on individual building blocks of artificial square spin ice. For this purpose a thermally-active cobalt-based spin ice structure was grown by focused electron beam induced deposition (FEBID) onto the surface of a lithographically defined μm-sized Hall-sensor based on a two-dimensional electron gas of an AlGaAs/GaAs heterostructure. This setup provides continuous access to the array's stray field during magnetization reversal. Using relatively simple temperature and magnetic field protocols, individual microstates were prepared and thermally-activated switching was observed. We demonstrate the feasibility of tuning the inter-macrospin interactions in artificial spin ice systems by additional deposition steps and electron irradiation at the lattice nodes.

MA 4.8 Mon 11:30 H 1012

Diffracted vectorial magneto-optical magnetometry of ferromagnetic dolmen-like structures — •Lisa Willig[1,2], Junjia Ding[3], Adekunle Adeyeye[3], Ivan Maksymov[2], Peter Metaxas[2], and Mikhail Koystylev[2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]School of Physics, University of Western Australia, Crawley, WA, Australia — [3]Electrical and Computer Engineering, National University of Singapore, Singapore, Singapore

Vector and Diffracted magneto-optical Kerr effect measurements were combined to study the magnetisation dynamics during magnetic reversal ferromagnetic dolmen-like structure. The unit cells of the two-dimensional Permalloy (NiFe) array consists of three elements in the submicrometer range (2μm × 0.8μm). This is the first investigation on a system with strongly dipole-dipole coupled unit cells, as the inter-element spacing is just 50nm. The periodicity of the structure leads to a diffraction pattern besides specular reflection. The hysteresis loops of the visible diffracted order beams as well as the specular reflected beam were obtained. In combination with micromagnetic simulations this enables a detailed analysis of the magnetisation reversal in each unit cell. The different diffraction orders correspond to a magnetic order with wavelengths smaller or equal to the length of the unit cell. Additionally measurements of more than one magnetisation component allow the reconstruction of the magnetisation vector during the reversal process.

MA 4.9 Mon 11:45 H 1012

Domain wall dynamics in asymmetric ferromagnetic rings — •Kornel Richter[1], Mohammad-A. Mawass[1], Andrea Krone[1], Benjamin Kruger[1], Markus Weigand[2], Hermann Stoll[2], Gisela Schutz[2], and Mathias Klaeui[1] — [1]Johannes Gutenberg Universität-Mainz, Institut of Physics, Staudinger Weg 7, 55128 Mainz, Germany — [2]Max-Planck-Institute for Intelligent Systems, Heisenbergstr. 3, Stuttgart 70569, Germany

Domain wall (DW) propagation in ferromagnetic nanorings is characterized by a non-constant DW velocity even if it is driven by rotating field of constant amplitude and frequency. Here, we examine ferromagnetic rings, in which the domain wall velocity can be additionally controlled on a local scale using variations of DW potential landscape that has been introduced to the sample via geometrical variations, such as a non-constant ring-width. Time-resolved observations of domain wall motion in asymmetric rings reveal that the phase shift between the direction of magnetic field and domain wall position is strongly related to the asymmetric shape of the sample, namely, the varying ring width. Such relative change of the phase shift result in variations of DW velocity profile, thus allowing one to control the DW velocity locally. In addition, the asymmetric shape of the sample give rise to the presence of DW motion that occurs even without the presence of external magnetic field (i.e. automotion). Such effects can be understood in terms of the minimization of the total energy.

MA 5: Thyssen-Krupp Electrical Steel Dissertationspreis

Vorträge a 20 Minuten + 5 Minuten Diskussion.

Nominiert sind:

Felix Büttner (U. Mainz): Dynamics of a magnetic bubble in thin films with perpendicular anisotropy

Vojtech Kaiser (TU Dresden): The Wien Effect in Electric and Magnetic Coulomb Systems: From Electrolytes to Spin Ice

Sebastian Wintz (TU Dresden/HZDR): Topological Spin Textures in Magnetic Multilayers

Bernd Zimmermann (FZ Jülich) : Ab initio description of transverse transport due to impurity scattering in transition metals

Time: Monday 9:30–11:30 Location: EB 202

Vorträge der Nominierten

MA 6: Surface Magnetism (Joint Session with O,TT) - Skyrmions

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

MA 6.1 Mon 9:30 EB 301

Dynamics of spin spirals and skyrmions in temperature gradient — •Rocio Yanes, Denise Hinzke, and Ulrich Novak — Universität Konstanz, Konstanz, Germany

Recently, Dzyaloshinskii-Moriya (DM) interaction has attracted attention in magnetism since it can lead to the formation of skyrmions and spin spirals with promising applications in spintronics [1,2]. Furthermore, it has been shown that temperature gradients can cause magnonic spin currents and with that spin transfer torques leading to a movement of a domain wall in a magnetic nanowire [3,4]. In this work, we combined both topics to analyze the dynamics of two dimensional non-collinear magnetic textures subject to a temperature gradient.

Numerical calculations of the dynamics of helical spin spiral (HSS), skyrmion lattices and isolated skyrmions are carried out for different values of the temperature gradient and damping parameter. Our results show that the HSS moves towards the hotter area driven by the temperature gradient. The velocity of this movement is asymmetric with respect to the sign of the temperature gradient due to the effect of the DM interactions. We observe a clear difference between the movement of isolated skyrmions and skyrmion lattices. While in the first case, the skyrmion motion is determine by the temperature gradient and the Magnus force, in the case of a lattice of skyrmions the interaction between skyrmions plays a fundamental role.

[1] A. Fert et al. Nature Nanotech., 8, 152, (2013). [2] N. Nogoasa et al., Nature Nanotech., 8, 899 (2013). [3] D. Hinzke and U. Novak, PRL, 107, 027205 (2011). [4] Schlickeiser et al., PRL, 113, 097201 (2014).

MA 6.2 Mon 9:45 EB 301

Interlayer Exchange Coupling: A route to stabilize skyrmions in magnetic multilayers — •Ashis K. Nandy, Nikolai S. Kiselev, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Magnetic skyrmion is a topologically nontrivial spin texture with particle like properties, which may emerge quite generally under an applied magnetic field of appropriate strength in any magnetic thin layer or multilayer with surface or interface induced Dzyaloshinskii-Moriya interaction (DMI). DMI chooses chirality i.e. the proper sense of rotation of spins [1]. However, the required magnetic field to stabilize skyrmions can be excessively large. We present a multiscale approach based on DFT calculations and atomistic spin-dynamic simulations, which allows us to stabilize skyrmions in magnetic multilayers even at zero magnetic field. It is based on fine tuning the interplay between internal and interfaces induced interactions by adjusting the thicknesses and interface compositions of multilayers. Our approach predicts the existence of a skyrmion lattice as well as isolated skyrmions in a thin film of a transition-metal monolayer grown on a heavy metal substrate. The simulated skyrmions exhibit high stability in an applied magnetic field and temperature. We provide a description for the complex phases occurring in such systems and present a magnetic phase diagram for a prototype example of Mn/W(001).

[1] M. Bode *et al.*, Nature **447**, 190 (2007).

MA 6.3 Mon 10:00 EB 301

Observation of spin transfer torques in the transverse magnetic susceptiblity of the Skyrmion lattice phase of MnSi — •Felix Rucker, Christoph Schnarr, Andreas Bauer, Alfonso Chacon, Philipp Köhler, and Christian Pfleiderer — Lehrstuhl für Topologie korrelierter Systeme, Technische Universität München, Garching, Germany

In the skyrmion lattice phase of MnSi the observation of sizeable spin transfer torques [1-3] in small angle neutron scattering and the Hall resistivity for current densities already five orders of magnitude smaller as compared to conventional magnetic materials promises easy experimental access to the precise qualitative and quantitative form of the Landau Lifshitz Gilbert equation. We report measurements of the transverse magnetic susceptibility, $\chi_\perp$, in the skyrmion lattice phase of MnSi. As our main result we find a distinct increase of $\chi_\perp$ with increasing current density around the critical current density j_c. We discuss the broader implications of our experimental findings, which provide, for the first time, a direct link between a thermodynamic property and the effects of spin transfer torques in skyrmion lattices.

[1] F. Jonietz et al., Science **330**, 1648 (2010)
[2] T. Schulz et al., Nat. Phys. **8**, 301 (2012)
[3] K. Everschor et al., Phys. Rev. B **86**, 054432 (2012)

MA 6.4 Mon 10:15 EB 301

Magnetic skyrmions stabilized at zero field — •Nikolai S. Kiselev[1], Ashis K. Nandy[1], Changhoon Heo[2], Theo Rathing[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Institute of Molecules and Materials, Radboud University Nijmegen, 6525 AJ Nijmegen, Netherlands

Magnetic skyrmions may appear as a metastable state in thin magnetic layers at zero magnetic field within certain range of Dzyaloshinskii-Moriya interaction and the uniaxial anisotropy. We present a comprehensive theoretical study of the statics and dynamics of such skyrmions. Important feature of this solution is a coexistence of two type of skyrmion solutions characterized by opposite polarity and opposite topological charge. We consider such skyrmions as a conceptually new approaches in data storage where switching between two of such skyrmion states is provided by sort magnetic field pulse. We discuss complex mechanism of such switching. The role of field pulse duration, damping, size and shape of host system are discussed in details. Our results are based on stochastic spin dynamics simulation applied to an extended Heisenberg model for different type of crystal lattices.

MA 6.5 Mon 10:30 EB 301

Emergent electrodynamics in $Mn_{1-x}Fe_xSi$ — •Christoph Schnarr, Felix Rucker, Christian Franz, Robert Ritz, Andreas Bauer, and Christian Pfleiderer — Lehrstuhl für Topologie korrelierter Systeme, Technische Universität München, Garching, Germany

The emergent electrodynamics of the skyrmion lattice phase in chiral magnets comprise of an emergent magnetic field of one flux quantum per skyrmion that gives rise to an emergent electric field, when the skyrmion lattice moves under the application of spin currents exceeding a critical current density j_c [1,2]. We report a study of the emergent electrodynamics in $Mn_{1-x}Fe_xSi$, where we exploit a well understood increase of the topological Hall resistivity by an order of magnitude with increasing Fe concentration [3]. On the one hand, this allows us to track j_c for increasing emergent magnetic field in the presence of increasing disorder. On the other hand, we observe evidence for emergent electric fields even in the magnetoresistance, reflecting, in combination with the emergent electric field in the Hall signal, the direction of motion of the skyrmion lattice.
[1] F. Jonietz et al., Science **330**, 6011, 1648-1651 (2010)
[2] T. Schulz et al., Nature Physics **8**, 4, 301-304 (2012)
[3] C. Franz et al., Physical review letters **112**, 18, 186601 (2014)

15 min. break

MA 6.6 Mon 11:00 EB 301

Advanced characterization of helical spin structures and domains in Skyrmion systems — •Peggy Schönherr[1], Antoine Dussaux[1], Naoya Kanazawa[2], Yoshinori Tokura[2], Christian Degen[1], Manfred Fiebig[1], and Dennis Meier[1] — [1]ETH Zürich, 8093 Zürich, Switzerland — [2]University of Tokyo, 113-8656 Tokyo, Japan

Magnetic whirls, so-called Skyrmions, emerge in various chiral magnets and attract tremendous attention due to their exotic properties. Skyrmions can, e.g., be moved at ultra-low current densities and give rise to the topological Hall Effect. Much less is known about the magnetic phases that surround the Skyrmion state, including fundamental aspects such as the domain formation and spin-defect interactions. The fragmented knowledge is partially due to the challenging experimental access and the general difficulty to image antiferromagnetic order at the nanoscale. Here, we show how helical magnetic structures in the Skyrmion system FeGe emerge and transform as a function of temperature and magnetic field. We discuss the magnetic field-driven response of multi-domain states, the influence of defects, as well as fingerprints of spontaneous jump-like movements of the periodic spin arrangement. The results are gained near room temperature using magnetic force microscopy (MFM) and diamond nitrogen-vacancy center microscopy. Besides providing new insight to the physics of Skyrmion materials, our results foreshadow a promising pathway for measuring complex spin textures with high spatial and temporal resolution.

MA 6.7 Mon 11:15 EB 301

Field-dependent Size and Shape of Single Magnetic Skyrmions — •Niklas Romming, André Kubetzka, Christian Hanneken, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, 20355 Hamburg, Germany

Skyrmions are spatially localised solitonic magnetic whirls with axial symmetry and fixed rotational sense. They have recently been observed in both non-centrosymmetric bulk crystals and in ultrathin transition metal films on heavy-element substrates as a result of sizable Dzyaloshinskii-Moriya interactions. In addition to their protected topology and nano-scale size, skyrmions can easily be moved by lateral spin currents and written as well as deleted by vertical spin-current injection. Here we use spin-polarised scanning tunnelling microscopy to directly reveal the field-dependent internal spin structure of individual skyrmions in a biatomic PdFe layer on Ir(111) [1] with atomic-scale precision. An analytical expression for the description of skyrmions is proposed, which can establish a connection between the original work - predicting magnetic skyrmions - and their experimentally determined magnetic-field dependent size and shape. Thus, the relevant material parameters responsible for skyrmion formation can be determined. [1] N. Romming et al., Science 341, 636 (2013).

MA 6.8 Mon 11:30 EB 301

Spin dynamics of spin-orbit coupled dimers on Pt(111) — •Manuel dos Santos Dias and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

The interaction between two magnetic adatoms becomes anisotropic in the presence of strong spin-orbit coupling (SOC). The broken inversion symmetry at the surface leads in particular to the Dzyaloshinksii-Moriya interaction, enabling chiral magnetic ground states. We study the impact of this interaction on the spin dynamics of magnetic dimers (e.g. Fe) on the Pt(111) surface, in connection to possible inelastic scanning tunneling spectroscopy (ISTS) experiments [1]. We employ our recently developed time-dependent density functional theory including SOC, based on the Korringa-Kohn-Rostoker Green function approach. An extension of our theoretical ISTS method [2] to incorporate SOC is in progress.

Work funded 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. **111**, 157204 (2013)
[2] B. Schweflinghaus et al., Phys. Rev. B **89**, 235439 (2014)

MA 6.9 Mon 11:45 EB 301

First-principles study of confined magnetic skyrmions in Pd/Fe/Ir(111) — •Dax Michael Crum[1,2], Benedikt Schweflinghaus[1], Mohammed Bouhassoune[1], Juba Bouaziz[1], Stefan Blügel[1], and Samir Lounis[1] — [1]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Microelectronics Research Center, The University of Texas at Austin, Austin Texas, 78758 USA

We investigate for the first time confined skyrmionic magnetic defects in an otherwise ferromagnetic thin film from first-principles. The system of choice is Pd/Fe on Ir(111) [1,2]. Utilizing the full-potential relativistic Korringa-Kohn-Rostoker Green functions formalism, we investigate in real-space the energetics of creating single chiral magnetic textures purely from *ab initio*. We find that the nano-skyrmion structures become energetically more favorable with increasing size. We interpret the results by extracting the tensors of magnetic exchange interactions and modeling the system within an extended Heisenberg Hamiltonian, where the Dzyaloshinskii-Moriya interaction plays a key role. We also investigate the theoretical scanning tunneling microscopy spectra by analysing the local density of states in vacuum near the skyrmion surface and make connection to available experiments [1].

This work is supported by the HGF-YIG Programme VH-NG-717 (Functional Nanoscale Structure and Probe Simulation Laboratory – Funsilab) and the US National Science Foundation (NSF).
[1] Romming *et al.*, Science **341**, 636 (2013).
[2] B. Dupé *et al.*, Nature Communications **5**, 4030 (2014).

MA 6.10 Mon 12:00 EB 301

Energy-dependent magnetic contrast of a nanoscale spin helix measured by STM — •Safia Ouazi, Soo-Hyon Phark, Jeison A. Fischer, Dirk Sander, and Jürgen Kirschner — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany

Helical spin order has been revealed for Fe bilayer islands on Cu(111) by spin-polarized scanning tunneling spectroscopy (SP-STS) in a magnetic field at 10 K [1]. We measure the magnetic contrast, as given by the difference in differential conductance for states with and without spin helix [1], as a function of the gap voltage applied between tip and sample. Thus, we obtain the first spatially- and energy-resolved map of spin contrast for a nanoscale spin spiral. The wave vector describing the helical spin order remains constant in the energy range -0.8eV to +0.5eV, whereas the spin contrast shows a strong modulation. This result identifies a novel aspect of SP-STM to characterize complex spin order with respect to the corresponding electronic band structure. We discuss the results in view of a partial energy gap associated with the non-collinear spin order.

[1] S.-H. Phark, J.A. Fischer, M. Corbetta, D. Sander, K. Nakamura, J. Kirschner, Nat. Commun. 5:5183 doi:10.1038/ncomms6183 (2014).

MA 6.11 Mon 12:15 EB 301

A Magnetic Nano-Skyrmion Lattice observed in a Si-wafer based Multilayer System — •Stefan Krause[1], Anika Schlenhoff[1], Philipp Lindner[1], Johannes Friedlein[1], Roland Wiesendanger[1], Michael Weinl[2], Matthias Schreck[2], and Manfred Albrecht[2] — [1]Department of Physics, University of Hamburg, Germany — [2]Institute of Physics, University of Augsburg, Germany

Recently, an atomic-scale two-dimensional magnetic skyrmion lattice at the Fe/Ir(111) interface has been discovered using spin-polarized scanning tunneling microscopy (SP-STM).[1] Skyrmions offer new exciting possibilities for spintronic applications, using them as digital information carriers. For these applications the mass production of devices using multilayer growth on large-scale substrates is indispensable.

In 2009, the heteroepitaxial growth of single crystal Ir(111) films on Si(111) wafers with yttria-stabilized zirconia buffer layers has been demonstrated.[2] For our study we epitaxially grow one monolayer of Fe on top of this multilayer substrate. The SP-STM experiments reveal a magnetic skyrmion lattice, being fully equivalent to the magnetic ground state that has previously been observed on an Ir(111) bulk single crystal substrate. In addition, it is found to be robust against local atomic lattice distortions induced by multilayer preparation. Our work paves the way towards spintronic applications of nano-skyrmions in ultrathin films and multilayer systems.

[1] S. Heinze *et al.*, Nature Physics **7**, 713 (2011).
[2] S. Gsell *et al.*, J. Cryst. Growth **311**, 3731 (2009).

MA 6.12 Mon 12:30 EB 301

Tailoring a Spin Spiral by Uniaxial Strain — •Pin-Jui Hsu, Aurore Finco, Lorenz Schmidt, Andre Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, Hamburg Univerisyt, 20355 Hamburg, Germany

Spin spirals typically result from competing magnetic interactions. In the presence of a sizable Dzyaloshinskii-Moriya (DM) interaction, the spin spirals exhibit a unique rotational sense and their periodicity is governed by the ratio of the exchange and DM-interaction strength. Spin-polarized scanning tunneling microscopy (SP-STM) experiments have already revealed several examples of cycloidal and conical spin spiral states in ultrathin films of magnetic transition metals (e.g. Fe, Mn, Cr) on heavy-element substrates (e.g. W, Ir). Here, we report on a SP-STM study on two monolayers of Fe on Ir(111) where a regular dislocation line structure with a periodicity of 3.71 ± 0.47 nm is observed due to the strain relief of bcc(110) Fe grown epitaxially on the Ir(111) substrate. SP-STM reveals the presence of cycloidal spin spirals with a period of 1.82 ± 0.15 nm which are guided by the dislocation lines to form a well-defined spin-ordered state. These ordered spin spirals form an undulating pattern perpendicular to the dislocation lines wiggling with an angle of about 155^o, indicating an interaction between structural relaxation and the observed spin structure, particularly along the three symmetrically equivalent crystallographic axes. In contrast, a disordered spin spiral state, which locally exhibits a period of 1.38 ± 0.22 nm is observed in the regions without dislocation lines.

MA 7: Magnetic Semiconductors

Time: Monday 11:30–13:15 Location: EB 202

MA 7.1 Mon 11:30 EB 202

Co-Doping GaMnP with Zn by Ion Implantation and Laser Annealing — •Hendrik Hentschel[1,2], Muhammad Khalid[1], Ye Yuan[1], Manfred Helm[1,2], and Shengqiang Zhou[1] — [1]HZDR, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany

Spintronics appears to be a new and exciting field of technology, but there is still a lag of suitable materials. In principle magnetic semiconductors (DMS) would be an excellent choice, but even their highest reached Curie temperature (T_C) in GaMnAs is still too low for practical usage. Ferromagnetism in DMS is suggested to be holes according to the Zener-Model. Therefore, it is expected to increase T_C by adding additional holes, e.g. co-doping. But there is a high risk to induce more defects, especially interstitial Mn atoms (Mn_I).Indeed, previous investigation revealed a lower T_C in carbon codoped GaMnAs [1]. Ion Implantation followed by laser annealing might overcome this problem. We choose ferromagnetic GaMnP since it shows insulating behavior [2]. Co-doping with shallow acceptors may lead to a more pronounced change in the conductivity of GaMnP. The samples were investigated with SQUID-VSM and Hall-Effect measurement. First results do not show an increase in T_C. Structural analysis is in progress to check if more defects appear upon carbon codoping.

[1] G. M. Schott, et al., Appl. Phys. Lett. 85, 4678 (2004).
[2] M. A. Scarpulla, et al., Phys. Rev. Lett., 95, 207204 (2005).

MA 7.2 Mon 11:45 EB 202

carbon p electron ferromagnetism in silicon carbide — •yutian wang[1,5], yu liu[1,2], gang wang[2], wolfgang anwand[3], catherine a jenkins[4], elke arenholz[4], frans munnik[1], ovidiu d gordan[6], dietrich r. t. zahn[6], xiaolong chen[2], sibylle gemming[1,6], manfred helm[1,5], and shengqiang zhou[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden, Germany — [2]Research & Development Center for Functional Crystals, Beijing National Laboratory for Condensed Matter Physics, Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China — [3]Institute of Radiation Physics, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden, Germany — [4]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA — [5]Technische Universität Dresden, 01062 Dresden, Germany — [6]Institute of Physics, Technische Universität Chemnitz , 09107 Chemnitz, Germany

Defect induced ferromagnetism has been reported in wide-bandgap semiconductors as well as in carbon-based materials. It is desirable to establish a direct relation between such ferromagnetism and defects. Here, we succeed to reveal the origin of defect-induced ferromagnetism using SiC by X-ray magnetic circular dichroism (XMCD). In combination with first-principles calculations. We show that the long-range ferromagnetic coupling is due to the p electrons of the nearest-neighbor carbon atoms around VSiVC divacancies. Thus, the ferromagnetism is traced down to its microscopic, electronic origin.

MA 7.3 Mon 12:00 EB 202

Intrinsic versus extrinsic ferromagnetism in HfO_{2-x} and Ni:HfO_{2-x} thin films — •Erwin Hildebrandt[1], Mehrdad Baghaie Yazdi[1], Jose Kurian[1], S. U. Sharath[1], Fabrice Wilhelm[2], Andrei Rogalev[2], and Lambert Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Straße 2, 64287 Darmstadt, Germany — [2]European Synchrotron Radiation Facility (ESRF), BP 220, 38043 Grenoble Cedex 9, France

We have investigated the possible evolution of an intrinsic stable ferromagnetic moment in oxygen deficient undoped and magnetically doped HfO_{2-x} thin films grown by reactive molecular beam epitaxy. Neither oxygen vacancies nor substituted Ni in combination with such vacancies results in an observable magnetic moment for a broad range of oxygen vacancy concentrations. By combining integral and element specific magnetization measurements we show that a fluctuating deposition rate of the magnetic dopant induces extrinsic ferromagnetism by promoting the formation of metallic clusters. We suggest the element specific measurement of an induced magnetic moment at the non-magnetic site as an unambiguous proof of intrinsic ferromagnetism in diluted magnetic semiconductors.[1]

[1] E. Hildebrandt, M. Baghaie Yazdi, J. Kurian, S. U. Sharath, F. Wilhelm, A. Rogalev, and L. Alff, Phys. Rev. B **90**, 134426 (2014)

MA 7.4 Mon 12:15 EB 202

Formation of stable bound magnetic polarons in depleted magnetic ZnO films — •Heidemarie Schmidt[1], Tim Kaspar[1], D. Bürger[1], I. Skorupa[1,2], S. Zhou[2], C. Timm[3], and O.G. Schmidt[1,4] — [1]TU Chemnitz — [2]HZDR — [3]TU Dresden — [4]IFW Dresden

The clear understanding of transport and optical properties of magnetic transition-metal oxides (TMO) in an external magnetic and electric field [1] is important for future transparent spintronics. To explain room-temperature ferromagnetism in intrinsically n-type conducting, magnetic TMO, Coey et al. [2] have proposed a ferromagnetic exchange mechanism involving oxygen vacancies, which form F-centers with two trapped electrons. The increase of the low-frequency dielectric constant of magnetic oxides with increasing concentration of isovalent magnetic ions has been neglected so far. Therefore, the reported necessary concentration of oxygen vacancies for percolating BMPs in magnetic oxides is overestimated. We have investigated the magnetic properties of ZnO thin films with stable BMPs and have adapted the existing hydrogenic BMP model to oxygen vacancies, which form F+ centers with one trapped electron [3]. Magnetic oxides with stable BMPs will allow for new device approaches which exploit the huge internal magnetic fields felt by charge carriers in magnetic oxide films with F+-center BMPs. [1] Q. Xu, H.S. et al., Phys. Rev. Lett. 101 (2008), Jpn. J. Appl. Phys. 49 (2010), [2] J.M.D. Coey et al., Nat.

Mat. 4 (2005), [3] T. Kaspar, H.S. et al., IEEE Elec. Dev. Lett. 34 (2013); Appl. Phys. Mat. 2 (2014)

MA 7.5 Mon 12:30 EB 202

Magnetic coupling and formation energy of oxygen vacancies in $ZnFe_2O_4$ — •Martin Hoffmann[1,2], Sanjeev K. Nayak[1], Waheed Adeagbo[1], Karen L. Salcedo Rodríguez[3], Claudia E. Rodríguez Torres[3], Wolfram Hergert[1], and Arthur Ernst[2,4] — [1]Martin Luther University Halle-Wittenberg, Germany — [2]Max Planck Institute for Microstructure Physics, Halle, Germany — [3]National University of La Plata, Argentina — [4]University Leipzig, Germany

Cation site inversion between regular and inverse spinel compositions and oxygen vacancy (V_O) mediated ferromagnetic coupling between Fe spins constitute two major physical mechanisms for the observed ferrimagnetism in $ZnFe_2O_4$ (ZFO) [PRB 89, 104411 (2014)]. We will discuss our studies on the magnetic coupling between the Fe ions in ZFO with and without V_O. The formation energy of defects is used to analyze the stability of V_O in ZFO for the experimental growth conditions. The Néel temperature (T_N) is determined from Monte Carlo (MC) simulations using the magnetic exchange interactions (J_{ij}) obtained from first-principles method. The correlation energy is treated using GGA+U, where it is found that the J_{ij} change almost linearly with increasing values of U.

For T_N comparable to the experimental results, the first neighbor interaction was small and positive as concluded from former experiments. With those J_{ij}, the estimated temperature-dependent saturation magnetization from the MC simulations is in good agreement with recent measurements.

MA 7.6 Mon 12:45 EB 202

Transient photocurrent studies on ZnO based materials under the effect of magnetic field — •Yogesh Kumar[1], Israel Lorite[1], Pablo Esquinazi[1], C. Zandalazini[2], and Silvia P. Heluani[3] — [1]Division of Superconductivity and Magnetism, University of Leipzig, D-04103 Leipzig, Germany — [2]Laboratorio de Física del Sólido, Dpto. de Física, FCEyT and CONICET, Universidad Nacional de Tucumán, 4000 Tucumán, Argentina — [3]Laboratorio de Física del Sólido, Dpto. de Física, FCEyT, Universidad Nacional de Tucumán, 4000 Tucumán, Argentina

We have performed measurements of the transient photocurrent (wavelengths 370 nm) on ZnO based thin films and microwires. Thin films were grown in different atmospheres on c-sapphire using PLD and microwires were prepared using carbothermal process. Samples with three different magnetic behaviors were measured: non-magnetic samples, with magnetic order at the near-surface region, and samples having defect-induced magnetism in bulk. Transient photocurrent data for different types of samples show distinct influence of the magnetic field. Non-magnetic thin film grown in oxygen does not show any effect of the field, while the transient photocurrent of bulk magnetic samples reduces after application of a magnetic field. On the other hand, samples with near surface magnetism exhibit faster reduction in transient photocurrent when a field is applied. Hence, transient photocurrent under magnetic field can be used as a sensitive tool for the localization of magnetic defects.

MA 7.7 Mon 13:00 EB 202

Structure and magnetism of the Zn-Co-O system: From n-type wurtzite Co:ZnO to p-type spinel $ZnCo_2O_4$ — •Bastian Henne[1], Verena Ney[1], Mariano de Souza[1], Katharina Ollefs[2], Fabrice Wilhelm[2], Andrei Rogalev[2], and Andreas Ney[1] — [1]Johannes Kepler Universität, Linz - Austria — [2]European Synchrotron Radiation Facility, Grenoble - France

The combined optical and transport properties of oxide semiconductors such as cobalt doped ZnO (Co:ZnO) and the related spinel $ZnCo_2O_4$ are of potential interest for applications. However, while the magnetic properties of Co:ZnO were subject of intense research activities, the magnetism of the spinel system $ZnCo_2O_4$ received only little attention so far (1). In this contribution we present the growth of both; phase pure n-type wurtzite Co:ZnO with extremely high Co content and p-type spinel $ZnCo_2O_4$ from a single oxide composite target by reactive magnetron sputtering. The structural properties were investigated by XRD and synchrotron techniques as XAS and XLD. The magnetic properties were analyzed by integral SQUID magnetometry down to 2 K and up to 5 T and using element specific XMCD up to 17 T. We see indications of uncompensated antiferromagnetism (2) well below room temperature for both systems and the low temperature $M(H)$-hystereses show history dependent behavior being reminiscent of an exchange bias.

(1) H.J. Kim, et al., J. Appl. Phys. 95, 7387 (2004).
(2) A. Ney et al., Phys. Rev. B 85, 245202 (2012).

MA 8: Focused Session on Ferroic Domain Walls I (DF with MA)

Part of the 3-days focus on ferroic domain walls:

Tutorial, Symposium (SYDW), three Focused Sessions, and Poster Session.

Organizers: Elisabeth Soergel (Universität Bonn) and Dennis Meier (ETH Zürich)

Time: Monday 15:00–18:30 Location: EB 107

Topical Talk MA 8.1 Mon 15:00 EB 107

Domain walls and phase boundaries - new nanoscale functional elements in complex oxides — •Jan Seidel — School of Materials Science and Engineering, UNSW Australia, Sydney, Australia

Interfaces and topological boundaries in complex oxide materials, such as domain walls and morphotropic phase boundaries, have recently received increasing attention due to the fact that their properties, which are linked to the inherent order parameters of the material, its structure and symmetry, can be completely different from that of the bulk material [1]. I will present an overview of recent results on electronic and optical properties of ferroelectric phase boundaries, domain walls, and topological defects in multiferroic materials [2, 3, 4, 5, 6]. The origin and nature of the observed confined nanoscale properties is probed using a combination of nanoscale transport measurements based on scanning probe methods, high resolution transmission electron microscopy and first-principles density functional computations. I will also give an outlook on how these special properties can be found in other material systems and discuss possible future applications [7].

1. J. Seidel, et al., Nature Materials 8, 229 (2009) 2. J. Seidel, et al., J. Phys. Chem. Lett. 3, 2905 (2012) 3. J. Seidel, et al., Phase Trans. 86, 53 (2013) 4. J. Seidel, et al., Adv. Mater., 26, 4376 (2014) 5. Y. Heo, et al., Adv. Mater., DOI: 10.1002/adma.201401958 (2014) 6. K.-E. Kim, NPG Asia Mater. 6, e81 (2014) 7. G. Catalan, J. Seidel, R. Ramesh, and J. Scott, Rev. Mod. Phys. 84, 119 (2012)

MA 8.2 Mon 15:30 EB 107

Dielectric properties of multiferroic hexagonal manganites — •Stephan Krohns[1], Eugen Ruff[1], Peter Lunkenheimer[1], Martin Lilienblum[2], Dennis Meier[2], Manfred Fiebig[2], and Alois Loidl[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany — [2]Multifunctional Ferroics, Department of Materials, ETH Zurich, Switzerland

Hexagonal manganites exhibit a broad variety of highly interesting features as, e.g., domain-wall structure, geometric improper ferroelectricity and antiferromagnetic ordering. The exact mechanism for ferroelectricity is still under debate as well as the impact of the domain-wall structure to macroscopic quantities (e.g., the dielectric constant). A technique to determine the multiferroic, ferroelectric and domain-wall polarisation phenomena is the measurement of the dielectric response to ac and dc electric fields. Here we thoroughly analyse the dielectric response of $YMnO_3$ single crystals in a broad temperature and frequency range. The crystals were subjected to precisely defined cooling rates from above the ferroelectric transition to vary their domain-wall densities. Two relaxation processes occur at temperatures below 350 K. The major one points to an extrinsic so-called Maxwell-Wagner relaxation, based on a thin insulating layer at the surface of the sample. The second, smaller relaxation seems to be of intrinsic origin. We address the question if the macroscopic dielectric properties are influenced by the ferroelectric domain-wall structure.

MA 8.3 Mon 15:50 EB 107

Domain wall motion in proper and improper ferroelastic materials — •Wilfried Schranz — University of Vienna, Faculty of Physics, Boltzmanngasse 5, Vienna, Austria

Many proper and improper ferroelastic materials display (at low measurement frequncies) a huge elastic softening below Tc. This giant elastic softening is caused by domain wall motion and can be supressed with uniaxial stress. Here we review our results on frequency and temperature dependent elastic measurements of $SrTiO_3$ [1], $KMnF_3$ and $KMn_{1-x}Ca_xF_3$ [2], $PbZrO_3$, $NH_4HC_2O_4 \cdot \frac{1}{2}H_2O$ [3] and $BaFe_2As_2$ [4] and put them into context with data from literature. We also present a model [5] based on Landau-Ginzburg theory to describe superelastic softening observed in some of the perovskite systems (improper ferroelastic) as well as in iron based superconductors (pseudo-proper ferroelastic) and show, how the theory can be extended to describe the effects of domain miniaturization (e.g. near morphotropic phase boundaries) on the macroscopic porperties of materials.

Supported by the Austrian FWF (P23982-N20).

[1] A.V. Kityk, W. Schranz, P.Sondergeld, D. Havlik, E.K.H. Salje and J.F. Scott, Phys. Rev. B 61, 946 (2000) [2] W. Schranz, P. Sondergeld, A.V. Kityk and E.K.H. Salje, Phys. Rev. B 80, 094110 (2009) [3] W. Schranz, H. Kabelka, A. Sarras and M. Burock, Appl. Phys. Lett. 101, 141913 (2012) [4] A.E. Böhmer, P.Burger, F. Hardy, T. Wolf, T. P. Schweiss, R. Fromknecht, M. Reinecker, W. Schranz and C. Meingast, Phys. Rev. Lett. 112, 047001 (2014) [5] W. Schranz, Phys. Rev. B 83, 094120 (2011)

Topical Talk MA 8.4 Mon 16:10 EB 107

Field-induced hysteresis of chiral vortices in ferroelectric $SrTiO_3$ twin walls. — •Ekhard Salje — University of Cambridge, Cambridge, UK

Resonant piezoelectric spectroscopy shows polar resonances in paraelectric $SrTiO_3$ at temperatures below 80 K. These resonances become strong at $T < 40$ K. This piezoelectric response does not exist in paraelastic $SrTiO_3$ nor at temperatures just below the ferroelastic phase transition. The interpretation of the resonances is related to ferroelastic twin walls which become polar at low temperatures in close analogy with the known behavior of $CaTiO_3$. $SrTiO_3$ is different from $CaTiO_3$, however, because the wall polarity is thermally induced; i.e., there exists a small temperature range well below the ferroelastic transition point at 105 K where polarity appears on cooling. As the walls are atomistically thin, this transition has the hallmarks of a two-dimensional phase transition restrained to the twin boundaries rather than a classic bulk phase transition. Simulations of polar twin walls in $SrTiO_3$ show nanoscopic vortices, which can be switched in orientation under an external electric field. The hysteresis of the vortex polarization inside the twin boundary leads to direct applications in non-volatile memory devices. E.K.H. Salje et al. Domains within Domains and Walls within Walls: Evidence for Polar Domains in Cryogenic $SrTiO_3$, Phys. Rev. Lett. 111, 24, 247603 (2014), Zykova-Timan T and Salje E.K.H. Highly mobile vortex structures inside polar twin boundaries in SrTiO3, APL 104, 082907 (2014).

10 min break

Topical Talk MA 8.5 Mon 16:50 EB 107

Spintronic functionality of $BiFeO_3$ domain walls — Ji Hye Lee[1,3], Ignasi Fina[1,2], Dietrich Hesse[1], and •Marin Alexe[1,2] — [1]Max Planck Institute of Microstructure Physics, 06120 Halle, Germany — [2]University of Warwick, Department of Physics, Coventry CV4 7AL, UK — [3]Division of Quantum Phase and Device, Department of Physics, Konkuk University, Seoul 143-701, Korea

Here we show that the FE domain walls (DWs) in the multiferroic material $BiFeO_3$ (BFO), which are intrinsically two dimensional nanoobjects, are not only conductive, but are also ferromagnetic, showing spin-dependent transport. We will show that the electronic transport across the * FM and FE * domain walls in BFO is modulated by an external magnetic field, resembling the anisotropic magnetoresistance (AMR) in archetypical metallic ferromagnets. The found AMR is accompanied by a visible hysteresis, which is ascribed to the coupling of the FM domain walls to the antiferromagnetic properties of the BFO domains, similar to those found in magnetically coupled FM/AFM structures. Since BFO preserves two switchable electric polarization states, one can manipulate the FE DWs and thus magnetization via an electric field. The electronic transport occurring through the FE DWs in common metal-ferroelectric-metal capacitors has been discriminated from the contribution occurring from the bulk, and the intrinsic conduction mechanism at the DWs is identified.

MA 8.6 Mon 17:20 EB 107

3D-mapping of ferroelectric domain walls by Cherenkov second-harmonic generation — •Thomas Kämpfe[1], Philipp Reichenbach[1], Mathias Schröder[1], Alexander Haussmann[1], Theo Woike[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr-Str. 1, 01069 Dresden, Germany — [2]Institut für Strukturphysik, Technische Universität Dresden, Zellescher Weg 16, 01069 Dresden, Germany

Ferroelectric domain walls (DWs) are a novel approach towards nanoelectronic circuitry since providing localized conduction within a fully insulating host matrix. The key factor is the DW inclination angle α with respect to the crystallographic axes determining the amount of polarization charge at the head-to-head DWs. Hence, the conductivity can be considerably tuned via doping concentration and poling conditions. We apply Cherenkov second-harmonic generation (C-SHG) to map such charged DWs in three dimensions throughout a mm-thick Mg:$LiNbO_3$ single crystal [1]. We will present domain wall topologies for different cases, also including surface domains, which are created upon external UV illumination and exhibiting also tail-to-tail DWs. We investigated the domain wall protrusion upon different illumination strengths. Moreover, we will also introduce into an extended version of C-SHG based on interferometric SHG (I-SHG). I-SHG provides several advantages as compared to C-SHG, such as an increased vertical resolution, a larger vertical imaging range, as well as easier imaging conditions.

[1] T. Kämpfe et al., Phys. Rev. B, 89, 035314 (2014).

MA 8.7 Mon 17:40 EB 107

UV-induced AC transport along conductive domain walls in $LiNbO_3$ single crystals — Mathias Schröder[1], Xi Chen[2], •Alexander Haussmann[1], Andreas Thiessen[1], Jan Poppe[3], Dawn A. Bonnell[2], and Lukas M. Eng[1] — [1]Institut für Angewandte Photophysik, Technische Universität Dresden, George-Bähr-Str. 1, D-01069 Dresden, Germany — [2]Materials Science and Engineering, University of Pennsylvania, Philadelphia, Pennsylvania 19104, USA — [3]Physikalische Chemie, Technische Universität Dresden, Bergstrasse 66 b, D-01062 Dresden, Germany

The impedance properties of UV-illuminated ($\lambda = 310$ nm) conductive domain walls (CDWs) in 5% Mg-doped $LiNbO_3$ single crystals (sc) are investigated both on the nm length scale using nanoimpedance microscopy (NIM), as well as macroscopically by comparing the transport properties of multi- and single domain samples. Similar to the DC transport, we find the CDWs to be highly conductive for AC currents as well, mostly pronounced for $f < 200$ Hz due to the strong influence of the bulk capacitance at higher frequencies. Moreover, simultaneously applying both an AC and DC voltage results in an increased real part of the AC CDW current. Equivalent circuits accurately describing both the domain and CDW contributions hence were developed; as a result we are able to analyze and quantify the complex dielectric conductive behavior of both bulk and CDWs in sc-$LiNbO_3$ within the framework of the mixed conduction model: Hopping of excited charge carriers along the CDWs was identified as the dominant charge transport process.

Topical Talk MA 8.8 Mon 18:00 EB 107

Functional ferroic domain walls - AC & DC transport — •Lukas M. Eng — Institute of Applied Physics, TU Dresden, 01062 Dresden, Germany

Wide band-gap ferroic oxides exhibit both ferroelectric and ferromagnetic properties that promise a novelty of tunable and spectacular applications such as magneto-electric storage devices [1] or metamaterial-based superlensing [2]. We focus here on the domain wall functionality which is clue in order to engineer devices as the ones mentioned above for modern-type applications. Surprisingly, we find such domain walls in $LiNbO_3$ and other single crystals to exhibit a metallic-like conductivity [3] that can even be tuned or switched on and off. Consequently, such charged domain walls allow for both AC [4] and DC [3] electron transport within a nanometer-wide discontinuity that is embedded in a fully insulating matrix. We investigated these novel topologies with a variety of scanning probe techniques, through transport measurements as well as with nonlinear optical methods [5], Since these metallic-like nanocontacts can be engineered on will, they provide a novel and elegant way for exploring nanoscale 2-dimensional transport properties.

[1] R. Streubel et al., Phys. Rev. B 87, 054410 (2013). [2] S.C. Kehr et al., Nature Comm. 2, 249 (2011). [3] M. Schröder et al., Adv. Funct. Mater. 22, 3936 (2012). [4] M. Schröder et al., Mater. Res. Express 1, 035012 (2014). [5] T. Kämpfe et al., Phys. Rev. B 89, 035314 (2014).

MA 9: Spin Excitations/Spin Torque

Time: Monday 15:00–18:45 Location: H 0112

Invited Talk MA 9.1 Mon 15:00 H 0112

Ultra-fast three terminal perpendicular Spin-Orbit MRAM — •Gilles Gaudin[1], Olivier Boulle[1], Murat Cubukcu[1], Marc Drouard[1], Nicolaï Mikuszeit[1], Liliana Buda Prejbeanu[1], Claire Hamelin[1], Ioan Mihai Miron[1], Stéphane Auffret[1], Nathalie Lamard[2], Marie-Claire Cyrille[2], Jürgen Langer[3], Berthold Ocker[3], Kevin Garello[4], Can Onur Avci[4], Manuel Baumgartner[4], Abhijit Ghosh[4], and Pietro Gambardella[4] — [1]Univ. Grenoble Alpes, CNRS, CEA, INAC-SPINTEC, F-38000 Grenoble, France — [2]CEA, LETI, Minatec Campus, F-38000 Grenoble, France — [3]Singulus AG, Kahl, Germany — [4]Department of materials, ETH Zürich, Switzerland

STT-MRAM has been identified as a promising candidate for the non-volatile replacement of L1 and L2 SRAM cache memory technology. However, STT-MRAM suffers from serious reliability and endurance issues due to the rapid aging of the tunnel barrier induced by the high write current density at large speed (˜ns for L1 cache) as well as erroneous writing by read current. We present a novel memory concept, named Spin Orbit Torque-MRAM (SOT-MRAM) that combines the advantages of STT and naturally solves these issues. The memory is based on the discovery that a current flowing in the plane of a magnetic multilayer with structural inversion asymmetry, such as Pt/CoAlOx, exerts a torque on the magnetization. This spin orbit torque can induce ultra-fast magnetization switching (<200ps in Pt/Co/AlOx). Micromagnetic simulations reveal that the magnetization reversal proceeds by domain nucleation followed by domain wall propagation.

15 min. break

MA 9.2 Mon 15:45 H 0112

Electron energy loss spectroscopy of spin waves in ultrathin films of cobalt on Cu(111) and W(110) — •Eugen Michel[1,2], Harald Ibach[1,2], and Claus M. Schneider[1,2] — [1]Peter-Grünberg-Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Jülich Aachen Research Alliance, Germany

For ultrathin fcc Co/Cu(100) films the dispersion of standing spin wave modes as function the film thickness was shown to be a sensitive probe for the layer dependence of layer exchange coupling constants [1]. We extend the method to hcp Co films grown on Cu(111) and W(110). In addition to the acoustic spin wave we observe up to two standing spin wave modes in films with thicknesses ranging from 2 to 8 atomic layers and wave vectors between 1.6 - 5 1/nm. We find that the layer-dependent dispersion curves obtained for both substrates are consistent with each other when the island growth of Co on Cu(111) is taken into account. Compared to fcc cobalt films on Cu(100) the standing spin waves have a substantially lower energy, which is consistent with the lower number of nearest neighbor interactions between subsequent layers. The results are discussed within the framework of a Heisenberg model with modified coupling constants at surface and interface.

[1] J. Rajeswari et al., Phys. Rev. Lett. 112, (12), pp 127202 (2014)

MA 9.3 Mon 16:00 H 0112

Direct and inverse spin-orbit torques from first principles — •Frank Freimuth, Stefan Blugel, and Yuriy Mokrousov — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Ferromagnetic (FM) layers asymmetrically sandwiched between non-magnetic (NM) layers can be switched by spin-orbit torques (SOTs) [1,2]. Conversely, an electric current can be induced by magnetization dynamics due to the inverse SOT (ISOT) [3]. We discuss exact relationships between SOTs and ISOTs. Based on DFT calculations [4] we study (I)SOTs in NM/FM thin films for various choices of NM (Pt, W, Ta, Ir, Au) and FM (Co, Fe, Mn). Resolving torques and spin-fluxes on the atomic scale allows us to differentiate between local and non-local contributions. An important contribution to the ISOT is the conversion of pumped spin current into charge current via the inverse spin Hall effect (ISHE). We investigate the spatial decay of the spin current pumped into NM via the ferromagnetic resonance (FMR) of the FM layer, its conversion into a charge current and its contribution to the Gilbert damping. We show that this ISHE-driven charge current is accompanied by a phase-shifted contribution originating in the interfacial spin-orbit coupling. Finally, we investigate (I)SOTs at finite frequencies and find that they can be very well approximated by the zero-frequency (I)SOTs in the GHz regime.

[1] F. Freimuth et al., PRB **90**, 174423 (2014)

[2] F. Freimuth et al., J. Phys.: Condens. Matter **26**, 104202 (2014)

[3] F. Freimuth et al., arXiv:1406.3866 [4] www.flapw.de

MA 9.4 Mon 16:15 H 0112

Domain wall motion in temperature gradients caused by maximization of entropy — •Frank Schlickeiser, Ulrike Ritzmann, Unai Atxitia, Denise Hinzke, and Ulrich Nowak — University Konstanz, 78457 Konstanz, Germany

A theoretical understanding of thermally driven domain wall (DW) motion is of great interest, since it potentially opens the door for new ways to control and manipulate domain structures in spintronic devices. Based on the Landau Lifshitz Bloch equation [1], we present an analytical calculation of the DW velocity as well as the Walker threshold, where we find, that the domain wall is mainly driven by the temperature dependence of the exchange stiffness [2,3]. Additionally we show that the effect of the entropic torques should be larger than the angular momentum transfer from the magnon current [4,5]. Since our argument on thermodynamic principles, mainly the maximization of entropy, is rather general, it should not be restricted to transverse domain walls in ferromagnets only. Therefore, we will also discuss its applicability for different magnetic systems as antiferromagnets, where we expect the DW to move to hotter regions as well. We acknowledge financial support by the DFG through SFB 767. References: [1] D. A. Garanin, Phys. Rev. B 55, 3050 (1997), [2] D. Hinzke and U. Nowak, Phys. Rev. Lett. 107, 027205 (2011), [3] F. Schlickeiser, et al., Phys. Rev. Lett. 113, 097201 (2014), [4] W. Jiang et al., Phys. Rev. Lett. 110, 177202 (2013), [5] D. A. Kovalev et al., Europhys. Lett. 97, 67002 (2012).

MA 9.5 Mon 16:30 H 0112

Probing the linear relation of interfacial Dzyaloshinskii-Moriya interaction and Heisenberg exchange — Hans Nembach[1], Justin Shaw[1], •Mathias Weiler[1,2], Emilie Jué[1], and Thomas Silva[1] — [1]National Institute of Standards and Technology, Boulder, CO, USA — [2]Walther-Meißner-Institut, Garching, Germany

The exchange interaction is the fundamental quantum-mechanical mechanism responsible for ferromagnetism. While the symmetric Heisenberg exchange favors the parallel alignment of spins, the antisymmetric Dzyaloshinskii-Moriya interaction (DMI) is responsible for chiral magnetic ordering. Moriya calculated that the DMI and Heisenberg exchange interactions should be proportional to each other in the bulk solid, hematite. Up to now, this theoretically predicted proportionality was untested. Here, we use optical spin-wave spectroscopy (Brillouin light scattering) to determine the DMI-induced asymmetric shift of the spin-wave dispersion for thermal Damon-Eshbach spin waves in a series of $Ni_{80}Fe_{20}$/Pt thin film bilayer samples [1]. This allows us to directly extract the magnitude and direction of the interfacial DMI. We compare the extracted DMI to the independently measured Heisenberg exchange integral. The $Ni_{80}Fe_{20}$-thickness-dependencies of both the microscopic symmetric- and antisymmetric-exchange are identical, as was originally proposed by Moriya for a bulk system. This allows to predict the influence of the DMI on spin-orbit torque applications.

[1] Nembach et al. arXiv:1410.6243

MA 9.6 Mon 16:45 H 0112

Interfacial Dzyaloshinskii-Moriya interaction in Ta\CoFeB\MgO nanowires — •R. Lo Conte[1,2], E. Martinez[3], A. Hrabec[4], A. Lamperti[5], T. Schulz[1], L. Nasi[6], L. Lazzarini[6], B. Ocker[7], C. H. Marrows[4], T. A. Moore[4], and M. Kläui[1,2] — [1]Johannes Gutenberg Universität-Mainz, Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Mainz, Germany — [3]Universidad de Salamanca, Salamanca, Spain — [4]University of Leeds, Leeds LS2 9JT, U.K. — [5]Laboratorio MDM, IMM-CNR, Agrate Brianza, Italy — [6]IMEM-CNR, Parma, Italy — [7]Singulus Technologies, Kahl am Main, Germany

We use domain wall motion due to spin orbit torques to quantify the Dzyaloshinskii-Moriya interaction (DMI) at the Ta\CoFeB interface in out-of-plane magnetized nanostructures with structural inversion asymmetry [1]. Current-induced domain wall motion (CIDWM) experiments were carried out in Ta\Co20Fe60B20\MgO nanowires and the DW motion is imaged by differential Kerr microscopy technique. We find that the velocity of the DW is strongly affected by the presence of a longitudinal magnetic field, resulting in a different velocity for the up-down and down-up domain walls at fixed current density and magnetic field. Such results are interpreted by the spin-Hall effect-torque model, where the chirality of the domain walls is fixed by the DMI at the [heavy metal]\ferromagnet interface. The DMI is found to depend on the B diffusion to the Ta interface, which is a consequence of the annealing process used to obtain the desired perpendicular magnetic anisotropy. [1] R. Lo Conte et al., arXiv: 1409.3753 (2014).

15 min. break

MA 9.7 Mon 17:15 H 0112

Spin-transfer torque effects in the dynamic forced response of the magnetization of nanoscale ferromagnets in superimposed ac and dc bias fields in the presence of thermal agitation — •William Coffey[1], Yuri Kalmykov[2], Sergey Titov[3], Declan Byrne[1], and Jean Wegrowe[4] — [1]Department of Electronic and Electrical Engineering, Trinity College, Dublin 2, Ireland — [2]Université de Perpignan Via Domitia, Laboratoire de Mathématiques et Physique, F-66860, Perpignan, France — [3]Kotelnikov Institute of Radio Engineering and Electronics of the Russian Academy of Sciences, Vvedenskii Square 1, Fryazino, Moscow Region, 141120, Russia — [4]Laboratoire des Solides Irradiés, Ecole Polytechnique, 91128 Palaiseau Cedex, France

Spin-transfer torque (STT) effects on the stationary forced response of nanoscale ferromagnets driven by an ac magnetic field of arbitrary strength in the presence of thermal fluctuations are investigated via the generic nanopillar model of a spin-torque device. The STT effects are treated via the magnetic Langevin equation generalized to include the Slonczewski STT term thereby extending the statistical moment method to the forced response. Hence, the dynamic susceptibilities, frequency-dependent dc magnetization, dynamic hysteresis loops, etc. are evaluated for arbitrary ac field direction, strength and spin polarization, highlighting STT effects on both the low-frequency thermal relaxation processes and the high-frequency ferromagnetic resonance, demonstrating a pronounced dependence of such characteristics on the spin polarization current, allowing interpretation of STT experiments.

MA 9.8 Mon 17:30 H 0112

Lifetime of high-energy magnons in ultrathin FePd(001) films — •Huajun Qin[1], Khalil Zakeri Lori[1], Arthur Ernst[1,2], Leonid M. Sandratskii[1], Pawel Buczek[1], Alberto Marmodoro[1], Tzu-Hung Chuang[1], Yu Zhang[1], and Jürgen Kirschner[1,3] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [2]Wilhelm Ostwald Institut für Physikalische und Theoretische Chemie, Universität Leipzig, Linnéstr. 2, 04103 Leipzig, Germany — [3]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany

The lifetime of high-energy magnons in itinerant ferromagnets is very short due to their decay into the single-particle Stoner excitations. This damping mechanism is commonly referred to as Landau damping.

We present the results of our investigations of magnons' lifetime in ultrathin FePd(001) alloy films grown on Pd(001), obtained by means of spin polarized electron energy loss spectroscopy. It is observed that the magnons' lifetime in ultrathin FePd alloy films is rather long compared to the one in Fe films grown on other substrates [1]. First-principles calculations revealed that the long magnons' lifetime has its origin in the peculiar electronic hybridizations between Fe and Pd atoms. These electronic hybridizations lead to the suppression of the relaxation channels of high-energy magnons and result in a long magnons' lifetime. We anticipate that the long lifetime of magnons in FePd films makes them as good candidates for terahertz magnonics.

[1] Y. Zhang, T.-H. Chuang, Kh. Zakeri, and J. Kirschner, PRL **109**, 087203 (2012).

MA 9.9 Mon 17:45 H 0112

Spin-orbit torques in $L1_0$-FePt/Pt thin films driven by electrical and thermal currents — •Guillaume Géranton, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Using the linear response formalism for the spin-orbit torque (SOT) we compute from first principles the SOT in a system of two layers of $L1_0$-FePt(001) deposited on an fcc Pt(001) substrate of varying thickness [1]. We predict SOTs of the same order of magnitude than the ones computed in Co/Pt thin films [2]. Moreover, the good matching of the lattice constants of Pt and $L1_0$-FePt(001) allows these films to be grown epitaxially. The comparison of theory with experiment would therefore be simplified and fruitful to understand the underlying mechanisms that contribute to SOTs in thin films. Taking the system at hand as an example, we also compute the values of the thermal spin-orbit torque (T-SOT). We predict that the gradients of temperature that can be experimentally created in this type of systems will cause a detectable torque on the magnetization.

We gratefully acknowledge funding under the HGF-YIG programme VH-NG-513 and SPP 1538 of DPG.

[1] G. Géranton, F. Freimuth, S. Blügel, Y. Mokrousov (2014), arXiv:1409.1767

[2] F. Freimuth, S. Blügel, Y. Mokrousov, PRB **90**, 174423 (2014)

MA 9.10 Mon 18:00 H 0112

Current-induced spin torque resonance of a magnetic insulator — •Michael Schreier[1,2], Takahiro Chiba[3], Arthur Niedermayr[1,2], Johannes Lotze[1,2], Hans Huebl[1,4], Stephan Geprägs[1], Saburo Takahashi[3], Gerrit E. W. Bauer[3,5,6], Rudolf Gross[1,2,4], and Sebastian T. B. Goennenwein[1,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, DE — [2]Physik-Department, TU München, Garching, DE — [3]Institute for Materials Research, Tohoku University, Sendai, JP — [4]Nanosystems Initiative Munich, DE — [5]WPI Advanced Institute for Materials Research, Tohoku University, Sendai, JP — [6]Kavli Institute of NanoScience, Delft University of Technology, Delft, NL

We report the observation of spin transfer torque induced ferromagnetic resonance in the ferromagnetic insulator yttrium iron garnet (YIG). An alternating current at gigahertz frequencies in the Pt layer of a YIG/Pt sample generates Oersted and effective anti damping (spin transfer) torque fields inducing ferromagnetic resonance in the YIG. This can be observed as DC spin pumping and spin Hall magnetoresistance rectification voltages. To disentangle the two excitation and detection processes we investigate YIG layers of different thickness, which impacts the magnitude of the effective damping torque field. In ultrathin yttrium iron garnet films the magnitude of the spin transfer torque actuated magnetization dynamics is substantially enhanced and dominates that generated by the Oersted field. We discuss the determination of spurious effects and present a quantitative analysis. Support by the DFG through SPP1538 is gratefully acknowledged.

MA 9.11 Mon 18:15 H 0112

Magnetic excitations in Co films on Ir(001) and Rh(001) substrates: The role of interfacial electronic hybridization — •Ying-Jiun Chen[1], Khalil Zakeri Lori[1], Arthur Ernst[1], Huajun Qin[1], Tzu-Hung Chuang[1], Yang Meng[1], and Jürgen Kirschner[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany

The hybridization between the electronic states of an ultrathin magnetic film and the substrate is a notable effect, which modifies the magnetic properties of the film. In order to address this effect we have investigated the magnetic properties and high-energy magnetic excitations in ultrathin Co films, with a thickness of 1-2 monolayer (ML), grown on Ir(001) and Rh(001). The magneto-optical Kerr effect measurements revealed that the magnetic easy axis for both systems is lying in the film plane. It was found that the in-plane magnetic anisotropy energy of the Co films grown on the Ir(001) surface is rather large, compared to the one of the Co films on Rh(001). The high-energy magnetic excitations were investigated by means of spin-polarized electron energy loss spectroscopy. It was observed that the magnon dispersion relation for both Co/Ir(001) and Co/Rh(001) systems is nearly the same. Combined with first-principles calculations, we discuss how the interfacial hybridization of the Co_{3d}-Ir_{5d} and Co_{3d}-Rh_{4d} electronic states influences the magnetic anisotropy energy and high-energy magnetic excitations in these systems.

MA 9.12 Mon 18:30 H 0112

Vortex Core Motion driven by Thermal Spin Transfer Torque — •Michael Vogel[1], Jean-Yves Chauleau[1], Claudia Mewes[2], Tim Mewes[2], and Christian Back[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany — [2]MINT Center / Depeartment of Physics and Astronomy, University of Alabama, Tuscaloosa, AL, USA

The dynamical properties of spin caloric devices play a key role in their design and functionality. Especially the estimation of the required temperature gradients is essential for a successful development of new spin caloritronic applications and experiments. We report on theoretical investigations of magnetic vortex motion driven by thermal spin transfer torque for static and time dependent temperature gradients. The magnetization dynamic of the vortex core is well described by the Landau-Lifshitz-Gilbert equation including the adiabatic and non-adiabatic spin transfer torque term [S. Zhang and Z. Li, Phys. Rev. Lett 93, 127204 (2004)]. Using the Onsager relations within a three current model [S.D. Brechet, and J.-P. Ansermet, Phys. Status Solidi RRL 5, No. 12, 423*425 (2011); K.M.D. Hals, A. Brataas, and G.E.W. Bauer, Solid State Com. 150, 461465 (2010)] one can write the involved current density as a spin polarization factor times a current density derived from the temperature gradient which is determined by experimental measurements in combination with finite element calculations. We report on the dynamic behavior of such systems and the importance of the interplay of the spatial and temporal shape of the heat gradient in combination with the geometry of the magnetic structure.

MA 10: Magnetic Heuslers, Half-metals, Semiconductors and Oxides

Time: Monday 15:00–18:45 Location: H 1012

MA 10.1 Mon 15:00 H 1012

The role of spin-orbit coupling and complex magnetism in the electronic structure of bulk and thin film $CaIrO_3$ — •Kerstin Dörr, Yuriy Mokrousov, Stefan Blügel, and Marjana Lezaic — Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

One of the very lively research fields in condensed-matter physics is focussing on transition-metal oxides (TMO), due to a large variety of interesting physical properties they present that can be exploited in potential applications. Especially the question what drives a TMO to become insulating or metallic is an ongoing discussion, owing to the complexity of the physical effects that play a role in such systems. E.g., in well studied $3d$ compounds the enhanced onsite Coulomb repulsion drives the system into an insulating state. In contrast to this, in $5d$ TMOs the Coulomb repulsion is reduced but its interplay with the spin-orbit coupling can again force the system to become insulating, undergoing the so called spin-orbital Mott transition. In this talk we will discuss these effects in the $5d$ TMO $CaIrO_3$ in orthorhombic perovskite form. Furthermore, we will present our first-principles study of the influence of magnetism and the modifications of the bulk bandstructure of this compound in thin films.

MA 10.2 Mon 15:15 H 1012

Anisotropy of magnetic interactions in β-Li_2IrO_3 — •Alexander Yaresko and Yoshiro Nohara — MPI FKF, Stuttgart, Germany

Iridium oxides α-Li_2IrO_3 and α-Na_2IrO_3 with a honeycomb lattice attracted much attention as possible candidates for realization of a Kitaev model with bond-dependent anisotropic magnetic interactions. Recently, another complex Ir oxide β-Li_2IrO_3 has been synthesized which is expected to be close to forming a Kitaev spin liquid. Ir ions in this oxide form a “hyper-honeycomb” lattice, a three-dimensional analogue of the honeycomb lattice of α-Na_2IrO_3. We performed LDA+U band structure calculations for β-Li_2IrO_3 with different magnetic orderings of Ir magnetic moments. The results are mapped onto a model which includes isotropic Heisenberg-like as well as bond-dependent anisotropic interactions. It is shown that the contribution of the anisotropic interactions to the magnetic energy is at least as strong as isotropic one.

MA 10.3 Mon 15:30 H 1012

Kitaev interactions in $4d_5$ honeycomb systems: Li_2RhO_3 vs $RuCl_3$ — •Ravi Yadav, Vamshi Mohan Katukuri, Satoshi Nishimoto, Liviu Hozoi, and Jeroen Van Den Brink — Institute forTheoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany

While electronic-structure calculations within either the wavefunction-based [1,2] or density functional theory [3] framework agree on the magnitude and the signs of the Kitaev couplings in $5d^5$ honeycomb iridates, much less is known on these effective exchange constants in the $4d^5$ analogues. We here discuss the outcome of many-body, wavefunction-based quantum chemistry computations for these interaction parameters in Li_2RhO_3 and $RuCl_3$. The ab initio values for the nearest-neighbor couplings, both isotropic and anisotropic, are further fed to an extended spin Hamiltonian that includes additionally 2^{nd}- plus 3^{rd}-neighbor Heisenberg terms and on the basis of exact-diagonalization calculations predictions are made for the nature of the magnetic ground states in these compounds.

[1] Vamshi M. Katukuri et al, New J. Phys. 16 (2014) 013056.
[2] Satoshi Nishimoto et al, arXiv:1403.6698.
[3] Youhei Yamaji et al, Phys. Rev. Lett. 113, 107201.

MA 10.4 Mon 15:45 H 1012

Magnetic excitations in the anomalous ferromagnetic metal $SrRuO_3$ — •Stefan Kunkemöller[1], A. Agung Nugroho[2], Yvan Sidis[3], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, D-50937, Germany — [2]Faculty of Mathematics and Natural Sciences, Jl. Ganesa 10 Bandung, 40132, Indonesia — [3]Laboratoire Léon Brillouin, CEA Saclay, F-91191 Gif sur Yvette Cedex, France

$SrRuO_3$ is the infinite-layer perovskite of the Ruddlesden-Popper series of ruthenates. It exhibits ferromagnetic ordering and highly anomalous electronic properties. At Cologne University we could recently grow several $SrRuO_3$ single-crystals with a mass of few grams each using a Canon Machinery image furnace. Inelastic neutron scattering experiments on the magnon dispersion were performed at the 2T thermal triple-axis spectrometer of the Laboratoire Léon Brillouin in Saclay. At intermediate energies and low temperature an isotropic magnon dispersion is observed as it is expected for a nearly cubic material. The magnon dispersion along the three main-symmetry directions of the pseudo-cubic material can be described by simple spin-wave theory with a gap of 1.7(2) meV and a magnetic stiffness constant of 95(5) meVÅ^2. Strong magnon-like scattering is observed till 280 K and there is no evidence for essential softening of the dispersion across the magnetic ordering in contrast to any simple Heisenberg model.

MA 10.5 Mon 16:00 H 1012

Induced magnetic monopoles on magnetoelectric surfaces — •Quintin Meier, Michael Fechner, and Nicola A. Spaldin — ETH Zürich, Department for Materials, Zürich, Switzerland

We calculate the magnetic fields caused by a point charge adjacent to the surface of a magnetoelectric, that is a material in which an electric field induces a magnetization and vice versa. The electric point charge induces monopolar and quadrupolar magnetic fields in the magnetoelectric[1]. However in the outside area the field is purely monopolar ($B \propto r^{-2}$). We show that this behaviour is valid not only for materials with isotropic magnetoelectric responses[2], but for the broader class of uniaxial magnetoelectric materials as well. Moreover, our analysis of the field strength shows that a already single charge near the prototypical uniaxial magnetoelectric, Cr_2O_3, induces a monopolar stray field which should be detectable by experiment. [1] Fechner, M. et al., Phys. Rev. B. 89, 184415 (2014) [2] Qi, X.-L. et al., Science, 323(5), 1184 (2009)

MA 10.6 Mon 16:15 H 1012

Ab initio study of the magnetic properties of Sr_2FeMoO_6 with defects — •Martin Hoffmann[1,2], Victor N. Antonov[3], Wolfram Hergert[1], Arthur Ernst[2,4], and Lev Bekenov[3] — [1]Martin Luther University Halle Wittenberg, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]Institute for Metal Physics, Kiev, Ukraine — [4]University Leipzig, Germany

We used first-principle calculations with the Korringa-Kohn-Rostoker Green function method to systematically investigate the electronic and magnetic properties of Sr_2FeMoO_6 (SFMO). We applied self-interaction correction and GGA+U to take into account the correlation effects and obtain the half-metallic nature of the material. The Curie temperature T_C was obtained from calculated magnetic exchange interactions which were used in a Monte Carlo simulation.

For a continuously increasing U parameter, SFMO became half-metallic but the T_C decreased below the reported values for bulk SFMO. We investigated possibilities to find a better agreement with experiment. This might be shortcomings in the description of the electronic structure, changes in the valency of Fe or the appearance of defects like antisite disorder and oxygen vacancies.

In addition, x-ray absorption spectra were simulated with the linear muffin-tin orbital method and compared to experimental results. A good agreement was only obtained by considering a contribution of Fe^{2+} and oxygen vacancies.

MA 10.7 Mon 16:30 H 1012

Electrical and magnetic characterization of electrospun $La_{1-x}Sr_xMnO_3$ nanowires — •Thomas Karwoth[1], Xian Lin Zeng[1], Andrew Kostrubanic[2], Michael Koblischka[1], and Uwe Hartmann[1] — [1]Institute of Experimental Physics, Saarland University, P.O.Box 151150, D-66041 Saarbrücken, Germany — [2]Drexel University, Philadelphia, Pennsylvania 19104, USA

Nanowires of the material class $La_{1-x}Sr_xMnO_3$ with different doping levels $x = 0.2$, 0.33, 0.5 were fabricated employing a sol-gel-process via electrospinning and a subsequent thermal treatment process based on thermal gravity analysis results. Investigations by means of scanning electron microscopy revealed an average diameter of the resulting nanowires of around 220 nm and a length of more than 50 μm. The chemical phases of the samples have been confirmed via X-Ray diffraction. The nanowires are polycrystalline with a grain size of about 15-17 nm, which corresponds to the result obtained from transmission electron microscopy. Analyses of the electronic transportation properties and of the magnetoresistive effects of the nanowire samples were carried out by a four probe measurement inside a bath cryostat. Of interest are size effects and the dependence of the properties on the stoichiometry. SQUID measurements of $M(T)$ and $M(H)$ at room temperature, 77 K and 4.2 K were carried out as well, revealing the soft magnetic character of the nanowires.

MA 10.8 Mon 16:45 H 1012

High quality Yttrium Iron Garnet grown by room temperature pulsed laser deposition and subsequent annealing — •Christoph Hauser[1], Tim Richter[1], Nico Homonnay[1], Bodo Fuhrmann[2], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale) , Germany

Yttrium Iron Garnet is a room temperature ferrimagnet, which has recently gained importance due to its application in spin pumping and the investigation of the inverse spin Hall effect [1]. The linewidth and damping which can be observed in ferromagnetic resonance are typically the most important quality criteria for YIG films. Ultrathin films with very low damping constants can been grown by pulsed laser deposition [2]. We have investigated different methods of PLD growth to obtain high quality YIG thin films. Using PLD at high substrate temperature, 20 nm thick YIG films with a FMR linewidth of 12 Oe at 9.6 GHz could be obtained. Even better quality is achieved when the YIG is deposited at room temperature and subsequently annealed in an oxygen atmosphere, where we can obtain a linewidth of less than 2 Oe at 9.6 GHz. The layers show high crystalline quality and subnanometer surface roughness in X-ray diffraction and reflectometry. We are going to present the results of various experiments using different layer thicknesses and annealing parameters. [1]K. Uchida et al., Appl. Phys. Lett. 97, 252504 (2010) [2]d'Allivy et al., Appl. Phys. Lett. 103, 82408 (2013)

15 min. break

MA 10.9 Mon 17:15 H 1012

Magnetostriction in pulsed magnetic fields up to 70 T - the spin states in $LaCoO_3$ — •Mathias Doerr[1], Martin Rotter[2], Sergey Granovsky[1], Michael Loewenhaupt[1], and Zhaosheng S. Wang[3] — [1]TU Dresden, Institut für Festkörperphysik, D-01062 Dresden — [2]MPI for Chemical Physics of Solids, D-01187 Dresden — [3]FZ Dresden-Rossendorf, Hochfeld-Magnetlabor, D-01314 Dresden

Magnetoelastic investigations in pulsed magnetic fields with a pulse duration of about 10 ms are still challenging. The new optical FBG method overcomes the difficulty of mechanical noise and offers a resolution in the order of 10^{-6}. As an example, the spin states in $LaCoO_3$, important for understanding of spin-dependent transport in oxides, were analyzed by longitudinal and transversal magnetostriction measurements up to 70 T. The data show a sharp magnetic transition at about 60 T accompanied by a large volume, but only small distortion effect. Supplemented by electronic energy calculations this confirms a correlated low-to-high spin (LS/HS) transition in contrast to the propagated intermediate spin-state scenario (LS-IS-HS).

MA 10.10 Mon 17:30 H 1012

Magnetic properties of the double perovskite Sr2FeOsO6: microscopic insights from ab-initio density-functional theory study — •sudipta kanungo[1], binghai yan[1,2], martin jansen[3], and claudia felser[1] — [1]Max-Planck-Institut fur Chemische Physik fester Stoffe, 01187 Dresden, Germany — [2]Max-Planck-Institut fur Physik komplexer Systeme, 01187, Dresden, Germany — [3]Max-Planck-Institut fur Festkorperforschung, 70569 Stuttgart, Germany

Using density-functional theory calculations, we investigated the electronic and magnetic properties of the ordered 3d-5d double perovskite Sr2FeOsO6, which has recently drawn attention for interesting two step antiferromagnetic (AFM) phase transitions at low temperature in experiments. The calculated effective magnetic exchange interactions reveal the importance of long-range super-super-exchange interactions in this compound. The competition between the weak ferromagnetic Os-O-Fe short-range interaction and strong AFM Os-O-Fe-O-Os long-range interaction induces strong magnetic frustration along the crystallographic c axis. This frustration is proposed to drive the magnetic phase transition between two AFM phases in the low temperature and related lattice distortion, which were observed in experiment.

[Ref: Sudipta Kanungo, Binghai Yan, Martin Jansen, and Claudia Felser; Phys. Rev. B 89,214414 (2014)]

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MA 10.11 Mon 17:45 H 1012

Structure and magnetic interactions in Ba3-xSrxCr2O8 — •Alsu Gazizulina, Henrik Grundmann, and Andreas Schilling — Physik-Institut of University of Zurich, Zurich, Switzerland

The spin dimer systems Ba3Cr2O8 and Sr3Cr2O8 are two candidates for the Bose Einstein condensation (BEC) of magnetic quasiparticles (triplons). We have recently reported on a peculiar non-linear tuning of the magnetic interaction constant J0 in the corresponding solid solution Ba3-xSrxCr2O8 by varying the Sr content x. By performing theoretical calculations based on the crystal structure, we could well reproduce the observed variation in J0. As the critical field Hc of the triplon BEC strongly depends on the magnetic interactions in the system, we have also probed the dependency of this critical field on x. Here, we report on the observed relationship between J0(x) and Hc(x) in Ba3-xSrxCr2O8.

MA 10.12 Mon 18:00 H 1012

Investigation Of Crystal Structure, Magnetic And Transport Properties Of La2Ni(1-X)Mn(1+X)O6 (X= -0.2; 0; 0.2; 0.4; 0.6; 0.8; 1.0) — •Gizem Aslan Cansever[1,3], Franziska Scheibel[2], Mehmet Acet[2], Ergun Tasarkuyu[1], and Michael Farle[2] — [1]Mugla Sitki Kocman University, Science Faculty,48000 Mugla, Turkey — [2]Faculty of Physics, University of Duisburg-Essen, D-47057 Duisburg — [3]IFW Dresden, Institute for Solid State Research, D-01069 Dresden, Germany

La2NiMnO6 double perovskit materials show semiconductor and ferromagnetic properties which are important in terms of spintronics applications. In this study, La2Ni(1-x)Mn(1+x)O6 materials were investigated in relation to structural, electrical and magnetic properties with varying Ni and Mn concentrations. The compounds were prepared by using the sol-gel method and then heat treated in a cylindrical furnace at 1000 °C for 24 hours. The energy dispersive x-rays (EDX) analysis shows that the actual compositions of the compounds are very close to the targeted compositions and no impurity phase is present. From the analysis of x-ray diffraction data, it was observed that La2Ni1.2Mn0.8O6 and La2NiMnO6 compounds have monoclinic structure (P21/n), but the rest of the compounds exhibit the orthorhombic (Pbnm) structure. Electrical resistivity measurements show that all compunds have semiconductor behaviour. The magnetization measurements show that La2Mn2O6 incorporates both antiferromagnetic and ferromagnetic interactions. All other investigated compounds show ferromagnetic behaviour.

MA 10.13 Mon 18:15 H 1012

Neutron scattering studies of the field-induced magnetic phases of the Helimagnetic Spinel compound $ZnCr_2Se_4$. — •Alistair Cameron[1], Dmytro Inosov[1], Pavlo Portnichenko[1], Maksym Surmach[1], and Vladimir Tsurkan[2] — [1]Institut für Festkörperphysik, Technische Universität Dresden, 01069 Dresden — [2]Universität Augsburg, 16135 Augsburg

$ZnCr_2Se_4$ is a magnetoelectric compound with a cubic spinel (m3m) structure. Magnetic materials with a spinel structure present a strong opportunity to study the interplay between spin, charge and orbital degrees of freedom in a topologically frustrated environment. Particularly, those exhibiting magnetoelectric effects are of particular interest. In zero applied field, the Cr^{3+} S=3/2 moments form an incommensurate magnetic ground state with a screw structure along the (001) direction with a T_N of 20 K, which transforms into a spin spiral state in a magnetic field.

We have performed small angle neutron scattering (SANS) measurements on this spin structure for fields applied along the (100) and (110) directions. We find a field and temperature dependent structure for both field directions, with the reciprocal space propagation vector decreasing with increasing temperature and applied field, and showing a sharp jump in propagation vector across the domain selection transition. The phase diagram deduced by SANS for both field directions appear identical. In addition to investigating the AFM phase, we also probed the proposed spin nematic phase observing no SANS signal in this state, suggesting a lack of long range order.

MA 10.14 Mon 18:30 H 1012

Intrinsic resonances in the Mn spin system of ZnMnSe quantum wells — •Janina Rautert[1], Jörg Debus[1], Vitalii Yu. Ivanov[2], Sergey M. Ryabchenko[3], Andrei A. Maksimov[4], Dmitri R. Yakovlev[1,5], and Manfred Bayer[1,5] — [1]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany — [2]Institute of Physics, Warsaw, Poland — [3]Institute of Physics, Kiev, Ukraine — [4]Institute of Solid State Physics, Chernogolovka, Russia — [5]Ioffe Physical-Technical Institute, St. Petersburg, Russia

Diluted magnetic semiconductors (DMS) are regarded as model structures for new types of spin electronic devices aiming at the control of the spin degree of freedom of the carriers. Although it is known that the spin-lattice interaction of the localized Mn spins is strongly accelerated by the concentration of these spins [1], a comprehensive understanding of the real mechanism of this acceleration is still missing. We observe in the stationary and time-resolved giant Zeeman energy of the exciton in ZnMnSe quantum wells a number of minima around specific magnetic fields below 10 T. These minima depend on the optical power and Mn concentration; the photoluminescence linewidth and amplitude are also affected. We propose that at these magnetic fields the levels of excited single Mn ions and quick-relaxing antiferromagnetically coupled pairs of Mn ions have anti-crossings, thus providing highly efficient magnetization relaxation. These novel results shall contribute to the understanding of spin interactions within the Mn spin system in II-VI DMS structures. [1] J. Debus et al., Phys. Rev. B 82, 085448 (2010).

MA 11: Focus: Progress in Spin-Polarized Electron Spectroscopies

Organizers W. Kuch, W. Wulfhekel, C.M. Schneider

The electron spin plays a major role for many effects in solid state physics. The advance of the field of spintronics will rely on the efficient manipulation and conservation of electronic spin states in matter. Experimental methods that allow the application or detection of spin-polarized electrons are highly desired for investigations of materials with complex spin textures. This field is receiving renewed interest, for example by the prospect of using topologically protected spin textures for the creation or manipulation of spin-polarized electron currents. Complex spin structures that owe their presence to the competition of different spin-orbit-coupling effects are also in the focus of current interest.

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

Invited Talk MA 11.1 Mon 15:00 EB 301

Acoustic und standing spin wave modes in ultra-thin 3d metal films — •Harald Ibach — Peter Grünberg Institute, Research Center Jülich, Germany

The spin wave spectrum of well-ordered ferromagnetic N-layer films consists of N modes with zero to N-1 nodes inside the film. The energy of these spin waves as function of the wave vector parallel to the surface may be studied by using inelastic scattering of low-energy electrons. Because of low energy resolution (FWHM=20-40meV) early work on cobalt and iron films had to focus on the high-energy and high wave vector regime q|| > 3nm-1 where the damping of the modes due to Stoner excitations is extremely large. For fcc cobalt films this has led to the erroneous interpretation that (i) electrons interact primarily with the surface mode of the film, that (ii) the surface mode is the lowest energy mode and (iii) that the dispersion of that mode is well described by a simple nearest-neighbor Heisenberg model with a single, layer-independent exchange coupling constant. With improved electron spectrometers featuring 3meV resolution we are now in the position to study the low momentum regime q|| < 3nm-1 where the spectrum consists of a series of separate, well-defined spin wave peaks. The study of these spin waves as function of the film thickness reveals that the exchange coupling constants near surface and interface differ substantially from those in the interior of the film. Spin wave spectroscopy has thus become a tool to study the layer dependence of the exchange coupling.

Invited Talk MA 11.2 Mon 15:45 EB 301

Magnetic structure and magnetic anisotropy on the atomic scale — •Chunlei Gao — Key Laboratory of Artificial Structures and Quantum Control (Ministry of Education), Department of Physics and astronomy, Shanghai Jiao Tong University, Shanghai, China

Spin-polarized scanning tunneling microscopy (Sp-STM) has demonstrated its ability in resolving magnetic structure on the atomic scale even in the complex noncollinear case. The exclusive determination of the moment orientation of each single magnetic atoms still remains as a challenge. In this presentation, I will show that by taking the advantage of Sp-STM operating in a vectorial field, magnetic structure and magnetic anisotropy are identified on various magnetic surfaces on the atomic scale.

15. min. break

Invited Talk MA 11.3 Mon 16:30 EB 301

Spin-resolved photoelectron spectroscopy with high efficiency and potential of full momentum analysis — •Shigemasa Suga — MPI of Microstructure Physics, Halle, Germany — Inst. of Sci. & Ind. Research, Osaka University, Osaka, Japan

Spin information on electronic structures in solids can directly be obtained by photoelectron spectroscopy (PES) and angle-resolved PES (ARPES) with use of spin detectors. However,the rather low efficiency of spin detection was a barrier for its wide use. In order to overcome this difficulty, various spin detectors were so far invented after Au Mott detector. W(001)-SPLEED[1], Fe(001)p1x1-O VLEED[2] as well as Au/Ir(001)[3] are such examples. Brief description of spin detectors and their performance as well as examples of experiments are discussed.

Since prompt measurement of spin polarization Ps with high resolutions of momentum and binding energy is required, simultaneous two-dimensional detection, Ps(EB(kx,ky)), by use of the so-called spin-momentum microscope based on a PEEM input lens and a tandem double hemispherical analyzer is developed[4]. Examples of relatively low photon energy experiments and the prospect of its use in the soft- and hard X-ray regions will be discussed.——[1]J.Kirschner, Polarized Electrons at Surfaces, Springer Tracts in Modern Physics, vol.106 (1985).[2] T.Okuda et al., J.Electron Spectrosc. Rel. Phenom. (2014) in press and Rev.Sci.Instrum.79,123117 (2008).[3] J.Kirschner et al., Phys.Rev.B88, 125419 (2013). [4] C.Tusche et al., Ultramicroscopy 130, SI 70-76 (2013) and an invited talk, Surface Science session in this conference.

Invited Talk MA 11.4 Mon 17:00 EB 301

High-efficiency spin-resolved ARPES with a TOF-based exchange polarimeter — •Chris Jozwiak — Advanced Light Source, Lawrence Berkeley National Lab, Berkeley, California, U.S.A.

A strong fundamental interest in the spin-degree of freedom in electronic systems has driven decades of persistence and creativity in developing a range of methods for spin-resolved photoemission spectroscopy. The demanding but powerful technique of Spin- and Angle-Resolved Photoemission Spectroscopy (Spin-ARPES) has steadily expanded in the last decade due to an increasing demand for probing momentum dependent electronic spin in a wide variety of materials. Strongly spin-orbit coupled materials, including Topological Insulators (TIs), have particularly stimulated advancement of the technique due to characteristic momentum-dependent spin-textures. I will present an overview of the "spin-TOF analyzer", an instrument developed at the ALS for high-resolution and high-efficiency spin-ARPES [1]. The analyzer combines the efficiency of low energy exchange scattering spin detection (e.g. [2]) with the parallel energy resolution of time-of-flight (TOF) detection (e.g. [3]). I will describe details of this unique combination and present examples of its use with both synchrotron light and lab-based laser systems, focusing on the observations of surprising spin-polarization effects in the photoemission from TIs [4]. — [1] C. Jozwiak et al., Rev. Sci. Instrum. 82, 053904 (2010). [2] Hillebrecht et al., Rev. Sci. Instrum. 73, 1229 (2002). [3] N. Müller et al., J. El. Spectr. Rel. Phenom. 72, 187 (1995). [4] C. Jozwiak et al., Nature Phys. 9, 293 (2013).

Invited Talk MA 11.5 Mon 17:30 EB 301

Prospects of Multichannel Spin Detection — •Gerd Schönhense — Institut für Physik, Johannes Gutenberg-Universität, 55128 Mainz

The high level of sophistication of a modern hemispherical analyzer (HA), detecting N>10^4 data points in parallel, contrasts with present days' spin detectors. Their figures of merit (FoM) only slightly improved during the last decades. Multichannel spin detection in combination with a HA [1] was a major step forward, owing to its 2D figure of merit FoM_2D=N*FoM (with N=800 in [1]). This detector e.g. allows probing the half-metallicity of Heusler compounds like Co2MnSi [2], whose high reactivity poses a challenge to reliable spin measurements. Going further in parallelization, an imaging spin filter in a cathode-lens type microscope yields unprecedented spin-resolving acquisition speed with N=5000 data points in parallel [3]. Finally, a 3D-method for spin-resolved momentum microscopy with utmost efficiency is developed by Univ. of Mainz and Max-Planck-Institute in Halle. This instrument implements the superior resolution and parallel acquisition capability of ToF photoemission microscopy. A challenging target for multichannel spin detection is Spin-HAXPES, suffering from extremely low cross sections. – [1] M.Kolbe et al., PRL 107 (2011) 207601; [2] M.Jourdan et al., Nature Mat. 5 (2014) 3974; [3] C.Tusche et al., APL 99 (2011) 032505 and C.Tusche, talk at this conference.

MA 12: Poster Session on Ferroic Domain Walls - Multiferroics (DF with KR/MA/TT)

Sponsored by NT-MDT

Part of the 3-days focus on ferroic domain walls:
Tutorial, Symposium (SYDW), and three Focused Sessions.

The goal of the poster session is to present the state of the art of the research on magnetic, ferroelectric, and multiferroic domain walls bringing interested scientist together in a stimulating environment in order to stimulate vivid topical discussions.

Time: Monday 19:00–21:00 Location: Poster C

MA 12.1 Mon 19:00 Poster C

Superdomains in $K_{0.9}Na_{0.1}NbO_3$ thin films on $NdScO_3$ substrates — •Jutta Schwarzkopf[1], Martin Schmidbauer[1], Dorothee Braun[1], Albert Kwasniewski[1], Jan Sellmann[1], and Michael Hanke[2] — [1]Leibniz Institute for Crystal Growth, Berlin, Germany — [2]Paul- Drude-Institut für Festkörperelektronik, Berlin, Germany

Incorporation of lattice strain in thin films gives rise to the creation of controlled arrays of domains and can lead to very complex domain structures. Understanding of strain induced domain formation will open the possibility to selectively influence film properties. Due to its orthorhombic symmetry (K,Na)NbO_3 films offer a large variety of ferroelectric and ferroelastic domain types. In this study $K_{0.9}Na_{0.1}NbO_3$ thin films were grown under slight compressive lattice strain on $NdScO_3$ substrates by MOCVD. Lateral PFM images of the (100) oriented films reveal bundles of ferroelectric domains along the [001] substrate direction and a width of 100-200 nm which are superimposed by ferroelastic domains forming regularly arranged herringbone patterns with a periodicity of 30 nm. The domain walls within the domain bundles are tilted alternatingly by $+15°$ and -15° with respect to the [110] orientation of the substrate. Grazing incidence x-ray diffraction experiments have shown that adjacent superdomain bands exhibit an in-plane monoclinic lattice distortion of 0.12°. We conclude that the hierarchical structure leads to a domain formation on two scales, which effectively release the misfit strain in the film induced by the substrate.

MA 12.2 Mon 19:00 Poster C

Advanced characterization of functional ferroelectric domain walls by X-ray photoelectron emission microscopy — •Jakob Schaab[1], Ingo P. Krug[2,3], Zewu Yan[4], Edith Bourret[4], Claus M. Schneider[3], Ramamoorthy Ramesh[4,5], Manfred Fiebig[1], and Dennis Meier[1] — [1]Department of Materials, ETH Zürich — [2]Institut für Optik und Atomare Physik, TU Berlin — [3]Forschungszentrum Jülich, PGI-6 — [4]Materials Science Division, LBNL Berkeley — [5]Department of Materials Science and Engineering, UC Berkeley

The observation of anomalous electronic transport at ferroelectric domain walls and its significance for nano-electronics triggered tremendous scientific interest. To date, the transport behavior and potential barriers at domain walls have been predominantly scrutinized by scanning probes. This, however, convolutes the intrinsic electronic properties with contact resistance and inhomogeneous probe fields, so that the detailed origin of the behavior remains obscured.

Here, we report on the capability of high-resolution X-ray photoemission electron microscopy (X-PEEM) to image and characterize ferroelectric domain walls contact-free and with nanometer resolution. In the ferroelectric semiconductor ErMnO3, we visualize ferroelectric domain walls by exploiting photo-induced charging effects and generate an electronic conduction map by analyzing the kinetic energy of photoelectrons. With this we open a pathway for non-destructive and element-specific studies of electronic and chemical domain-wall structures bypassing previous experimental limitations and significantly expanding the accessible parameter space.

MA 12.3 Mon 19:00 Poster C

Strain-induced defect-polarization coupling in $SrMnO_3$ films — •Carsten Becher[1], Laura Maurel[2], Ulrich Aschauer[1], Martin Lilienblum[1], Cesar Magen[2], Dennis Meier[1], Eric Langenberg[2], Morgan Trassin[1], Javier Blasco[3], Ingo Krug[4], Pedro Algarabel[3], Nicola Spaldin[1], Jose Pardo[2], and Manfred Fiebig[1] — [1]ETH Zürich, Zürich, Switzerland — [2]Instituto de Nanoscienciencia de Aragon, Zaragoza, Spain — [3]Departemento der Fisica de la Materia Condensada, Zaragoza, Spain — [4]Institut für Optik und Atomare Physik, Berlin, Germany

Epitaxial strain can stabilize new matter phases in thin films and is thus a degree of freedom to increase functionality. Here we demonstrate a novel polar phase in 20 nm $SrMnO_3$ films that are epitaxially grown under tensile strains by pulsed laser deposition. High resolution X-Ray diffraction and transmission electron microscopy confirm the crystalline quality of the tetragonal films. We use nonlinear optics to proof that strain induces polarity, and density functional theory to show that it simultaneously increases the concentration of oxygen vacancies. These vacancies accumulate at the polar domain walls where they establish an electrostatic barrier to electron migration. As a consequence, scanning probe microscopy shows that the electrical conductance is structured into isolated "nanocapacitors" which can be charged individually.

MA 12.4 Mon 19:00 Poster C

Raman spectroscopy for the characterization of ferroelectric materials: An Overview — •Michael Rüsing[1], Peter Mackwitz[1], Gerhard Berth[1,2], and Artur Zrenner[1,2] — [1]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [2]Center of Optoelectronics and Photonics Paderborn (CeOPP), 33098 Paderborn, Germany

Nonlinear ferroelectrics are a key material class for application in integrated optics from the high power to the single photon level. The exploitable properties range from the electro-optic effect, to large nonlinear susceptibilities and the possibility to achieve quasi-phase matching by periodic poling. But design and fabrication of devices requires an extensive knowledge on the limiting factors, such as intrinsic and extrinsic defects. Here Raman spectroscopy offers a versatile tool for characterization of material properties due to its sensitivity to a wide range of effects. This work provides an overview on performed Raman studies in various ferroelectrics, including Lithium-Niobate-Tantalate mixed crystals and KTP. Determined properties include the relative scattering tensor strengths, material composition in mixed crystals and dielectric properties. Of particular interest is the study of ferroelectric domain structures, whose behavior influenced by the presence of defects.

MA 12.5 Mon 19:00 Poster C

Laser induced poling inhibition of $LiNbO_3$ using an amorphous Si absorber — Grigoris Zisis[1], Gregorio Martinez-Jimenez[1], Yohann Franz[1], Noel Helay[1], David Grech[2], Harold Chong[2], Elisabeth Soergel[3], Anna Peacock[1], and •Sakellaris Mailis[1] — [1]Optoelectronics Research Centre, University of Southampton, Highfield, Southampton, SO17 1BJ, U.K. — [2]School of Electronic and Computer Science, University of Southampton, Highfield, Southampton SO17 1BJ, U.K. — [3]Institute of Physics, University of Bonn, Wegelerstrasse 8, 53115 Bonn, Germany

Here we demonstrate laser-induced inhibition of poling in lithium niobate by irradiating a thin absorbing layer of amorphous Si, deposited on the surface of the crystal. The absorption of a-Si in the visible range is sufficiently high to produce significant temperature gradients in the substrate causing a local change in the stoichiometry of the crystal, which in turn modifies the coercive field locally.

This arrangement enables domain engineering using readily available visible laser sources instead of costly and power limiting UV lasers which were previously used to obtain inhibition of poling in this material.

Examination of the topography and piezoresponse of the PI domains, which are formed using this laser assisted method shown a "soft" domain boundary where the domain wall is not sharp but rather consists of isolated nano-domains whose density and size is a function of the distance from the centre of the laser irradiated track.

MA 12.6 Mon 19:00 Poster C

Raman Spectroscopy and Spin-Phonon-Coupling of Multiferroic $Eu_{1-x}Ho_xMnO_3$ — •Sebastian Elsässer[1], Jean Geurts[1], Vladimir V. Glushkov[2], and Anatoly M. Balbashov[2] — [1]Exp. Phys. III, University of Würzburg, Germany — [2]Prokhorov GPI, Russian Academy of Sciences, Moscow, Russia

The revival of studies on magneto-electric (ME) effects has led to rich insights in the physics of charge and spin degrees of freedom and their mutual interaction via ME coupling [1]. One of the most extensively studied effects is the inverse Dzyaloshinskii-Moriya interaction. Hereby, the ordering of the magnetic moments leads to a lattice distortion which, in turn, can induce in a permanent electric polarization. This manifests itself in the perovskite-like rare-earth manganites $RMnO_3$. Here, the average size of the rare-earth ions R^{3+} directly influences the octahedron tilting angle. This can be used to tune the coupling between the magnetic Mn sites yielding model system for the interplay of crystalline distortion, magnetic frustration and electric polarization. In this study, R= Eu^{3+} ions are partially replaced with Ho^{3+} (<30%) to achieve the multiferroic phase. Spin-phonon-coupling (SPC) is probed by temperature-dependent Raman spectroscopy. We identify the elusive peak at 650cm^{-1} to be the $B_{3g}(1)$ mode. Upon cooling renormalisation of phonon energies due to SPC-effects starts already well above T_N. We observe that the SPC-shift is mode-specific, being strongest (up to 1%) for the $B_{2g}(1)$ and $B_{3g}(1)$, which are both octahedron breathing modes.

[1] M. Fiebig, Journal of Physics D-Applied Physics **38**, 8 (2005)

MA 12.7 Mon 19:00 Poster C

Domain walls in lithium niobate investigated by Raman spectroscopy and density functional theory — •Sergej Neufeld[1], Michael Rüsing[2], Gerhard Berth[2], Artur Zrenner[2], Wolf Gero Schmidt[1], and Simone Sanna[1] — [1]Lehrstuhl für Theoretische Physik, Universität Paderborn — [2]Department Physik, Universität Paderborn

The intensity of the Raman signal associated to different phonon modes of $LiNbO_3$ is strongly modified by the presence of ferroelectric domain boundaries [1]. The intensity modulation can be exploited to map domain structures, thus using Raman spectroscopy as a non-destructive imaging tool for the investigation of polarization-domains and domain walls [2]. Unfortunately, the origin of the modifications in the Raman signal is currently unknown. In an attempt to understand the mechanisms leading to the modification of the measured intensity, we have modeled Raman scattering efficiencies from first-principles. Thereby the Raman susceptibility tensor is calculated within the density functional theory following the approach proposed by Ghosez and co-workers [3]. The approach is validated with the TO bulk phonon modes of A_1 and E symmetry and then applied to domain boundaries. The bulk Raman intensities calculated for all possible combinations of the polarization of incoming and scattered photons are in good agreement with the measured spectra. Results for simplified domain wall models are presented and discussed. [1]P. S. Zelenovskiy et. al., Appl. Phys. A 99, 741 (2010). [2]G. Berth et al., Ferroelectrics 420, 44 (2011). [3]M. Veithen et al., Phys. Rev. B 71, 125107 (2005).

MA 12.8 Mon 19:00 Poster C

Evolution of ferroelectric domain patterns in $BaTiO_3$ at the orthorhombic ↔ tetragonal phase transition — •Thorsten Limböck and Elisabeth Soergel — Institute of Physics, University of Bonn, Nussallèe 12, 53115 Bonn, Germany

Domain patterns in barium titanate (BTO) were investigated by piezoresponse force microscopy (PFM) using a variable-temperature scanning force microscope. By analyzing the vertical and the lateral PFM images, the directions of polarization of the individual domains, i. e. 6 directions for the tetragonal and 12 for the orthorhombic phase, could be identified. The change of a domain pattern when submitting the crystal to a temperature ramp between +20° and −20° synchronized to the PFM scanning process, was directly monitored. Finally, the possible conversions between specific domain orientations upon heating/cooling the crystal across the phase transition were experimentally confirmed.

MA 12.9 Mon 19:00 Poster C

Domain wall conductivity in gold-patterned single-crystal bulk samples using c-AFM — •Thorsten Adolphs and Elisabeth Soergel — Physikalisches Institut, Universität Bonn, Wegel-

erstrasse 8, 53115 Bonn

Domain wall conductivity is generally measured by c-AFM, thereby applying moderate voltages between the tip and a large-area back electrode. This technique being very attractive because of its ease of use it has, however, a couple of drawbacks: (i) the voltage applied to the tip leads to electric fields at the tip apex locally exceeding E_c. Since the displacement of a domain wall is energetically favorable (when compared to the creation of new domains), local poling predominantly takes place at the domain walls, leading to a local poling current which is also seen by c-AFM; (ii) the electrical connection between the tip and the domain wall is not reliable; and (iii) different materials of the tip and the back electrode might lead to Schottky-barrier behavior of the domain-wall current. In order to overcome these drawbacks, we propose the use of small, some μm^2-sized gold-patterns evaporated on top of the sample surface, partially connecting to the domain walls. We will present first experimental results obtained with bulk, single crystalline samples prepared for c-AFM in such a way.

MA 12.10 Mon 19:00 Poster C

Local poling at domain walls in $LiNbO_3$ crystals in connection with c-AFM measurements — •Jakob Frohnhaus and Elisabeth Soergel — Physikalisches Institut, Universität Bonn, Wegelerstrasse 8, 53115 Bonn

An electrical current localized at ferroelectric domain walls recorded by means of conductive atomic force microscopy (c-AFM) can basically have two origins: electrical conductivity of the domain wall or local poling. We show that also local poling leads to c-AFM images which cannot straightforwardly be distinguished from those c-AFM images displaying the electrical conductivity of the domain wall.

MA 12.11 Mon 19:00 Poster C

Signature of domain walls in PFM measurements — •Tim Flatten and Elisabeth Soergel — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

Piezoresponse force microscopy (PFM) is at present the technique the most used for mapping ferroelectric domain patterns. However, the unambiguous determination of the direction of polarization of the individual domains based on PFM-images is generally not straightforward. Not only the careful analysis of a set of vertical- and lateral-PFM images are required, but possibly also a set of images after the rotation of the sample by 90° are necessary for fully determining the domain pattern. In addition to the PFM-signal obtained on top of the domain faces, on might, however, also make use of the signature of the domain walls (DW) in the PFM-signal. For ↑↓ domain walls the PFM-signal shows a symmetric, tangent-like transition between the two domains. This transition, however, should exhibit different features depending on the direction of polarization of the domains adjacent to the DW and the inclination angle of the DW relative to the sample surface. Using this additional information, the full determination of the domain pattern should be facilitated.

MA 12.12 Mon 19:00 Poster C

Measurement system for the magnetoelectric effect — •Ulrich Straube and Kathrin Doerr — Martin-Luther-University Halle, Institute of Physics, FoG, Von-Danckelmann-Platz 3, 06120 Halle, Germany

Magnetoelectric materials have different and frequency-dependent magnetoelectric effects. The correct determination of these effects is difficult because of various problems including electric and magnetic shielding, sample preparation and pretreatment. A simple measurement arrangement containing a Helmholtz coil, a pair of NdFeB permanent magnets and a special preamplifier is presented. Some results obtained from magnetoelectric ceramic materials are shown.

MA 12.13 Mon 19:00 Poster C

The magnetoelectric effect across scales — •Doru C. Lupascu[1], Heiko Wende[2], Jörg Schröder[3], Matthias Labusch[3], Morad Etier[1], Ahmadshah Nazrabi[1], Irina Anusca[1], Harsh Trivedi[1], Yanling Gao[1], Marianela Escobar[1], Vladimir V. Shvartsman[1], Joachim Landers[2], Soma Salamon[2], and Carolin Schmitz-Antoniak[4] — [1]Materials Science & Center for Nanointegration Duisburg-Essen (CENIDE) — [2]Faculty of Physics & CENIDE — [3]Institute of Mechanics, all at University of Duisburg-Essen — [4]Peter-Grünberg-Institut (PGI-6), Forschungszentrum Jülich

Magnetoelectric coupling can arise in intrinsic multiferroics as well as composites. We will outline how for intrinsic BiFeO3 nanoparticles yield different magnetoelectric properties at room temperature than larger grains or bulk material. Magnetoelectric nanoscale composites of $BaTiO_3$ and $CoFe_2O_4$ display rather poor magnetoelectric coupling macroscopically. Their micron scale counterparts on the other hand yield nice macroscopic response. The mechanical, electrical, and magnetic effects are analyzed using techniques including Mössbauer spectroscopy, magnetic force microscopy, piezoforce microscopy, and macroscopic techniques. It will be shown that microscopic coupling is strong also for (partly) conducting magnetic inclusions and nanosystems while macroscopic properties are highly dependent on good insulation of the samples. Experimental asymmetries in determining the magnetoelectric coupling coefficient are discussed.

Support via FP7 Marie Curie Initial Training Network *Nanomotion* (grant n° 290158) & Forschergruppe 1509 are acknowledged.

MA 12.14 Mon 19:00 Poster C

Insitu X-ray studies of mechanical coupling at piezoelectric/magnetostrictive interfaces — •Philipp Jordt[1], Stjepan Hrkac[1], Olaf M. Magnussen[1,2], and Bridget M. Murphy[1,2] — [1]Institut für Experimentelle und Angewandte Physik, ChristianAlbrechts-Universität zu Kiel, Germany — [2]Ruprecht Haensel Laboratory, Christian-Albrechts-Universität zu Kiel, Germany

To optimize magnetoelectric composites for magnetic sensor applications it is necessary to understand the coupling at the interface between a piezoelectric and a magnetostrictive material. To study the coupling at the interface, we measure the lattice deformation of the piezoelectric substrate *insitu* by grazing incidence X-ray diffraction in an external magnetic field and for different thicknesses of the magnetostrictive layer grown by magnetron sputtering, using the high resolution and high intensity X-ray beam provided by Petra III (P08). We investigate the magnetic field induced strain of $(Fe_{90}Co_{10})_{78}Si_{12}B_{10}$ on ZnO and InP substrates. From the Bragg peak positions we determined the interplanar spacings in the substrates and the corresponding strain as a function of the applied magnetic field. We measure the strain for different thicknesses and get a critical thickness for the magnetostrictive layer. We thanks the DPG for funding through PAK 902.

MA 12.15 Mon 19:00 Poster C

Influence of piezoelectric induced strain on the Raman spectra of $BiFeO_3$ films — •Cameliu Himcinschi[1], Andreas Talkenberger[1], Jens Kortus[1], Alexander Schmid[2], Er-Jia Guo[3,4], and Kathrin Dörr[3,4] — [1]TU Bergakademie Freiberg, Institute of Theoretical Physics, D-09596 Freiberg, Germany — [2]TU Bergakademie Freiberg, Institute of Applied Physics, D-09596 Freiberg, Germany — [3]Institute for Physics, Martin-Luther-University Halle-Wittenberg, 06099 Halle, Germany — [4]Institute for Metallic Materials, IFW Dresden, 01069 Dresden, Germany

$BiFeO_3$ epitaxial thin films were deposited on piezoelectric $0.72Pb(Mg_{1/3}Nb_{2/3})O_3$-$0.28PbTiO_3$ (PMN-PT) substrates with a conductive buffer layer ($La_{0.7}Sr_{0.3}MnO_3$, or $SrRuO_3$) using pulsed laser deposition. The calibration of the strain values induced by the applied voltage on the piezoelectric PMN-PT substrates was realised using X-Ray Diffraction measurements. Raman spectra monitoring as a function of the applied voltage (and hence strain) was performed in resonant conditions, using the 442 nm line of a HeCd laser. The piezoelectric induced strain in the $BiFeO_3$ films causes shifts in the phonon position. The method of piezoelectrically induced strain allows to obtain a quantitative correlation between strain and the shift of the Raman-active phonons, ruling out the influence of extrinsic factors, as growth conditions, crystalline quality of substrates, or film thickness.

This work is supported by the German Research Foundation DFG HI 1534/1-2.

MA 12.16 Mon 19:00 Poster C

Control of the magnetic properties of magnetostrictive thin films by crossing the phase transition on a Mott insulator — S. Finizio[1], A. Fantini[1,2], •T. Lenz[1], M.V. Khanjani[1], S. Altendorf[2,3], D. Passarello[2], S.S.P. Parkin[2], and M. Kläui[1] — [1]Institut für Physik, Universität Mainz, Mainz, Germany — [2]IBM Almaden Research Center, San Jose, CA, USA — [3]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

The study of strongly correlated materials such as the Mott insulator VO_2 has recently attracted interest, due to the possibility of manipulating materials properties on ultrafast timescales. VO_2, in particular, has been object of attention as a metal-insulator-transition (MIT) from an insulating monoclinic phase to a conducting rutile phase occurs at accessible temperatures just above RT. These changes in crystalline order within the MIT induce strain at the interface. Combined with magnetostrictive materials such as Ni, the MIT of VO_2 is exploited to study the dynamics of the magneto-elastic coupling. Here, we present MOKE and SQUID magnetometry studies of the influence of the MIT of VO_2 on the magnetic properties of a Ni thin film. VO_2 thin films were heteroepitaxially deposited by pulsed-laser-deposition on (100) TiO_2 substrates, onto which Ni film were deposited by thermal evaporation. The magnetic properties of the Ni thin films were then determined upon thermally crossing the MIT. Our results show that strong changes in the magnetic anisotropy of the Ni films occur upon crossing the MIT leading to changes in the switching fields and characteristics as needed for ultra-fast strain-induced switching.

MA 12.17 Mon 19:00 Poster C

Structural investigation of erythrosiderites by single crystal X-ray diffraction — •Tobias Fröhlich[1], Ladisliv Bohatý[2], Petra Becker[2], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln

Erythrosiderites $A_2[FeX_5(H_2O)]$, where A stands for an alkali metal or ammonium ion and X for a halide ion, are antiferromagnets with Néel-temperatures ranging from 6 to 23 K [1]. This family of compounds allows to investigate the impact of structural parameters on the magnetoelectric properties by comparing their closely related structures. The compound $(NH_4)_2[FeCl_5(H_2O)]$ was found to be multiferroic with strong magnetoelectric coupling [2]. While most structures of erythrosiderites crystallize in the space group Pnma, $Cs_2[FeCl_5(H_2O)]$ structurally deviates from the other erythrosiderides and crystallizes in space group Cmcm [3]. The structures of $(NH_4)_2[FeCl_5(H_2O)]$ and $Cs_2[FeCl_5(H_2O)]$ are investigated by single-crystal X-ray diffraction. Additionally, the non-magnetic compound $(NH_4)_2[InCl_5(H_2O)]$ is structurally investigated. Irrespective the absence of magnetism, its crystal structure is very similar to that of $(NH_4)_2[FeCl_5(H_2O)]$, therefore it can be used as a reference material to separate magnetoelectric effects.

[1] J. Luzón et al., Physical Review B, **78**, 054414 (2008). [2] M. Ackermann, D. Brüning, T. Lorenz, P. Becker, L. Bohatý, New Journal of Physics **15**, 123001 (2013). [3] M. Ackermann, T. Lorenz, P. Becker, L. Bohatý, J. Phys.: Condens. Matter **26**, 206002 (2014).

MA 12.18 Mon 19:00 Poster C

Multiferroic magnonics: quantum interference, dissipationless energy transport, and Majorana fermions — •Wei Chen[1], Manfred Sigrist[2], Andreas P. Schnyder[1], Peter Horsch[1], and Dirk Manske[1] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]ETH-Zurich, Zurich, Switzerland

We demonstrate the broad applications of multiferroic materials based on their noncollinear magnetic order and magnetoelectric effect. Upon mapping the noncollinear magnetic order into a spin superfluid, the magnetoelectric effect enables the electrically controlled quantum interference of spin superfluid, indicating the possibility of a room temperature SQUID-like quantum interferometer that manifests the flux quantization of electric field. Because the magnetoelectric effect enables changing the noncollinear magnetic order by electric field, we propose that applying an oscillating electric field with frequency as low as household frequency can generate a fast, coherent rotation of the magnetic order that is free from energy loss due to Gilbert damping, and can be used to deliver electricity up to the distance of long range order. At a superconductor/multiferroic interface, the noncollinear magnetic order imprints into the superconductor via $s-d$ coupling, which can produce Majorana fermions at the edge of the superconductor without the need to adjust chemical potential.

MA 12.19 Mon 19:00 Poster C

Optical properties of Sm-doped $BiFeO_3$ close to the morphotropic phase boundary — •Florian Burkert[1], Michaela Janowski[1], Xiaohang Zhang[2], Ichiro Takeuchi[2], and Christine Kuntscher[1] — [1]Experimentalphysik II, Universität Augsburg, 86159 Augsburg, Germany — [2]Department of Materials Science and Engineering, University of Maryland, College Park, Maryland 20742, USA

The perovskite $BiFeO_3$ is a rare example for a magnetoelectric multiferroic above room temperature. It has been demonstrated on $Bi_{1-x}Sm_xFeO_3$ thin films that Sm-doping drives $BiFeO_3$ towards a morphotropic phase boundary with enhanced piezoelectric properties, concomitant with a rhombohedral to pseudo-orthorhombic structural phase transition [1]. We studied the reflectance of a similar, Sm-doped $BiFeO_3$ thin film in the far-infrared range at room temperature and ambient pressure by means of FTIR spectroscopy. With increasing Sm doping, we observe changes in the phonon spectrum, especially at Sm content around $x = 0.14$, indicating the occurrence of a structural phase transition in agreement with earlier studies.

[1] I. Takeuchi et al., Appl. Phys. Lett. **92**, 202904 (2008).

MA 12.20 Mon 19:00 Poster C

Inelastic neutron scattering studies on $LuFe_2O_4$ — •Hailey Williamson[1], Petr Čermák[3], Jörg Voigt[1], Ryoichi Kajimoto[4], Geetha Balakrishnan[2], and Manuel Angst[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Germany. — [2]Department of Physics, The University of Warwick, UK. — [3]Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at MLZ, Germany. — [4]Neutron Science Section, MLF Division, J-PARC Centre, Japan

Multiferroic oxides, which exhibit a coupling between magnetism and charge order (CO), constitute a strong and competitive avenue of research. The well-known $LuFe_2O_4$, the first proclaimed multiferroic through CO due to mixed valence $Fe^{2+/3+}$ bilayers separated by Lu monolayers, was initially thought to produce ferroelectricity through polarization, from the specific CO configuration within the bilayers. This fuelled intense investigation, leading to the conclusion through XMCD, bond valence sum analysis of data and macroscopic characterization, that the bilayers are charged and not polar. With much of the static crystallographic and magnetic properties uncovered, it is now essential to elucidate the dynamic properties to understand how the spin and charge are coupled. Here we present quasi-elastic magnetic scattering with a profound temperature dependence, as well as phonon dispersions at higher energies. Finally, we show an indication of a spin gap opening, on cooling through the magnetic ordering temperature.

MA 12.21 Mon 19:00 Poster C

Investigation of low-frequency Raman modes in $BiFeO_3$ epitaxial thin films with respect to azimuthal orientation — •Andreas Talkenberger[1], Cameliu Himcinschi[1], Christian Röder[1], Ionela Vrejoiu[2,3], Florian Johann[2], and Jens Kortus[1] — [1]TU Bergakademie Freiberg, Institute of Theoretical Physics, Leipziger Str. 23, D-09596 Freiberg — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle — [3]Max Planck Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart

In this work we present results of highly accurate Raman spectroscopic experiments applied in azimuthal rotation measurements on epitaxial $BiFeO_3$ thin films grown on different scandate substrates. We observe periodic changes in Raman position, full width at half maximum and intensity for some phonon modes as a function of the azimuthal angle Φ. Further analysis revealed the possibility of the so far controversial assignment of Raman modes at low frequencies (< 250 cm^{-1}) through rotational Raman measurements, that show high sensitivity towards the mentioned parameters. We successfully simulated the azimuthal behaviour of Raman intensity and position of selected modes offering a symmetry assignment for them. In addition our results support the domain character of the BFO/DSO thin film identified by piezoresponse-force microscopy measurements.

This work is supported by the German Research Foundation DFG HI 1534/1-2.

MA 12.22 Mon 19:00 Poster C

X-ray diffraction on stoichiometric YFe_2O_4 single crystals. — •Thomas Müller and Manuel Angst — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany.

$LuFe_2O_{4-\delta}$ was long considered to be the primary example for a charge order multiferroic. $YFe_2O_{4-\delta}$ is isostructural, but the ionic radius of Y is much larger compared to Lu, leading to completely different ordering phenomena. We have grown highly stoichiometric single crystals of $YFe_2O_{4-\delta}$ by the optical floating zone method, showing for the first time 3D charge ordering in x-ray diffraction at low temperature. The phase at 200 K can be indexed using a propagation vector of $(\frac{1}{7}\frac{1}{7}\frac{9}{7})$ considering 6 twin components and second order. Likewise the 160 K phase can be index with $q = (\frac{1}{4}\frac{1}{4}\frac{3}{4})$. While cooling not only the threefold symmetry but in contrast to $LuFe_2O_4$ also the mirror plane of the room temperature $R\bar{3}m$ structure of $YFe_2O_{4-\delta}$ are lost according to symmetry-analysis.

MA 12.23 Mon 19:00 Poster C

Photoemission electron microscopy study of two-phase Fe/BaTiO$_3$ multiferroic system — •Ashima Arora, Matteo Cialone, Akin Ünal, Sergio Valencia, and Florian Kronast — Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Str. 15, 12489 Berlin, Germany

The phenomenon of magneto-electric coupling is of great technological importance in devices such as data storage due to possible electric field control of magnetic properties. However, a single material possessing different ferroic orders which can be exploited practically is difficult to find. Therefore we study a two-phase ferroic system made up of Fe wedge on top of a BaTiO$_3$ single crystal. Here, we study the magnetization of the ferroelectric film by Photoemission Electron Microscopy (PEEM). The capability of PEEM to be element selective and sensitive to magnetic structure of the sample using the tool of X-Ray Magnetic Circular Dichroism (XMCD) makes it possible to get laterally resolved images of magnetic state for individual element in the sample. We have visualized the magnetic domains on the Fe wedge and observed that they are influenced by the BTO substrate at the bottom. In addition, the spectroscopic information using X-ray Absorption Spectroscopy (XAS) provides a deeper insight on the interplay between the ferroelectric and ferromagnetic properties at the interface of Fe and BaTiO$_3$ in the multi-ferroic system.

MA 12.24 Mon 19:00 Poster C

Towards an experimental evidence of the linear magnetoelectric coupling — •Alexander Sukhov[1], Levan Chotorlishvili[1], Paul P. Horley[2], Chenglong Jia[3], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther-Universität, Halle-Wittenberg, 06099 Halle (Saale), Germany — [2]Centro de Investigacion en Materiales Avanzados (CIMAV S.C.), Chihuahua/Monterrey, 31109 Chihuahua, Mexico — [3]Key Laboratory for Magnetism and Magnetic Materials of the MOE, Lanzhou University, Lanzhou 730000, China

We present a theoretical study combining simulations of ferromagnetic resonance (FMR) for interfacesof Co/BaTiO$_3$ and Fe/BaTiO$_3$ [1] and calculations of the mean first passage times for a system of single-domain Fe-nanoparticles deposited on a ferroelectric BaTiO$_3$-substrate [2]. The study is focused on the consequences of the magnetoelectric coupling - which is considered to be linear in polarization and magnetization due to a screening mechanism - on the spectra of absorbed power [1] and the mean switching times of the Fe-nanoparticles [2]. In particular, we demonstrate and discuss how to extract an information on the symmetry and the strength of the magnetoelectric coupling from FMR-experiments, which was recently evidenced in the experiments of Ref. [3] or from eventual telegraph-noise-like experiments.

[1] A. Sukhov, P.P. Horley, C.-L. Jia, J. Berakdar, J. Appl. Phys. **113**, 013908 (2013). [2] A. Sukhov, L. Chotorlishvili, P.P. Horley, C.-L. Jia, S. Mishra, J. Berakdar, J. Phys. D: Appl. Phys. **47**, 155302 (2014). [3] N. Jedrecy *at al.*, Phys. Rev. B **88**, 121409(R) (2013).

MA 12.25 Mon 19:00 Poster C

Optical investigation of ferroic domains beyond the resolution limit — •Christoph Wetli, Viktor Wegmayr, Thomas Lottermoser, and Manfred Fiebig — Department of Materials, ETH Zurich, Zurich, Switzerland

In recent years optical second harmonic generation (SHG) has been shown to be a versatile, non-destructive tool to investigate the often complex domain structures of ferroic and multiferroic materials. Ferroic domains vary broadly in structure and size, depending on the nature of the ferroic ordering. So far, however SHG was restricted to domains larger than the optical resolution limit of 1 μm. Here we present a method by applying a numerical model and simulation to overcome this limitation and to analyze ferroic domain structures some orders of magnitude smaller than the optical resolution limit.

The method is based on the relation between the orientation of the ferroic order parameter and the phase of the nonlinear optical signal. It gives a relation between domain size and density, optical resolution and the intensity of the SHG signal. To show the reliability of the model, we applied it to several simulated domain structures. The simulation of the domain structures is based on an iterative geometrical algorithm, which allows us to generate complex domain patterns like the ferroelectric vortex structures or the irregular bubble like antiferromagnetic domains in hexagonal YMnO$_3$. The numerical calculations were compared with experimental data and found to be in excellent agreement.

MA 12.26 Mon 19:00 Poster C

Emergence of ferroelectricity in multiferroic h-YMnO$_3$ — •Martin Lilienblum[1], Thomas Lottermoser[1], Sebastian Manz[1], Sverre M. Selbach[2], Andres Cano[3], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich, Vladimir-Prelog-Weg 4, 8093 Zurich, Switzerland — [2]Department of Material Science and Engineering, NTNU, N-7491 Trondheim, Norway — [3]CNRS, Université de Bordeaux, ICMCB, UPR 9048, F-33600 Pessac, France

Universal scaling laws, interfacial nano-electronics, and topological defects are currently studied using hexagonal manganites RMnO$_3$ (R= Sc, Y, Dy-Lu) as model system. In spite of the remarkably broad interest in the system, surprisingly little is known about the origin of the ferroelectric state. Here we solve the controversy about the emergence of the spontaneous polarization and its coupling to the underlying structural distortion by applying scanning probe microscopy (SPM) and optical second harmonic generation (SHG). We trace the spontaneous polarization by SHG from 100 K to 1450 K directly and contact-free. We find that only a single transition exists in which the polarization arises slower than expected as by-product of the structural distortion. By thermal treatments close to the structural transition and subsequent SPM scans, we show that the exceptionally robust ferroelectric domain pattern is determined only by the structural distortion. In summary we reveal that the ferroelectric order results from an interplay of electric polarization, topological effects, and temperature.

MA 12.27 Mon 19:00 Poster C

Strain-induced defect-polarization coupling in SrMnO$_3$ films — •Carsten Becher[1], Laura Maurel[2], Ulrich Aschauer[1], Martin Lilienblum[1], Cesar Magen[2], Dennis Meier[1], Eric Langenberg[2], Morgan Trassin[1], Javier Blasco[3], Ingo Krug[4], Pedro Algarabel[3], Nicola Spaldin[1], Jose Pardo[2], and Manfred Fiebig[1] — [1]ETH Zürich, Zürich, Switzerland — [2]Instituto de Nanosciencia de Aragon, Zaragoza, Spain — [3]Departemento der Fisica de la Materia Condensada, Zaragoza, Spain — [4]Institut für Optik und Atomare Physik, Berlin, Germany

Epitaxial strain can stabilize new matter phases in thin films and is thus a degree of freedom to increase functionality. Here we demonstrate a novel polar phase in 20 nm SrMnO$_3$ films that are epitaxially grown under tensile strains by pulsed laser deposition. High resolution X-Ray diffraction and transmission electron microscopy confirm the crystalline quality of the tetragonal films. We use nonlinear optics to proof that strain induces polarity, and density functional theory to show that it simultaneously increases the concentration of oxygen vacancies. These vacancies accumulate at the polar domain walls where they establish an electrostatic barrier to electron migration. As a consequence, scanning probe microscopy shows that the electrical conductance is structured into isolated "nanocapacitors" which can be charged individually.

MA 12.28 Mon 19:00 Poster C

Magnetoelectric domain control in multiferroic TbMnO$_3$ — •Sebastian Manz[1], Masakazu Matsubara[1,2], Masahito Mochizuki[3,4], Teresa Kubacka[1], Ayato Iyama[5], Nadir Aliouane[6], Tsuyoshi Kimura[5], Steven Johnson[1], Dennis Meier[1], and Manfred Fiebig[1] — [1]ETH Zürich — [2]Tohoku University — [3]Aoyama Gakuin University — [4]Japan Science and Technology Agency — [5]Osaka University — [6]Paul Scherrer Institute

Spin-spiral multiferroics exhibit a strong coupling between the electric and magnetic subsystems which is of potential interest for technological applications. Although these systems have been investigated for more than a decade, the magnetoelectric domain evolution under external fields is still largely unknown. Using optical second harmonic generation we resolve how electric and magnetic fields affect the multiferroic domains in the archetypal spin-spiral multiferroic TbMnO$_3$. In consecutive electric switching cycles, varying multi-domain patterns emerge before a single-domain state is obtained. This observation reflects that the domain walls can easily move without being pinned by, e.g., structural defects. In striking contrast to the electric-field response, multi-domain patterns persist when the polarization direction is flopped by applied magnetic fields. Here, a uniform polarization rotation is observed within all domains, which incorporates a transformation of neutral into nominally charged domain walls. Our results are explained based on numerical Landau-Lifshitz-Gilbert simulations and provide first evidence for the scalability of macroscopic magnetoelectric properties onto the level of domains.

MA 12.29 Mon 19:00 Poster C

Ab initio expression of magneto-electric coupling coefficients

in terms of current response function — •Ronald Starke[1] and Giulio Schober[2] — [1]Institut f. Theo. Physik, Bergakademie Freiberg — [2]Institut f. Theo. Physik, Uni Heidelberg

Based on the Functional Approach to electrodynamics of media, we show that the Maxwell equations imply closed, analytical expressions of the magneto-electric coupling coefficients in terms of the current response functions. On the linear level, these expressions include all effects of inhomogeneity, anisotropy and relativistic retardation. Moreover, we relate the 36 component functions of the constitutive tensor used in the context of bi-anisotropic media to only 9 causal response functions which specify the current response to an external vector potential.

MA 12.30 Mon 19:00 Poster C

First-principles study of magnetic properties of $BaFeO_{3-\delta}$ — •Igor Maznichenko[1], Sergey Ostanin[2], Arthur Ernst[2], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany

Oxides with a perovskite atomic structure are ideally suited to grow two-component multiferroics, in which a ferroelectric oxide barrier is sandwiched between magnetic electrodes. For example, the perovskites $ATiO_3$ (A = Ba, Pb) can be used as ferroelectric barrier, while ferromagnetic perovskites (La,Sr)MnO_3 or $SrRuO_3$ can serve as ferromagnetic electrodes. Oxide materials are preferable in such a tunnel junction because of their compatibility and growth. Since the number of ferromagnetic conducting oxides is restricted, a search of new suitable oxide electrodes is highly desirable. Recently, the perovskite $BaFeO_3$ was reported to be ferromagnetic in bulk and as thin film [1]. Here, using a first-principles Green function method within the density functional theory, we present a study on magnetic and electronic properties of bulk $BaFeO_3$ especially focusing on the impact of structural deformations and intrinsic defects.

[1] S. Chakraverty et al., Applied Physics Letters 103, 142416 (2013).

MA 13: Focused Session on Ferroic Domain Walls II (DF with MA)

Part of the 3-days focus on ferroic domain walls:

Tutorial, Symposium (SYDW), three Focused Sessions, and Poster Session.

Organizers: Elisabeth Soergel (Universität Bonn) and Dennis Meier (ETH Zürich)

Time: Tuesday 9:30–13:00 Location: EB 107

Topical Talk MA 13.1 Tue 9:30 EB 107

Polarization charge as a reconfigurable dopant in wide-bandgap ferroelectrics — •Tomas Sluka — Ceramics Laboratory, EPFL Swiss Federal Institute of Technology, Lausanne, CH-1015 Switzerland — DPMC-MaNEP, University of Geneva, 24 Quai Ernest-Ansermet, 1211 Geneva 4, Switzerland

Tuning the charge carrier density in semiconductors by spatially fixed chemical impurities has been the cornerstone of electronics for over 50 years. As the miniaturization of CMOS technology approaches critical limits, efforts are turned to conceptually new devices based on emerging electronic properties of materials and interfaces. Recently it has been shown that the effect of chemical doping in semiconductors can be also induced by the polarization charge at Charged Domain Walls (CDWs) in wide-bandgap ferroelectrics. The polarization-charge doping, unlike the chemical doping, implies the intriguing possibility to write, displace, erase and re-create channels having a metallic-type conductivity inside an excellent insulator. This suggests the possible use of CDWs as real-time doping switches in hardware reconfigurable electronics. The talk will introduce methods of CDW engineering in ferroelectric crystals and thin films, the intrinsic properties of individual CDWs, their nanoscale manipulation and implementation into submicron device structures. Nanometers thick CDWs ranging from millimeters to tens of nanometers sizes and having metallic-type conductivity which exceeds 10^3 - 10^9 times the thermally activated conductivity of the bulk and neutral domain walls will be discussed.

MA 13.2 Tue 10:00 EB 107

Nonlinear characteristic of ferroelectric domains: From single domain wall to the periodic structure — •Kai Spychala[1], Moritz Grothe[1], Alex Widhalm[1], Gerhard Berth[1,2], and Artur Zrenner[1,2] — [1]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [2]Center for Optoelectronics and Photonics Paderborn (CeOPP), 33098 Paderborn, Germany

On the way to smaller periods of periodically poled structures in ferroelectrica a comprehensive acknowledgement of the domain wall's nonlinear response is necessary. In this approach the analysis of the ferroelectric domain structures have been realized by means of second harmonic (SH) microscopy. In our study the nonlinear characteristic of an isolated transition between two contrarily poled ferroelectric domains has been determined. Here for the nonlinear sequence in the region of a single domain wall, a symmetric trend transverse to the domain transition was initially detected. A detailed depth-resolved and polarization-dependent study hints at a SH-signature conditioned by the orientation of the crystals. Additionally a functional dependence on depth of such sequences was observed. Here an influence of surface charge and inner electric field distribution can be assumed. Furthermore specific nonlinear signatures which are directly connected to the period of the do-main grating were detected in the system's nonlinear response. Due to the long-range character of the correlation between the domain boundaries, an assumed direct link with the inner electric field distribution is suggested.

MA 13.3 Tue 10:20 EB 107

Ferroelectric 180° domain wall motion controlled by biaxial strain — •Robert Roth[1], Er-Jia Guo[1,2], Andreas Herklotz[1,2], Dietrich Hesse[3], and Kathrin Dörr[1,2] — [1]MLU Halle-Wittenberg, Institute for Physics, 06099 Halle, Germany — [2]Institute for Metallic Materials, IFW Dresden, Postfach 270116, 01171 Dresden, Germany — [3]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

Switching polarization in a ferroelectric proceeds by nucleating reversed domains which subsequently expand. Therefore, wall velocity (v) limits the speed of switching. In thin films, measured values of v are many orders below sound velocity [1], whereas bulk crystals showed larger v. Why are domain walls in films so slow? New insights can be derived from local studies of domain wall velocity by piezoresponse force microscopy in in-situ controlled elastic strain states of the sample. In c-oriented epitaxial $PbZr_{0.2}Ti_{0.8}O_3$ films on piezoelectric substrates, the velocity of non-ferroelastic 180° walls has been investigated employing the approach of Tybell et al. [2]. Remanent circular domains showed strong strain dependences of both, domain relaxation / shrinking in zero electric field and field-driven velocity. We discuss results in the light of known physical mechanisms, identify a strain-induced change of the driving field arising from built-in Schottky junctions at electrodes and suggest a new mechanism of strain-induced charging of tilted domain walls (wall sections).

[1] A. Grigoriev et al., Phys. Rev. Lett. 96, 187601 (2006)
[2] T. Tybell et al., Phys. Rev. Lett. 89, 097601 (2002)

Topical Talk MA 13.4 Tue 10:40 EB 107

Influence of defects on domain wall mobility in ferroelectrics — •Susan Trolier-McKinstry[1], Daniel Marincel[1], Stephen Jesse[2], Sergei Kalinin[2], Huiaruo Zhang[3], and Ian Reaney[3] — [1]Penn State University, University Park, PA, USA — [2]ORNL — [3]University of Sheffield

The dielectric and piezoelectric properties of ferroelectric thin films depend both on the intrinsic response of the material, as well as the motion of domain walls. There are a host of factors that can affect domain wall motion, including grain boundaries, other ferroelectric or ferroelastic domain walls, phase boundaries, dislocations, point defects, some electrode/dielectric interfaces, and core-shell microstructures. One of the challenges that faces the field is the difficulty in isolating the role played by a single type of pinning center or domain wall in controlling the response of an electroded ferroelectric. Instead the amalgamated response of millions of domains and domain walls is probed. This paper will describe the use of scanning probe microscopy and transmission electron microscopy to characterize the motion of domain walls in ferroelectric films, with a concentration on how mechanical stresses at the film * substrate interface and grain boundaries influence the correlated motion of domain walls. Measurements were made on 3 compositions of PZT with a variety of different grain boundary angles. It was found that the domain structure at the grain boundary controlled the width of influence on the domain wall motion. Depending on the angle this width ranged from 0 to hundreds of nm from the boundary.

10 min break

Topical Talk MA 13.5 Tue 11:20 EB 107

The electronic structure of longitudinal domain walls: a DFT perspective — •Gustav Bihlmayer, Kourosh Rahmanizadeh, Daniel Wortmann, and Stefan Blügel — Peter Grünberg Institut (PGI-1) & Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Whenever ferroelectric domains meet "head-on", a local accumulation of charge and/or defects compensating this charge can arise. As there is no general atomistic picture of these charged domain walls (DWs), ab-initio studies are still rather scarce. Motivated by detailed transmission electron microscopy images of transversal and longitudinal DWs in PZT [1,2], we studied these walls in $PbTiO_3$ using density functional theory (DFT). We explore the possibility of introducing defects acting as electron-acceptors or -donors at the DWs, as well as the localization of electrons due to correlation effects at the Ti site and compare the DW profiles with experimental data. Our calculations allow to investigate the distribution of defects in the DWs as well as the electronic structure of the bands hosting the accumulated charges. We find that states with magnetic- charge- and orbital order allow to realize an insulating (or semiconducting) behavior even in charged DWs [3]. We further discuss spin-polarization effects in the electron gas forming at the DWs due to relativistic phenomena in charged 90° walls.
[1] C. L. Jia et al., Nature Mater. **7**, 57 (2008). [2] Y. L. Tang et al., Sci. Rep. **4**, 4115 (2014). [3] K. Rahmanizadeh et al., Phys. Rev. B **90**, 115104 (2014). *Financial support of the EU grant NMP3-LA-2010-246102 (IFOX) is gratefully acknowledged.*

MA 13.6 Tue 11:50 EB 107

***Ab initio* investigation of ferroelectric domain walls in barium fluorides** — •Maribel Núñez Valdez and Nicola Spaldin — Materials Theory, ETH Zürich, Wolfgang-Pauli-Strasse 27, CH-8093 Zürich, Switzerland

We present results of first-principles calculations of the ferroelectric domain walls in the layered perovskite-related barium fluorides, $BaMF_4$ (M = Mg, Zn).

The ferroelectricity in the barium fluorides is driven by the softening of a single polar phonon mode consisting of both rotations of the MF_6 octahedra and polar displacements of Ba cations. This so-called "geometric ferroelectricity" is a strikingly different mechanism from that in conventional ferroelectrics [C. Ederer and N.A. Spaldin Phys. Rev. B **74**, 024102,2006].

Using density functional theory (DFT) within the general gradient approximation (GGA) we perform detailed structural relaxations of neutral domain walls (parallel to the polar c axis) and calculate the corresponding energies.

Based on comparisons of the total energies, we determine which domain wall orientations and configurations are most likely to form, and we compare their structural and electronic properties to those of domain walls in conventional ferroelectrics.

Finally we explore the strain dependence of the ferroelectric polarization, again comparing to that of conventional ferroelectrics.

MA 13.7 Tue 12:10 EB 107

Advanced characterization of functional ferroelectric domain walls by X-ray photoelectron emission microscopy — •Jakob Schaab[1], Ingo P. Krug[2,3], Zewu Yan[4], Edith Bourret[4], Claus M. Schneider[3], Ramamoorthy Ramesh[4,5], Manfred Fiebig[1], and Dennis Meier[1] — [1]Department of Materials, ETH Zürich — [2]Institut für Optik und Atomare Physik, TU Berlin — [3]Forschungszentrum Jülich, PGI-6 — [4]Materials Science Division, LBNL Berkeley — [5]Department of Materials Science and Engineering, UC Berkeley

The observation of anomalous electronic transport at ferroelectric domain walls and its significance for nano-electronics triggered tremendous scientific interest. To date, the transport behavior and potential barriers at domain walls have been predominantly scrutinized by scanning probes. This, however, convolutes the intrinsic electronic properties with contact resistance and inhomogeneous probe fields, so that the detailed origin of the behavior remains obscured.

Here, we report on the capability of high-resolution X-ray photoemission electron microscopy (X-PEEM) to image and characterize ferroelectric domain walls contact-free and with nanometer resolution. In the ferroelectric semiconductor $ErMnO_3$, we visualize ferroelectric domain walls by exploiting photo-induced charging effects and generate an electronic conduction map by analyzing the kinetic energy of photoelectrons. With this we open a pathway for non-destructive and element-specific studies of electronic and chemical domain-wall structures bypassing previous experimental limitations and significantly expanding the accessible parameter space.

Topical Talk MA 13.8 Tue 12:30 EB 107

Electronic reconstruction and transport at ferroelectric domain walls — •Dennis Meier — ETH Zürich, Switzerland

Unusual electronic properties arise at ferroelectric domain walls due to the low local symmetry and hypersensitivity of these natural oxide interfaces to electrostatics and strain. Such domain walls can, for instance, be highly conducting even when the host material is rather insulating. A major challenge is to understand the complex domain wall physics at the nanoscale and gain control of their properties with the ultimate goal to exploit them for designing domain-wall-based next-generation devices. In my talk I will discuss the case of domain walls in so-called improper ferroelectrics, i.e., systems in which the ferroelectric domain formation is determined by a primary order parameter other than the polarization. Due to the secondary nature of the polarization unusual domain wall configurations are stabilized, which leads to novel degrees of freedom and functionalities. Here, the multiferroic hexagonal manganites are a striking example. I will show that both positively and negatively charged ferroelectric domain walls naturally form in the as-grown state. Driven by the polarity mismatch at these walls, a variety of exotic interface effects emerge giving rise to, e.g., orientation-dependent conduction properties as well as local variations in the electrochemical interface structure. Results gained by electron microscopy, scanning-probe microscopy, and nonlinear optics will be shown, providing novel insight to the domain-wall physics across all relevant length scales from the nanometer to the millimeter regime.

MA 14: Electronic Structure of Magnetism, Computational Magnetism

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

MA 14.1 Tue 9:30 H 0112

Spin-orbit coupling effects on spin-dependent inelastic electronic lifetimes in ferromagnets — •Dennis Nenno, Steffen Kaltenborn, and Hans Christian Schneider — Physics Department and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern

We present results for spin-dependent inelastic electronic lifetimes in the 3d ferromagnets iron, cobalt, and nickel due to carrier-carrier Coulomb interactions including spin-orbit coupling in the band structure and in the wave functions. Including the spin-orbit interaction in the electronic wave functions presents an important step towards the resolution of a long standing discrepancy between theoretical and experimental results for spin-dependent electronic lifetimes. This subject has recently received renewed attention due to its importance for hot-electron spin transport [1]. Our approach is based on density functional theory and an accurately determined dielectric function [2]. With this numerical framework we find that the spin-dependent density of states at the Fermi energy does not, in general, determine the spin dependence of the lifetimes because of the effective spin-flip transitions allowed by the spin mixing [3]. Thus, the majority and minority electron lifetimes computed including spin-orbit coupling for these three 3d ferromagnets do not differ by more than a factor of 2, and agree with experimental results.

[1] M. Battiato, K. Carva, and P. M. Oppeneer, PRB 86, 024404 (2012). [2] S. Kaltenborn and H. C. Schneider, PRB 88, 045124 (2013). [3] S. Kaltenborn and H. C. Schneider, PRB 90, 201104(R) (2014).

MA 14.2 Tue 9:45 H 0112

Systematic derivation of an effective spin-Hamiltonian based on a modified multi-orbital Hubbard model — •Markus Hoffmann and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Theoretical descriptions of magnetic ground states, dynamical or thermodynamical properties of magnetic systems are often achieved through a multi-scale approach: DFT calculations are mapped onto a lattice spin-Hamiltonian whose properties are then evaluated carrying out Monte-Carlo or spin-dynamic simulations. For many bulk materials, the well-known Heisenberg exchange provides a sufficient description of the properties, whereas at surfaces or thin films occasionally so-called higher-order exchange interactions play a significant role. Those interactions are motivated from a single-band Hubbard model of a spin $S = 1/2$ system. However, typical magnetic moments at surfaces are in the order of 2 or 3 μ_B equivalent to $S = 1$ or $S = 3/2$. In this contribution, we present a systematic derivation of effective lattice spin-Hamiltonians based on a rotational invariant multi-orbital Hubbard model including a term ensuring Hund's rule coupling. The model is derived down-folding the degree of freedom into the proper low-energy spin sector using Löwdin's partitioning. Up to fourth order perturbation we found for $S \geq 1$ beyond the conventional Heisenberg term a biquadratic, 3-spin and 4-spin interaction. We show that the so-far not considered 3-spin interaction explains the puzzling energy spectrum of the magnetic states for a single Fe monolayer on Rh(111).

MA 14.3 Tue 10:00 H 0112

Navigation on the energy surface of the noncollinear Alexander-Anderson model using a magnetic force theorem — •Pavel Bessarab[1,2], Valery Uzdin[2,3], and Hannes Jónsson[4,5] — [1]Royal Institute of Technology KTH, Stockholm, Sweden — [2]St. Petersburg State University, St. Petersburg, Russia — [3]St. Petersburg National Research University of Information Technologies, Mechanics and Optics, St. Petersburg, Russia — [4]University of Iceland, Reykjavik, Iceland — [5]Aalto University, Espoo, Finland

Magnetic force theorem is derived within the multiple impurity, noncollinear Alexander-Anderson (NCAA) model - an important tool for efficient calculation of the total energy gradient with respect to orientation of magnetic moments, the magnetic 'forces'. Efficient evaluation of magnetic forces is of great importance for the large scale simulation of spin dynamics, minimization of the energy to identify stable and metastable magnetic states, or, in general, navigation on the energy surface of a magnetic system. NCAA model and magnetic force theorem are applied to calculate minimum energy paths between stable magnetic states of the monolayer Fe clusters on a W(110) surface, revealing complex mechanism of the magnetization reversal. Moreover, a noncollinear magnetic state is identified in a 7 x 7 atomic row Fe island where the magnetic moments are arranged in an antivortex configuration with the central ones pointing out of the (110) plane. The minimum energy path between this antivortex state and the collinear ground state is also calculated and the thermal stability of the antivortex state estimated.

MA 14.4 Tue 10:15 H 0112

Non-harmonic quantum dynamics of single spin systems — •Mario Krizanac, David Altwein, Elena Vedmedenko, and Roland Wiesendanger — Institute of Applied Physics and Interdisciplinary Nanoscience Center Hamburg , Germany

The time evolution of single quantum spins became accessible to the experimental observation in the last years [J. Phys. D:Appl. Phys.44(2011)]. Therefore, it was our motivation to study the dynamics of single quantum spin systems with uniaxial anisotropy in an external magnetic Bz-field from a theoretical perspective within the Schroedinger formalism. It has been found that the spin dynamics shows a very complicated non-harmonic periodicity. The period depends on the ratio of the external magnetic Bz-field and the uniaxial anisotropy in Sz direction. We observed two cases, the first one of very high periodicity and a second one of low periodicity. The conditions for these cases can be formulated in the form of a simple equation, which can be easily generalized to describe these conditions for single quantum spin systems of any size.

Atomic magnetism revealed by spin-resolved scanning tunnelling spectroscopy [J. Phys. D: Appl. Phys.44(2011)] Jens Wiebe, Lihui Zhou and Roland Wiesendanger Institute of Applied Physics, Hamburg University, Jungiusstrasse 11, D-20355 Hamburg, Germany

MA 14.5 Tue 10:30 H 0112

Real-time dynamics of a classical spin exchange coupled to a Fermi sea — •Mohammad Sayad and Michael Potthoff — I. Institut für Theoretische Physik , University of Hamburg, Germany

Using a numerical time-step propagation technique, we study the real-time dynamics of a single classical spin locally coupled via an antiferromagnetic exchange J to a system of non-interacting electrons. The dynamics is initiated by suddenly switching a local magnetic field B. In the regime of weak J and B, linear-response theory and the separation of time scales can be employed to derive the Landau-Lifshitz-Gilbert equation. We show, however, that this theory must break down and that the Gilbert damping becomes ill-defined in the case of one-dimensional systems. The reversal time of the spin is systematically calculated in the entire parameter regime. For strong J we find an incomplete relaxation on a short time scale followed by a slow drift towards saturation. Retardation effects and deviations from adiabatic spin dynamics are discussed for systems with a single and with two classical spins.

15 min. break

MA 14.6 Tue 11:00 H 0112

Finite temperature and magnetic field transport in 1D quantum magnets — •Xenophon Zotos — Physics Department - University of Crete — Crete Center for Quantum Complexity and Nanotechnology — FORTH - IESL

I'll present recent exact results on the finite temperature and magnetic field magneto-thermal transport in the one dimensional spin-1/2 Heisenberg model obtained using the Bethe ansatz (BA) method. In particular, I'll discuss the behavior of spin Drude weight as a function of magnetic field down to low temperatures. These new results are based on a previous analysis by the author of the spin Drude weight in zero magnetic field.

Furthermore, I'll discuss the thermodynamics, thermal transport and dynamics (ESR), of the spin S=1 easy-plane quasi-one dimensional quantum magnet NiCl2-4SC(NH2)2 (DTN). The analysis is based on an effective spin-1/2 anisotropic (s= 1/2) Heisenberg model description that is put on a firm basis by comparing the thermodynamics of the S=1 model, obtained using TMRG, with exact BA specific heat and magnetisation results for the s=1/2 Heisenberg model. For the thermal conductivity in a magnetic field, Ill compare numerical data on the S=1 model obtained using exact diagonalization techniques to exact results using the BA method. For the ESR data, using a recently developed BA technique, I'll show that the extremely sharp line observed in experiments, is due to a singular excitation to a single excited state.

MA 14.7 Tue 11:15 H 0112

Multi-scale modelling of magnetization dynamics — •Andrea De Lucia, Mathias Kläui, and Bejnamin Krüger — Institut für Physik, Johannes Gutenberg Universität, Mainz

A Multi-scale Magnetization Dynamics Simulation scheme was developed and applied to systems with special spin structures and properties. The MicroMagnum simulator was used as starting point and expanded to include a Multi-scale approach. The software selectively simulates different regions of a ferromagnetic sample employing the most suitable discretization and model according to the properties of each region. Simulating magnetization dynamics in a Multi-scale environment allows one to rapidly evaluate the Landau-Lifshitz-Gilbert equation in a mesoscopic sample with nanoscopic accuracy where needed. Possible application of this software include Skyrmion Dynamics, Domain Wall motion and Spin Wave generation.

MA 14.8 Tue 11:30 H 0112

Effective models for exchange bias systems based on atomistic spin dynamics simulations — •Irina Stockem, Stefan Muschack, and Christian Schröder — Bielefeld Institute for Applied Materials Research, University of Applied Sciences Bielefeld, Wilhelm-Bertelsmann-Str. 10, 33602 Bielefeld, Germany

The exchange bias anisotropy was observed at stacked ferromagnetic and antiferromagnetic layers by Meiklejohn and Bean in the 1950$^{\text{th}}$ [1]. The exchange bias leads to an asymmetric shift of the hysteresis loop, which is fixed during the fabrication process in conventional systems. In novel systems, like Co/Cr_2O_3, this shift can be switched [2]. Although the discovery of the exchange bias is more than half a century ago a comprehensive theoretical model is still missing. Many simplified and analytical solvable models exist but these are not applicable to real exchange biased structures. In order to obtain a better understanding of the dominating factors of exchange bias systems we have developed effective models and investigated these by spin dynamics simulations [3]. We compare our results to existing models and to atomistic spin dynamics simulations of a three dimensional Co/Cr_2O_3 model system.

[1] W. H. Meiklejohn and C. P. Bean, Phys. Rev. **105**, 904 (1957).
[2] Y. Shiratsuchi et al., Appl. Phys. Lett. **100**, 262413 (2012).
[3] L. Engelhardt and C. Schröder, in Molecular Cluster Magnets, World Scientific Publishers, Singapore (2011).

MA 14.9 Tue 11:45 H 0112

Simulation of coercivities and magnetization reversal mechanisms in fourfold ferromagnetic systems of different dimensions and orientations — •Tomasz Blachowicz[1] and Andrea Ehrmann[2] — [1]Silesian University of Technology, Institute of Physics, Poland — [2]Niederrhein University of Applied Sciences, Faculty of Textile and Clothing Technology, Germany

The stability of magnetic states during magnetization reversal, especially at remanence, belongs to the important issues in examination of magnetic nanosamples. Our presentation gives an overview of different fourfold magnetic wire systems, simulated by Magpar. Wire lengths have been chosen from 30 nm to 70 nm, while the single wires have length-to-diameter ratios between 3 and 11. Simulations have been carried out for angular in-plane directions of the externally applied field from 0° (parallel to one pair of wires) to 45°. Depending on system dimensions and external field angle, different magnetization reversal mechanisms could be observed as well as changes between stable and instable magnetic states [1].

Intermediate states at vanishing external field, reached by minor loops starting at steps in the hysteresis loop, are of special interest for application in novel data storage media systems. The presentation shows different possibilities to create such states and examines their stability by comparing hysteresis loops, special distribution of magnetization, and exchange energy as function of the externally applied field for a number of sample dimensions and external field angles.

[1] T. Blachowicz, A. Ehrmann, J. Appl. Phys. 113, 013901 (2013)

MA 14.10 Tue 12:00 H 0112

Micromagnetic analysis of nucleation and pinning processes in supermagnets — Dagmar Goll[1], Therese Dragon[2], Matthias Katter[3], and •Helmut Kronmueller[2] — [1]Aalen University, Materials Research Institute (IMFAA), Aalen — [2]Max Planck Institute for Intelligent Systems — [3]Vacuumschmelze GmbH & Co. KG, Hanau

The large discrepancy between theoretical predictions and realized magnetic properties of hysteresis loops of high-quality permanent magnets, known as Brown-paradox, has been the matter of discussions over decades of years. In particular whether the leading hardening mechanism is due to a nucleation mechanism or to domain wall pinning has been the topic of many publications with contrary statements. Here the existence of single or multi-domain grains plays a central role. This contribution presents the following basic results which allow a distinction between the two types of hardening mechanisms: 1. Coercive field H_{c} as a function of maximum applied magnetic field. 2. Change of domain patterns as a function of applied magnetic field. 3. Angular dependence of H_{c}. 4. Temperature dependence of H_{c}. Experimental results obtained for nanocrystalline systems of FePt and MnBi and sintered Nd-Fe-B based permanent magnets are compared with micromagnetic analytical results. It is shown that for high-quality permanent magnets the dominant hardening mechanism corresponds to the nucleation process.

MA 14.11 Tue 12:15 H 0112

Nonlinear frequency-dependent effects in the dc magnetization of uniaxial magnetic nanoparticles in superimposed strong alternating current and direct current fields — •William Coffey[1], Nijun Wei[1], Sergey Titov[1], Yuri Kalmykov[2], and Declan Byrne[1] — [1]Department of Electronic and Electrical Engineering, Trinity College, Dublin 2, Ireland — [2]Université de Perpignan Via Domitia, Laboratoire de Mathématiques et Physique, F-66860, Perpignan, France

The dc component of the magnetization of noninteracting fine magnetic particles possessing simple uniaxial anisotropy and subjected to strong ac and dc bias magnetic fields is calculated via the magnetic Langevin equation. In the presence of an ac driving field, the dc component of the magnetization of uniaxial particles alters drastically leading to new nonlinear effects; in particular, it becomes frequency-dependent. In axial symmetry, where the strong ac field is parallel to the easy axis of a particle, two distinct dispersion regions in the dc magnetization at low and mid-frequencies emerge, corresponding to longitudinal overbarrier and intrawell relaxation modes. Such frequency-dependent behavior allows one to estimate the magnetization reversal time via the half-width of the low-frequency dispersion band. Otherwise, by applying the strong ac field at an angle to the easy axis of a particle so breaking the axial symmetry, a third high-frequency nonlinear resonant dispersion in the dc component of the magnetization appears accompanied by parametric resonance behavior due to excitation of transverse modes with frequencies close to the precession frequency.

MA 15: Magnetic measurement methods

Time: Tuesday 9:30–12:15 Location: H 1012

MA 15.1 Tue 9:30 H 1012

Magnetic SANS correlation functions of bulk ferromagnets — •Denis Mettus and Andreas Michels — Physics and Materials Science Research Unit, University of Luxembourg

Small-angle neutron scattering (SANS) is a very powerful method for structure determination which can be utilized in a wide range of scientific disciplines such as material science, physics, or chemistry. For bulk ferromagnets, the magnetic neutron scattering cross section is usually dominated by the so-called spin-misalignment scattering, which is related to the transversal magnetization Fourier coefficients. In this talk, we discuss model computations (based on the continuum theory of micromagnetics) for the magnetic correlation function of bulk ferromagnets. Specifically, we provide results for the magnetic correlation function of bulk ferromagnets as a function of applied magnetic field, particle volume fraction, and magnetic-interaction parameters (exchange constant, magnetic anisotropy field, magnetostatic field due to magnetization jumps at internal interfaces).

MA 15.2 Tue 9:45 H 1012

Ab initio calculation of Spin Polarized Low-Energy Electron Diffraction for the systems Fe(001) and Fe(001)-p(1x1)-O — •Stephan Borek[1], Jürgen Braun[1], Ján Minár[1,3], Christian Langenkämper[2], Christian Thiede[2], Anke B. Schmidt[2], Markus Donath[2], and Hubert Ebert[1] — [1]Ludwig-Maximilians-Universität München — [2]Westfälische-Wilhelms Universität Münster — [3]University of West Bohemia, Pilsen

For the implementation of a new type of spin detector at Bessy II a spin filter using the principle of exchange and spin-orbit scattering has to be designed. Among the suitable materials a promising candidate is Fe(001)-p(1x1)-O. The passivated surface has a long lifetime in vacuum and shows a high figure of merit. We will demonstrate the impact of the passivation of a Fe(001) surface on the diffraction patterns by calculating the Spin Polarized Very Low Energy Electron Diffraction (VSPLEED). We investigated two different types of scattering geometries where according to symmetry relations the first one has only exchange scattering whereas for the second both exchange and spin-orbit scattering occurs. Beside we investigated the effect of strong correlations on the basis of the dynamical mean field theory (DMFT). Complementary is the calculation of the so-called target current which also gives insight into the electronic structure. We calculated the target current for the system Fe(001)-p(1x1)-O for a large range of polar angle and kinetic energy. For both the spin polarized diffraction of electrons at the Fe(001)-p(1x1)-O surface as well as for the target current a comparison between theory and experiment will be made.

MA 15.3 Tue 10:00 H 1012

Generation of circularly polarized radiation from a compact plasma-based extreme ultraviolet light source for tabletop X-ray magnetic circular dichroism studies — •Daniel Wilson[1,2,4], Denis Rudolf[1,2,4], Christian Weier[3,4], Roman Adam[4,5], Gerrit Winkler[4,5], Robert Frömter[4,5], Serhiy Danylyuk[4,5], Klaus Bergmann[4,5], Detlev Grützmacher[2,4], Claus M. Schneider[3,4], and Larissa Juschkin[1,2,4] — [1]Experimental Physics of EUV, RWTH Aachen University — [2]Peter Grünberg Institut (PGI-9), Research Centre Jülich GmbH — [3]Peter Grünberg Institut (PGI-6), Research Centre Jülich GmbH — [4]Institut für Angewandte Physik, Universität Hamburg — [5]Chair for Technology of Optical Systems, RWTH Aachen University

We present a compact apparatus for generation of linearly and circularly polarized EUV radiation from a gas-discharge plasma light source between 50 eV and 70 eV photon energy. In this spectral range, the 3p absorption edges of Fe (54 eV), Co (60 eV), and Ni (67 eV) offer a high magnetic contrast often employed for magneto-optical and electron spectroscopy as well as for magnetic imaging. We simulated and designed an instrument for generation of linearly and circularly polarized EUV radiation and performed polarimetric measurements of the degree of linear and circular polarization. Furthermore, we demonstrate first measurements of the X-ray magnetic circular dichroism at the Co 3p absorption edge with a plasma-based EUV light source. Our approach opens the door for laboratory-based, element-selective spectroscopy of magnetic materials and microscopy of ferromagnetic domains.

MA 15.4 Tue 10:15 H 1012

***Ab initio* calculation of *d*-metal L-edge RIXS spectra using many-body quantum chemistry methods** — •Nikolay A. Bogdanov[1], Valentina Bisogni[2], Jochen Geck[3], Liviu Hozoi[1], and Jeroen van den Brink[1,4] — [1]Brookhaven National Laboratory, USA — [2]Institute for Solid State Research, IFW Dresden, Germany — [3]Institute for Theoretical Solid State Physics, IFW Dresden, Germany — [4]Department of Physics, TU Dresden, Germany

We designed a fully *ab initio* quantum chemistry scheme for the computation of both *d*-*d* excitation energies and intensities as measured by resonant inelastic x-ray scattering (RIXS) in *d*-electron systems. RIXS has recently emerged as a powerful tool to reliably probe the charge, spin, and orbital degrees of freedom of correlated electrons in solids [1,2]. As a first application we picked up Li_2CuO_2, a quasi-1D Cu $3d^9$ oxide with a simple valence configuration in the intermediate state. We use embedded-cluster MCSCF and MRCI techniques [3], including scalar relativistic effects, spin-orbit coupling, and the valence orbital relaxation in the presence of the core hole. The transition matrix elements of the dipole operator are obtained by non-orthogonal configuration interaction. A careful analysis of the RIXS spectra is important for understanding the interplay between local distortions and longer-range lattice anisotropy and its effect on the *d*-level electronic structure [3,4] and magnetic interactions [4]. [1] L. Ament *et al.* Rev. Mod. Phys. **83**, 705 (2011); [2] J. Schlappa *et al.* Nature **485**, 82 (2012); [3] H.-Y. Huang *et al.* Phys. Rev. B **84**, 235125 (2011); [4] N. A. Bogdanov *et al.* Phys. Rev. Lett. **110**, 127206 (2013).

MA 15.5 Tue 10:30 H 1012

A hybrid sensor based on nitrogen-vacancy center in diamond and piezomagnetic film for nanoscale probing of stress — •Phani Peddibhotla[1], Benjamin Riedmueller[2], Liam McGuinness[1], Farzaneh Vaghefikia[1], Alexander Gerstmayr[1], Jianming Cai[3], Martin Plenio[3], Berndt Koslowski[4], Ulrich Herr[2], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, University of Ulm, 89081 Ulm, Germany — [2]Institute for Micro- and Nanomaterials, University of Ulm, 89081 Ulm, Germany — [3]Institute for Theoretical Physics, University of Ulm, 89081 Ulm, Germany — [4]Institute for Solid State Physics, University of Ulm, 89081 Ulm, Germany

We report on the development of a hybrid diamond-piezomagnetic system for the measurement of stress (force) [1]. Our experimental setup comprises of an atomic force microscope (AFM) integrated into a confocal microscope. A thin magnetostrictive film is deposited onto the diamond sample containing nitrogen-vacancy (NV) centers. An AFM cantilever tip is used to apply a local force or stress on the thin film, thereby resulting in a change in the stray magnetic field outside the magnetostrictive material. Optical readout of the spin quantum state of the NV center encodes information about the change in the magnetic field thereby resulting in a transduction of force.

[1] J. Cai et al., Nat. Commun. 5:4065 (2014).

MA 15.6 Tue 10:45 H 1012

Temperature dependence of the ferromagnetic resonance in magnetic films — •Kristof M. Lebecki — Nanotechnology Centre, VSB-TU Ostrava, Czech Republic

Ferromagnetic resonance (FMR) is an important experimental tool. The well-known FMR line width equation can be extended *e.g.* by including the Bloch-Bloembergen relaxation. Thus, two-magnon scattering is included. We present here a different approach. Recently proposed Landau-Lifshitz-Bloch approach (LLB) is namely an extension of the Landau-Lifshitz-Gilbert equation (LLG). Contrary to LLG, LLB is valid in the whole temperature range, up to the Curie temperature. We have theoretically analyzed the LLB equation and derived the resonance conditions for the case of a thin film and an in-plane DC field. As a result we got a complex equation for the resonance field that must be solved numerically. However, we propose a handy approximation working well in the whole temperature range. Basing on the resonance field, the FMR line width can be calculated analytically. We show the results of our calculations considering a permalloy film. The resonance field grows remarkably with the temperature. The line width dependence on the microwave frequency is no more linear, a fact that has been observed experimentally in the past. Also, the line width grows with the temperature.

MA 15.7 Tue 11:00 H 1012

All electrical coherent control of the magnetization in a thin Yttrium Iron Garnet film — •Olga Wid[1], Martin Wahler[1], Nico Homonnay[1], Tim Richter[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale) , Germany

We have investigated the magnetic properties of Yttrium Iron Garnet (YIG) thin films using Time Domain Ferromagnetic Resonance (FMR). The sample is placed on a coplanar waveguide and a voltage step is used to induce a precession of the magnetization in the sample which is then detected by the induced voltage. A second voltage step which can be applied with variable time delay allows us to coherently control the precession. With suitable delay times the amplitude of the precession can either be maximized or the precession can be completely stopped. This method allows for a very precise investigation of the precession dynamics. The high quality of the YIG films (best FMR linewidth 2 Oe @ 9.6 GHz) permits us to observe the precession over a time of more than 50 ns (for comparison: Permalloy shows a precession over 5 ns). Our experiments are supported by micromagnetic dynamic simulations using OOMMF and MuMax2 which nicely confirm our experimental results.

MA 15.8 Tue 11:15 H 1012

A Ferromagnetic Resonance scanner with 20 μm resolution — •Carola Lottis, Ralf Meckenstock, Christian Schöppner, and Michael Farle — Faculty of Physics and CENIDE, University Duisburg-Essen, Germany

The enlarged surface-to-volume ratio of nano structures, inhomogeneous demagnetizing fields due to confined geometries, roughness and morphology have considerable influence on magnetic properties and lead to complex magnetic excitations. Here, we present a micro resonator technique used in combination with a submicrometer positioning system to determine magnetic properties of single nano magnets, that do not have to be prepared specially for- or in the micro resonator, but stay in their natural environment.

To reach a sensitivity of 10^6 spins for FMR detection, a micro resonator is evaporated on a silicon-nitrite membrane (250 μm x 250 μm and 200 nm thick). The FMR sensitive area is 20 μm ∅ and at a distance of <10 μm above the sample. An optical microscope is mounted above the FMR scanner to facilitate the positioning of the sample in the FMR sensitive area. The positioning system has a working range of 6.1 mm in all three directions with a resolution of 1 nm. First results on an iron silicon ferromagnetic stripe with a "zig-zag" form (65 μm long, 1.5 μm wide and 18 nm thick) will be shown. Small deviations of the FMR due to the zig-zag structure's dipole field can be resolved.

The authors thank the DFG for financial support within the program LI1567/3-1.

MA 15.9 Tue 11:30 H 1012

Sensitivity enhancement in microscale cantilever magnetometry — •Julia Körner[1], Christopher F. Reiche[1], Bernd Büchner[1,2], and Thomas Mühl[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung IFW Dresden — [2]Institut für Festkörperphysik, Technische Universität Dresden

The study of magnetic properties of increasingly smaller single particles poses great challenges to researchers. As the probe's size shrinks according to the particle size, an increasing effort has to be taken to gain reliable data from measurements. In case of cantilever magnetometry very low stiffness cantilevers are usually employed. [1]

We have developed a sensor concept which combines a nanowire, e.g. a multi walled carbon nanotube (MWCNT) oscillator, with state-of-the-art cantilever deflection measurement techniques. Due to the small size and low stiffness of the nanowire, it offers high sensitivity for measuring small magnetic particles positioned at its tip when the system is mechanically excited to oscillate. The oscillation states are detected by using conventional laser-deflection.

[1] B. C. Stipe, H. J. Mamin, T. D. Stowe, T. W. Kenny, D. Rugar, Phys. Rev. Lett. 86 (13), 2001

MA 15.10 Tue 11:45 H 1012

Cross-correlation spin noise spectroscopy of heterogeneous interacting spin systems — •Dibyendu Roy[1,2,3], Luyi Yang[4], Scott A. Crooker[4], and Nikolai A. Sinitsyn[2] — [1]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Str. 38, 01187 Dresden, Germany — [2]Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [3]Center for Nonlinear Studies, Los Alamos National Laboratory, Los Alamos, NM 87545, USA — [4]National High Magnetic Field Laboratory, Los Alamos National Laboratory, Los Alamos, NM 87545, USA

We develop and apply a minimally invasive approach for characterization of inter-species spin interactions by detecting spin fluctuations alone. We consider a heterogeneous two-component spin ensemble in thermal equilibrium that interacts via binary exchange coupling, and we determine cross-correlations between the intrinsic spin fluctuations exhibited by the two species. Our theoretical predictions are experimentally confirmed using two-color optical spin noise spectroscopy on a mixture of interacting Rb and Cs alkali vapors [arXiv:1408.5399]. The results allow us to explore the rates of spin exchange and total spin relaxation under conditions of strict thermodynamic equilibrium.

MA 15.11 Tue 12:00 H 1012

Spin-resolved hard x-ray photoemission from buried magnetic layers. — •X. Kozina[1], E. Ikenaga[2], C.E. Viol Barbosa[3], G.H. Fecher[3], C. Felser[3], K. Kobayashi[4], D. Kutnyakhov[1], K. Medjanik[1], and G. Schönhense[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany — [2]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan — [3]Max Planck Institut for Chemical Physics of Solids, Dresden, Germany — [4]Japan Atomic Energy Agency, SPring-8, Hyogo, Japan

We discuss the present status and future potential of spin-resolved hard X-ray photoemission (HAXPES). Recently, deeply buried CoFe layers have been studied at the BL09XU end station of SPring-8, Japan, using a large hemispherical analyzer (Scienta R-4000) and a single-channel SPLEED-type polarimeter [1]. The excitation energy of 6 keV assures significantly enhanced probing depth to access buried layers. A spin polarization of about 20% is retained during transmission of the photoelectrons emitted from the Fe 2p3/2 state through a 3-nm-thick oxide capping layer. Single-channel spin detection suffers from the low figure of merit, thus for future measurements in the valence region a multichannel spin detector is indispensable.

Therefore the Mainz group in cooperation with Univ. Wuerzburg (R. Claessen et al.) are developing a novel multichannel spin detector that will be implemented in the HAXPES endstation at PETRA III, Germany (equipped with a Specs Phoibos-225 analyzer). The status of the development is reported.

[1] G. Stryganyuk et al. Jpn. J. Appl. Phys. 51 (2012) 016602

MA 16: Bio- and Molecular magnetism

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

MA 16.1 Tue 9:30 EB 202

Ferromagnetic Cluster Spin Wave Excitation in the High Spin Molecules $Mn_{18}Sr$ and Mn_{19} — •Siyavash Nekuruh[1], M. Klingele[1], J. Nehrkorn[1], K. Prsa[1], B. Burger[2], A.M. Ako[2], C.E. Anson[2], Y. Lan[2], A.K. Powell[2], and O. Waldmann[1] — [1]Physikalisches Institut, Universität Freiburg, Germany — [2]Institut für Anorganische Chemie, Karlsruhe Institut für Technologie (KIT)

The ferromagnetically coupled molecule Mn_{19} has attracted considerable interest in the past because of its huge high-spin ground state $S = 83/2$. From the chemistry point of view determining the exchange coupling constants and their comparison to e.g. ab initio result is of interest, while physically it is highly interesting to understand the spin-wave excitations in such a molecule. The huge Hilbert space and intricate topology of Mn_{19} complicate the analysis of experimental data enormously, and hence the simpler molecules Mn_{10} and $Mn_{18}Sr$, which can be regarded as model compounds for Mn_{19}, were studied.

We here present a detailed study of the magnetic excitations in $Mn_{18}Sr$ and Mn_{19} by INS. For the determination of the exchange constants of $Mn_{18}Sr$ we used the positions of two cold peaks in the measured INS spectra and the magnetic susceptibility simultaneously for fitting. In Mn_{19} one excitation is observed at low energies, which is not present in Mn_{10} and $Mn_{18}Sr$ and shows an uncommon temperature dependence. As a result Mn_{19} cannot be treated by a non-interacting spin-wave picture, but requires an inherent many-body description.

MA 16.2 Tue 9:45 EB 202

High-field ESR study of a new ferrous cubane SMM — •Azar Aliabadi[1], Felix J Klinke[2], Serhiy Demeshko[2], Vladislav Kataev[1], Franc Meyer[2], and Bernd Büchner[1] — [1]IFW Dresden, Dresden, Germany — [2]Institute of Inorganic Chemistry, Georg-August-University, Göttingen, Germany

Magnetic properties of a cube-like tetranuclear complex with a $\{Fe_4O_4\}$ core have been investigated by means of the high-field high-frequency tunable electron spin resonance (HF-ESR). Four Fe(II) spins $S = 2$ in the complex are coupled ferromagnetically yielding a high-spin ground state with $S_{total} = 8$. The ESR spectra consist of a single line in a frequency range $\leq$ 332 GHz, whereas at higher frequencies a low magnetic field line appears at 4 K. The second line at the low magnetic field arises with increasing temperature. A transfer of the spectral weight to higher magnetic field at high temperatures gives evidence for an easy axis magnetic anisotropy for the entire cube. Simulated powder averaged ESR spectra for the case of the collinear alignment of four Fe(II) spins with an easy axis magnetic anisotropy agrees well with the experimental data. The calculated energy levels scheme of this system suggests a spin doublet ground state $|8, \pm 8>$ which confirms the negative sign of the axial magnetic anisotropy parameter D.

The observation of a high spin ground state with the easy axis magnetic anisotropy for the $\{Fe_4O_4\}$-cube suggests a single-molecule magnet (SMM) behavior of the studied complex.

MA 16.3 Tue 10:00 EB 202

Electron spin density on the N atoms of CuII- bis(oxamidato) complexes: a pulse ELDOR detected NMR study — •Azar Aliabadi[1], Ruslan Zaripov[2], Mohammad A. Abdulmalic[3], Evgeniya Vavilova[2], Violeta Voronkova[2], Tobias Rüffer[3], Vladislav Kataev[1], Kev Salikov[2], and Bernd Büchner[1] — [1]IFW Dresden, Dresden, Germany — [2]Zavoisky Physical Technical Institute, RAS, Kazan, Russia — [3]Institute of Chemistry, TU Chemnitz, Chemnitz, Germany

Mononuclear $Cu(II)$- bis(oxamidato) complexes are used for the synthesis of their corresponding trinuclear complexes which are excellently suited to study magnetic superexchange phenomena.

To estimate the spin density distribution, which is a measure of the exchange constant, we have determined the hyperfine (HF) tensors for four N atoms of mononuclear $Cu(II)$- bis(oxamidato) complexes containing phenylene, ethyl and alkyl nitrogen ligands ($CuN_2^{aryl}N_2^{ethyl}/CuN_2^{aryl}N_2^{alkyl}$) by a pulse ELDOR detected NMR (EDNMR) experiment at 35 GHz and 20 K. We discuss a relationship between the spin density distribution of mononuclear complexes and the magnetic exchange couplings in their corresponding trinuclear complexes.

In particular, the obtained spin densities enable us to explain unexpectedly low J values of trinuclear Cu(II)-bis(oxamidato) complexes ($J = -[52 - 66]cm^{-1}$) compared to the larger value for trinuclear Cu(II)-bis(oxamato) complex ($J = -89cm^{-1}$).

MA 16.4 Tue 10:15 EB 202

Quantum signatures of a molecular nanomagnet in direct magnetocaloric measurements — Joseph W. Sharples[1], David Collison[1], Eric J. L. McInnes[1], Elias Palacios[2], Marco Evangelisti[2], and •Jürgen Schnack[3] — [1]Chemistry, The University of Manchester, UK — [2]CSIC, Universidad de Zaragoza, Spain — [3]Physics, Bielefeld University, Germany

Geometric spin frustration in low-dimensional materials, such as the two-dimensional kagome or triangular antiferromagnetic nets, can significantly enhance the change of the magnetic entropy and adiabatic temperature following a change in the applied magnetic field, that is, the magnetocaloric effect. In principle, an equivalent outcome should also be observable in certain high-symmetry zero-dimensional, that is, molecular, structures with frustrated topologies. Here we report experimental realization of this in a heptametallic gadolinium molecule. Adiabatic demagnetization experiments reach $\sim$ 200 mK, the first sub-Kelvin cooling with any molecular nanomagnet, and reveal isentropes (the constant entropy paths followed in the temperature-field plane) with a rich structure. The latter is shown to be a direct manifestation of the trigonal antiferromagnetic net structure, allowing study of frustration-enhanced magnetocaloric effects in a finite system.

J.W. Sharples, D. Collison, E.J.L. McInnes, J. Schnack, E. Palacios, M. Evangelisti, Nature Communications **5** (2014) 5321

MA 16.5 Tue 10:30 EB 202

Magnetic coupling in unligated and ligated FePc sandwiches — •Heike C. Herper and Barbara Brena — Department of Physics and Astronomy, Uppsala University, Sweden

Molecular magnetic materials are intensively discussed as candidates for future electronic devices however switching the spin state or changing the magnetic coupling is still a challenging task. We have performed an ab initio study of the magnetic and structural properties of sandwiches of FePc molecules which serve as a model system for transition metal based Pc complexes. Investigations include molecules in gas phase as well as adsorbed on a metal substrate. The two FePc molecules are weakly bonded and the calculated exchange coupling is smaller than 20 meV such that a flipping from ferromagnetic (FM) to antiferromagnetic (AF) coupling can be achieved. The magnetic coupling can be even more reduced (< 1meV) by ligating the two FePc molecules with Cl whereby the ground state configuration changes from FM to AF. If the unligated $(FePc)_2$ is deposited on a Co(001) substrate the lower FePc couples in agreement with previous findings [1,2] FM to the Co film but the intermolecular coupling switches from FM to AF whereby the coupling strength is similar to the one of the free $(FePc)_2$.

[1] D. Klar *et al.*, Phys. Rev. B **88**, 224424 (2013)
[2] H. C. Herper *et al.*, Phys. Rev. B **89**, 085411 (2014)

15 min. break

MA 16.6 Tue 11:00 EB 202

Electron correlation in organometallics: insights from density functional theory and exact diagonalization — Sumanta Bhandary[1], Tim Wehling[2], Olle Eriksson[1], and •Biplab Sanyal[1] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Institute for Theoretical Physics, University of Bremen, Otto-Hahn-Allee 1, 28359 Bremen, Germany and Bremen Center for Computational Materials Science, University of Bremen, Am Falturm 1, 28359, Bremen, Germany

A proper theoretical description of electronic structure of the 3d orbitals in the metal centers of functional organometallic molecules is a challenging problem. Here, we have used density functional theory and an exact diagonalization method in a many body approach to study the ground state electronic configuration of an iron porphyrin (FeP) molecule. Our study reveals that dynamical correlation effects are important, and FeP is a potential candidate for realizing a spin crossover due to a subtle balance of crystal field effects, on-site Coulomb repulsion and hybridization between the Fe d-orbitals and ligand N p-states. Moreover, the mechanism of switching between two close lying electronic configurations of Fe-d orbitals is revealed. We discuss the generality of the suggested approach and the possibility to properly describe the electronic structure and related low energy physics of the whole class of correlated metal centered organometallic molecules.

MA 16.7 Tue 11:15 EB 202

Enhanced magnetic interactions in an lanthanide molecular cluster — •Krunoslav Prsa[1], J. Nehrkorn[1], S. Nekuruh[1], W.J. Evans[2], J.R. Long[3], T. Guidi[4], and Oliver Waldmann[1] — [1]Physikalisches Institut Universität Freiburg, Germany — [2]Department of Chemistry, University of California, Irvine, USA — [3]Department of Chemistry, University of California, Berkeley, USA — [4]ISIS Facility, STFC Rutherford Appleton Laboratory, United Kingdom

Technological applications of molecular magnets critically depend on the enhancement of their blocking temperatures. Molecules containing rare-earth ions are promising candidates because of strong anisotropy and large individual magnetic moments. However, the first polynuclear lanthanide clusters suffered from a low interaction strength between the magnetic moments. An N_2^{3-} radical–bridged dinuclear lanthanide molecular complex, $Tb_2N_2^{3-}$, was recently synthesized to overcome this problem [1]. Inelastic neutron scattering data on this molecule, its parent compound $Tb_2N_2^{2-}$ as well as the non-magnetic analogue $Y_2N_2^{3-}$, were recorded at the LET instrument at the ISIS neutron source. In addition to the ligand field levels, we observe excitations due to exchange coupling between the lanthanide magnetic moments which present a direct evidence of enhancement of interactions in this system.

[1] J.D. Rinehart *et. al.*, Nat. Chem. 538-542 (**3**), 2011.

MA 16.8 Tue 11:30 EB 202

X-ray induced demagnetization of single-molecule magnets — •Jan Dreiser[1,2], Rasmus Westerström[2,3,4], Cinthia Piamonteze[2], Frithjof Nolting[2], Stefano Rusponi[1], Harald Brune[1], Shangfeng Yang[5], Alexey Popov[6], Lothar Dunsch[6], and Thomas Greber[3] — [1]Institute of Condensed Matter Physics, Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — [2]Swiss Light Source, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland — [3]Physik-Institut, Universität Zürich, 8057 Zürich, Switzerland — [4]Department of Physics and Astronomy, Uppsala University, 751 20 Uppsala, Sweden — [5]Hefei National Laboratory for Physical Sciences at Microscale, Department of Materials Science and Engineering, University of Science and Technology of China, Hefei 230026, China — [6]Department of Electrochemistry and Conducting Polymers, Leibniz Institute of Solid State and Materials Research, 01069 Dresden, Germany

X-ray magnetic circular dichroism measurements on the endohedral single-molecule magnet $DySc_2N@C_{80}$ [1] at the Dy $M_{4,5}$ edges exhibit a shrinking of the hysteresis opening with increasing x-ray flux. Our data reveal that this effect can neither be explained by irreversible structural damage nor by a homogeneous temperature rise due to x-ray absorption. The observed large demagnetization cross sections indicate that the resonant absorption of one x-ray photon induces the demagnetization of many molecules [2].

[1] Westerström *et al.*, J. Am. Chem. Soc. **134**, 9840 (2012).
[2] Dreiser *et al.*, Appl. Phys. Lett. **105**, 032411 (2014).

MA 16.9 Tue 11:45 EB 202

Light-Induced Switching of the Spin of Fe Complexes on Surfaces — •Matthias Bernien[1], Holger Naggert[2], Christian F. Hermanns[1], Fabian Nickel[1], Lucas M. Arruda[1], Lalminthang Kipgen[1], Jorge Miguel[1], Alex Krüger[1], Dennis Krüger[1], Enrico Schierle[3], Eugen Weschke[3], Felix Tuczek[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin — [2]Institut für Anorganische Chemie, Christian-Albrechts-Universität zu Kiel, 24098 Kiel — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin

Sublimable spin-crossover complexes have recently gained a lot of attention due to their potential application as building blocks for molecular spintronic devices. These molecules possess a metastable spin state that reacts sensitively to tiny perturbations in temperature, light exposure, or intermolecular interactions. If these complexes are immobilized on a solid surface, the spin transition is often quenched. We have studied submonolayers of the Fe(II) spin-crossover complex $[Fe(bpz)_2(phen)]$ (bpz=dihydrobis(pyrazolyl)borate, phen=1,10-phenanthroline) by means of x-ray absorption spectroscopy. Using highly oriented pyrolytic graphite (HOPG) as a weakly interacting substrate we show that even molecules that are in direct contact with a solid surface can undergo a spin-crossover transition as a function of temperature. X-ray magnetic circular dichroism shows that the spin of $[Fe(bpz)_2(phen)]$ can be switched from $S = 0$ to $S = 2$ highly efficiently using green light of 520 nm wavelength at $T = 5$ K. — Financial support by the DFG (Sfb's 658 and 677) is gratefully acknowledged.

MA 16.10 Tue 12:00 EB 202

Magnetotransport in carbon nanotube networks: influence of morphology, oxidation, and covalent functionalization with tetranuclear metal complexes — •Marlou Slot[1], Michael Schnee[2,4], Claire Besson[2,3,4], Robert Frielinghaus[2,4], Paul Kögerler[2,3,4], Claus M. Schneider[2,4], and Carola Meyer[2,4] — [1]Debye Institute for Nanomaterials Science, Utrecht University, The Netherlands — [2]Peter Grünberg Institut (PGI-6), Forschungszentrum Jülich, Germany — [3]Institut für Anorganische Chemie, RWTH Aachen, Germany — [4]JARA - Fundamentals of Future Information Technologies

Carbon nanotube networks (CNTNs) are a promising material for applications in plastic electronics and spintronics, constituting an electrically and mechanically robust alternative to single CNTs. The range of possible applications is broadened by functionalization. Covalent functionalization with antiferromagnetic tetranuclear metal coordination complexes, facilitated by sidewall oxidation, results in a defined angle of the complex with respect to the tube and a net spin near the CNT.

Low-temperature electrical transport characteristics of the CNTNs, consisting of semiconducting and metallic tubes, exhibit a shift from localized hopping behavior to dominating metallic conduction upon increasing network density. Short thermal oxidation results in an enhanced conductivity. The CNTNs exhibit a negative magnetoresistance (MR). Covalent functionalization with $\{Co_4\}$-complexes is observed to affect the magnitude of the MR at low temperatures, which corroborates the influence of these complexes on the transport in the CNTN.

MA 16.11 Tue 12:15 EB 202

Investigation of hexagonal spin tubes using DMRG — •Michael Czopnik and Jürgen Schnack — University of Bielefeld, Germany

The Density Matrix Renormalization Group (DMRG) is one of the most powerful numerical techniques for studying many-body systems. It was developed to overcome the problems arising in the application of the Numerical Renormalization Group (NRG) to quantum lattice many- body systems such as the Hubbard model of strongly correlated electrons.

The physics of spin tubes has attracted much attention in recent years. A so-called "spin tube" is a spin ladder with periodic boundary condition in the rung direction. It has a geometrical frustration in case the number of legs is odd and the frustration induces a variety of interesting phenomena.

We study the ground state and the magnetization of a Heisenberg spin tube made of nickel spins, using Den- sity Matrix Renormalization Group technique (DMRG) and exact diagonalization.

Special emphasis is put on unusual features of the magnetization curve, such as extended plateaus or jumps.

MA 17: Spintronics: Excitons and local spins (HL with MA/TT)

Time: Tuesday 9:30–11:30 Location: ER 270

MA 17.1 Tue 9:30 ER 270

Transport and manipulation of indirect exciton spins in GaAs double quantum well structures — Adriano Violante, Serkan Büyükköse, Klaus Biermann, and •Paulo Santos — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Indirect excitons in double quantum well (DQW) structures are interesting particles for information storage due to the electrically controlled coupling to photons. Here, we report on the coherent control and transport of IX spins in GaAs DQWs using spatially and polarization resolved photoluminescence (PL). We show that optically IXs spins optically excited by a focused, circularly polarized light spot precess around the spin-orbit magnetic field while moving over distances exceeding 20 μm from the excitation spot. The spatial precession frequency depends on the spin transport direction and can be controlled by the bias applied across the DQW structure. From the dependence of the spin dynamics on transport direction, bias, and external magnetic fields we directly determined the Dresselhaus and Rashba electron spin splitting coefficients for the DQW structure. The long *IX* lifetimes, together with the negligible contribution of holes to the spin dynamics, are attributed to spatial separation of the electron and hole wave functions by the electric field, which reduces the electron-hole exchange interaction. If extended to the single exciton regime, the present results imply that IXs can be used as flying spin qubits for application in the quantum information processing.

MA 17.2 Tue 9:45 ER 270

Spin properties of the indirect exciton in indirect band-gap (In,Al)As/AlAs quantum dot ensembles — •Jörg Debus[1], Victor F. Sapega[2], Timur S. Shamirzaev[3], Daniel Dunker[1], Evgeny L. Ivchenko[2], Dmitri R. Yakovlev[1,2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany — [2]Ioffe Physical-Technical Institute, St. Petersburg, Russia — [3]Institute of Semiconductor Physics, Novosibirsk, Russia

The band structure of type-I (In,Al)As/AlAs quantum dots with band gap energy exceeding 1.63 eV is indirect in momentum space, leading to long-lived exciton states with potential applications in quantum information. Optical access to these excitons is provided by mixing of the Γ- and X-conduction band valleys. We report on spin properties of the indirect exciton studied by time-resolved photoluminescence (TRPL) and resonant spin-flip Raman scattering (SFRS) [1-3]. The SFRS characterizes the Γ-X-valley electron state mixing, provides access to the fine structure of the indirect exciton and enables the preparation of its spin states as well as the determination of the spin-flip mechanisms. From the TRPL we evaluate very long longitudinal spin relaxation times (200 μs at 4 T and 1.8 K) that are rather robust against temperature changes. The temporal evolution of the circular polarization degree of the photoluminescence moreover changes its sign in the μs-range thus hinting at dark and bright indirect excitons contributing by their different spin dynamics. [1] T. S. Shamirzaev et al., Phys. Rev. B **84**, 155318 (2011). [2] D. Dunker et al., Appl. Phys. Lett. **101**, 142108 (2012). [3] J. Debus et al., Phys. Rev. B **90**, 125431 (2014).

MA 17.3 Tue 10:00 ER 270

Coherent control and readout of single spins in silicon carbide — •Matthias Widmann[1], Sang-Yun Lee[1], Torsten Rendler[1], Nguyen Tien-Son[2], Helmut Fedder[1], Erik Janzén[2], and Jörg Wrachtrup[1] — [1]3.Physikalisches Institut, Universität Stuttgart — [2]Department of Physics, Chemistry and Biology, Linköping University

Single spin manipulation is one of the main subjects in research not only for quantum information processing (QIP) but also for quantum metrology. Having isolated spins in solids has advantages of stability and fabrication. Deep level defects in diamond and impurity donors in silicon have been considered as promising candidates and several key steps towards QIP have been achieved. However, there exist disadvantages which have hindered their successful integration into modern electronic devices; cryogenic temperature mandatory for readout of spins in silicon, and difficulty in electrical initialization and readout in diamond. These motivate to investigate other host materials such as silicon carbide (SiC). SiC combines the advantages of silicon and diamond, because electrical detection and optical access of spin ensembles at room temperature (RT) is possible, and it also benefits from modern fabrication techniques. Addressing individual spin states have not been shown yet, however, is highly demanded to set up a base for scalable atomic-scale quantum technologies. By presenting coherent control and readout of single spins in SiC at RT we prove that SiC is a promising platform for the scalable spintronic devices [1]. [1] M. Widmann et al., Coherent control of single spins in silicon carbide at room temperature, to be published in Nature Materials.

MA 17.4 Tue 10:15 ER 270

Nuclear magetic resonance on a single quantum dot — •Gunter Wüst[1], Mathieu Munsch[1], Andreas Kuhlmann[1], Martino Poggio[1], Arne Ludwig[2], Andreas Wieck[2], Dirk Reuter[3], and Richard J Warburton[1] — [1]University of Basel, Switzerland — [2]Ruhr-Universität Bochum, Germany — [3]Universität Paderborn, Germany

The spin coherence of an electron trapped to a GaAs or InGaAs quantum dot is limited by noise in the nuclear spins of the host material [1]. Understanding and controlling the nuclear spins is therefore important for quantum applications. We report here nuclear magnetic resonance (NMR) experiments on the 100,000 nuclear spins that have a contact hyperfine interaction with a quantum dot electron spin [2]. The main technique is to sweep the frequency of an in-plane magnetic field. In this way, all nuclear spins are addressed despite the presence of four main isotopes with different gyromagnetic ratios. The nuclear spins are polarized and read-out via resonant spectroscopy allowing us to reach a sensitivity to about 1,000 nuclear spins. We evidence a plateau in the NMR sweep rate dependence associated to the existence of quadrupole interactions. Detailed analysis allows the quadrupole distributions for each isotope to be determined, along with an effective nuclear spin temperature following polarization (8 mK) and an In concentration (20%). Ongoing experiments determined in addition the Hahn echo coherence times (1 ms) and their dependence on quantum dot charge.

[1] R. J. Warburton et al, Nature Materials 12, 483-493 (2013) [2] M. Munsch, Nature Nanotechnology 9, 671-675 (2014)

MA 17.5 Tue 10:30 ER 270

Distinct Nuclear Spin Signatures in the Spin Noise of Donor Bound Electrons — •Fabian Berski[1], Pavel Sterin[1], Jens Hübner[1], Andreas Wieck[2], and Michael Oestreich[1] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Ruhr-Universität Bochum, Angewandte Festkörperphysik, Universitätsstr. 150, D-44780 Bochum, Germany

The hyperfine interaction acts as a main source of decoherence for localized electron spins in III-V semiconductor material systems and is thus a challenge for quantum information processing [1]. However, this interaction can also serve as a subtle probe of nuclear dynamics, which manifests itself in the spin dynamics of electrons.

Here, we study an ensemble of non-interacting donor bound electrons (D^0X) in a strain-free, high purity Gallium Arsenide host matrix, and find intriguing features of the nuclear spin dynamics in the electronic spin noise. The ideal tool to study such an interplay is spin noise spectroscopy, since it allows to control the dissipated amount of energy in the system and is a potential quantum non-demolition measurement [2]. However, by selecting the detuning between the D^0X transition and the energy of the used laser light, we find strong evidence for a significant nuclear polarization, even at low laser power, linearly polarized light and vanishingly small transversal magnetic fields.

[1] Chekhovich, et al., Nature Mat. **12**, 6 (2013).

[2] Hübner, et al., Phys Status Solidi B **251**, 1824 (2014).

MA 17.6 Tue 10:45 ER 270

Spin Dynamic of Electrons and Holes in Single Quantum Dots — •Ramin Dahbashi[1], Julia Wiegand[1], Jens Hübner[1], Klaus Pierz[2], Arne Ludwig[3], Andreas Wieck[3], and Michael Oestreich[1] — [1]Leibniz Universität Hannover, Institut für Festkörperphysik, Abteilung Nanostrukturen, Appelstr. 2, D-30167 Hannover, Germany — [2]Physikalisch Technische Bundesanstalt, Bundesallee 100, D-38116 Braunschweig, Germany — [3]Ruhr-Universität Bochum, Angewandte Festkörperphysik, Universitätsstr. 150, D-44801 Bochum, Germany

We present new insights into single quantum dot (QD) spin noise spectroscopy (SNS) [1]. We have performed world's first measurements of the single heavy hole spin dynamic in an individual (InGa)As QD by SNS [2]. These measurements reveal (a) very long T_1 hole spin lifetimes of up to 180 μs even in the low magnetic field range of up to 30 mT as well as (b) charge fluctuations in the QD surrounding. In order to suppress the parasitic influence of charge fluctuations, we move to QDs embedded in a Schottky diode structure which yields three main advantages: (i) the charge state of the QD, i.e., electron or hole, can be changed facilitating different coupling strength to the nuclear spin bath, (ii) the sharp single QD resonance can be tuned via the quantum confined Stark shift, and (iii) charge fluctuations are strongly reduced.

[1] J. Hübner, F. Berski, R. Dahbashi, and M. Oestreich, physica status solidi (b) **251**, 1824 (2014).

[2] R. Dahbashi, J. Hübner, F. Berski, K. Pierz, and M. Oestreich, Phys. Rev. Lett **112**, 156601 (2014).

MA 17.7 Tue 11:00 ER 270

Induced nuclear spin polarization in ZnSe:F epilayers — •Johan Erik Kirstein[1], Fabian Heisterkamp[1], Evgeny A. Zhukov[1], Alex Greilich[1], Dmitri R. Yakovlev[1,2], Irina A. Yugova[1,3], Vladimir L. Korenev[2], Alexander Pawlis[4], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44221 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Physical Faculty of St. Petersburg State University, 198504 St. Petersburg, Russia — [4]Department Physik, Universität Paderborn, 33098 Paderborn, Germany

We study the interaction of electron and nuclear spins in fluorine-doped ZnSe epilayers. Using the time-resolved optical pump-probe spectroscopy in the regime of resonant spin amplification we are able to resolve nuclear magnetic resonances (NMR) of ^{77}Se and ^{67}Zn isotopes with non-zero spin. The effective nuclear fields show a dispersive form of its strength around NMR as a function of magnetic field. In the RSA signal this leads a shift of the resonances of the electron spins. Dependences are measured as a function of external parameters, like: pump power, polarization modulation frequency and temperature. In a further experiment an external radio frequency field is applied to investigate the strength of the resulting nuclear field. Theoretical considerations support our findings.

MA 17.8 Tue 11:15 ER 270

Effect of electron spin inertia in II-VI semiconductors — •Fabian Heisterkamp[1], Evgeny A. Zhukov[1], Alex Greilich[1], Vladimir L. Korenev[1,2], Dmitri R. Yakovlev[1,2], Alexander Pawlis[3], Grzegorz Karczewski[4], Tomasz Wojtowicz[4], Jacek Kossut[4], and Manfred Bayer[1] — [1]Experimentelle Physik 2, Technische Universität Dortmund, 44227 Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [3]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [4]Institute of Physics, Polish Academy of Sciences, 02668 Warsaw, Poland

An electron bound to a fluorine donor impurity in ZnSe has been considered as a good candidate for a quantum bit [1]. We study the spin relaxation time (T_1) in fluorine-doped ZnSe epilayers using optical pump-probe spectroscopy. We fix the time-delay between pump and probe pulse and scan the magnetic field in Faraday geometry to measure the polarization recovery curve for different pump helicity modulation frequencies. While the spin polarization is able to reach its steady-state value for low modulation frequencies, the spins cannot be polarized completely, if the pump helicity changes too fast. We present a theoretical model for this effect of electron spin inertia. To test this approach we determine the spin relaxation time also for resident electrons in CdTe QWs. For further information on the optical properties of the samples we refer to Refs. [2] and [3]. [1] Sanaka et al., Phys. Rev. Lett. 103, 053601 (2009). [2] Greilich et al., Phys. Rev. B 85, 121303(R) (2012). [3] Zhukov et al., Phys. Rev. B 76, 205310 (2007).

MA 18: PhD symposium of the Division of Magnetism and the jDPG 2015: Quantum Phase Transitions: Emergent phenomena beyond elementary excitations

Organizers: G. Benka, P. Geselbracht, F. Rucker, S. Säubert, and C. Schnarr (TU München)

Traditionally, physics has focused on understanding the stable phases of matter like superconductivity or magnetism. Particle like states, dominating the low-energy physics of such systems, so-called elementary excitations, have been studied extensively in the past century and play an important role in our understanding of solid state physics. Modern material science and new experimental techniques, however, led to the discovery of completely different types of states, in which all electronic properties are dominated by a continuum of fluctuations. Such states arise in the vicinity of phase transitions, which are accessed by the variation of a non-thermal control parameter at zero temperature, so-called quantum phase transitions. Even though quantum phase transitions are strictly defined to be at zero temperature, the quantum critical continuum which surrounds continuous quantum phase transitions can influence electronic systems over a wide range of the phase diagram. This leads to the emergence of unique properties, new phenomena as unconventional superconductivity and the breakdown of the concept of elementary excitations. While the research on quantum phase transitions has started in a small community with the investigation of materials with strong electronic correlations, the interest in this field of research has grown fundamentally in the past years. This is attributed to the discovery of materials, which are much easier to access experimentally, as well as to the fact that the theoretical concepts are relevant to a broad range of physics. This makes quantum phase transitions one of the most vivid research topics in physics over the past decade. This symposium brings together the most recognized international speakers of this field to give a tutorial introduction to conventional and unconventional quantum criticality as well as to highlight recent experimental and theoretical advances. The interplay between tutorials and up to date research talks addresses a very broad audience and will stimulate an interdisciplinary exchange of knowledge which makes this field of research attractive for a larger community. Quantum phase transitions represent a very important area of research for a broad community of PhD students with rather different background. Keeping up to date with such an active field of research, however, is very demanding and time consuming for PhD students, as appropriate further training possibilities are only rarely offered and often focus on extremely specialised topics. This symposium will offer such an opportunity for PhD students working on quantum phase transitions, as well as for students and physicists working in other areas.

Time: Tuesday 9:30–16:30 Location: EB 301

Invited Talk MA 18.1 Tue 9:30 EB 301

Experimental Studies of Quantum Phase Transitions — •Andrew Mackenzie — Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany

In my lecture I will review what is known about quantum criticality produced by tuning systems close to magnetic instabilities. I will discuss the key physics behind quantum criticality, and then describe some model experimental systems. I will concentrate on the importance of thermodynamic measurements in classifying both quantum criticality and the novel phases that form in its vicinity.

Invited Talk MA 18.2 Tue 10:15 EB 301
Metallic Quantum Ferromagnets — •Manuel Brando — Max Planck Institute for Chemical Physics of Solids, Noethnitzer Str. 40, 01187 Dresden, Germany

In my talk I will review studies on quantum criticality with focus on metallic ferromagnets. The existence of a ferromagnetic quantum critical point has been a matter of discussion as long as 40 years ago, but had been dismissed in the past 15. During the last years several ferromagnetic metals have been tuned across the ferromagnetic quantum phase transition. Here, astonishing discoveries were made that are extending our understanding of ferromagnetic quantum criticality.

MA 18.3 Tue 10:45 EB 301
Neutron-Depolarisation Imaging of the Ferromagnetic Quantum Phase Transition in ZrZn2 — •Philipp Schmakat[1,2], Marco Halder[1], Georg Brandl[1,2], Michael Schulz[2], Stephen Hayden[3], Robert Georgii[2], Peter Böni[1], and Christian Pfleiderer[1] — [1]Physik Department E21, Technische Universität München, Germany — [2]Forschungs-Neutronenquelle Heinz Maier-Leibnitz, D-85748 Garching, Germany — [3]H. H. Wills Physics Laboratory, University of Bristol, Bristol BS8 1TL, United Kingdom

When a polarised neutron beam traverses a ferromagnetic material, the orientation and strength of the polarisation changes sensitively as a function of the ferromagnetic moment and the size of the ferromagnetic domains. We have developed an experimental set up that allows to perform neutron depolarisation imaging as a function of magnetic field. In a study of the ferromagnetic quantum phase transition in the weak itinerant ferromagnet ZrZn2 under pressure we find, that a peculiar field dependence of the neutron depolarisation survives on the paramagnetic side of the temperature versus pressure phase diagram. This provides putative evidence for the emergence of complex magnetic textures.

30 min. Coffee Break

Invited Talk MA 18.4 Tue 11:30 EB 301
Theoretical Concepts of Quantum Phase Transitions — •Matthias Vojta — Technische Universität Dresden, Germany

This tutorial will cover theoretical concepts and ideas for the description of quantum phase transitions. Starting from order parameters and order-parameter field theories, it will discuss critical exponents and scale invariance, the fascinating interplay of classical and quantum mechanical fluctuations at finite temperatures, and the quantum-to-classical correspondence. Further topics will include interaction-driven metal-insulator transitions, topological phase transitions, and the role of quenched disorder. Throughout the talk, microscopic models will be used for illustration.

Invited Talk MA 18.5 Tue 12:15 EB 301
Quantum criticality and beyond — •Andrew Schofield — School of Physics and Astronomy, University of Birmingham, Edgbaston, Birmingham, B15 2TT United Kingdom.

The exploration of quantum critical points has provided an extraordinarliy fruitful direction for experimentalists and theorists alike to investigate new ordering principles for correlated matter. Beyond the basic concepts, the field has a number of outstanding questions which motivate current research - from the interplay between critical fluctuations and other forms of order, to the theoretical framework which governs quantum critical behaviour in physical systems. My talk will explore these questions and their context.

MA 18.6 Tue 12:45 EB 301
Universal Postquench Prethermalization at a Quantum Critical Point — •Pia Gagel[1], Peter Orth[1], and Jörg Schmalian[1,2] — [1]Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Institute for Solid State Physics, Karlsruhe Institute of Technology (KIT), 76021 Karlsruhe, Germany

We consider an open system near a quantum critical point that is suddenly moved towards the critical point. The bath-dominated diffusive nonequilibrium dynamics after the quench is shown to follow scaling behavior, governed by a critical exponent that emerges in addition to the known equilibrium critical exponents. We determine this exponent and show that it describes universal prethermalized coarsening dynamics of the order parameter in an intermediate time regime. Implications of this quantum critical prethermalization are: (i) a power law rise of order and correlations after an initial collapse of the equilibrium state and (ii) a crossover to thermalization that occurs arbitrarily late for sufficiently shallow quenches.

Lunch Break

Invited Talk MA 18.7 Tue 14:00 EB 301
Quantum Criticality in Quantum Magnets — •Christian Rüegg — Paul Scherrer Institute, Laboratory for Neutron Scattering and Imaging, Switzerland — University of Geneva, Department of Quantum Matter Physics, Switzerland

Quantum magnets are exceptional solid-state model systems for high-precision studies of quantum criticality [1]. Recent results from such studies include complex phases like spin Luttinger-liquids and excitations realized in low-dimensional and frustrated systems [2-4], the exciting physics of impurities and quenched disorder [5], and fractionalization and the emergence of novel excitations near quantum critical points [2,6]. Studies of model oxides and halides by neutron scattering and complementary experimental techniques will be presented. These experimental results will be discussed in the context of recent developments of powerful computational methods enabling fully quantitative analysis and of related work on other model systems like gases of ultracold atoms.

[1] T. Giamarchi et al., Nature Physics 4, 198 (2008). [2] B. Thielemann et al., Phys. Rev. Lett. 102, 107204 (2009). [3] Y. Kohama et al., Phys. Rev. Lett. 109, 167204 (2012). [4] F. Casola et al., Phys. Rev. Lett. 110, 187201 (2013). [5] S. Ward et al., J. Phys.: Condens. Matter 25, 014004 (2013). [6] P. Merchant et al., Nature Physics 10, 373 (2014).

MA 18.8 Tue 14:30 EB 301
Spin Hall effect in two-dimensional systems — •Annika Johansson[1], Christian Herschbach[1,2], Dmitry Fedorov[2,1], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany

A relativistic phase shift model (RPSM), derived as a generalization of the resonant scattering model [1-4], was introduced recently [5] to describe the skew-scattering mechanism of the spin Hall effect (SHE) caused by impurities in bulk crystals. The RPSM was found to be an appropriate model to obtain a simple qualitative description of the SHE for dilute bulk alloys based on host crystals with free-electron like Fermi surfaces and weak spin-orbit coupling [6].

Here, we present its analogue for two-dimensional (2D) systems. The proposed 2D-RPSM provides good qualitative agreement with *ab initio* results obtained for dilute alloys based on one-monolayer noble metal films. However, the colossal SHE caused by Bi impurities [7] is not reproduced due to a strong influence of vertex corrections for these systems not properly taken into account by the model. The relation of the 2D-RPSM to the 2D resonant scattering model [8] is also discussed.

[1] A. Fert *et al.*, J. Magn. Magn. Mater. **24**, 231 (1981); [2] G.Y. Guo *et al.*, PRL **102**, 036401 (2009); [3] A. Fert and P.M. Levy, PRL **106**, 157208 (2011); [4] P.M. Levy *et al.*, PRB **88**, 214432 (2013); [5] D.V. Fedorov *et al.*, PRB **88**, 085116 (2013); [6] A. Johansson *et al.*, J. Phys.: Condens. Matter **26**, 274207 (2014); [7] C. Herschbach *et al.*, PRB **90**, 180406(R) (2014); [8] B. Gu *et al.*, arXiv:1402.3012.

Invited Talk MA 18.9 Tue 14:45 EB 301
Beyond quantum phase transitions — •Wilhelm Zwerger — TU Muenchen

The talk will discuss quantum phase transitions in the context of ultra cold gases in optical lattices. Moreover, it will address the issue of quantum phase transitions which show up only in dynamical properties, the so called many-body localization.

MA 18.10 Tue 15:15 EB 301

Topological superconductivity and unconventional pairing in oxide interfaces — •Mathias Scheurer[1] and Jörg Schmalian[1,2] — [1]Institut für Theorie der kondensierten Materie (Karlsruher Institut für Technologie), Karlsruhe, Deutschland — [2]Institut für Festkörperphysik (Karlsruher Institut für Technologie), Karlsruhe, Deutschland

To pinpoint the microscopic mechanism for superconductivity has proven to be one of the most outstanding challenges in the physics of correlated quantum matter. Thus far, the most direct evidence for an electronic pairing mechanism is the observation of a new symmetry of the order parameter, as done in the cuprate high-temperature superconductors. Alternatively, global, topological invariants allow for a sharp discrimination between states of matter that cannot be transformed into each other adiabatically. In this talk we present an unconventional pairing state for the electron fluid in two-dimensional oxide interfaces and establish a direct link to the emergence of nontrivial topological invariants. Topological signatures, in particular Majorana edge states, can then be used to detect the microscopic origin of superconductivity. In addition, we show that the density wave states that compete with superconductivity have very rich spatial textures (magnetic vortices, Skyrmions) and sensitively depend on the nature of the pairing interaction.

MA 18.11 Tue 15:30 EB 301

Quantum criticality in frustrated $CePd_{1-x}Ni_xAl$ — •Akito Sakai[1], Stefan Lucas[2], Veronika Fritsch[1,3], Philipp Gegenwart[1], Oliver Stockert[2], and Hilbert v. Löhneysen[3] — [1]Universität Augsburg, Institut für Physik, Elektronische Korrelationen und Magnetismus, Germany — [2]Max-Planck-Institut für chemische Physik fester Stoffe, Dresden, Germany — [3]Karlsruher Institut für Technologie, Physikalisches Institut, Germany

Various interesting behaviors such as non-Fermi liquid and unconventional superconductivity have been observed in the vicinity of quantum critical points (QCPs), which are induced by the competition between Kondo effect and RKKY interaction. Another route to achieve the QCP is geometric frustration. CePdAl is one of the candidates of such quantum critical frustrated systems [1, 2]. In addition to the heavy fermion behaviors, a partial antiferromagnetic ordering is revealed below $T_N = 2.7$ K, where one third of the Ce moments in the distorted kagomé lattice are still paramagnetic [1]. In this presentation, we discuss the possible QCP in $CePd_{1-x}Ni_xAl$ revealed by the specific heat measurement in the dilution refrigerator.

[1] A. Dönni *et al.*, J. Phys.: Condens. Matter **8**, 11213 (1996).
[2] V. Fritsch *et al.*, Phys. Rev. B **89**, 054416 (2014).

MA 18.12 Tue 15:45 EB 301

Resonant inelastic x-ray scattering of magnetic excitations in the novel 5d^4 iridate Ba_2YIrO_6 — •Maximilian Kusch[1,2], T. Dey[1], A. Maljuk[1], S. Wurmehl[1], B. Büchner[1,2], V. M. Katakuri[3], B. H. Kim[3], D. V. Efremov[3], J. van den Brink[3], M. Moretti[4], M. Krisch[4], and J. Geck[1] — [1]Institute for Solid State and Materials Research, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [2]Institut für Festkörperphysik, Technische Universität D-01062 Dresden, Germany — [3]Institute for Theoretical Solid State State Physics, IFW Dresden, Germany — [4]ESRF, B.P.220, 38043 Grenoble, France

In contrast to the much studied 5d^5 iridates with a spin-orbit coupled J=1/2 ground state, Ba_2YIrO_6 is a realization of a Ir-5d^4 system. For this case, a ground state J=0 is expected, i.e, Ba_2YIrO_6 should be non-magnetic. Surprisingly, our measurements of the magnetic susceptibility reveal sizable magnetic moments whose microscopic origin is still unclear. Theoretical studies indicate the important role of low-lying magnetic excitations, thereby providing a possible explanation for the unexpected magnetic susceptibility [Khaliullin Phys. Rev. Lett. 111 (2013)]. In addition, our theoretical models predict a considerable dispersion of the J=1 and J=2 excitations in Ba_2YIrO_6. To elucidate the unconventional magnetism of Ba_2YIrO_6 and to determine the dispersions of the J=1 and J=2 excitations experimentally, we performed RIXS studies of this novel 5d^4 compound. Here we present the results, focusing on the magnetic dispersions in a large region of q-space in comparison to our model calculations.

Posters

MA 18.13 Tue 16:15 EB 301

Fermi surface on the border of Mott transition in NiS_2 — •Hui Chang[1], Sven Friedemann[1,2], Monika Gamza[3], William Coniglio[4], David Graf[4], Stan Tozer[4], and Malte Grosche[1] — [1]Cavendish Laboratory, University of Cambridge, UK — [2]HH Wills Laboratory, University of Bristol, UK — [3]Department of Physics, Royal Holloway, University of London, Egham, UK — [4]National High Magnetic Field Laboratory, Tallahassee, Florida 32310, USA

The transition from a metallic to a correlated, or Mott, insulating state is a long-standing theme of fundamental interest in condensed matter research. Using quantum oscillation measurements in high magnetic fields to probe the electronic Fermi surface and effective carrier mass on the metallic side of the transition could provide much needed microscopic information. In the cuprates, such studies in samples doped into the metallic state have identified the Fermi surface structure in underdoped and overdoped regimes. Because the quantum oscillation signal is strongly suppressed in the presence of disorder, pressure rather than doping should ideally be used to reach the metallic state. We present the first observation of quantum oscillations from a pressure-metallised 3D Mott insulator. NiS_2 can be tuned through the Mott transition at a modest pressure of 30kbar. Quantum oscillations near the Mott transition are observed with the tunnel diode oscillator technique in magnetic fields up to 31T. The main observed oscillation frequency is consistent with the Fermi surface obtained within density functional theory, whereas the effective mass is significantly enhanced over the band mass.

MA 18.14 Tue 16:15 EB 301

Transport properties across the quantum phase transitions in $Mn_{1-x}Fe_xSi$ — •Fabian Jerzembeck[1], Marlies Gangl[1], Anna Kusmartseva[1,2], Andreas Bauer[1], and Christian Pfleiderer[1] — [1]Physik Department, Technische Universität München, D-85747 Garching, Germany — [2]Department of Physics, Loughborough University, UK-LE11 3TU Leicestershire, United Kingdom

Recent theory identify the thermal and electrical transport properties as a sensitive probe of the validity of the Fermi liquid description of the metallic state [1]. A prime example for a well understood, weakly spin-polarized Fermi liquid ground state has long been established in the weak itinerant helimagnet MnSi. We report a detailed study of the evolution of the thermal and electrical transport properties across the quantum phase transitions in $Mn_{1-x}Fe_xSi$ [2] down to temperatures of $\sim$2 K under magnetic fields up to 14 T. These data are complemented by additional selected measurements in $Mn_{1-x}Co_xSi$. As our main objective we consider the validity of the Wiedemann-Franz law across the quantum phase transitions in $Mn_{1-x}Fe_xSi$.

[1] R. Mahajan, M. Berkeshli, S. A. Hartnoll, Phys. Rev. B **88**, 125107 (2013). [2] A. Bauer *et al.*, Phys. Rev. B **82**, 064404 (2010).

MA 18.15 Tue 16:15 EB 301

Identification of a Brazovskii quantum phase transition in the Chiral Magnet MnSi — •Jonas Kindervater[1], Stefan Ernst[1], Andreas Bauer[1], Wolfgang Häussler[1,2], Nicolas Martin[1,2,3], Peter Böni[1], Markus Garst[4], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, Germany — [2]Heinz Maier-Leibnitz Zentrum, Technische Universität München, Germany — [3]CEA Saclay, DSM/IRAMIS/Laboratoire Leon Brillouin, France — [4]Institute for Theoretical Physics, Universität zu Köln, Germany

In the chiral magnet MnSi the transition into the ordered phase is driven to first-order due to strongly interacting fluctuations, which can be explained within the framework of the Brazovskii scenario [1]. We report a small angle neutron scattering and high resolution neutron spin echo spectroscopy study on the quantum phase transition in $Mn_{1-x}Fe_xSi$. Upon suppressing the helimagnetic order by iron doping a putative quantum phase transitions is observed [2]. According to theory [3], a possible Brazovskii quantum phase transition might thereby be realized either as a first- or second-order transition or, alternatively, as a tricritical point. Our study gives insight in the precise nature of the strongly interacting chiral fluctuations and the nature of the quantum phase transitions realized in $Mn_{1-x}Fe_xSi$.

[1] M. Janoschek *et al.*, PRB **87**, 134407 (2013); [2] A. Bauer *et al.*, PRB **82**, 064404 (2010); [3] J. Schmalian and M. Turlakov, PRL **93**, 036405 (2004)

MA 18.16 Tue 16:15 EB 301

Tuning $ZrFe_4Si_2$ by Ge substitution: confirming the proximity to a magnetic quantum critical point — •Katharina Weber[1,2], Nandang Mufti[1], Til Goltz[2], Theo Woike[3], Hans-Henning Klauss[2], Christoph Bergmann[1], Helge Rosner[1], and Christoph Geibel[1] — [1]Max Planck Institute for Chemical Physics

of Solids, Dresden, Germany — [2]Institute of Solid State Physics, TU Dresden, Germany — [3]Institute for Structural Physics, TU Dresden, Germany

Magnetic systems with reduced dimensionality or frustration are attracting strong interest because these features lead to an increase of quantum fluctuations which often results in unusual, very interesting properties. Our previous studies evidence the $A\mathrm{Fe}_4X_2$ family (A = Y, Lu, Zr and X = Ge, Si) to cover the whole regime from frustrated antiferromagnetic (AFM) order up to the quantum critical point (QCP) separating the frustrated AFM ground state from the paramagnetic ground state. $ZrFe_4Si_2$ showed evidence for an unusual type of weak magnetic order and was therefore suspected to be near the QCP. In order to get a deeper insight into its ground state, we performed a detailed study of Ge substituted $ZrFe_4Si_2$, where Ge is suspected to stabilize the magnetic state because of a negative chemical pressure effect. We synthesized polycrystalline samples of $ZrFe_4(Si_{1-x}Ge_x)_2$ with $x = 2\,\%$ to $50\,\%$ and investigated their magnetic, thermodynamic, structural and transport properties. As expected with increasing Ge content the magnetic state is stabilized towards a well defined AFM order at high Ge content. This confirms the near-by QCP in $ZrFe_4Si_2$.

MA 19: POSTER Ia

Time: Tuesday 9:30–13:00 Location: Poster A

MA 19.1 Tue 9:30 Poster A

Tracking Temperature Dependent Relaxation Times of Individual Protein Molecules using NV-Magnetometry — •Lukas Schlipf[1], Eike Schäfer-Nolte[1], Thomas White[1], Markus Ternes[1], Amit Finkler[2], Friedemann Reinhard[2], Jörg Wrachtrup[1,2], and Klaus Kern[1,3] — [1]Max-Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]3rd Institute of Physics and Research Center SCoPE, University Stuttgart, 70569 Stuttgart, Germany — [3]Institut de Physique de la Matière Condensée, Ecole Polytechnique Fédérale de 8 Lausanne (EPFL), CH-1015 Lausanne, Switzerland

The nitrogen-vacancy (NV) center in diamond is a true single-spin magnetometer, whose spin-state can be initialized and read-out optically enabling sensing of even single-electron spins in various systems, including molecules. We demonstrate the tracking of the spin dynamics of ensemble and individual magnetic ferritin proteins using this magnetic sensor in an ultra high vacuum environment and a temperature from 4 K to 300 K [1]. We employ different detection protocols to probe the influence of the ferritin nanomagnets on the longitudinal and transverse relaxation times of the NV center. The temperature dependence of the observed spectral features can be well understood by the thermally induced magnetization reversals of the ferritin [2]. Using an integrated scanning probe we can also increase the spatial resolution of our measurements with the goal of reaching single-molecule sensitivity. [1] E. Schäfer-Nolte et al., Rev. Sci. Instr. 85, 013701 (2014) [2] E. Schäfer-Nolte et al., Phys. Rev. Lett. 113, 217204 (2014).

MA 19.2 Tue 9:30 Poster A

Thermodynamics of the frustrated J_1-J_2 Heisenberg ferromagnet on a BCC lattice with arbitrary spin — •Patrick Müller[1], Johannes Richter[1], Andreas Hauser[1], and Dieter Ihle[2] — [1]Institut für Theoretische Physik, Otto-von-Guericke-Universität Magdeburg, D-39016 Magdeburg, Germany — [2]Institut für Theoretische Physik, Universität Leipzig, D-04109 Leipzig, Germany

The so-called J_1-J_2 models with competing nearest-neighbor (J_1) and next-nearest-neighbor (J_2) couplings are canonical models to study frustration effects in magnetic systems. Such models have been widely studied in low dimensions, see, e.g. [1]. In the present study we investigate the influence of frustration on the thermodynamic properties of the J_1-J_2 spin-S ferromagnet ($J_1 = -1,\ J_2 > 0$) on the BCC lattice. We use a second order Green's function (GF) approach to calculate the spin-wave spectrum, the Curie temperature T_C, the magnetization, the specific heat, the susceptibility and the magnetic correlation length. We complement our GF results with data from a high-temperature expansion [2]. Both methods are used to determine T_C as a function of the frustration parameter J_2 and the spin quantum number S and derive empirical formulas for $T_C(J_2, S)$. We find that T_C vanishes at a critical value J_2^c that is very close to the classical transition point $J_2^{c,clas} = \frac{2}{3}$. [1] M. Härtel, J. Richter, D. Ihle, and S.-L. Drechsler, Phys. Rev. B 81, 174421 (2010); M. Härtel, J. Richter, O. Götze, D. Ihle and S.-L. Drechsler, Phys. Rev. B 87, 054412 (2013). [2] A. Lohmann, H.-J. Schmidt and J. Richter, Phys. Rev. B 89, 014415 (2014).

MA 19.3 Tue 9:30 Poster A

Magnetic properties of the covalent chain antiferromagnets $RbFeSe_2$ and $TlFeX_2$ (X=S, Se) — •Zakir Seidov[1,2], Vladimir Tsurkan[2,3], Hans-Albrecht Krug von Nidda[2], Axel Günther[2], Irina Filipova[3], and Alois Loidl[2] — [1]Institute of Physics, Azerbaijan National Academy of Sciences, H.Cavid ave.131, AZ-1143 Baku, Azerebaijan — [2]EP V, Center for Electronic Correlations and Magnetism, University of Augsburg, D-86159 Augsburg, Germany — [3]Institute of Applied Physics, Academy of Sciences of Moldova, MD-202208 Chisinau, Moldova

Single crystals of the ternary iron chalcogenides $RbFeSe_2$, $TlFeS_2$, and $TlFeSe_2$ (with linear chains consisting of FeX_4 tetrahedra, X=S, Se) have been investigated by means of magnetic susceptibility, magnetization, specific heat and ESR measurements. All three compounds exhibit three-dimensional collinear antiferromagnetic order with strongly reduced moments below T_N=248K, 196K, and 290K, respectively. The magnetic moments are oriented perpendicular to the chain direction. The specific heat measurements of $TlFeX_2$ (X=S, Se) do not show any anomaly at T_N[1], while there is a λ anomaly in $RbFeSe_2$. However, the calculated entropy value for $RbFeSe_2$ is much smaller than expected for a low-spin $S = 1/2$ Fe^{3+} spin system. The linear increase of the paramagnetic susceptibility and ESR intensity of $RbFeSe_2$ and $TlFeX_2$ (X=S, Se) strongly suggests a one-dimensional metallic character.

[1] M.Aldzhanov et al., phys. stat. sol. (b) 159, 1990, K107.

MA 19.4 Tue 9:30 Poster A

Polaron dynamics and evolution of polaronic microstructure in manganites — •Sangeeta Rajpurohit[1] and Peter Blöchl[1,2] — [1]Institute of Theoretical Physics, Clausthal Institute of Technology — [2]Institute of Material Physics, University of Göttingen

Mixed-valence manganites exhibit interesting transport properties because of their complex interplay between charge, orbital, lattice and spin degrees of freedom. Strong electron-phonon coupling due to Jahn-Teller distortion localizes the electrons in the e_g states as polarons. These polarons dictate the charge transport, structural and magnetic ordering properties of manganites. We investigate the dynamics on long length and time scales with Car-Parinello molecular dynamics for a model Hamiltonian. The model Hamiltonian takes into account the electrons in the e_g orbitals of Mn, the classical spin of the t_{2g} electrons on Mn and the cooperative Jahn-Teller distortions of the oxygen octahedra. The electrons are treated as two-component spinors, allowing for non-collinear spin arrangements. So far, we explored the complex phase diagram of one-dimensional model manganites as function of the model parameters. These studies provide guidance for the study of the dynamics and the microstructure evolution of realistic two and three dimensional manganates. The parameters used in the model will be extracted from Density Functional Theory using hybrid functionals. The work has been supported by the DFG through SFB 1073 B03.

MA 19.5 Tue 9:30 Poster A

Coupled spin-charge order in frustrated itinerant triangular magnets — •Sahinur Reja[1], Rajyavardhan Ray[2], Jeroen van den Brink[1], and Sanjeev Kumar[2] — [1]IFW Dresden, Dresden, Germany — [2]IISER Mohali, India

We uncover four new spin-charge ordered ground states in the strong coupling limit of the Kondo lattice model on triangular geometry. Two of the states at one-third electronic filling ($n = 1/3$) consist of decorated ferromagnetic chains coupled antiferromagnetically with the neighboring chains. The third magnetic ground state is noncollinear, consisting of antiferromagnetic chains separated by a pair of canted ferromagnetic chains. An even more unusual magnetic ground state is discovered at $n = 2/3$. The state is coplanar, similar to the 120° Yafet-Kittel phase. However, unlike the 120° state, it consists of three types of spin triangles repeating over the lattice. These magnetic orders are stabilized by opening a gap in the electronic spectrum: a "band effect". In addition to the peculiar spin textures, all these phases support modulations in the electronic charge density. In particular the charge disproportionation at $n = 2/3$ is large with an ordering pattern resembling the observed charge ordering in various triangular lattice systems, such as, 2H-$AgNiO_2$, 3R-$AgNiO_2$ and Na_xCoO_2.

MA 19.6 Tue 9:30 Poster A

Critical behavior at the order-disorder transition in multiferroic $DyMnO_3$ — •Markus Schiebl, Alexey Shuvaev, Anna Pimenov, Graeme Eoin Johnstone, Uladzislau Dziom, and Andrei Pimenov — Institute for Solid State Physics, Vienna University of Technology, 1040 Vienna Austria

We present the results of detailed dielectric investigations of the relaxation dynamics in $DyMnO_3$ multiferroic manganite. In addition to known domain wall relaxation a second strong mode is observed at low frequencies. We provide an experimental evidence that the new relaxation mode is coupled to the chirality switching of the spin cycloid. We demonstrate that the relaxation dynamics in $DyMnO_3$ is typical for an order-disorder phase transition. Therefore, $DyMnO_3$ follows an order-disorder transition scenario implicating that a short range cycloidal order of Mn-spins exists above T_C. The results suggest that the paramagnetic sinusoidal phase should be explained as a dynamic equilibrium between the clockwise and counterclockwise cycloidal magnetic orders. The short range order in the paraelectric phase is transformed to a long range cycloid at the ferroelectric transition temperature.

MA 19.7 Tue 9:30 Poster A

Magneto-optical study of the insulating helimagnet Cu_2OSeO_3 — Rolf B. Versteeg[1], •Simon Schäfer[1], Aisha Aqeel[2], Graeme R. Blake[2], Thomas T.M. Palstra[2], and Paul H.M. van Loosdrecht[1] — [1]II. Physikalisches Institut, Universität zu Köln, 50937 Cologne, Germany — [2]Zernike Institute for Advanced Materials, University of Groningen, Groningen, The Netherlands

The Mott insulator Cu_2OSeO_3 has recently gained considerable scientific interest owing to the presence of a Skyrmion lattice phase. We report our findings of a comprehensive study of the magneto-optical properties of bulk Cu_2OSeO_3. The different optical transitions observed in the light polarization rotation spectra allow us to map out the magnetic phase diagram of Cu_2OSeO_3.

MA 19.8 Tue 9:30 Poster A

Electronic structure of $Pr_xCa_{1-x}MnO_3$ using local hybrid DFT calculation — •Mohsen Sotoudeh[1] and Peter Blöchl[1,2] — [1]Institute of Theoritical Physics, Clausthal University of Technology, Leibnizstr. 10, D-38678 Clausthal-Zellerfeld, Germany — [2]Institute of Materials Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37085 Göttingen, Germany

The manganite group of perovskites exhibits a complex phase diagram due to the competition of charge, orbital,spin and structural degrees of freedom. Of particular interest is the metal-insulator transition responsible for the collossal magneto-resistance effect. We performed first-principles calculations of $Pr_xCa_{1-x}MnO_3$ for $0 \leq x \leq 1$ with local hybrid density-functional calculations. The atomic structure for $x = 0, \frac{1}{2}, 1$ has been compared with experimental data. The comparison of the calculated spectra with x-ray photoelectron spectroscopy (XPS), electron energy loss near edge structure (ELNES) provides a choice for the mixing factor of the hybrid functionals. We studied the ferromagnetic (B-type) and selected antiferromagnetic (A-, C-, and G-type) arrangements for $x = 0, \frac{1}{4}, \frac{1}{2}, \frac{3}{4}, 1$ to explore the competition between the various ordering phenomena. We will furthermore discuss effects of magnetic ordering on the electronic structure related to excitation and transport.The work has been supported by the DFG through SFB 1073 C03.

MA 19.9 Tue 9:30 Poster A

Optimierung von Spindynamik-Simulationen grosser Strukturen mittels räumlicher Dekomposition unter Verwendung der Message Passing Interface (MPI) Bibliothek — •Simon Bekemeier, Thomas Hilbig und Christian Schröder — Bielefelder Institut für Angewandte Materialforschung (BIfAM), Computational Materials Science and Engineering (CMSE), Fachhochschule Bielefeld, Wilhelm-Bertelsmann-Str. 10, 33602 Bielefeld

Atomistische Spindynamik-Simulationen grosser Strukturen, wie z.B. Nanopartikel oder Multi-Schichtsysteme, benötigen enorme Ressourcen, sowohl hinsichtlich der Rechenzeit als auch bzgl. des Speicherbedarfs. Um Simulationen dieser Art bewältigen zu können, müssen die zugrunde liegenden Algorithmen derart angepasst werden, dass die vorhandenen, aber verteilten, Ressourcen von Hochleistungsrechen-Clustern effizient genutzt werden können. In diesem Beitrag wird ein Dekompositionsalgorithmus vorgestellt, der die verschiedenen die Effizienz der Parallelisierung beeinflussenden Faktoren berücksichtigt. Auf Basis dieses Algorithmus wurden Untersuchungen zur Optimierungen der Verteilung der Rechenlast und der Daten sowie der notwendigen Kommunikation durchgeführt, deren Ergebnisse vorgestellt und diskutiert werden.

MA 19.10 Tue 9:30 Poster A

Magnetization reversal process modeling in systems with different anisotropies — •Andrea Ehrmann[1] and Tomasz Blachowicz[2] — [1]Niederrhein University of Applied Sciences, Faculty of Textile and Clothing Technology, Germany — [2]Silesian University of Technology, Institute of Physics, Poland

Examinations of magnetic systems by use of a single macro-spin can support understanding magnetization reversal processes in principal. Such a macro-spin calculation based on constant energy minimization during the reversal process from positive to negative saturation and vice versa has been implemented in PTC(c) Mathcad. It describes the coherent rotation of a single magnetic moment using the total energy density, consisting of different magnetic anisotropies as well as the external magnetic field. In this way, hysteresis loops of longitudinal and transverse magnetization components can be calculated. Besides coercive fields and shapes of the magnetization loops, the calculation can also be used to detect angular orientations of the sample relative to the external magnetic field for which the transverse signals vanish.

The calculated loops differ slightly from experimental results concerning shape and position, which can be attributed to the simplicity of the model neglecting the coupling between the single magnetic moments and the resulting fanning, as evident from more realistic Monte Carlo simulations. However, the simple macro-spin model can reproduce qualitatively all important features of the magnetization reversal in many thin-film and nano-structured samples [1].

[1] A. Ehrmann and T. Blachowicz, AIP Advances 4, 087115 (2014)

MA 19.11 Tue 9:30 Poster A

Investigating the magneto-dynamics of magnetic nanoparticle ensembles by hybrid molecular and spin dynamics simulations — •Lisa Teich and Christian Schröder — Bielefeld Institute for Applied Materials Research, University of Applied Sciences Bielefeld, Wilhelm-Bertelsmann-Str. 10, 33602 Bielefeld, Germany

Ensembles of magnetic nanoparticles immersed in conductive gel matrices show promising features for the development of novel magnetoresistive sensor devices [1]. In order to simulate the structuring process of such systems one has to consider the magnetic and mechanical degrees of freedom simultaneously. Here, we present a new approach that couples molecular dynamics simulations based on HOOMD-blue [2] and classical spin dynamics simulations based on Monte Carlo and stochastic spin dynamics methods [3]. Using this approach we have investigated the magneto-dynamics of various Cobalt nanoparticle ensembles and will discuss the results.

[1] J. Meyer, T. Rempel, M. Schäfers, F. Wittbracht, C. Müller, A. V. Patel, A. Hütten, *Smart Mater. Struct.* **22**, 025032 (2013)

[2] J. A. Anderson, C. D. Lorenz, and A. Travesset, *J. Comp. Phys.* 227 (10): 5342-5359 (2008)

[3] L. Engelhardt, C. Schröder, in *Molecular Cluster Magnets*, Ed. R. E. P. Winpenny, World Scientific Publishers, Singapore (2011)

MA 19.12 Tue 9:30 Poster A

Simulation of skyrmionic bubbles in thin layers — •Kai Litzius[1,2], Benjamin Krüger[1], and Mathias Kläui[1,2] — [1]Johannes Gutenberg-Universität Mainz, Institut für Physik, Staudingerweg 7 55128 Mainz, Germany — [2]Graduate School Materials Science, Staudinger Weg 9, 55128 Mainz, Germany

Magnetic bubbles are circular regions of out-of-plane magnetization that is orientated in the opposite direction compared to the surrounding parts of the film [1]. As skyrmionic states, they show a special topology and are thus energetically protected from being deformed into a ferromagnetic uniform state. This ensures a high stability of a bubble and makes them promising candidates for spintronic devices [2].

Here, the static and dynamic properties of magnetic bubbles in thin layers with out-of-plane easy axis are investigated by micromagnetic simulations including the Dzyaloshinskii-Moriya interaction (DMI). We can show that a bubble can indeed be stabilized for a certain parameter range. The obtained states are highly dependent of the choosen saturation magnetization (Ms) and DMI resulting in significant differences in appearance and shape of topology. From our results, we can identify, which materials are ideally suited to stabilize skyrmion states.

[1] P. Milde et al., Science. 2013; 340(6136): 1076-1080.
[2] F. Büttner et al., Nature Physics (in press 2014)

MA 19.13 Tue 9:30 Poster A

Observation of Binary Vortex Core States in Magnetic Mutlilayers — •Sebastian Wintz[1,2], Mi-Young Im[2], Anja Banholzer[2], Tobias Schneider[2], Markus Weigand[3], Jörg Raabe[4], Roland Mattheis[5], Peter Fischer[2], Artur Erbe[1], and Jürgen Fassbender[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Lawrence Berkeley National Laboratory, Berkeley, USA — [3]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany — [4]Paul Scherrer Institut, Villigen, Switzerland — [5]Leibniz Institut für Photonische Technologien, Jena, Germany

Topological spin textures such as skyrmions or vortices are attracting significant attention because of their fundamentally interesting magnetostatic and dynamic properties. In particular, magnetic vortices have been studied intensively during the past decade. Such a spin vortex consists of a planar, flux-closing magnetization curl that tilts out of the plane in the central core. Although being relatively small, the core is of crucial importance for the overall vortex structure. For a stacked trilayer geometry, two basic vortex core configurations can be expected, namely parallel (PL) and antiparallel (AP) cores. In the present contribution, we address the direct observation of both PL and AP core configurations in trilayer vortex pairs. Transmission x-ray microscopy is used to directly image the congruent cores in a Co(48)/Ru(0.8)/Ni81Fe19(43) (nm) trilayer stack. Moreover, switching between both configurations in the same vortex pair was achieved by applying high frequency in-plane magnetic fields.

MA 19.14 Tue 9:30 Poster A

Thermodynamics and magnetism at the first-order magnetostructural transition in Mn_3GaC powder and single crystal samples — •Franziska Scheibel[1], Tino Gottschall[2], Mahdiyeh Ghorbani Zavareh[3], Moritz Riebisch[1], Öznur Çakir[4], Michael Farle[1], and Mehmet Acet[1] — [1]Faculty of Physics and CENIDE Universität Duisburg-Essen, Duisburg, Germany — [2]Material Science Technische Universität Darmstadt, Darmstadt, Germany — [3]High Magnetic Field Laboratory HZDR, Dresden-Rossendorf, Germany — [4]Physics Department Yildiz Technical University, Istanbul, Turkey

For magnetic refrigeration materials with a large adiabatic temperature-changes ΔT and large entropy changes ΔS are required. Such large changes are possible at first-order magnetostructural transitions (FOMST). At a FOMST, the thermal hysteresis limits the reversibility of ΔT. Therefore, materials with narrow thermal hysteresis play a major role in applications. Mn_3GaC powder shows a FOMST from a ferromagnetic (FM) to an antiferromagnetic (AF) phase at 155 K with ΔS=15 Jkg^{-1}K^{-1} and ΔT=4.8 K in 2 T field. Direct ΔT measurements show a high degree of reversibility at the transition. ΔT measurements for magnetic field rates of $1.1\cdot10^{-2}$ Ts^{-1}, 0.7 Ts^{-1} and $7.8\cdot10^{2}$ Ts^{-1} were done to understand the time-dependent properties of the transition process and the effect of hysteresis. The magnetocrystalline anisotropy energy for this material was determined from ferromagnetic resonance measurements on a Mn_3GaC single crystal around the FOMST.

Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).

MA 19.15 Tue 9:30 Poster A

Functional Approach to Electrodynamics of Media — •Ronald Starke[1] and Giulio Schober[2] — [1]Institut f. Theo. Physik, Bergakademie Freiberg — [2]Institut f. Theo. Physik, Uni Heidelberg

We put forward a new approach to electrodynamics of materials allowing us to derive universal (material-independent) relations between electromagnetic response functions such as the dielectric tensor, the magnetic susceptibility and the microscopic conductivity tensor. Our formulae include all effects of inhomogeneity, anisotropy, magnetoelectric coupling and relativistic retardation. Moreover, we relate the 36 component functions of the constitutive tensor used in the context of bi-anisotropic media to only 9 causal response functions which specify the current response to an external vector potential.

MA 19.16 Tue 9:30 Poster A

Quantum information processing based on multiferroic helical spin chain — •maryam azimi[1], levan chotorlishvili[1], sunil kumar mishra[2], sebastian greshner[3], teimuraz vekua[3], wolfgang hübner[4], and jamal berakdar[1] — [1]Institute of Physics, Martin-Luther University, 06120 Halle, Germany — [2]Department of Physics, Indian Institute of Technology, Banaras Hindu University, Varanasi 221005, India — [3]Institute of Theoretical Physics, Leibniz University, 30167 Hannover, Germany — [4]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, PO Box 3049, D-67653 Kaiserslautern, Germany

We show that quantum information features and quantum phases are extremely sensitive to an external electric field applied to one dimensional frustrated spin 1/2 chains[1]. The electric field leads to the formation of chiral spin structure and simultaneously generates entanglement characterized by many spin correlation[2]. We also use this system as a working substance for a quantum Otto heat engine[3,4]and detect a direct connection between the chirality, the entanglement and the efficiency of the engine. Also a relation between the threshold temperature of pair entanglement with the spin chirality and the minimum of the fidelities related to the electric and the magnetic field is obtained. By increasing the electric field the efficiency of the quantum Otto cycle reaches a saturation status. [1] M. Menzel et al., Phys. Rev. Lett. 108, 197204 (2012). [2] M. Azimi et al., Phys. Rev. B 89, 024424 (2014). [3] H. T. Quan et al., Phys. Rev.E. 76, 031105 (2007). [4] M. Azimi et al., New Journal of Physics 16, 063018 (2014).

MA 19.17 Tue 9:30 Poster A

Synthesis, structure, and magnetic properties of dilithium orthosilicates Li_2MSiO_4 (M = Fe, Mn, Ni, Co) — •Kiryl Batvinyeu[1], Christoph Neef[1], Hans-Peter Meyer[2], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, University of Heidelberg, Heidelberg, Germany — [2]Institute of Earth Sciences, University of Heidelberg, Heidelberg, Germany

We report on the synthesis and characterization of dilithium orthosilicates Li_2MSiO_4 with M = Fe, Mn, Ni, and Co. We have obtained various polymorphs such as beta(II) ($Pmn21$), gamma(s) ($P12_1/n1$) of Li_2FeSiO_4 and gamma(II) ($Pmnb$), gamma(0) ($P12_1/n1$) of Li_2MnSiO_4 by means of solid state reactions. In all polymorphs, the transition metal ions are coordinated tetrahedrally. Our magnetic studies enable to construct the magnetic phase diagrams which are characterized by long range magnetic ordering of the respective transition metal moments in the high-spin state. The magnetic phase diagrams are discussed against the background of the actual structures, lattice parameters, and possible exchange paths.

MA 19.18 Tue 9:30 Poster A

ESR studies of the $S = 1/2$ ladder compound $Cu(Qnx)Cl_2$ — •A. Ponomaryov[1], M. Ozerov[1], E. Čižmár[2], J. Wosnitza[1], K. Povarov[3], A. Zheludev[3], A. Zvyagin[4], and S. Zvyagin[1] — [1]High Magnetic Field Laboratory (HLD), Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Institute of Physics, P.J. Šafárik University, Košice, Slovakia — [3]Neutron Scattering and Magnetism, Laboratory for Solid State Physics, ETH Zürich, Switzerland — [4]Institute for Low Temperature Physics and Engineering, Kharkov, Ukraine

By means of electron spin resonance we systematically studied $Cu(Qnx)Cl_2$ (Qnx - quinoxaline), a Heisenberg $S = 1/2$ spin-ladder compound with J_{leg} = 18.6 K and J_{rung}= 34.2 K. The linewidth, g-factor shift, and absorption intensity were investigated in the temperature range from 2 to 300 K. The low-temperature measurements revealed an ESR line splitting, which is a signature of a finite anisotropy. The observed results were analyzed using mean-field theory. The uniform Dzyaloshinskii-Moriya interaction was suggested to play a key role, strongly affecting the ESR properties of this compound at low temperature.

The work was partly supported by the DFG.

MA 19.19 Tue 9:30 Poster A

Effect of Microstructure on Spinodal Decomposition and Magnetic Properties of Melt-Spun Alnico — •Konrad Loewe[1], Michael Duerrschnabel[2], Rajasekhar Madugundo[3], George C. Hadjipanayis[3], and Oliver Gutfleisch[1,4] — [1]TU Darmstadt, Materialwissenschaft, Alarich-Weiß-Str. 16, 64287 Darmstadt, Germany — [2]TU Darmstadt, Angewandte Geowissenschaften, Schnittspahnstraße 9, 64287 Darmstadt , Germany — [3]Department of Physics and Astronomy, University of Delaware, Newark, DE, USA — [4]Fraunhofer ISC, IWKS Group Materials Recycling and Resource Strategy, Hanau, Germany

The aim of this work is to investigate the effect of very fine grain sizes on the spinodal decomposition in the Alnico system. Commercial Alnico 8 was melted and melt-spun with varying copper wheel speeds, which led to a grain size of around 2 micron. This value was further reduced to sub-micrometer size by a small addition of Boron (1at%). The spinodal decomposition was induced through a two-step annealing treatment under magnetic field in the range of 600-900°C. It was found that the nanometer-sized spinodal structures become bigger with increasing wheel speeds and smaller with the addition of Boron. Contrary to expectations, the coercivity of the sample containing Boron is slightly reduced compared to the one without it, which is attributed to the formation of unwanted secondary phases.

MA 19.20 Tue 9:30 Poster A

Correlation between the magnetic properties of a carboxylic acid and its coordination to a metal surface: An paramagnetic and ferromagnetic resonance (EPR/FMR) study — •S. Masur, T. Marzi, S. Liébana Viñas, R. Meckenstock, and M. Farle — Faculty of Physics, University of Duisburg-Essen, Germany

To get stable mono-disperse and artificially shaped magnetic nanoparticles carboxylic acids are often used. While studying the static and dynamic magnetic properties of the single crystalline Fe_2O_3 nanoparticles by FMR the interface to the carboxyl group provides a paramagnetic center that can be influenced by the FMR signal. The same paramagnetic center is found at the interface of carboxylic acids and Ag nanoparticles. Therefore this type of paramagnetic active interfaces are perfect candidates for monitoring spin transport properties through those interfaces. Here we characterize the principal behavior of these EPR interfaces. Oleic acid gets chemisorbed as a carboxylate, leading to the formation of two covalent COO- bonds and a delocalized electron. Covering a substrate with a monolayer of this cubic Fe_2O_3 nanoparticles (all cubes have a (001) direction perpendicular to the substrate and are randomly oriented in plane) and performing an angle dependent EPR from in-plane to out-of-plane a fourfold anisotropy in the EPR-signal is observed, which is not visible for a pure in-plane EPR. This indicates that the hard direction of the g-tensor of the carboxyl Fe_2O_3 interface is correlated with the [111]-cube-direction. This Effect was further investigated on oxidized Iron-films layered with oleic acid.

MA 19.21 Tue 9:30 Poster A

Magnetism and defects in V-doped TiO2 — •Alevtina Smekhova[1,2], Roman Baulin[2], Oguz Yildirim[3], Maik Butterling[3], Steffen Cornelius[3], Andrei Novikov[2], Anna Semisalova[2], Andrei Orlov[4], Elena Ganshina[2], Nikolai Perov[2], Wolfgang Anwand[3], Andreas Wagner[3], Kay Potzger[3], and Alexander Granovsky[2] — [1]Universität of Duisburg-Essen und CENIDE, Duisburg, Germany — [2]Lomonosov Moscow State University, Moscow, Russia — [3]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Dresden, Germany — [4]Federal State Research and Design Institute of Rare Metal Industry, Moscow, Russia

The idea about defect-induced ferromagnetic long-range order at RT in some semiconducting materials is not new, but still needs to be further proved. In the case of TiO2 doped by 3d transition atoms the most interesting situation within this thought is with doping by Vanadium. Recently we found that in 1at% and 3at% V-doped TiO2 thin films prepared by magnetron sputtering the saturation magnetization correlates well with an amount of negatively charged defects estimated by Doppler-Broadening technique of Positron Annihilation Spectroscopy (PAS) and only slightly depends on the film conductivity. Meanwhile the MO spectroscopy showed a principal difference between these two doping levels and strong dependence on film resistivity. So, negatively charged defects and free carriers have to be taken into account separately from each other for the explanation of RT ferromagnetism in titanium dioxide films. Support by a German-Russian joint research group HRJRG-314 & RFBR 12-02-91321-SIGa is acknowledged.

MA 19.22 Tue 9:30 Poster A

Investigation and optimization of magnetic properties of micro-patterned Permalloy structures for giant magneto-impedance sensors — •Gregor Büttel, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D66041, Saarbrücken, Germany

Permalloy (Ni81Fe19) structures were fabricated by lithography and dc magnetron sputtering. Aspect ratio and sputtering parameters were varied and their influence on domain structures and hysteresis were studied by vibrating sample magnetometry and magneto-optical Kerr effect microscopy in an applied external field. We obtained a very high Kerr contrast for Permalloy by post-processing data algorithms and sputtered dielectric coating layer. Coercivity and anisotropy were optimized by control of sputter rate, biasing field and magnetic annealing to yield soft magnetic films with a thickness between 200 and 1000 nm with low anisotropy, perpendicular to the long axis of the rectangular structures and to the underlying waveguide. The often reported perpendicular anisotropy and stripe domains above a critical thickness of the elements were found in our samples as well. The critical thickness changes slightly depending on the possible waveguide substrate like Cu, Au and Al vs. SiO2. However, we could obtain films without stripe domains and a transcritical shape of the hysteresis curve above a thickness of 500 nm by adjusting the sputter rate accordingly. For films within the thickness regime of 200-500 nm we could diminish strongly the transcritical shape of the hysteresis curve by magnetic annealing, although stripe domains remain.

MA 19.23 Tue 9:30 Poster A

Microscopic investigation of laser-induced ferromagnetic domain formation in FeRh thin films and microstructures — •Ahmet Akin Ünal[1], Adem Parabas[2], Yuriy Aleksandrov[3], Hatice Doganay[4], Florian Kronast[1], and Fikret Yildiz[2] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [2]Gebze Institute of Technology, Department of Physics, Kocaeli, Turkey — [3]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [4]Forschungszentrum Jülich, Peter Grünberg Institut (PGI-6), Jülich, Germany

The temperature dependent transition from the antiferromagnetic (AF) to the ferromagnetic (FM) order in FeRh takes place via nucleation and growth of microscopic magnetic domains. Since this transition can be induced by femtosecond laser pulses, FeRh has become a promising material for establishing ferromagnetism in ultrashort time scales. Although the system is extensively investigated, the dynamics of the FM domain formation and the subsequent disappearance in the AF matrix is still under strong debate. A better understanding of the AF-FM phase coexistence at the microscopic level and of the parameters influencing the FM domain evolution such as sample temperature and laser fluence is important for device applications. Here, we report our recent magnetic imaging experiments in FeRh thin films and microstructures using X-ray photoemission electron microscope.

MA 19.24 Tue 9:30 Poster A

Influence of domain wall substructures on the domain structures of Permalloy elements — •Sukhvinder Singh, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P O. Box 151150, D66041, Saarbrücken, Germany

Substructures (Bloch lines, cross-tie wall components, vortex-antivortex pairs) of domain walls significantly affect the magnetic properties of patterned materials [1, 2]. In this study we have investigated their influences on the magnetization configurations of microstructured thin films. The patterns were prepared in rectangular shapes of various aspect ratios by means of e-beam lithography. Thin films of Permalloy (Ni81Fe19) in the range of 20 nm to 150 nm thickness were prepared by DC sputtering. Substructures of domain walls were observed by magnetic force microscopy. The results were compared with micromagnetic simulations and the relative contributions of different magnetic energies were investigated. The magnetic energies of the Landau state, the diamond state and cross-tie configurations were calculated. The increase in the total energy and the stabilization of the magnetic flux more efficiently due to the nucleation of new vortex-antivortex pairs was observed. The existence of seven domain states and the change in their statistical distribution were explained in terms of structural variations in dependence of the applied field sweep rate.

[1] C. Y. Kuo et al. J. Magn. Magn. Mater. 310, e672 (2007) [2] C. Zinoni et al. Phys. Rev. Lett. 107, 207204 (2011)

MA 19.25 Tue 9:30 Poster A

The Coercivity Hc Change in Spinel Ferrite Compound Alloyed with Metals — •Ali Alidoust and Mahboubeh Houshiar — Shahid Beheshti University,Tehran,Iran

In this work, magnetic nanoparticles Co1-xNixFe2O4 with nickel concentration x=0.0, 0.5 and 1 has been prepared by coprecipitation method and their structural and magnetic properties were obtained by XRD, SEM and VSM techniques. XRD analysis shows cubic inverse spinel structures for all the nanoparticles, with space group Fd-3m without extra phases in nano dimensions. The average size of the crystals is estimated to be between 23-35 nm. This is in agreement with the SEM results. The lattice constant was seen to decrease with concentration. The analysis of VSM results with external magnetic field up to 15kOe shows that the cobalt ferrite nanoparticles are feromagnetic with high Ms and Hc at room temperature. These values dencrease with increasing x. The S shape hysteresis loop for NiFe2O4 shows nickel ferrite nanoparticles have superparamagnetic properties. The reason for this behavior can be due to the substitution of Ni ions in Octahedral cubic spinel sites which can also explain their magnetic behaviours.

MA 19.26 Tue 9:30 Poster A

Exchange Bias Tubes for controlled fuel-free transport of superparamagnetic particles — •Timo Ueltzhöffer[1], Robert Streubel[2], Dennis Holzinger[1], Iris Koch[1], Denys Makarov[2], Oliver G. Schmidt[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]Leibniz Institute for Solid State and Materials Research Dresden, Helmholtzstraße 20, D-01069 Dresden

Magnetically stripe patterned exchange bias tubes were fabricated and studied in respect to their suitability for fuel-free transport of superparamagnetic particles. For that purpose a CoFe/IrMn Exchange Bias (EB) system was fabricated via sputter deposition on a strained Ti-layer. The EB layer system is magnetically patterned with 5 μm parallel stripe domains with their magnetizations oriented head-to-head / tail-to-tail and subsequently rolled up by removal of the underlying sacrificial layer [1]. The resulting tubular system is suitable for being used as a substrate for the directed near surface transport of superparamagnetic particles [2]. In this study we were able to show that the transport system could be rolled up successfully to tubular structures while the magnetic properties are preserved.

[1] E. Bermúdez Urena, Y. Mei, E. Coric, D. Makarov, M. Albrecht and O. G. Schmidt, J. Phys. D: Appl. Phys. 42 (2009) 055001

[2] D. Holzinger, D. Lengemann, F. Göllner, D. Engel and A. Ehresmann, Appl. Phys. Lett. 100, (2012) 153504

MA 19.27 Tue 9:30 Poster A

Investigation of Magnetic Vortices in Cap Structures — •Dennis Nissen[1], Senoy Thomas[2], Sri Sai Phani Kanth[3], and Manfred Albrecht[1] — [1]Institute of Physics, University of Augsburg, 86159 Augsburg, Germany — [2]Materials Science and Technology Division, National Institute for Interdisciplinary Science and Technology, 695015 Thiruvananthapuram, India — [3]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany

Vortex states, characterized by the circularity of the in-plane magnetization and the out-of-plane component of the vortex core, are of great fundamental importance and relevant for application. One approach to realize such magnetic vortex states is to manufacture large arrays of spherical SiO_2-particle monolayers followed by film deposition of permalloy. In this way, it is possible to obtain magnetic cap structures on the particles forming vortex states[1].

We show the dependence of Py cap structures on the nucleation and annihilation field as function of the aspect ratio. Furthermore, we show how the magnetization reversal in exchange coupled IrMn/Fe caps with a diameter of 900 nm occurs. In this regard, the magnetic vortex at zero magnetic field vanishes as the temperature approaches the blocking temperature of IrMn accompanied by an increase in coercivity[2].

[1]R. Streubel et al., Phys. Rev. B 85, 174429 (2012).

[2] S. Thomas, D. Nissen, and M. Albrecht, Appl. Phys. Lett. 105, 022405 (2014).

MA 19.28 Tue 9:30 Poster A

Lifetime measurements for CoFeB/MgO/CoFeB tunneling junctions — •Andres Conca[1], Frederick Casper[2,3], Johannes Paul[4], Ronald Lehndorff[4], Mathias Kläui[3], Britta Leven[1], and Burkard Hillebrands[1] — [1]FB Physik und Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Institute of Inorganic and Analytical Chemistry, Johannes Gutenberg-Universitaet Mainz, 55099 Mainz, Germany — [3]Institute of Physics, Johannes Gutenberg-Universitaet Mainz, 55099 Mainz, Germany — [4]Sensitec GmbH, Hechtsheimer Str. 2, 55131 Mainz, Germany

An analysis of the lifetime of TMR elements using the Weibull statistical distribution is presented. The distribution is governed by two parameters, the characteristic lifetime η and the shape parameter β, which gives information about the presence of an *infant mortality* in the population. First of all, the suitability of the Weibull distribution for the description of breakdown processes in MgO-based tunneling junctions at different voltages is proven. Secondly, a study of the dependency of the characteristic lifetime extrapolated to the low voltage regime, and the parameter on the nominal barrier thickness, the RA product and the deposition power for the MgO barrier is shown. Finally, a discussion of the absolute overall values and the dependencies and the suitability of the elements for sensor production is given.

Support by the state of Rhineland-Palatinate (MBWWK and MWKEL) and by the ERDF programm in the frame of the Spintronic Technology Platform (STeP) is gratefully acknowledged.

MA 19.29 Tue 9:30 Poster A

Dynamics and thermodynamics of interacting magnetic dipoles — •Eva Hägele[1], Christian Schröder[1], Heinz-Jürgen Schmidt[2], and Marshall Luban[3] — [1]Bielefeld Institute for Applied Materials Research (BIfAM), Computational Materials Science & Engineering (CMSE), University of Applied Sciences Bielefeld, 33602 Bielefeld, Germany — [2]Department of Physics, University of Osnabrück, 49069 Osnabrück, Germany — [3]Department of Physics and Astronomy, Iowa State University, Ames, IA 50011, USA

We investigate the dynamical and thermodynamical properties of magnetic dipoles interacting solely via their magnetic fields. We find that in the case of two interacting magnetic dipoles all relevant thermodynamic and dynamic quantities such as specific heat, zero field susceptibility and the thermal expectation value of the autocorrelation function can be calculated analytically and numerically. We expand our investigations to complex systems such as rings of N dipoles. Further, we show that our numerical methods can be used to model and simulate nanomagnetic logic applications. With regard to this our investigations concentrate on modeling real experimental structures by means of point-dipoles. Based on these models we have performed finite temperature spin dynamics simulations. We compare our results to recent experimental findings.

MA 19.30 Tue 9:30 Poster A

Magnetic characterization of self-assembled arrays of magnetite nanoparticles — •Alexander Fabian[1], Matthias Thomas Elm[1], Hans-Albrecht Krug von Nidda[2], and Peter Jens Klar[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität Giessen, Heinrich-Buff-Ring 16, D-35392 — [2]Institut für Physik, Universität Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

Magnetite (Fe_3O_4) is one of the oldest magnetic materials used by mankind. Its high spin polarization of nearly 100% at the Fermi-energy and its high Curie temperature of about 850 K makes it interesting for applications in miniaturized spintronic devices. Reducing the size of a bulk material to the nanoscale may strongly alter the magnetic properties. In order to build magnetic nanodevices using nanoparticles it is therefore not only necessary to arrange the nanoparticles in a controlled way, but also to investigate their magnetic properties as well as the interaction between them. Here we present a bottom up approach to arrange spherical shaped magnetite nanoparticles with a diameter of about 20 nm. For this purpose rectangular openings are written into PMMA resist by electron beam lithography. These openings are then filled during a horizontal dip coating process by using the meniscus force deposition method. Several arrangements with different aspect ratios are prepared. The arrangements were characterized by SQUID measurements showing a superparamagnetic behavior of the nanoparticles. Additionally nanoparticle thin films were investigated by ferromagnetic resonance measurements showing typical spectra of magnetite.

MA 19.31 Tue 9:30 Poster A

Theoretical investigation of the magnetic ground state in DUT-8(Ni) — •Kai Trepte and Gotthard Seifert — Technical University of Dresden, Institute for Theoretical Chemistry

Ab initio calculations using density functional theory (DFT) have been carried out to study the magnetic ground state (ferromagnetic (FM)

or antiferromagnetic (AFM)) of the metal organic framework (MOF) DUT-8(Ni) [1]. This MOF is flexible, which means that it has an open and a close structure. For these structures the coupling constant J has been calculated in order to identify the energetically favoured magnetic ordering.
The ground state of the open as well as the close structure has been found to be AFM. These theoretical results are in agreement with recent experimental observations using EPR measurements.

[1] Klein, N. et.al., Physical Chemistry Chemical Physics, 12 (2010).

MA 19.32 Tue 9:30 Poster A

Magnetic domain wall sensing — •Benjamin Borie[1,2], Johannes Paul[2], Matthias Bürkle[2], Mathias Kläui[1], and Hubert Grimm[2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Sensitec GmbH, 55131 Mainz, Germany.

An extensive effort is made by industry to introduce magnetic technologies using domain walls into sensors [1]. Domain wall quasiparticles are of interest for storing the state of a device and they can be operated at very low power. Magnetic domain walls are strongly influenced by the external and internal parameters of the material, the shape and the environment of the device. To reduce undesired effects such as non-reproducible operation, the device materials and geometries need to be engineered and high reproducibility can be achieved [2]. We study the influence of roughness, crystallisation, shape and material stacks on the magnetic operating field window of a free layer of a multi-turn sensor driven by a rotating external field. The magnetic operating window is limited by the nucleation field and the propagation field. The roughness and crystallisation are likely to induce a potential landscape that can result in a decrease of the nucleation field and the stacks may induce an asymmetry in this value. A large number of samples can be rapidly fabricated and tested by Kerr microscopy technique and using the GMR effect to ascertain the necessary statistics.

[1] Marco Diegel, et. al., IEEE Transaction on magnetics, vol.45, No.10, October 2009 [2] A. Bisig et al., Nature Communications 4, 2328 (2013).

MA 19.33 Tue 9:30 Poster A

Study of Spin flop transition in Fe/Cr multilayer grown on nanorippled Si substrate — •Sarathlal Koyiloth Vayalil[1], Ajay Gupta[2], and Stephan V. Roth[1] — [1]Photon Science, Deutsches Elektronen-Synchrotron, Notkestrasse-85, 22607, Hamburg, Germany — [2]Amity Center for Spintronic Materials, Amity University, Sector 125, NOIDA, 201313, India

In this work, Fe/Cr giant magneto resistance multilayer prepared on nano-rippled Si (100) substrate has been studied. It has been demonstrated that, one can do a systematic study of spin flop transition in a polycrystalline films deposited on a nano-rippled substrate, by using the possibility of controlling the exchange field by varying the Cr spacer layer thickness and anisotropy field by varying the modulation depth of the ripples. The multilayer having a nominal structure [Fe (3.0 nm)/ Cr (1.0 nm)] x10 was deposited the nano-rippled Si substrate using electron beam evaporation. The multilayer exhibits a spin flop transition when magnetic field is applied in a direction along the easy axis. On the other hand when the field is applied normal to the easy axis, no spin flop transition is observed. This is in conformity with the theory of antiferromagnetic system. In our knowledge this is the first observation of spin flop transition in polycrystalline antiferromagnetically coupled multilayers.

MA 19.34 Tue 9:30 Poster A

Lorentz microscopy of laser-induced vortex formation in microstructures — •Tim Eggebrecht[1], Jan Gregor Gatzmann[2], Vladyslav Zbarsky[3], Sascha Schäfer[2], Claus Ropers[2], Markus Münzenberg[3], and Konrad Samwer[1] — [1]I. Physikalisches Institut, Universität Göttingen — [2]IV. Physikalisches Institut, Universität Göttingen — [3]Grenz- und Oberflächenphysik, Universität Greifswald

For many years magnetic microstructures have been used for storing data in the hard drive industry. Several new methods were developed in order to save bits faster and with higher density in space. We present one of these potential methods in this work.

To produce magnetic microstructures, we show the focused ion beam method on thin Si_3N_4 membranes. Magnetically soft CoFeB thin films are capable to achieve a predictable long-range magnetic order. Thereby, we are able to investigate single magnetic vortices caused by shape anisotropy in single elements. We used a modified transmission electron microscope (TEM) to introduce a laser beam, which can be positioned on the sample. The laser system facilitates single femtosecond pulses and the Lorentz imaging mode of the TEM provides a direct observation of change in magnetization. After excitation with a single pulse, we see a reversing in rotation of vortices to the opposite. Furthermore, we examine the dependence on shape and size of the microstructures of this process.

We acknowledge support by the DFG via SFB 1073.

MA 19.35 Tue 9:30 Poster A

Control of the Magnetic Structure of Co/Pd Thin Films by Direct Laser Interference Patterning — •Philipp Graus[1], Martin Stärk[1], Frank Schlickeiser[1], Elke Scheer[1], Manfred Albrecht[2], Paul Leiderer[1], Ulrich Nowak[1], Mikhail Fonin[1], and Johannes Boneberg[1] — [1]Uni Konstanz — [2]Uni Augsburg

Pulsed two-beam laser interference is used to generate two-dimensional temperature patterns on a magnetic sample. We show that the original domain structure of a Co/Pd multilayer thin film can be switched into a small grain size state upon exceeding the Curie temperature by thermal demagnetization. This finding is supported by numeric simulations using the Landau-Lifshitz-Bloch formalism. The small domains can be switched back into the original domain sizes by demagnetization. At even higher temperatures the multilayer system is irreversibly changed. In this area no out-of-plane magnetization can be found after a subsequent demagnetization. Thus, a two-dimensional temperature pattern can be transferred into a magnetic stripe pattern. In this way one can achieve magnetic nanowire arrays with lateral dimensions in the order of 100 nm. Typical patterned areas are in the range of several millimeters. Hence, the parallel Direct Laser Interference Patterning (DLIP) method of magnetic thin films is an attractive alternative to the conventional serial electron beam writing of magnetic nanostructures.

MA 19.36 Tue 9:30 Poster A

Detection of magneitc vortex core switching by MOKE Microscopy — •Georg Dieterle[1], Joachim Gräfe[1], Matthias Noske[1], Ajay Gangwar[1,2], Johannes Förster[1], Markus Weigand[1], Hermann Stoll[1], Georg Woltersdorf[3], Christian H. Back[2], and Gisela Schütz[1] — [1]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [2]Department of Physics, University of Regensburg, Regensburg, Germany — [3]Department of Physics, Martin Luther University Halle, Halle, Germany

Experimental detection of the switching of the magnetic vortex core, 10 - 20 nm in diameter, so far requires instrumentations like synchrotron based X-ray microscopes. Here we show how vortex core switching can be detected by a table top MOKE microscope in combination with a sophisticated lock-in technique. In that way vortex core reversal can be measured in about 2 minutes by switching the vortex core about 2000 times per second and averaging the Kerr Signal for vortex core up and vortex core down. In addition our technique enables the determination of switching probabilities during the measurement by performing a continuous calibration of the 100 % switching probabilities. For that purpose an excitation sequence is applied in which, in addition to the excitation to be investigated, excitations known for 100% vortex core reversal, are added. Experimental data will be demonstrated for vortex core reversal by excitation of the vortex core gyromode with in-plane rotating fields. The vortex core will be switched up and down using varying amplitudes and frequencies of the excitation field.

MA 19.37 Tue 9:30 Poster A

Exchange coupling between soft magnetic materials and hard magnetic Dysprosium layers — •Markus Ehlert, Thomas Hupfauer, Markus Schitko, and Dieter Weiss — Institute of Experimental and Applied Physics, University of Regensburg, Germany

The control of the magnetic properties of thin ferromagnetic films is crucial for the functionality of spintronic devices, e.g., for the detection of the spin Hall effect [1]. The goal of our work is to improve the magnetic stability of commonly used soft ferromagnets by making use of the exchange coupling between soft and hard magnetic materials. We report on measurements of the magnetic interplay between soft magnetic Fe or Co layers and hard magnetic Dysprosium (Dy) layers. Microstructured thin films of Fe, Co, Dy and multilayers of Fe/Dy and Co/Dy were prepared by electron-beam lithography and ultra-high vacuum sputtering. The magnetic properties of the materials were determined by means of the Anisotropic Magnetoresistance (AMR) effect. All measurements were carried out below the Curie temperature of Dy at 4.2 K in a high magnetic field cryostat with fields up to 10 T. By analyzing and comparing the corresponding AMR data we show that the presence of a Dy layer on top of a soft magnetic material significantly influences its magnetic properties. In our experiments we could enhance, e.g., the in-plane coercive field by one order of magnitude. We also investigate the dependence of this effect on the thickness of the soft magnetic material. All experimental results can consistently be explained with the model of the AMR effect.

[1] M. Ehlert *et al.*, Phys. Status Solidi B **251**, 1725-1735 (2014).

MA 19.38 Tue 9:30 Poster A

Huge exchange bias in polycrystalline MnN/CoFe bilayers at room temperature — •Mareike Dunz and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

In spintronics, the exchange bias effect is used to pin a ferromagnetic layer to an antiferromagnet, making its magnetization less sensitive to external magnetic fields.

We present a polycrystalline MnN/CoFe bilayer system that shows huge exchange bias of more than 1000 Oe at room temperature. The antiferromagnetic MnN was reactively sputtered on a buffer layer and found to crystallize in the tetragonal face centered θ-phase by x-ray diffraction. To activate exchange bias, the samples were annealed at various temperatures in a vacuum furnace and field cooled for 30 minutes. We discuss the temperature and film thickness dependence of the exchange bias in detail.

MA 19.39 Tue 9:30 Poster A

Electrical and magnetic properties of cuprate-manganate multilayers grown by metalorganic aerosol deposition — •Philipp Busse, Florian Fischgrabe, Sebastian Hühn, Markus Jungbauer, Markus Michelmann, and Vasily Moshnyaga — I. Physikalisches Institut, Universität Göttingen, Germany

Multilayers of superconducting cuprates and ferromagnetic manganates reveal interesting effects like spin injection, proximity effects, giant magnetoresistance and interlayer magnetic coupling [1], [2]. The growth of cuprate layers by metalorganic aerosol deposition (MAD) was studied for different deposition parameters (temperature, deposition rate and precursor molarity) and the used substrates (Al2O3, MgO and SrTiO3). Epitaxial growth of La2-xSrxCuO4 (LSCO) on SrTiO3 (100) substrates was evidenced by global (x-ray diffraction) and local (STM) structural characterization. A magnetic coupling between LCO and La0.7Sr0.3MnO3 (LSMO) was indicated by an increase of coercive field of ferromagnetic LSMO in the LSMO/LCO bilayer. Acknowledgment goes to the SFB 1073-B04 for support.

[1] J. F. Ding et al., Appl. Phys. Lett. 102, 032401 (2013) [2] A. M. Goldman et al., J. Magn. Magn. Mater. 200, 69 (1999)

MA 19.40 Tue 9:30 Poster A

Ramifications of the bombardment of exchange bias bilayers with low energy Helium ions — •Henning Huckfeldt and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, 34132 Kassel, Germany

The use of low energy Helium ions as flexible and feasible tool to modify the magnetic properties of exchange bias material systems in magnitude and/or coupling direction is known for more than a decade. While a number of models were proposed describing the link between structural effects evoked by ion bombardment and the change in magnetic properties experimental proof was hard to find. We present results of a novel experimental approach to investigate the effect using Helium ion bombardment of exchange bias layers in the absence of an external magnetic field to separate between the effects of local heating leading to a relaxation of the coupling direction and effects caused by structural defects due to collision cascades in the material.

MA 19.41 Tue 9:30 Poster A

Exchange bias in perpendicularly magnetized AFM/FM double layers — •Orestis Manos, Manuel Glas, Jan Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany.

Recently, the combination of exchange bias (EB) systems and perpendicularly magnetized electrodes in magnetic tunnel junctions (pMTJs) has attracted considerable scientific interest. Exchange bias refers to the shift of the magnetic hysteresis loop away from zero field, due to the exchange interaction between a ferromagnet (FM) and an antiferromagnet (AFM) (e.g., FeMn) across their common interface, which is usually accompanied by an increase in coercivity. The EB in in-plane magnetized systems is based on the alignment of the crystal plane parallel to the sample surface. It is already realized that the crystallographic growth of the AFM material affects critically the existence of exchange bias. In principle, the first aim concerns the change of the growth direction of FeMn (111) perpendicular to the sample plane. Therefore, we have fabricated perpendicularly magnetized stacks consisting of A/Fe-Mn/Co-Fe-B/MgO with A = Pt, Ru, and Ta [1]. Afterwards, the samples were ex-situ post-annealed at several temperatures and their crystallographic properties were investigated by X-ray diffraction (XRD) spectroscopy. A [111] growth direction was obtained for all seed layer. Laue oscillations on the (111) FeMn reflex suggest a highly ordered thin film.The samples with Pt seed layer showed an exchange bias field of 50 Oe.

[1] F. Garcia et al., J. Appl. Phys. 91, 6905 (2002)

MA 19.42 Tue 9:30 Poster A

Investigation of 3d-5d double perovskites as potential room temperature multiferroics — •Ashish Kulkarni[1,2], Vikas Shabadi[1], Philipp Komissinskiy[1], Rajeev Gupta[2,3], and Lambert Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Strasse 2, 64287 Darmstadt, Germany — [2]Materials Science Programme, Indian Institute of Technology Kanpur, 208016 Kanpur, India — [3]Department of Physics, Indian Institute of Technology Kanpur, 208016 Kanpur, India

In the search for multiferroic materials with ferromagnetic and ferroelectric order in a single phase, the $A_2BB'O_6$ double perovskites hold the potential for room-temperature functionality. The fabrication challenge with these multi-cation complex oxides lies in the precise control of oxidation states of the elements and achieving a high degree of B-site chemical order. Based on recent theoretical investigations to identify potential ferromagnetic insulators among $3d$-$5d$ double perovskites, the compound Bi_2MnReO_6 was predicted to have magnetic ordering temperatures well above 300 K. We report on the fabrication of epitaxial thin films of the analogous novel compound La_2MnReO_6 on single crystal $SrTiO_3$ (001) substrates, using pulsed laser deposition. Given the specific configuration of the outer electronic shells and the 150° Mn-O-Re bond angle, the magnetic moments on Mn and Re are expected to be coupled via superexchange in a ferrimagnetic state. Detailed structural investigations were performed by X-ray diffraction and the magnetic properties were studied by SQUID magnetometry.

MA 19.43 Tue 9:30 Poster A

Structural and magnetic properties of MnBi thin films grown by magnetron sputtering — •Sareh Sabet, Erwin Hildebrandt, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Germany

The intermetallic compound MnBi is a promising rare-earth-free permanent magnet material. The low-temperature phase (LTP) of MnBi has attracted much attention due to its high intrinsic coercivity (H_{ci}) with a positive temperature coefficient and a high magnetocrystalline anisotropy (H_A). These properties make MnBi unique among all candidates for high-temperature applications. Thin films of LTP-MnBi were deposited onto silica glass substrates by alternating sputter deposition of Bi and Mn layers, as well as from an alloyed MnBi target with 55 at.% Mn content, followed by a subsequent annealing at different temperatures ranging from 400 to 600° C for 1 h. We present the structural and magnetic properties of the resulting thin films in correlation with fabrication parameters.

MA 19.44 Tue 9:30 Poster A

Magnetic charactarization of pure and doped epitaxial γ'-Fe_4N thin films — •Philipp Zilske and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Because of their excellent magnetic properties, iron nitrides are potential materials for spintronic devices. For example, negative TMR of -75% was demonstrated in MTJs with one Fe_4N electrode [1].

To study the influence of doping, epitaxial γ'-Fe_4N films were grown on MgO (001) substrates by reactive magnetron sputtering. Diffraction measurements revealed that films with the correct stoichiometry can be grown at 450°C. The magnetic properties of the γ'-Fe_4N were studied by vectorial Kerr magnetometry. The hysteresis loops reveal a biaxial anisotropy due to the cubic perovskite structure and very sharp switching. Particularly the latter points to high crystal quality of the films. The loops characterize the crystalline [100] direction as the easy magnetization axis.

In addition, epitaxial Fe_3MnN, Fe_3NiN and Fe_3CoN films were prepared successfully and we discuss their magnetic properties.

[1] Y. Komasaki et al., *J. Appl. Phys.* **105**, 07C928 (2009)

MA 19.45 Tue 9:30 Poster A

Study of spontaneously induced chemical ordering in epitaxial thin films of the double perovskite La_2FeCrO_6 — •Supratik Dasgupta, Vikas Shabadi, Philipp Komissinskiy, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Strasse 2, 64287 Darmstadt

In double perovskites ($A_2BB'O_6$), antisite disorder plays a crucial role for their functional properties. A large difference in ionic radii and the formal valence states of the two B-site cations is known to favour a chemically ordered state. In the case of the ferrimagnetic insulator La_2FeCrO_6, Fe and Cr have nearly the same ionic radii and the same valence state, making chemical order difficult to achieve. Recently, for La_2FeCrO_6 nearly 90% ordering was reported in epitaxial thin films grown by pulsed laser deposition (PLD) with a saturation magnetization of $2\,\mu_B$/f.u. corresponding to a Fe-O-Cr superexchange interaction [1]. We have systematically studied the influence of various PLD parameters on the growth of epitaxial thin films of La_2FeCrO_6 along with an extensive structural, chemical and magnetic characterization. Laser fluence and substrate temperature have been found to be the most critical parameters that determine chemical order.

[1] S. Chakraverty *et al.*, Phys. Rev. B **84**, 064436 (2011).

MA 19.46 Tue 9:30 Poster A

Temperature and magnetic field dependent Raman spectroscopy on $(La_{0.65}Pr_{0.45})_{0.7}Ca_{0.3}MnO_3$ — •Sebastian Merten[1], Oleg Shapoval[2], Bernd Damaschke[1], Vasily Moshnyaga[1], and Konrad Samwer[1] — [1]I. Physikalisches Institut, Georg-August-Universität Göttingen, Friedrich-Hund-Platz 1, D-37077 Göttingen, Germany — [2]IIEN, Academy of Science of Republic Moldova, Academia 3/3, MD-2028 Chinisau, Republic of Moldova

Mixed valence manganites are still in the focus of fundamental research due to their rich phase diagramm with different electronic and magnetic phases. Crucial for the understanding oft he physics of manganites ist he strong electron-phonon coupling due to the Jahn-Teller effect. Here we report on a detailed Raman study of $(La_{0.65}Pr_{0.45})_{0.7}Ca_{0.3}MnO_3$ thin films. To assign the observable Raman modes, we performed polarized Raman spectroscopy at room temperature (λ = 532 nm, P = 1.2 mW). We observed four pronounced modes at 235 cm^{-1}, 434 cm^{-1}, 485 cm^{-1} and 609 cm^{-1}. The 485 cm^{-1} and 609 cm^{-1} mode can be assigned to an anti-stretching and stretching mode, respectively, due to the Jahn-Teller effect in agreement with previous work [1]. Furthermore, the temperature as well as magnetic field dependent Raman spectra show a correlation with the metall-insulator transition and the collosal magnetoresistance. Financial support from DFG, SFB 1073 (TP B04) is acknowledged.*

[1] M. N. Iliev, M. V. Abrashev et al., Phys. Rev. B, Vol. 57 (p.2872), 1998;Phys. Rev. B, Vol. 73 (p.064302), 2006

MA 19.47 Tue 9:30 Poster A

Quadratic magnetooptic spectroscopy of bcc Fe and Co_2MnSi thin films — •Robin Silber[1,2], Gerhard Götz[2], Lukáš Beran[3], Daniel Král[3], Jaromír Pištora[1], Günter Reiss[2], Martin Veis[3], Timo Kuschel[2], and Jaroslav Hamrle[1] — [1]VSB - Technical University of Ostrava, Czech Republic — [2]CSMD, Physics Department, Bielefeld University, Germany — [3]Charles University in Prague, Czech Republic

The magnetooptic Kerr effect (MOKE) is a well known physical phenomena that enables detailed characterization of magnetic material properties. However, quadratic MOKE (QMOKE) is not well understood yet. Hence, QMOKE anisotropy measurements [1] or QMOKE spectroscopy are methods convenient for investigations of the magnetooptic effect quadratic in magnetization. Within the materials having a cubic crystal symmetry, any dependence of the permittivity elements on the direction of the magnetizaton (within the second order in magnetization) can be expressed by two, generally complex parameters G_{11}-G_{12} and $2G_{44}$ [2]. We present here QMOKE spectra of those parameters for the bcc Fe and the Co_2MnSi Heusler alloy thin films as a novel spectroscopic approach revealing detailed magnetooptic information within the second order effects in magnetization. Both materials exhibit change of the QMOKE spectra with change of the crystallographic structure, which is achieved by post annealing at different temperatures.

[1] K. Postava et al., J. Appl. Phys. 91, 7293 (2002)
[2] J. Hamrle et al., J. Phys. D: Appl. Phys. 40, 1563 (2007)

MA 19.48 Tue 9:30 Poster A

Structural and magnetic properties of Fe/Pt epitaxial bilayers — •Sascha Keller[1], Andres Conca[1], Thomas Brächer[1], Jochen Greser[1], Laura Mihalceanu[1], Jörg Lösch[2], Burkard Hillebrands[1], and Evangelos Th. Papaioannou[1] — [1]Fachbereich Physik, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany — [2]Institut für Oberflächen- und Schichtanalytik (IFOS) and Forschungszentrum OPTIMAS, Trippstadter Str. 120, 67663 Kaiserslautern, Germany

The FePt system in the form of multilayers and alloys has attracted large attention from the magnetic research community especially for technological applications in storage media. However many questions are still open concerning the correlation between magnetic properties and structure of Fe and Pt layers. Here, we address this topic with the fabrication of high quality epitaxial thin Fe/Pt bilayer structures on MgO (001) substrates by using different growth temperatures. Both, Fe and Pt surfaces are analysed by *in situ* ultra high vacuum scanning tunnelling microscopy and structural parameters are derived using height-height-correlation, as well as grain size analysis. X-Ray diffraction pole figures shows the 45° in plane epitaxial relation between the Fe layer and the MgO substrate for all growth temperatures while the Pt layer exhibits different characteristics with different growth temperatures. Longitudinal magneto-optical Kerr effect measurements show the co-existence of two kinds of anisotropies: that of a cubic term plus a uniaxial anisotropy term. The strength of each term can be manipulated according to the structural properties of the films.

MA 19.49 Tue 9:30 Poster A

Skyrmions close to room-temperature – epitaxy and magnetism of FeGe thin films — •David Schroeter, Josefin Engelke, and Dirk Menzel — Institut für Physik der Kondensierten Materie, Technische Universität Braunschweig, Mendelssohnstr. 3, 38106 Braunschweig, Germany

Non-centrosymmetric chiral magnets in the cubic B20 structure with broken space-inversion symmetry show intriguing properties involving the existence of skyrmions. An application of skyrmions in spintronic devices requires materials with magnetic ordering close to room temperature. Among the chiral B20 magnets, FeGe has the highest ordering temperature (278 K). However, since the synthesis of single crystals is difficult, only very small-sized species of single-crystalline FeGe exist. We have grown FeGe as a thin film on Si(111) substrates using molecular beam epitaxy. The films have been structually characterized by RHEED and AFM. A detailed magnetic characterization has been obtained by SQUID magnetometry. We have investigated the complex magnetic phase diagram in comparison to that of bulk FeGe and explored the modification of the skyrmionic phase under the influence of the reduced dimensionality and the strain in the thin films.

MA 19.50 Tue 9:30 Poster A

Suppression of magnetic order in epitaxial $Mn_{1-x}Fe_xSi$ thin films — •Patricia Herbst, Josefin Engelke, David Schroeter, and Dirk Menzel — Institut für Physik der Kondensierten Materie, Technische Universität Braunschweig, Mendelssohnstr. 3, 38106 Braunschweig, Germany

The chiral magnet MnSi, which crystallizes in the cubic B20 structure and has evoked much interest due to the existence of skyrmions, orders magnetically below T = 29.5 K. The magnetic order can be suppressed by iron doping and vanishes completely for a Fe substitution of 15% in bulk material. Thin films of the B20 magnets, however, are known to show different magnetic properties, which are modified due to strain and film anisotropy. Therefore, we have investigated epitaxial $Mn_{1-x}Fe_xSi$ grown on Si(111) substrate by molecular beam epitaxy. A first series of samples was prepared by codeposition and a second series was codeposited and additionally annealed afterwards. The properties of these two different types of films are compared and discussed. For all films with Fe doping a decreased ordering temperature is observed and the complete suppression of magnetic order is investigated. At low temperature a Kondo minimum masks the possibly occurring deviation from the T^2-law, which is known from bulk material and which corresponds to non-Fermi liquid behavior.

MA 19.51 Tue 9:30 Poster A

Low-field AMR in planar Hall effect structured manganites — •Eduard Unger[1], Camillo Ballani[1], Alexander Belenchuk[2], Sabastian Hühn[1], Markus Jungbauer[1], Markus Michelmann[1], and Vasile Moshnyaga[1] — [1]I. Physikalisches Institut, Universität Göttingen — [2]IIEN, Academy of Sciences of Moldova, 3/3 Academiei street, MD-2628 Chisinan, Republic of Moldova

The anisotropic magnetoresistance (AMR) is widely used for sensing of both direction and absolute value of magnetic fields. Besides conventionally used ferromagnetic metallic materials, like permalloy ($Ni_{80}Fe_{20}$), thin epitaxial manganite films, e.g. $La_{0.7}(Sr_{1-y}Ca_y)_{0.3}MnO_3$, show large AMR ratios at temperatures slightly below T_C, which can be tuned close to room temperature by changing the Sr/Ca ratio. For a special AMR geometry, called "planar Hall effect", the transverse voltage is a measure for the samples magnetization, M, thus allowing one to achieve very high field sensitivity by applying a small bias magnetic field close to coercive field H_C, where the largest effect dM/dH is expected. With the goal to achieve low H_C and high AMR ratios, we have grown thin manganite films on $SrTiO_3$ substrates with different orientations by metalorganic aerosol deposition (MAD) technique and studied the dependence of planar Hall effect on the temperature, applied magnetic field, film thickness and form anisotropy by combining electrical measurement with a MOKE setup in order to link magnetic and electrical properties. Financial support from EU FP 7 Project IFOX (interfacing oxides) is acknowledged.

MA 19.52 Tue 9:30 Poster A

Out-of-plane and in-plane vector MOKE investigations of CoFeTb thin films — •Timo Oberbiermann, Gerhard Götz, Christoph Klewe, Günter Reiss, and Timo Kuschel — CSMD, Physics Department, Bielefeld University, Germany

Ferromagnetic thin films with an out-of-plane (oop) magnetic easy axis are of great interest, due to their potential for realizing next-generation spintronic devices like magnetic tunnel junctions which are capable of current-induced magnetization switching.

We used vectorial magnetometry based on the magnetooptic Kerr effect to investigate the magnetic properties of $(CoFe)_{1-x}Tb_x$ thin films which exhibit a partial oop-directed magnetization.

An established method uses the change in polarization for reflected s- and p-polarized light as well as different orientations of the sample and the external field directions in order to determine all three components of the magnetization vector [1]. Therefore, this technique needs several changes in the setup. However, another recently reported method [2] allows to obtain the in-plane components without setup changes by measuring the changes in polarization and reflectivity at the same time.

As a combination we now observe the changes in polarization and reflectivity simultaneously, both for s- and p-polarized light. This allows a quantitative determination of all three magnetization components during the reversal process of the magnetization in $(CoFe)_{1-x}Tb_x$ thin films without altering the experimental setup.

[1] T. Kuschel et al., J. Phys. D: Appl. Phys. 44, 265003 (2011)
[2] E. Jiménez et al., Rev. Sci. Instrum. 85, 053904 (2014)

MA 19.53 Tue 9:30 Poster A

Temperature and bias-voltage dependence of atomic-layer-deposited HfO_2-based magnetic tunnel junctions — •Savio Fabretti[1], Robert Zierold[2], Kornelius Nielsch[2], Carmen Voigt[3], Carsten Ronning[3], Patrick Peretzki[3], Michael Seibt[4], and Andy Thomas[1,5] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Institute of Nanostructure and Solid State Physics, Universität Hamburg, 20355 Hamburg, Germany — [3]Institute for Solid State Physics, Friedrich-Schiller-University Jena, 07743 Jena, Germany — [4]4. Physikalisches Institut, Georg-August University Göttingen, 37077 Göttingen — [5]Institut für Physik, Johannes Gutenberg Universität Mainz, 55128 Mainz, Germany

Magnetic tunnel junctions with HfO_2 tunnel barriers were prepared through a combination of magnetron sputtering and atomic layer deposition. The atomic layer deposition leading to a polycrystalline electrode-barrier system revealed by high-resolution transmission electron microscopy. We investigated the tunnel magnetoresistance ratio and the current-voltage characteristics between room temperature and 2 K. Here, we achieved a tunneling magneto resistance ratio of 10.3% at room temperature and 19.3% at 2 K. Furthermore, we studied the bias-voltage and temperature dependencies and compared the results with those of commonly used alumina- and magnesia-based magnetic tunnel junctions. We observed a polycrystalline/amourphous electrode-barrier system via high-resolution transmission electron microscopy [1].

[1] Fabretti et al., APL 105, 132405 (2014) doi: 10.1063/1.4896994

MA 19.54 Tue 9:30 Poster A

Spin pumping in epitaxially grown Fe/Pt systems with an MgO interlayer — •Laura Mihalceanu, Sascha Keller, Viktor Lauer, Jochen Greser, Andrés Conca, Burkard Hillebrands, and Evangelos Th. Papaioannou — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Understanding interface effects on spin pumping is a very exciting challenge in the field of spin currents excitation via magnetization dynamics. Here, we address the influence of the interface quality on spin pumping by using epitaxially grown samples. We use the Fe/Pt system as a model system to investigate the interface. For this purpose we study the interlayer effects by varying material composition, layer thickness and deposition temperature [1]. We focus on the impact of layer thickness of Pt on the spin-pumping efficiency. This efficiency can be obtained by measuring the current of the inverse spin Hall effect. Furthermore, we choose the Pt thickness which presents the highest spin-pumping efficiency and modify the interface by using an insulating layer of MgO. We show the dependence of spin pumping on the thickness of MgO and on the structural quality of the grown samples.

[1] E. Th. Papaioannou, P. Fuhrmann, M. B. Jungfleisch, T. Brächer, P. Pirro, V. Lauer, J. Lösch, and B. Hillebrands, Applied Physics Lettres 103, 162401 (2013).

MA 19.55 Tue 9:30 Poster A

Sputtered and annealed polycrystalline La0.67Sr0.33MnO3 and PbZr0.2Ti0.8O3 layers on Silicon (111) — •Oana T. Ciubotariu[1,2], Manuel Monecke[2], Patrick Thoma[2], Roxana Dudric[1], Romulus Tetean[1], Dietrich R. T. Zahn[2], and Georgeta Salvan[2] — [1]Faculty of Physics, Babeş-Bolyai University, RO-400084 Cluj-Napoca, Romania — [2]Semiconductor Physics, Technische Universität Chemnitz, D-09107 Chemnitz, Germany

In a new approach to fabricate organic spintronic devices, heterostructures of La0.67Sr0.33MnO3 (LSMO) and PbZr0.2Ti0.8O3 (PZT) thin films were proposed. By sandwiching ferroelectric layers between the ferromagnetic electrode and the organic semiconductor, the resistance of such devices can be controlled by applying electric and magnetic fields [1]. In this work we studied: LSMO, PZT, and PZT/LSMO layers on Si(111) substrates. The LSMO and PZT layers were deposited in a high vacuum chamber by pulsed radio frequency magnetron sputtering at room temperature. After the deposition, the LSMO layers were annealed in ambient atmosphere at 775 °C. Their crystallinity was confirmed via X-ray diffraction. The PZT films were annealed in ambient atmosphere at temperatures in the range 500-700 °C for one hour. For the LSMO films the annealing time was observed to influence the magnetic properties which were investigated using a SQUID magnetometer. The Curie temperature, the remanence, and the coercitive field increase with annealing time while the saturated magnetic moment reaches a constant value for annealing times larger than three hours.

[1] Sun, D. et al. Nat. Commun. 5:4396 doi: 10.1038/ncomms5396 (2014)

MA 19.56 Tue 9:30 Poster A

Local probe of disorder-induced magnetism in Fe60Al40 thin films by Mössbauer and X-ray spectroscopy — •Alevtina Smekhova[1,3], Dirk Walecki[1], Rantej Bali[2], Kay Potzger[2], Steffen Cornelius[2], Oscar Liedke[2], Jürgen Lindner[2], and Heiko Wende[1] — [1]Universität of Duisburg-Essen, Fakultät für Physik und CENIDE, Experimentalphysik, 47048 Duisburg, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf (HZDR), Institut für Ionenstrahlphysik and Materialforschung, DE - 01314 Dresden, Germany — [3]Lomonosov Moscow State University, Faculty of Physics, 119991 Moscow, Russia

It is known for decades that $Fe_{60}Al_{40}$ system is paramagnetic at RT in the chemically ordered simple cubic B2 (CsCl) phase but exhibits ferromagnetism being chemically disordered in the A2 one [1]. This phenomenon is appealing for different applications where the delicate control of magnetic properties is needed. In $Fe_{60}Al_{40}$ thin films of different thicknesses chemical disorder can be induced by ion beam irradiation technique with ions possessing sufficient energy to disarray Fe and Al atoms; and nowadays it is successfully used in combination with lithography for magnetic pattern creation with a sub-50nm resolution [2]. We report on recent results of Mössbauer and element-specific X-ray spectroscopy studies of $Fe_{60}Al_{40}$ thin films which reveal that local environment and/or related magnetic properties strongly depend on the degree of disorder, annealing temperature and film thickness (40nm or 250nm). [1] G. Huffman et al., J.Appl. Phys. **38** (1967) 735 [2] R. Bali et al, Nano Lett. **14** (2014) 435

MA 19.57 Tue 9:30 Poster A

Investigation on new TMR stacks for inverse magnetrostrictive sensors — •Niklas Dohmeier[1], Günter Reiss[1], Karsten Rott[1], Ali Tavassolizadeh[2], Dirk Meyners[2], and Eckhard Quandt[2] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Institute for Materials Science, Christian-Albrechts-Universität zu Kiel

We show new approaches for magnetostrictive sensors based on tunneling magnetroresistive (TMR) elements. The key materials in these stacks are *CoFeB* and *MgO* which are standard materials for TMR stacks.
Since the inverse magnetostriction in this material leads only to increasing or decreasing (depending on the inital magnetization) of the resistance, the measurement of the bending through this effect is limited. That is why new TMR stacks were developed in which the magnetizations of the two ferromagnetic layers are not parallel or antiparallel. This leads to new opportunities for the application of magnetrostrictive sensors, e.g., in AFM.
We will discuss different approaches such as double-exchange biasing, shaping or the combination of in-plane and out-of-plane anistropy.
These TMR stacks have been made by magnetron sputtering and investigated by magneto-optical Kerr effect (MOKE), alternating-gradient magnetometry (AGM) and TMR measurements.

MA 19.58 Tue 9:30 Poster A

Tayloring granular FePt films for electrolytic gating — Karin Leistner, Kenny Duschek, Ludwig Schultz, Ludwig Reichel, Sebastian Fähler, and •Christian Kozalla — Leibniz Institute for Solid State and Materials Research, Dresden, Germany

Reversible changes of magnetism in metals are of key interest in today's research. Electric control of magnetization and anisotropy has already been achieved by electrolytic charging of continuous FePt films [1]. Here we aim for charging granular FePt films in order to study electric field effects at the superparamagnetic limit [2]. To allow for charging a granular film, a conduction path must be realized in a first step. In comparison to the well established FePt/MgO architecture we study the growth of granular L10 ordered FePt films on a Nb-doped SrTiO3 substrate. L10 ordering in this case is achieved at lower substrate temperatures. However, the conduction volume of the substrate turns out to be too large for reasonable anomalous Hall-Effect (AHE) measurement, needed for in situ magnetic characterization during charging. The AHE measurement is successful when an additional Fe layer is sputtered on granular L10 FePt. In these Fe/FePt bilayers a sufficient conduction path and at the same time single phase hard magnetic behavior can be realized. These exchange coupled films are promising candidates for future electrolytic gating experiments.

[1] K. Leistner et al. Physical Rev. B 87, 224411, (2013); doi: 10.1103/PhysRevB.87.224411
[2] F. Kurth et al. Physical Rev. B 82, 184404, (2010); doi:10.1103/PhysRevB.82.184404

MA 19.59 Tue 9:30 Poster A

Laser-induced changes of electronic transport properties in manganites — •Manuel Mchalwat[1], Henning Ulrichs[1], Bernd Damaschke[1], Vasily Moshnyaga[1], Markus Münzenberg[2], and Konrad Samwer[1] — [1]1. Physikalisches Institut, Georg-August-Universität, Göttingen — [2]Institut für Physik, Ernst-Moritz-Arndt Universität, Greifswald

Manganites show structural phenomena at a variety of spatial and time scales ranging from nanometers and picoseconds for single polarons up to microns and seconds for the electronic phase separation. Many of these influence physical properties, e. g. the metal-insulator transition, which is accompanied by a change of the crystal structure and believed to be driven by the formation of correlated polarons near the transition temperature.

By exciting the sample near the transition by short laser pulses we change the electronic tranport properties by influencing the electronic correlations. These changes show up in a change in the third harmonic voltage.

The work has been supported by the DFG through SFB 1073 TP B01 and by Femtolasers.

MA 19.60 Tue 9:30 Poster A

Control of stoichiometry in $LaMnO_3/La_2MnO_4$ thin films grown by pulsed laser deposition — •Arun Singh Chouhan[1,2], Supratik Dasgupta[1], Vikas Shabadi[1], Aldin Radetinac[1], Philipp Komissinskiy[1], Ajay D Thakur[2], and Lambert Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Strasse 2, 64287 Darmstadt — [2]Department of Physics, Indian Institute of Technology Patna, India

Growth of perovskites (ABO_3) by pulsed laser deposition (PLD) requires a simultaneous precise control of multiple process parameters. In particular, the interplay between laser fluence, growth atmosphere, and pressure affects the stoichiometry and, thereby, also the physical properties of compounds such as $LaMnO_3$ where the B-site cation is known to have multiple stable oxidation states. Although stoichiometric bulk $LaMnO_3$ is an A-type antiferromagnetic insulator, several independent studies have reported a ferromagnetic order in thin films, attributed to an off-stoichiometry driven double exchange interaction between the mixed Mn^{3+} and Mn^{4+} oxidative states. In spite of repeated efforts, as grown thin films with magnetic saturation below $\sim 0.4\,\mu_B$/f.u. have so far not been reported. Here, we present a systematic growth study with a fine control of cation stoichiometry and oxidation state, allowing to stabilize $LaMnO_3$ (with Mn^{3+}) and La_2MnO_4 (with Mn^{2+}) from the same target by choosing the appropriate deposition conditions.

MA 19.61 Tue 9:30 Poster A

Structural and magnetic characterization of $\alpha'-Fe_8N_x$ thin films — •Tim Helbig, Imants Dirba, Oliver Gutfleisch, and Lambert Alff — Material Science, TU Darmstadt, Alarich-Weiss-Str. 16, 64287 Darmstadt, Germany

Buffer-free and epitaxial $\alpha-$Fe and $\alpha'-Fe_8N_x$ thin films have been grown by RF magnetron sputtering onto MgO (100) substrates. With increasing nitrogen content in the plasma during deposition, an expansion of the $\alpha-$Fe unit cell along the c$-$axis was observed resulting in a tetragonal distortion of approximately 10% (c = 3.15 Å) which corresponds to the value for $\alpha'-Fe_8N$ (002). Fe bcc lattice expansion led to an increase in magnetic moment up to 2.61 ± 0.06 μ_B per Fe atom and an increased anisotropy of around 6000 Oe compared to that of pure Fe film (at 10 K temperature). Magnetic Force Microscopy (MFM) measurements have been performed indicating a transition from in plane magnetization due to shape anisotropy, to out of plane magnetization caused by the strain-induced magnetocrystalline anisotropy along the c$-$axis.

MA 19.62 Tue 9:30 Poster A

New magnetic phase in $LaMnO_3/SrMnO_3$ superlattices on $SrTiO_3$ (001) substrate — •Danny Schwarzbach, Markus Jungbauer, Sebastian Hühn, Markus Michelmann, and Vasily Moshnyaga — I. Physikalisches Institut, Georg-August-Universität Göttingen

Interface effects in perovskite oxide heterostructures have proven to result in interesting novel magnetic phenomena. We studied $(LaMnO_3)_{2ML\cdot n}/(SrMnO_3)_{1ML\cdot n}$ superlattices of $n \approx 3$ grown on $SrTiO_3$ substrates with (001) orientation by Metalorganic Aerosol Depistion (MAD) technique. These samples exhibit two ferromagnetic phases: the low T_C phase with $T_C \approx 270$ K is likely originated from LMO and has already been observed by other groups. We also detected high temperature FM phase with $T_C \approx 355$ K. The high T_C phase reveals a strong uniaxial in plane anisotropy, with easy axis aligned parallel to the monoatomic crystal steps of the substrate. The low temperature saturation magnetization of this phase corresponds to a fully saturated Mn monolayer, indicating a two-dimensional nature of high-T_C ferromagnetic phase.
Support by the Seventh Framework Programme of the EU is acknowledged.

MA 19.63 Tue 9:30 Poster A

Interplay of magnetization, heat and charge currents in FeCo thin films in the presence of magnetic field — •Sasmita Srichandan, Matthias Kronseder, Christian Back, Josef Zweck, and Christoph Strunk — Institute of Experimental and Applied Physics, University of Regensburg, 93040 Regensburg, Germany

We present the magneto thermoelectric response to currents in 20 nm thick Fe_xCo_{1-x} films with compositions x= 0.3, 0.5, 0.6, 0.7, 0.8 deposited on 100 nm thick SiN_x membranes. The anisotropic magnetoresistance (AMR) has contributions from both coherent rotation of magnetization and domain switching. The angular dependence of the switching field H_{sw} at room temperature has a minimum at 20°. The shift of this minimum to 20° from 45° as predicted by the Stoner-Wohlfarth model owes to the aspect ratio of our FM strip, which causes inhomogeneous demagnetization fields at the ends of the strip. On the same films, features of H_{sw} in magneto thermopower (MTEP) measured in temperature gradients $\vec{\nabla}T$ of up to 250 K/mm are similar to those in the AMR. Additionally the membranes allow measurement of all 4 transport coefficients on the same film.

20 nm Fe_xCo_{1-x} films were also deposited on very thin 30 nm SiN_x membranes to study the effects of charge current and $\vec{\nabla}T$ on domain walls in TEM. The Lorentz microscopy images show two domain walls nucleated at both ends of the FM strip and via the microscopy we demonstrate the response to applied field and temperature gradient.

MA 19.64 Tue 9:30 Poster A

In-situ Polarised Neutron Reflectometry during Thin Film Growth by DC Magnetron Sputtering — Sina Mayr[1], Wolfgang Kreuzpaintner[1], Birgit Wiedemann[1], •Jingfan Ye[1], Andreas Schmehl[2], Thomas Mairoser[2], Alexander Herrnberger[2], Jean-Francois Moulin[3], Jochen Stahn[4], Panagiotis Korelis[4], Martin Haese-Seiller[3], Matthias Pomm[3], Amitesh Paul[1], Peter Böni[1], and Jochen Mannhart[5] — [1]Technische Universität München, Garching — [2]Zentrum für elektronische Korrelation und Magnetismus, Universität Augsburg — [3]Helmholtz Zentrum Geesthacht, Instrument REFSANS, Garching — [4]Paul Scherrer Institut, Villigen PSI, Schweiz — [5]Max Planck Institut für Festkörperforschung, Stuttgart

Since thin magnetic layers are used in many magneto-electronic devices the understanding of their texture and the coupling between them is essential to improve functionality. As these parameters are likely to change during the deposition process, in-situ polarised neutron reflectometry (PNR) is used to monitor the development of the structural and magnetic thin film properties during growth. We carry out in-situ PNR measurements using a specially designed sputtering chamber as sample environment combined with modern neutron optical elements at AMOR at PSI. In this contribution, the epitaxial growth of Fe and Cr on a Cu(100)/Si(100) substrate and the evolution of the magnetic properties, particularly the exchange coupling effects in a Fe/Cr heterostructure as a function of film thickness will be presented.

MA 19.65 Tue 9:30 Poster A

Structural and magnetic properties of epitaxially grown Fe/Cu multilayers — •Amir Syed Mohd[1], Sabine Pütter[1], Stefan Mattauch[1], Alexandros Koutsioubas[1], Stephan Geprägs[2], and Thomas Brückel[1,3] — [1]Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at MLZ, 85747 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [3]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institute, JCNS-2, PGI-4: Scattering Methods, Forschungszentrum Jülich GmbH, 52428 Jülich, Germany

Alternate magnetic layers separated by non-magnetic layers are known for exhibiting interlayer coupling and its applications in memory devices. Fe/Cu multilayers are interesting to study because the lattice spacing and the crystal structure of Fe layer vary with thickness which may lead to change in magnetic ordering.

In this work we have deposited [Fe(x)/Cu(y)]x10 multilayers with Fe layer thickness of x (~1.5, 2.0 and 2.5 nm) and corresponding Cu layer thickness of y (~2.5, 2.0 and 1.5 nm), on Cu (100) buffer layer epitaxially grown on Si (100) substrate at ~280 K using MBE. In-situ RHEED measurements were performed to monitor the epitaxial growth during deposition. SQUID measurements suggest that the interlayer coupling is increasing with decreasing Fe layer thickness. Further, in order to determine depth dependent magnetization profile, polarized neutron reflectivity measurements are underway. The obtained results will be discussed in this presentation.

MA 19.66 Tue 9:30 Poster A

Ferromagnetism of nonstoichiometric manganese monosilicides at room temperature — •Anna S. Semisalova[1,2], Konstantin Yu. Chernoglazov[3], Nikolai S. Perov[1], Elena A. Gan'shina[1], Alexander B. Granovsky[1], Andrey V. Zenkevich[4], Shengqiang Zhou[2], and Vladimir V. Rylkov[3] — [1]Lomonosov MSU, Moscow, Russia — [2]HZDR, Dresden, Germany — [3]NRC Kurchatov Institute, Moscow, Russia — [4]MIPT, Dolgoprudny, Russia

Ferromagnetic Si-Mn alloys attract increasing interest due to their interesting properties - recently it was found that these alloys prepared by PLD method exhibit unusual magnetic characteristics which cannot be adequately interpreted within the framework of available theoretical models. Curie temperature TC in nonstoichiometric Si1-xMnx alloys slightly enriched in Mn (x ~ 0.52-0.55) was shown to be on order of magnitude higher (TC ~ 300 K) in comparison to the stoichiometric MnSi (TC ~ 30 K). The mechanism of high-temperature ferromagnetism is still not clear. The ferromagnetic exchange is associated with the formation of defects with localized magnetic moments coupled via spin fluctuations of itinerant electrons in the host. Also we suppose that structural defects have a strong influence on the formation of metastable phases with enhanced ferromagnetic response. In this contribution the recent experimental results on ferromagnetosm of PLD deposited SiMn alloys are summarized. Supported by RFBR (15-57-78022). 1. Rylkov et al. EPL 103, 57014 (2013) 2. Rylkov et al. JMMM, doi:10.1016/j.jmmm.2014.09.028

MA 19.67 Tue 9:30 Poster A

Investigation of the chiral spin structure of the double layer Fe on Ir(111) using SP-STM in a 3D vector magnetic field system — •Aurore Finco, Pin-Jui Hsu, Lorenz Schmidt, Andre Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

The detailed magnetic structure of the second atomic layer Fe on Ir(111) has been investigated with spin-polarized scanning tunneling microscopy (SP-STM). The second layer Fe exhibits reconstruction lines along which cycloidal spin spirals are guided. The low temperature measurements in a 3D-vector magnetic field system on the three rotational domains have revealed that these spirals have a unique rotational sense. In addition, no magnetic phase transition occurred when an out-of-plane magnetic field was applied up to 9T. The chirality of this complex spin structure indicates that the Dzyaloshinskii-Moriya interaction plays a crucial role in its formation.

MA 19.68 Tue 9:30 Poster A

Magnetic linear dichroism in angular resolved photoemission of the valence band of 3d metal thin films on W(110) — •Tobias Löffler[1], Torsten Veltum[1], Mathias Gehlmann[2], Sven Döring[2], Lukasz Plucinski[2], and Mathias Getzlaff[1] — [1]Institut für Angewandte Physik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf — [2]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52428 Jülich

The technique of magnetic linear dichroism in the angular distribution (MLDAD) of photoelectrons allows the study of the electronic band structure as well as the study of magnetic properties of metallic thin films and single crystals. We are interested in a deeper understanding of the magnetic linear dichroism of ferromagnetic 3d metals. Special attention is turned to the question, which parts of the band structure are responsible for this phenomenon. In this study, linearly polarized synchrotron radiation in the VUV regime is used. The investigated system consists of epitaxially grown 3d metal thin films on a W(110) single crystal.

The exciting photon energy is varied to investigate the electronic structure of the valence band. At lower energies, existing dichroism measurements of Co(0001) on W(110) are confirmed [1] and extended to off-normal geometry. To investigate similarities, angle-resolved spectra of Co(0001) and Fe(110) on W(110) are compared.

[1] J. Bansmann et al., Surf. Sci. 454-456 (2000), 686-691

MA 19.69 Tue 9:30 Poster A

Stability of Single Skyrmionic Bits — •Julian Hagemeister, Niklas Romming, Kirsten von Bergmann, Elena Y. Vedmedenko, and Roland Wiesendanger — Institute of Applied Physics and Interdisciplinary Nanoscience Center Hamburg, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

The switching between topologically distinct skyrmionic and ferromagnetic states has been proposed as a bit-operation for information storage. Generally, long lifetimes of the bits in combination with short switching times are required for data storage devices. To study the feasibility of realizing these preconditions for skyrmionic bits, we have investigated their energy landscape in a broad range of magnetic fields and temperatures theoretically by means of classical Monte-Carlo (MC) simulations. A critical field B_c at which the mean lifetimes of the skyrmionic (Sk) and ferromagnetic (FM) states are identical has been identified. Notably, the field dependent mean lifetimes of the two states show a high asymmetry with respect to B_c in contrast to conventional uniaxial magnetic bits. The main reason for the asymmetry has been found to be a different field dependence of the skyrmionic and ferromagnetic activation energies. We were also able to correlate the stability of skyrmions in systems on discrete lattices with their attempt frequency rather than with their activation energy. We use this knowledge to propose a procedure permitting the determination of effective material parameters and the quantification of the MC time scale from the comparison of theoretical and experimental data.

MA 19.70 Tue 9:30 Poster A

Surface-Orientation-Dependent Spin Quenching of Adsorbed Co Porphyrin Molecules — •Lucas M. Arruda[1], Matthias Bernien[1], Fabian Nickel[1], Lalminthang Kipgen[1], Christian F. Hermanns[1], Jorge Miguel[1], Alex Krüger[1], Dennis Krüger[1], Nino Hatter[1], Jens Kopprasch[1], Qingyu Xu[1,2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin — [2]Department of Physics, Southeast University, 211189 Nanjing

Metalloporphyrin molecules on surfaces have been attracting the attention of the scientific community since their metal ion is fourfold coordinated within the molecular plane and displays two empty coordination sites that can be occupied by additional ligands or a surface. We have investigated submonolayers of Co octaethyl porphyrin molecules on Cu(001) and Cu(111) as well as on Au(001) and Au(111) surfaces by means of x-ray absorption spectroscopy and x-ray magnetic circular dichroism in an external magnetic field of 6 T at a temperature of 5 K. We find the Co magnetic moment quenched when the molecule is adsorbed on Cu(111), Au(001), and Au(111). On Cu(001), on the contrary, the Co ions display a significant magnetic moment. We attribute this modification of the molecular magnetic properties to the formation of a hybrid electronic state at the metal-organic interface. — Financial support by project VEKMAG (BMBF 05K13KEA) is gratefully acknowleged.

MA 20: POSTER Ib

Magnetisierungsdynamik, Spintransport, Spintronics

Time: Tuesday 9:30–13:00 Location: Poster A

MA 20.1 Tue 9:30 Poster A

Annealing influence on the spin-dynamic properties of CoFeB thin films — •Tobias Fischer[1], Thomas Meyer[1], Thomas Brächer[1], Björn Heinz[1], Andrés Conca[1], Evangelos Papaioannou[1], Stefan Klingler[1], Jochen Greser[1], Thomas Sebastian[1,2], Britta Leven[1], Jörg Lösch[3], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Current affiliation: Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden — [3]Institut für Oberflächen- und Schichtanalytik GmbH (IFOS) and Landesforschungszentrum OPTIMAS, Trippstadter Str. 120, 67663 Kaiserslautern, Germany

Materials and material systems with ultra-low Gilbert damping parameters are a crucial requirement for the realization of spin-wave logic devices. For that, CoFeB is a promising candidate due to its intrinsically low damping. Our aim is to investigate the suitability of an annealing step to further decrease the damping in CoFeB-based systems. Ferromagnetic resonance measurements as well as the magneto-optical Kerr effect reveal the dependence of the Gilbert damping parameter, the exchange constant, the saturation magnetization, and the coercive field on the annealing temperature. The correlation of these parameters with the crystalline properties is determined using X-ray diffractometry. Furthermore, we present Brillouin light scattering spectroscopy measurements of spin waves in waveguides showing the influence of annealing on the spin-dynamic properties.

MA 20.2 Tue 9:30 Poster A

***Ab initio* investigation of light-induced relativistic spin-flip effects in femtosecond magneto-optics** — •Ritwik Mondal[1], Marco Berritta[1], Karel Carva[1,2], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Charles University, Prague, Czech Republic

Excitation of a metallic ferromagnet such as Ni with an intensive fs laser pulse causes an ultrafast demagnetization within ~300 fs. It was proposed that this could be due to relativistic light-induced processes: direct light-induced spin-flip[1] or coherent relativistic electrodynamic processes[2] (see also[3]). We perform an *ab initio* study of the influence of these relativistic effects on the magneto-optical response of Ni. We compute the influence of relativistic spin-flip transitions and develop response theory for ultra-relativistic terms due to the electromagnetic field. Our *ab initio* calculations of relativistic spin-flip optical excitations predict that these give only a very small contribution to the laser-induced demagnetization. Support from the EU (grant No. 281043, FemtoSpin) is acknowledged.

[1]G.P. Zhang *et al.*, Nature Phys. **5**, 499 (2009). [2]J.-Y. Bigot *et al.*, Nature Phys. **5**, 515 (2009). [3] K. Carva *et al.*, Nature Phys. **7**, 665 (2011).

MA 20.3 Tue 9:30 Poster A

Determination of the Exchange Stiffness Constant in Ultrathin Magnetic Films by Ferromagnetic Resonance — •Manuel Langer[1,2], Kai Wagner[1], Thomas Sebastian[1], Helmut Schultheiss[1], Kilian Lenz[1], Jürgen Lindner[1], and Jürgen Fassbender[1,2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [2]Technical University Dresden, 01069 Dresden

In ultrathin magnetic films of 10 — 20 nm thickness, it is hardly possible to determine the exchange constant A using conventional techniques, such as Brillouin light scattering. In this work, a method is presented allowing for analytical determination of the exchange constant A in ultrathin magnetic films.

Periodical surface modulations are introduced by electron beam lithography with subsequent sub-nanometer etching. The periodical stray field induces two-magnon scattering leading to a coupling of the uniform excitation with higher in-plane spin waves.

An analytical model is presented, that can be used to precisely calculate the exchange constant A under usage of the measured ferromagnetic resonance spectra (frequency versus field dependence).

This work is supported by DFG grant LE2443/5-1.

MA 20.4 Tue 9:30 Poster A

Phase-to-amplitude conversion by parallel parametric amplification of propagating spin waves in microstructured $Ni_{81}Fe_{19}$ waveguides — Thomas Brächer, •Frank Heussner, Philipp Pirro, Thomas Meyer, Alexander Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

We report on controlling the intensity of a propagating spin wave after passing through a localized amplification area in a transversally magnetized $Ni_{81}Fe_{19}$ (Py) waveguide by phase matching. A microwave current inside a microstrip transmission line with a narrowing underneath the Py waveguide creates a locally enhanced dynamic magnetic field parallel to the static magnetization. By applying an alternating magnetic field of frequency $2f_{SW}$, parametric interactions can lead to an amplification of a coherently excited spin wave of frequency f_{SW}. This effect is known as parallel parametric amplification (PPA).

The amplification is phase-sensitive, i.e., it depends on the phase difference $\Delta\Phi$ between the phase Φ_{2f} of the magnetic pumping field and the phase Φ_f of the propagating spin wave. By utilizing Brillouin light scattering (BLS) microscopy, we demonstrate that the level of the transmitted spin-wave intensity behind the amplification area can be continuously tuned by adjusting the phase difference $\Delta\Phi$. The result of this work commends itself for applications in information processing as it allows for the realization of a phase-to-amplitude conversion based on phase-sensitive parallel parametric amplification.

MA 20.5 Tue 9:30 Poster A

Ultrafast Magnetostriction of Antiferromagnetic Holmium

studied by Femtosecond X-ray Diffraction — •Jan-Etienne Pudell[1], Alexander von Reppert[1], Flavio Zamponi[1], Matthias Rössle[1], Daniel Schick[2], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Wilhelm-Conrad-Röntgen Campus, BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany

We present time-resolved X-ray diffraction on a Holmium thin film after femtosecond laser excitation. The lattice shows rich spatio-temporal dynamics, where the contraction and expansion are driven by the excitation of electrons, magnons and phonons.

The indirect exchange interaction (RKKY) in the 80 nm Holmium film leads to an incommensurate helical antiferromagnetic (AFM) spin structure below the Néel temperature of approx. 131 K. The strong magnetostriction in Holmium results in an decrease of the lattice constant with temperature. The sub-pico to nanosecond lattice dynamics after photoexcitation are studied by ultrafast X-ray diffraction (UXRD) using a laser-driven Plasma X-ray Source (PXS). The sample is excited with 800 nm femtosecond laser pulse of different fluences starting at various temperatures below and above the Néel temperature of Holmium. The phonon driven lattice expansion takes place within 15 ps and is sound velocity limited. Below the Néel temperature, the heating of the magnetic system induces an ultrafast magnetostriction, which leads to a contraction within 25 ps.

MA 20.6 Tue 9:30 Poster A

Threshold photoemission magnetic circular dichroism as a tool for high-resolution imaging of magnetization structures — •Maximilian Staab[1,2], Hans Joachim Elmers[1], Mathias Kläui[1,2], and Gerd Schönhense[1] — [1]Johannes Gutenberg-Universität Mainz — [2]MAINZ Graduate School of Excellence

Time-resolved imaging of magnetic structures and their dynamics is the domain of Kerr microscopy (being limited in resolution) and Synchrotron-based XMCD PEEM. On the quest to faster imaging we pursue the excitation with a laboratory-based Ti-sapphire laser exploiting magnetic circular dichroism in threshold photoemission (TPMCD). Our experiment uses a photoemission electron microscope (PEEM) and photoelectron excitation by circularly polarized light of 1.6 eV (fundamental of the laser) and 3.2 eV (second harmonic). The TPMCD asymmetries are based on different probabilities of transitions between spin-dependent electronic bands in the near photoemission threshold region. The TPMCD exists in one-photon-photoemission (1PPE) [1] and also in two-photon-photoemission (2PPE) [2]. In order to do spatially resolved imaging of a magnetic domain pattern we fabricated thin magnetic films consisting of a few monolayers of Co on top of a Pt(111) single crystal and performed PEEM measurements. Using a femtosecond laser as photon source will allow pump-probe experiments to add high time resolution to the PEEM setup. Project funded by DFG EL172/15. [1] K. Hild et al., Phys. Rev. B Vol. 80(22), pp. 224426, (2009) [2] K. Hild et al., Phys. Rev. Lett. 102, 057207, (2009)

MA 20.7 Tue 9:30 Poster A

Femtosecond demagnetization of Nickel/Gold: rotation vs ellipticity — •Moritz Barkowski, Oliver Schmitt, Jurij Urbancic, Steffen Eich, Jingyi Mao, Sakshath Sadashivaiah, Daniel Steil, Mirko Cinchetti, Stefan Mathias, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Using femtosecond time-resolved MOKE to study ultrafast demagnetization is today a standard experimental approach. However, there is still an ongoing debate on the so called optical artifacts in the signal, and when and how true magnetization dynamics are extracted. In our measurements of ultrafast demagnetization of Ni/Au we have the peculiar situation that the MOKE rotation & ellipticity signals differ by demagnetization constants of a factor of two. In order to distinguish demagnetization from non-magnetic effects, we study this system with different fs-techniques and for varying material compositions.

MA 20.8 Tue 9:30 Poster A

Sign change of MOKE-signals in engineered AOS materials — •Ute Bierbrauer[1], Sabine Alebrand[1], Michel Hehn[2], Charles-Henri Lambert[2], Daniel Steil[1], Oliver Schmitt[1], Eric Fullerton[3], Stéphane Mangin[2], Mirko Cinchetti[1], Stefan Mathias[1], and Martin Aeschlimann[1] — [1]TU Kaiserslautern, Deutschland — [2]IJL Nancy, Frankreich — [3]CMR San Diego, USA

Since the discovery of a transient ferromagnetic-like state in amorphous rare-earth transition-metal alloy films [1] a connection between this ultrafast magnetization process and helicity-dependent all-optical switching (AOS) is assumed.

Here we demonstrate that a sign change of the magnetization within a fs demagnetization experiment [2] can also be observed in the recently discovered [3,4] more complex AOS systems, including ferrimagnetic and ferromagnetic multilayer structures. We show our recent results in this field with regard to the ultrafast magnetization dynamics of these materials, particularly with a closer view on the magnetization reversal occurring on the femtosecond timescale. The presented results link the appearance of a transient negative MOKE signal as a required property of AOS materials.

[1] Radu et al. Nat. 472 (7342), 205-8 (2011)
[2] Alebrand et al., PRB 89, 144404 (2014)
[3] Mangin et al.Nat. Mat. 13, 286-292 (2014)
[4] Lambert et al. Science 325 (6202), 1337-1340 (2014)

MA 20.9 Tue 9:30 Poster A

Band Structure calculation of thin film YIG based magnetic crystal — •Tobias Stückler, Ping Che, Sa Tu, and Haiming Yu — Spintronics Interdisciplinary Center, Department of Electronic and Information Engineering, Beihang University Beijing, 100191, China

Magnonic crystals (MCs) are a new class of magnetic nanostructures. They become the key to provide the possibility of studying frequency bands and band gaps of magnetic materials. MCs can be used to develop new applications, like spin filters. We study spin wave propagation in MCs based on magnetic insulator thin film YIG and report simulation of band information and forbidden band gap for frequencies tuned by the crystal lattice and the materials.

MA 20.10 Tue 9:30 Poster A

Transport effects and ultrafast magnetization dynamics in laser-excited metals — •Linda Thesing[1], Benedikt Y. Mueller[2], and Baerbel Rethfeld[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Max-Planck-Institut fuer Intelligente Systeme, Stuttgart, Germany

The equilibration of intense thermodynamic variables has been found to dominate ultrafast magnetization dynamics [1]. In itinerant ferromagnets, these variables may be considered separately for spin-up and spin-down electrons. The temporal evolution of electron and phonon temperatures as well as chemical potentials can be described with help of the μT model [2], which is based on a phenomenological two temperature description. The μT model has identified the minimum of magnetization as a transient equilibrium state. It also explains the experimentally observed slowing down of the magnetization dynamics by a critical region in the magnetic phase diagram [2]. Considering spatial effects, the excitation of a ferromagnetic sample with an ultrashort laser pulse does not only result in gradients of electron temperatures but also of the chemical potential of the electrons. The μT model allows to trace the equilibration of such gradients, and additionally accounts for transport effects such as Seebeck or Peltier effect. Therefore, it opens the possibility to describe ultrafast magnetization dynamics driven by different chemical potentials [1] *and* transport effects.

[1] B. Y. Mueller et al., PRL 111, 167204 (2013)
[2] B. Y. Mueller and B. Rethfeld, PRB 90, 144420 (2014)

MA 20.11 Tue 9:30 Poster A

Altering the spin wave frequency spectra in vortex structures by simultaneous excitations of the vortex gyromode — •Markus Härtinger[1], Hans G. Bauer[1], Hermann Stoll[2], and Christian Back[1] — [1]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany

In nano-sized ferromagnetic disks recent experiments and micromagnetic simulations of simultaneous excitations of both, the gyromode and spin wave modes, result in a significant reduction of the vortex core (VC) switching threshold[1]. By micromagnetic simulations H.G. Bauer et al.[2] revealed that two frequency excitation below the switching-threshold results in a frequency splitting of the lowest spin wave mode.

Here we report on an experimental verification by VNA-FMR measurements of the frequency spectrum of the azimuthal spin waves when the sub-GHz gyromode is resonantly excited simultaneously in $Ni_{80}Fe_{20}$ disks, 1.6 μm in diameter. Without excitation of the gyromode, the first two magnetostatic spin wave modes ($n = 1, m = \pm 1$) are observed at about 5 GHz and 6.5 GHz. After additional simultaneous excitation at the gyromode eigenfrequency (about 250 MHz) we observe a decrease and broadening of the lower frequency spin wave absorption peak for the increased gyro-excitation amplitude as predicted by micromagnetic simulations[2].

[1] M. Sproll et al. Appl. Phys. Lett. **104**, 012409 (2014)
[2] H.G. Bauer et al. Phys. Rev. Lett. **112**, 077201 (2014)

MA 20.12 Tue 9:30 Poster A

Ultrafast Magnetization Dynamics of Gd and Tb studied by XMCD — •Kamil Bobowski[1], Robert Carley[1,2], Björn Frietsch[1], Markus Gleich[1], Martin Teichmann[1,2], Christoph Trabant[1], Marko Wietstruk[1], and Martin Weinelt[1] — [1]Fachbereich Physik der Freien Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

Our recent time- and angle-resolved photoemission study [1] questions the ultrafast Gd 4f spin dynamics measured previously on sandwiched polycrystalline Gd films using X-ray magnetic circular dichroism (XMCD) in transmission [2]. To answer this question, we performed pump-probe experiments on single-crystalline Gd combining optical excitation and femtosecond XMCD in reflection. In a first preparatory beamtime, we showed the feasibility of this experiment by measuring simultaneously the reflection and absorption signal while varying the temperature from 100 K to above the Curie temperature. For comparative measurements, a Tb sample was investigated in the same way. Furthermore, we present preliminary results of the magnetization dynamics of the Gd 4f spins which were measured at the FEMTOSPEX beamline at BESSY II.

[1] B. Frietsch *et. al.*, submitted.
[2] M. Wietstruk *et. al.*, *Phys. Rev. Lett. 106* **25**, 127401 (2011).

MA 20.13 Tue 9:30 Poster A

Laser induced meta-stable magnetic structures probed by Lorentz microscopy — •Marcel Möller[1], Jan Gregor Gratzmann[1], Armin Feist[1], Nara Rubiano da Silva[1], Vladyslav Zbarsky[2], Markus Münzenberg[3], Claus Ropers[1], and Sascha Schäfer[1] — [1]IV. Physical Institute, University of Göttingen, 37077 Göttingen, Germany — [2]I. Physical Institute, University of Göttingen, 37077 Göttingen, Germany — [3]Institut fur Physik, Greisfwald University, 17489 Greifswald, Germany

Ultrashort laser excitation allows for an all-optical control of magnetic structures [1]. On the micrometer-scale, laser-induced magnetic changes can be imaged using, for example, Faraday microscopy.

Here, we employ in-situ Lorentz microscopy to study meta-stable magnetic structures generated by femtosecond optical pulse pairs with variable polarization states. As a first example, we investigate homogenous iron thin-films and observe an optically triggered switching of ripple domains at low excitation fluence. For laser pulse energies above a well-defined threshold, new meta-stable magnetic structures are formed, consisting of a dense network of vortices and antivortices with a charateristic correlation length of about 500 nm. Furthermore, we present first results using Lorentz microscopy in an ultrafast transmission electron microscope (UTEM) utilizing sub-picosecond electron pulse probing.

[1] Mangin, S., et al. "Engineered materials for all-optical helicity-dependent magnetic switching." Nature materials 13.3 (2014): 286-292.

MA 20.14 Tue 9:30 Poster A

Spin pumping by magnetization precession in a wide frequency range — •Viktor Lauer, Thomas Brächer, Burkard Hillebrands, and Andrii Chumak — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaisterslautern, Germany

Spin pumping refers to the spin-current generation in a normal metal film caused by the magnetization precession in an attached magnetic film. Via the inverse spin Hall effect (ISHE) this spin current is transformed into a conventional charge current.

Various parameters influence the spin-pumping induced ISHE voltage and require experimental analysis in order to understand the physical principles behind. In our study we address the dependence of spin pumping on the frequency of the magnetization precession, for frequencies 1-45 GHz. Our spin-pumping experiments were performed on a YIG(100nm)|Pt(10nm) bi-layer system. Theoretical predictions show that the generated voltage should decrease monotonically with increase in frequency. However, we observe a more complex ISHE voltage dependence on frequency, that exhibits a pronounced maximum at 11 GHz. The behaviour above 11 GHz qualitatively agrees with theoretical predictions. The deviation from theory below 11 GHz may be due to the frequency dependent excitation efficiency because of the precession ellipticity, as well as due to the change of pinning conditions by the external magnetic field.

MA 20.15 Tue 9:30 Poster A

Anisotropy of anomalous Hall effects in YIG|Pt hybrids — Sibylle Meyer[1,2], •Richard Schlitz[1,2], Stephan Geprägs[1], Matthias Opel[1], Hans Huebl[1,3], Rudolf Gross[1,2,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

The generation, manipulation and detection of pure spin currents are fascinating challenges in the field of spintronics. Recently, the spin Hall magnetoresistance (SMR) effect based on the interplay of spin and charge currents was reported [1]. The SMR allows to determine the imaginary part of the spin mixing interface conductance from measurements of anomalous Hall-type effects (spin Hall anomalous Hall effect, SHAHE [2]). Here, we present the analysis of ordinary and anomalous Hall signals observed in magnetotransport measurements in yttrium iron garnet|platinum (YIG|Pt) bilayers. We discuss the dependence on film thickness and temperature of the AHE voltage signals in terms of the SHAHE. Whereas the usual AHE voltage signal observed in metallic ferromagnets depends linearly on the magnetization component $M_\perp$ perpendicular to the film, we observe a more complex AHE-type response in our YIG|Pt samples. In particular, we observe higher order terms $\propto M_\perp^n$ at low temperatures.
This work is supported by the DFG via SPP 1538 (GO 944/4).

[1] H. Nakayama *et al.*, Phys. Rev. Lett. **110**, 206601 (2013).
[2] Y.-T. Chen *et al.*, Phys. Rev. B **87**, 144411 (2013).

MA 20.16 Tue 9:30 Poster A

Spin current experiments in Ga-doped Yttrium Iron Garnets — •Michaela Lammel[1,2], Stephan Geprägs[1], Matthias Opel[1], Sebastian T.B. Goennenwein[1,2,3], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

Garnets, in particular yttrium iron garnet (YIG), are widely used for experiments with spin currents. A particularly interesting aspect hereby are the different sublattice magnetizations. To clarify the specific role of the magnetic moments of the two iron sub-lattices of YIG, we investigate gallium substituted YIG ($Y_3Fe_{5-x}Ga_xO_{12}$, Ga:YIG) samples. Varying the Ga concentration, the compensation temperature T_{comp}, at which the magnetic moments on the two iron sublattices cancel each other, can be tuned. We fabricated Ga:YIG thin films on $Y_3Al_5O_{12}$ substrates by pulsed laser deposition (PLD). The crystalline quality was determined by high-resolution X-ray diffractometry. No parasitic phases could be detected and a high crystalline quality of the epitaxial films could be inferred from the small FWHM of the measured rocking curves. Using SQUID magnetometry, the temperature dependence of the magnetization was studied at different applied magnetic fields. Our results show that the compensation temperature T_{comp} depends crucially on the deposition parameters. — This work is supported by the DFG via SPP 1538.

MA 20.17 Tue 9:30 Poster A

Temperature Dependence of the Spin Seebeck Effect in Iron Garnets — •Francesco Della Coletta[1,2], Andreas Kehlberger[3], Tomek Schulz[3], Christian Mix[3], Sibylle Meyer[1,2], Matthias Althammer[1], Hans Huebl[1,4], Gerhard Jakob[3], Stephan Geprägs[1], Rudolf Gross[1,2,4], Sebastian T. B. Goennenwein[1,4], and Mathias Kläui[3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Institute of Physics, University of Mainz, 55099 Mainz, Germany — [4]Nanosystems Initiative Munich, 80799 München, Germany

In spin Seebeck effect (SSE) experiments, pure spin currents are driven across a magnetic insulator/normal metal interface by thermal gradients, and detected via the inverse spin Hall effect. Upon using ferrimagnetic insulators, e.g. iron garnets $A_3Fe_5O_{12}$ (AIG), comprising different magnetic sublattices in SSE experiments, the question arises whether the spin current properties simply are connected to the net magnetization, or whether the different magnetic sublattices contribute in a more subtle way. We have measured the temperature dependence of the SSE signal in AIG/Pt bilayers with $A = \mathrm{Gd, Dy}$, and find two consecutive sign changes. The first sign change occurs near the magnetic compensation temperature, where the net magnetization of the three sub-lattices is zero. The second sign change shows that the SSE signal results from a complex interplay of the three magnetic sublattices involved. — This work is supported by the DFG via SPP 1538.

MA 20.18 Tue 9:30 Poster A

Optical Detection of Electrical Spin Injection into a High Mobility 2DEG System — •Martin Buchner, Martin Oltscher, Mariusz Ciorga, Josef Loher, Dieter Schuh, Dominique Bougeard, Dieter Weiss, and Christian Back — Department of Physics, Regensburg University, 93053 Regensburg, Germany

In 1990 Datta and Das proposed a novel transistor concept, which utilizes the electron's spin as a new degree of freedom [1]. The current modulation arises from spin precession, which originates from the Bychkow-Rashba-term of spin-orbit-interaction. One key ingredient for the experimental realization of the device is spin injection into a two-dimensional electron gas (2DEG), which turned out to be a challenging task.

In this study, we demonstrate spin injection into a high mobility 2DEG, investigated by means of scanning Kerr microscopy at the cleaved edge of the sample. In detail, we investigate samples with the 2DEG confined at an (Al,Ga)As/GaAs interface; ferromagnetic (Ga,Mn)As contacts are used as spin aligners. The spatial distribution of the spins is probed by a diode laser directly underneath the injecting contact. Hanle depolarization gives a measure for the spin lifetimes.

[1] S. Datta, B. Das, Appl. Phys. Lett. 56, 665 (1990).

MA 20.19 Tue 9:30 Poster A

Magnetotransport of arrays of hybrid magnetic nanowires grown in porous alumina templates — •Sergej Andreev, Julian Braun, and Torsten Pietsch — Department of Physics, University of Konstanz, Universitätsstraße 10, 78464 Konstanz, Germany

Highly ordered hexagonal arrays of metallic and semiconducting nanowires recently attracted considerable interrest due to potential applications in energy storage and -conversion as well as catalysis and communication technologies. Porous alumina templates have been widely used to fabricate such nanowires with diameters in the range of 50 nm to hundreds of nanometers. Here, we investigate novel types of hetero-nanowires fabricated via deposition of different metals into porous alumina templates. The nanowires with diameters down to 20 nm are prepared via co-electrodeposition of different magnetic metals. We show that micrometer sized arrays of nanowires can be integrated into lithographically designed circuits and we investigate the (magneto)-transport properties of magnetic hetero-nanowires at low temperatures.

MA 20.20 Tue 9:30 Poster A

Separation of the longitudinal spin Seebeck effect and additional magnetothermopower effects in Pt/YIG bilayers — •Panagiota Bougiatioti, Daniel Meier, Christoph Klewe, Gerhard Götz, Günter Reiss, and Timo Kuschel — CSMD, Physics Department, Bielefeld University, Germany

In the emerging fields of spintronics and spin caloritronics recently discovered phenomena such as the spin Hall effect, the spin Hall magnetoresistance and the longitudinal spin Seebeck effect (LSSE), enable the generation, manipulation and detection of spin polarized currents. Further, the spin Nernst effect and the spin Nernst magnetothermopower (SMTP) are expected to be reported soon. Pt has been employed quite often for generating and detecting a pure spin current, if adjacent to a magnetic insulator, although the question of proximity effects has to be taken into account [1]. In this project we investigate the separation of the LSSE and additional magnetothermopower effects in Pt/YIG bilayers. Therefore, a temperature gradient was generated by heating the electric contacts [2] or by applying a charge current along the Pt stripe. In magnetic field rotation measurements we detect several voltage contributions which can be attributed to the LSSE and to additional magnetothermopower effects. We separate the contributions and discuss the probable amount of classical anisotropic magnetothermopower effects and of the new SMTP.

[1] T. Kuschel et al., submitted (2014), arxiv: 1411.0113
[2] D. Meier et al., Phys. Rev. B 88, 184425 (2013)

MA 20.21 Tue 9:30 Poster A

Rotation of in-plane thermal gradients in spin caloric measurements — •Oliver Reimer, Michel Bovender, Daniel Meier, Lars Helmich, Andreas Hütten, Jan-Michael Schmalhorst, Günter Reiss, and Timo Kuschel — CSMD, Physics Department, Bielefeld University

In spin caloric measurements ∇T acts as a driving force for spin currents. A ferromagnet exposed to ∇T in an external magnetic field generates a spin current parallel to ∇T (longitudinal spin Seebeck effect [1]) which can be detected in materials with high spin orbit coupling (e.g. Pt) by the inverse spin Hall effect. In paramagnets the spin Nernst effect is expected to cause a transverse spin current which can induce a spin torque transfer at the interface to a magnetic material. Thus, ∇T can be used in combination with an external magnetic field to manipulate the electric resistance in the paramagnet (spin Nernst magnetothermopower) similar to the current driven spin Hall magnetoresistance [2,3]. Since all these spin caloric effects are characterized by using a spatial fixed ∇T varying only the base temperature and the difference of the temperatures, we introduce a new setup which allows the rotation of ∇T. First experiments on different substrates controlled by an infrared camera show the successful rotation of ∇T. Further calibration experiments will be presented.

[1] K. Uchida et al., *Appl. Phys. Lett.* **97**, 172505 (2010)
[2] H. Nakayama et al., *Phys. Rev. Lett.* **110**, 206601 (2013)
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MA 20.22 Tue 9:30 Poster A

Investigation of the tunnel magneto-Seebeck effect via I-V curve symmetries of heated and non-heated Magnetic Tunnel Junctions — •Torsten Huebner[1], Alexander Boehnke[1], Marvin von der Ehe[2], Markus Münzenberg[2], Timo Kuschel[1], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Greifswald University, Germany

The Seebeck coefficient of a Magnetic Tunnel Junction (MTJ) depends on its magnetic state known as the tunnel magneto-Seebeck effect (TMS) [1]. It has been extensively studied with indirect Joule and laser induced heating [2][3]. Zhang et al. [4] proposed a third method using the intrinsic Joule heating by the tunneling current generated by a bias voltage without any external temperature gradient. Thus, they extract the Seebeck coefficients by evaluating the symmetric contribution of the I-V curves. Here, we investigate I-V curves of CoFeB/MgO/CoFeB MTJs obtained with and without external laser heating. Thus, we are able to identify tunneling currents originating solely from the induced temperature gradient by taking the difference between the signals from the heated and non-heated MTJ. The symmetric and antisymmetric contribution of the I-V curves for various laser heating powers are discussed in detail.

[1] Walter et al., Nat. Mater 10, 742 (2011)
[2] Liebing et al., Phys. Rev. Lett. 107, 177201 (2011)
[3] Boehnke et al., Rev. Sci. Instrum. 84, 063905 (2013)
[4] Zhang et al., Phys. Rev. Lett. 109, 037206 (2012)

MA 20.23 Tue 9:30 Poster A

Magneto-Seebeck Effect in Magnetic Tunnel Junctions with different barriers — •Ulrike Martens[1], Marvin von der Ehe[1], Jakob Walowski[1], Stefan Niehörster[2], Alexander Böhnke[2], Savio Fabretti[2], Karsten Rott[2], Günter Reiss[2], Andy Thomas[2], and Markus Münzenberg[1] — [1]Inst. f. Phys., Ernst-Moritz-Arndt-Universität Greifswald, Germany — [2]CSMD, Physics Department, Bielefeld University, Germany

The first measurements of the tunnel magneto-Seebeck effect (TMS) were reported on magnetic tunnel junctions (MTJs) with a crystalline MgO barrier [1, 2]. Later, Lin *et al.* have observed the TMS effect in MTJs with Al_2O_3 tunnel barriers [3]. They found a correlation between TMR and TMS that were in the same range and giant thermovoltages of 1 mV, both explained by non-magnetic resonance in the tunnel spectrum responsible for the large thermoelectric effects. For the samples investigated for this presentation, the tunnel magnetoresistance (TMR) and the tunnel magneto-Seebeck effect (TMS) were measured. The MTJs are heated by a modulated diode laser which achieves powers of up to 150 mW. The laser is focused onto the sample in a standard confocal microscope setup. We investigate the power dependence of the TMS ratios. For the different materials, the TMS dependence on the applied bias voltage is studied as well. The first results are used to compare the various barrier materials.

[1] Walter, M., et al.; Nat. Mater. 10, 742-746 (2011)
[2] Liebing, N., et al.; Phys. Rev. Lett. 107, 177201 (2011)
[3] Lin, W., et al.; Nat. Commun. 3, 744 (2012)

MA 20.24 Tue 9:30 Poster A

Different temperature and Co thickness dependencies of the anomalous Hall and Nernst effect in Co/Pd multilayers — •Michael van Straaten, Tristan Matalla-Wagner, Daniel Meier, Jan-Michael Schmalhorst, Timo Kuschel, and Günter Reiss — CSMD, Physics Department, Bielefeld University, Germany

The Hall and Nernst effects are related due to a corresponding electrically and thermally induced transport behavior. The anomalous parts of these effects (AHE and ANE) are affected by the magnetization. Therefore, they show a hysteresis of the voltage, which is antisymmetric with respect to the external field. In perpendicularly magnetized Co/Pd multilayers the AHE has a temperature and Co thickness dependent sign change in the voltage [1].

In this work we describe an experimental setup for a simultaneous detection of transverse voltages generated by the AHE and the ANE. By applying a voltage parallel to the in-plane temperature gradient, both effects can be separated by a subsequent measurement with reversed electrical current. Two series of samples with different Co thicknesses are tested. The observed voltage changes with varying thicknesses and temperatures. The results are discussed to point out the fundamentally different behavior between the AHE and ANE in these multilayer systems.

[1] V. Keskin et al., Appl. Phys. Lett. 102, 022416 (2013)

MA 20.25 Tue 9:30 Poster A

Linear and quadratic Nernst effects in a CoFeTb thin film — •Tristan Matalla-Wagner[1], Daniel Meier[1], Zoe Kugler[1], Jaroslav Hamrle[2], Günter Reiss[1], and Timo Kuschel[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]VSB - Technical University of Ostrava, Czech Republic

Nernst effects describe the generation of charge voltages driven by temperature gradients and can occur as side effects in spin Seebeck experiments [1,2]. We investigated the angle dependence of Nernst voltages for various external magnetic field directions on a 30 nm thick Cobalt-Iron-Terbium alloy thin film. We further separated the measured curves into antisymmetric and symmetric parts with respect to the external magnetic field. This method can be used to identify effects which have linear or quadratic dependencies with respect to either the magnetization of the sample or the external magnetic field, such as the linear and quadratic Nernst effect (LNE/QNE). This method was already used by Meier et al. [3] to separate the anomalous from the planar Nernst effect of a permalloy sample with a platinum strip on it. The separation method combined with the angle dependence is used to investigate the contribution of LNE and QNE to the total Nernst voltage. Furthermore, we discuss how a misalignment of the effective direction of the temperature gradient affects the LNE and the QNE.

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[2] M. Schmid et al., Phys. Rev. Lett. 111, 187201 (2013)
[3] D. Meier et al., Phys. Rev. B 88, 184425 (2013)

MA 20.26 Tue 9:30 Poster A

***Ab initio* investigation of the tunneling magneto Seebeck effect** — •Christian Franz, Michael Czerner, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University, Giessen, Germany

The Seebeck coefficient describes the thermoelectric voltage induced in a junction by a temperature gradient. In a magnetic tunnel junction the Seebeck coefficient depends on the relative orientation of the magnetizations; this effect is termed tunneling magneto-Seebeck effect (TMS). The TMS has been predicted theoretically [1] and confirmed experimentally [2].

In this contribution we investigate the TMS in MgO-based tunnel junctions using *ab initio* methods [3]. We investigate the TMS for Fe_xCo_{1-x} leads [4,5] with varying alloy composition, barrier thickness, temperature, and applied bias voltage. We find that the TMS depends sensitively on the parameters, in particular the alloy composition. This behavior can be traced back to the respective dependence of the transmission function. We also show recent results using Heusler alloys for the leads.

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[2] M. Walter et. al, Nat. Mater. 10, 742 (2011).
[3] C. Franz, M. Czerner, C. Heiliger, J. Phys.: Condens. Matter 25, 425301 (2013).
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MA 20.27 Tue 9:30 Poster A

Spin-wave modes and grating coupler effect in bicomponent magnetic periodic lattices of different topology — •Stefan Mändl[1], Florian Heimbach[1], Haiming Yu[1,2], and Dirk Grundler[1] — [1]Physik Department E10, TU München, Garching, Germany — [2]present address: Spintronics Interdisciplinary Center, Beihang University, China

Recently the so called magnonic grating coupler (MGC) effect was observed in bicomponent magnetic lattices consisting of e.g. a two-dimensional (2D) array of Py nanodisks partly embedded in a CoFeB thin film. [Yu13] It was shown that the periodic lattice provoked backfolding of the fundamental mode. We present spin-wave spectroscopy and simulations on bicomponent MGCs where we inverted the materials composition and varied the structural composition (topology) to optimize the backfolding effect. In experiments on 2D arrays of CoFeB nanodisks integrated to a Py film a series of spin-wave resonances were resolved that we attributed to MGC modes radiated in up to 16 different directions. This way a spin-wave nanograting coupler with almost omnidirectional spin-wave emission was created. We provide microscopic insight into the MGC performance by comparing micromagnetic simulations and spectroscopy data. The work was funded by the Cluster of Excellence Nanosystems Initiative Munich and in the SPP 1538 via GR1640/5.

[Yu13] H. Yu, G. Duerr, R. Huber, M. Bahr, T. Schwarze, F. Brandl, D. Grundler, Omnidirectional spin-wave nanograting coupler, Nature Communications 4, 2702 (2013)

MA 20.28 Tue 9:30 Poster A

Spin pumping inverse spin Hall effect and spin transfer torque ferromagnetic resonance in NiFe/Pt and NiFe/Ta bilayers — •Islinger Robert, Obstbaum Martin, Härtinger Markus, and Back Christian H. — Institute for Experimental and Applied Physics, University Regensburg, 93040 Regensburg, Germany

Spin pumping in NiFe/normal metal bilayers together with the inverse spin Hall effect (SP-ISHE) constitutes a reliable method for determining spin Hall angles α_{SH} [1]. Another method to determine α_{SH} is the spin transfer torque ferromagnetic resonance (STT-FMR) technique recently introduced by Liu et al for ferromagnet/normal metal bilayers [2,3]. Whereas for platinum (Pt) both SP-ISHE and STT-FMR yield consistent results for tantalum (Ta) the two methods are contradictory. We present an extensive study of SP-ISHE and STT-FMR for both Pt and Ta. The two methods will be explained in detail and possible physical explanations for conflicting results will be discussed. [1] M. Obstbaum et al., Phys. Rev. B 89, 060407 (R) (2014) [2] L. Liu et al., Phys. Rev. Lett. 106, 036601 (2011) [3] L. Liu et al., Science 336, 555 (2012)

MA 20.29 Tue 9:30 Poster A

Asymmetric spin wave dispersion relation due to interfacial Dzyaloshinskii-Moriya interaction — •Helmut Körner[1], Johannes Stigloher[1], Hans Bauer[1], Hiroshi Hata[2], Takuya Taniguchi[2], Takahiro Moriyama[2], Teruo Ono[2], and Christian Back[1] — [1]Department of Physics, Regensburg University, 93053 Regensburg, Germany — [2]Laboratory of Nano Spintronics, Division of Materials Chemistry, Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan

The interfacial Dzyaloshinskii-Moriya interaction (DMI) has attracted much attention lately due to its possible usage in future spintronic devices. It occurs in any trilayer structure when the first nonmagnetic layer provides spin-orbit coupling, the middle layer is a ferromagnet, and the third layer is nonmagnetic, but different from the first layer to break symmetry.

In our experiment, we study propagating magnetostatic spin waves in the Damon-Eshbach geometry by means of time-resolved scanning Kerr microscopy in 70 μm wide Ta(2)/Pt(2)/Co(0.4)/Py(5)/MgO(5) stripes. Due to the DMI present at the Pt/Co interface, an asymmetry in the spin wave dispersion relation is expected with respect to both their propagation direction and the equilibrium magnetization direction [1,2]. From the observed asymmetry in the shift in the wave-vector amplitude we can quantify the DMI in our system.

[1] J.-H. Moon et al., Phys. Rev. B 88, 184404 (2013), [2] M. Kostylev, J. Appl. Phys. 115, 233902 (2014)

MA 20.30 Tue 9:30 Poster A

Investigation of spin waves dispersion in Co thin films on W(110) from first-principles — •Flaviano José Dos Santos, Manuel Dos Santos Dias und Samir Lounis — Peter Grünberg

Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We perform first-principles calculations based on the Korringa-Kohn-Rostoker Green functions method in order to extract the magnetic exchange interactions for Co thin films on W(110) surface. We analyze the strength and oscillatory behavior of the intra-layer and inter-layer magnetic interactions and investigate the resulting dispersion of spin waves as a function of the thickness of Co films. We compare our results to previous [1] and recent [2] measurements based on electron energy loss spectroscopy. In particular, we demonstrate the strong impact of hybridization of the electronic states at the interface of Co and W on the magnetic exchange interactions and on the spin-waves dispersion curve.

Work supported by the Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior - CAPES (BRAZIL) and HGF-YIG Programme FunSiLab - Functional Nanoscale Structure Probe and Simulation Laboratory (VH-NG-717). [1] M. Etzkorn, P. S. Anil Kumar, W. Tang, Y. Zhang, and J. Kirschner, Phys. Rev. B **72**, 184420 (2005). [2] E. Michel, H. Ibach, and C. M. Schneider, private communication.

MA 20.31 Tue 9:30 Poster A

Interfacial spin-orbit effect in Ta/CoFeB/MgO — •Gurucharan V. Karnad[1], Roberto Lo Conte[1,2], Eduardo Martinez[3], Ales Hrabec[4], Andrei P. Mihai[4], Tomek Schulz[1], Christopher H. Marrows[4], Thomas A. Moore[4], and Mathias Kläui[1,2] — [1]Johannes Gutenberg Universität-Mainz, Institut für Physik, Staudinger Weg 7, 55128 Mainz, Deutschland — [2]Graduate School of Excellence Materials Science in Mainz (MAINZ), Staudinger Weg 9, 55128 Mainz, Deutschland — [3]Universidad de Salamanca, Plaza de los Caidos s/n E-37008, Salamanca, Spain — [4]School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, U.K.

Spin-orbit effects in out-of-plane magnetized materials have been an area of intense research due to efficient current induced domain wall motion (CIDWM) and current induced magnetization switching (CIMS) observed in these systems. Here we report the measurements of spin-orbit torques and Dzyaloshinskii-Moriya interaction (DMI) in heavy metal(HM)/ ferrmomagnet(FM)/oxide(Ox)systems.We found the DW velocity to be strongly affected by the presence of a longitudinal magnetic field, resulting in a different velocity for the up-down and down-up domain walls at fixed current densities and magnetic fields. These results can be interpreted by the spin-Hall effect-torque model [1,2], where the chirality of the domain walls is fixed by the DMI at the HM/FM interface.

[1]S. Emori,et al., Nat. Mat.12, 611-616 (2013).
[2]K.-S. Ryu,et al., Nat. Nanotech.8, 527-533 (2013).

MA 20.32 Tue 9:30 Poster A

Spin Wave Doppler Experiments using Current Modulation — •Johannes Stigloher, Helmut Körner, Hans Bauer, Jean-Yves Chauleau, and Christian Back — Department of Physics, Regensburg University, 93053 Regensburg, Germany

Spin transfer torques (STT) have been an active field of research for the last 20 years and arise when an electric current interacts with a non-homogenous region of magnetic texture such as magnetic domain walls, magnetic vortex cores or spin waves. In the latter case a spin wave Doppler shift can be observed [1]. It was shown already that this technique enables a self-consistent determination of the key STT parameters [2] on one single sample. Here, we modify the technique presented in [2] by the modulation of the electric current at a low frequency and subsequent detection using two lock-in amplifiers. Hence, we achieve a substantial noise reduction along with a direct access to the effect of the electric current on spin wave characteristics. Furthermore, this approach offers the possibility to determine the temperature dependence of the key STT parameters.

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[2] J.-Y. Chauleau et al., Phys. Rev. B. 89, 020403(R) (2014)

MA 20.33 Tue 9:30 Poster A

Dynamics and inertia of skyrmionic spin structures — F. Büttner[1,2,3], C. Moutafis[4], •B. Krüger[1], M. Schneider[3], C. M. Günther[3], J. Geilhufe[5], C. von Korff Schmising[3], J. Mohanty[3], A. Bisig[1], M. Foerster[1], T. Schulz[1], C. A. F. Vaz[1,6], J. H. Franken[7], H. J. M. Swagten[7], M. Kläui[1], and S. Eisebitt[3,5] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Graduate School Materials Science in Mainz, Mainz, Germany — [3]Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany — [4]Swiss Light Source, Paul Scherrer Institut, Villigen PSI, Switzerland — [5]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany — [6]SwissFEL, Paul Scherrer Institut, Villigen PSI, Switzerland — [7]Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

In nano-patterned magnetic thin-film elements bubble skyrmions emerge. Their magnetization points out-of-plane opposite to the remaining part. The dynamics of these structures resembles that of composite quasi-particles. Magnetic bubbles are skyrmions characterized by the topology of their spin vector field. Here, we study the GHz gyrotropic motion of a skyrmion spin structure experimentally using pump-probe X-ray holography. Tracking the bubble position with 3 nm accuracy we report the first experimental observation of the GHz gyrotropic motion of a skyrmion. We found that the inertial mass of the magnetic bubble is much larger than inertia found in any other magnetic system. [F. Büttner, et al., Nature Phys. (accepted)]

MA 20.34 Tue 9:30 Poster A

intuitive explanation of anisotropic magnetoresistance (AMR) effect and necessary condition for half-metallic ferromagnet "negative AMR" — •satoshi kokado[1], yuta kitagawa[1], takuya ito[1], and masakiyo tsunoda[2] — [1]Graduate School of Engineering, Shizuoka University, Hamamatsu, Japan — [2]Graduate School of Engineering, Tohoku University, Sendai, Japan

The anisotropic magnetoresistance (AMR) effect is a phenomenon in which the electrical resistivity depends on the relative angle between the magnetization direction and the electric current direction. The AMR ratio, which is the efficiency of the effect, is defined by $(\rho_{//} - \rho_{\perp})/\rho_{\perp}$. Here, $\rho_{\|}$ ($\rho_{\perp}$) represents a resistivity for the case of the electrical current parallel to the magnetization (a resistivity for the case of the current perpendicular to the magnetization). The AMR effect has been experimentally studied for various ferromagnets since about 150 years ago. The intuitive explanation about the AMR effect, however, has scarcely been reported. In this study, we first derive a general expression of the AMR ratio extending the conventional model to a more general one [1 - 3]. Using the general expression, we next give the intuitive explanation about the AMR effect [2]. In addition, we show that the negative AMR ratio is a necessary condition for half-metallic ferromagnets [1, 2].

[1] S. Kokado *et al.*, J. Phys. Soc. Jpn. **81** 024705 (2012).
[2] S. Kokado *et al.*, Adv. Mater. Res. **750-752** 978 (2013).
[3] S. Kokado *et al.*, Phys. Status Solidi C **11** 1026 (2014).

MA 20.35 Tue 9:30 Poster A

Towards a straightforward semiclassical ab initio description of the side-jump mechanism in the SHE — •Christian Herschbach[1,2], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]H. H. Wills Physics Laboratory, University of Bristol, Bristol, United Kingdom

The investigations of the spin Hall effect rely on the separation between intrinsic and extrinsic contributions, where the latter ones imply the skew-scattering and side-jump mechanisms. While the first-principles description of the skew scattering was already successfully implemented [1], a corresponding semiclassical approach for the side-jump mechanism is still missing.

We present a first step into this direction by considering two different simplified approaches. The first one follows a suggestion of Sinitsyn et al. [2] focussing on the host properties expressed in terms of the Berry curvature, which is calculated from first principles [3]. The second approach puts the emphasis on the properties of the impurities by extending the resonant scattering model [4] similarly to the case of skew scattering [5]. Here, the required scattering phase shifts are obtained by means of *ab initio* calculations.

[1] M. Gradhand *et al.*, PRL **104**, 186403 (2010); [2] N.A. Sinitsyn *et al.*, PRB **73**, 075318 (2006); [3] M. Gradhand *et al.*, PRB **84**, 075113 (2011); [4] A. Fert and P.M. Levy, PRL **106**, 157208 (2011); [5] D.V. Fedorov *et al.*, PRB **88**, 085116 (2013).

MA 20.36 Tue 9:30 Poster A

Spin-curvature and local density of states in PdFe/Ir(111) — Christian Hanneken[1], •André Kubetzka[1], Niklas Romming[1], Kirsten von Bergmann[1], Roland Wiesendanger[1], Fabian Otte[2], Bertrand Dupé[2], and Stefan Heinze[2] — [1]Department of Physics, University of Hamburg — [2]Institute of Theoretical Physics

and Astrophysics, University of Kiel

In many magnetic systems the spin-averaged local density of states (LDOS) depends on the magnetization direction due to spin-orbit interaction. This effect can be measured e.g. with scanning tunneling spectroscopy and is typically on the order of 10% [1].

Here we employ the same technique to investigate the influence of the magnetic non-collinearity (spin-curvature) in a PdFe bilayer on Ir(111) [2,3] onto the LDOS measured in the vaccum above the surface. The effect is surprisingly strong and can be tuned by changing the spin-curvature of a skyrmion in applied magnetic fields. Tight-binding calculations show that it stems from the mixing between majority and minority spin bands which scales with the local spin-curvature.

[1] M. Bode *et al.*, Phys. Rev. Lett. **89**, 237205 (2002).
[2] N. Romming *et al.*, Science **341**, 636 (2013).
[3] B. Dupé *et al.*, Nature Commun. **5**, 4030 (2014).

MA 20.37 Tue 9:30 Poster A

Spin Seebeck effect in the GHz regime — •Franz Kramer[1,2], Michael Schreier[1,2], Hans Huebl[1,3], Stephan Geprägs[1], Rudolf Gross[1,2,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

In the spin Seebeck effect(SSE) experiments pure spin currents are generated via a thermal nonequilibrium at the interface between a ferromagnet and a normal metal. Time-resolved SSE experiments allow to gain insight into the microscopic origin of the spin current generation, but published results are inconclusive.[1,2] We revisit our previous time-resolved Spin Seebeck effect studies[1] and expand the frequency range of the temperature modulation up to several Gigahertz, corresponding to time constants below one nanosecond. This also gives insight into a potential thickness dependence of the spin Seebeck effect as reported earlier,[3] as the thermal length (determining the volume in which the temperature modulation occurs) is of the order of some ten nanometers for GHz frequencies . We present our recent results and critically discuss them in view of the existing SSE models.

[1]Roschewsky et al., Appl. Phys. Lett **104**, 202410 (2014),
[2]Agrawal et al.,Phys. Rev. B **89**, 224414 (2014),
[3]Kehlberger et al., arXiv:1306.0784

MA 20.38 Tue 9:30 Poster A

Anomalous Hall Effect within a phase shift model — •Albert Hönemann[1], Christian Herschbach[1,2], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]University of Bristol, Bristol, United Kingdom

The spin Hall effect (SHE) and the anomalous Hall effect (AHE) are closely related transport phenomena both caused by spin-orbit coupling (SOC). Their straightforward theoretical description requires rigorous but demanding *ab initio* calculations based on relativistic codes. Recently, phase shift models [1,2] were developed as a generalization of the resonant scattering models [3-6]. They provide a simplified description of the SHE with a good qualitative agreement to first-principles results obtained for dilute alloys based on host crystals with free-electron like Fermi surfaces and weak SOC [7].

Here, we employ these phase shift models for a description of the AHE caused by 3*d* impurities in noble metals. The obtained results are compared to the corresponding *ab initio* calculations performed within a semiclassical approach of Ref. [8].

[1] Fedorov *et al.*, PRB **88**, 085116 (2013); [2] Herschbach *et al.*, PRB **88**, 205102 (2013); [3] Fert *et al.*, J. Magn. Magn. Mater. **24**, 231 (1981); [4] Guo *et al.*, PRL **102**, 036401 (2009); [5] Fert and Levy, PRL **106**, 157208 (2011); [6] Levy *et al.*, PRB **88**, 214432 (2013); [7] Johansson *et al.*, J. Phys.: Condens. Matter **26**, 274207 (2014); [8] Zimmermann *et al.*, arXiv:1406.2712.

MA 20.39 Tue 9:30 Poster A

Correlating spin orbit effects and structural inversion asymmetry in multilayer stacks — •Samridh Jaiswal[1,2], Berthold Ocker[2], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]SINGULUS TECHNOLOGIES AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany

Recently there has been wide spread interest to exploit multilayer materials and use them for memory and logic devices based on current-induced magnetization dynamics. One of the associated problems to overcome is being able to achieve low threshold currents for switching of the magnetic state and to achieve a high thermal stability in these devices. A possible solution to solve the issues associated with memory based devices is to achieve a strong perpendicular magnetic anisotropy[1] and then to use Structural Inversion Asymmetry (SIA) in multilayers to study the effects of Spin Orbit Torques(SOTs) in the presence of the Dzyaloshinskii Moriya interaction. Current induced magnetization switching is gathering much interest as a means of low power magnetic switching and relies on the spin orbit effects in these materials [2]. In this contribution we investigate the growth of multilayer stacks with SIA and we discuss the effects of the underlayers on the magnetic anisotropy and the viability to use these materials for studying SOTs. Financial support by the EU Marie Curie ITN project WALL is gratefully acknowledged.

[1] Yang, H. X. et al. Phys. Rev. B, 84, 054401 (2011) [2] Lo Conte, R. et al , Appl. Phys. Lett., 105, 122404 (2014)

MA 20.40 Tue 9:30 Poster A

The tunnel magnetoresistance and shot noise of triple quantum dots in the sequential and cotunneling regimes — •Kacper Wrześniewski and Ireneusz Weymann — Faculty of Physics, Adam Mickiewicz University in Poznań, ul. Umultowska 85, 61-614 Poznań, Poland

We study the spin-dependent transport through a coherent triple quantum dot system weakly coupled to external ferromagnetic electrodes. The calculations are performed with the aid of the real-time diagrammatic technique up to the second order of the perturbation theory with respect to the coupling to the leads. We discuss the behavior of the current, tunnel magnetoresistance and shot noise in both the linear and nonlinear response, focusing on the role of cotunneling processes. It is shown that, depending on the device geometry, parameters of the model and applied voltages, the system can exhibit negative tunnel magnetoresistance, negative differential conductance and super-Poissonian shot noise. The mechanisms leading to the above effects are thoroughly analyzed.

MA 20.41 Tue 9:30 Poster A

Domain wall motion in a ferromagnet induced by pure diffusive spin currents in graphene — •Fabienne Musseau[1], Michele Voto[2], Alexander Pfeiffer[1], Nils Richter[1], Luis Lopez Diaz[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Departamento de Física Aplicada, Universidad de Salamanca, 37008 Salamanca, Spain

Due to the miniaturization of systems to the nanoscale, the physics of surfaces and interfaces is a major area of research. On the applications side, novel storage concepts, such as the racetrack memory use spin currents [1] in ferromagnetic nanowires where data is encoded as a pattern of magnetic domains. Alternatively synchronous motion of domains can also be obtained by special field geometries [2]. Another possibility is to use pure diffusive spin currents to manipulate the magnetization in a ferromagnet [3,4]. As here the limitation is the spin transport in the spin conduit, we use graphene as due to its low spin-orbit coupling and high mobility a large spin diffusion length ensues, allowing for large spin currents [5]. We investigate the displacement of domain walls via spin torques exerted by pure diffusive spin currents in a non-local spin valve geometry [3,4]. We compare our results to micromagnetic simulations to understand the acting torques.

References [1] Parkin et al., Science 320, 190 (2008) [2] Kim et al., Nat. Commun. 5, 3429 (2014) [3] Motzko et al., Phys. Rev. B, 88, 214405 (2013) [4] Ilgaz et al., Phys. Rev. Lett. 105, 076601 (2010) [5] Tombros et al., Nature 448, 571 (2007)

MA 20.42 Tue 9:30 Poster A

Dependence of the spin Hall magnetoresistance on ferromagnet surface termination and thickness — •Hannes Maier-Flaig[1,2], Stephan Geprägs[1], Rudolf Gross[1], and Sebastian T.B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik - Department, TU München, Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

In recent years, considerable efforts have been made to understand the effect of interface properties on the transport of (spin) angular momentum across the interface between an insulating ferromagnet and a normal metal [1]. The recently discovered spin Hall magnetoresistance (SMR)[2] describes the impact of spin current flow on the resistance of the metal. We use magnetization orientation dependent SMR measurements to investigate the dependence of this effect in $Y_3Fe_5O_{12}$|Platinum (YIG|Pt) heterostructures. In particular, we study the impact of surface termination and magnetic layer thickness on spin current transport. More specifically, we deposited Pt layers in-situ on epitaxially grown YIG films with thicknesses down to a single unit cell. The crystalline orientation (and thus the different interface termination), as well as the thickness of the YIG layers was systematically varied. We discuss how the SMR depends on these parameters and address the impact of the interface termination. This work was supported by the DFG via SPP 1538 (project no. GO 944/4).

[1] Weiler *et al.*, Phys. Rev. Lett. 111, 176601 (2013)
[2] Nakayama *et al.*, Phys. Rev. Lett 110, 206601 (2013)

MA 20.43 Tue 9:30 Poster A

Anisotropic interface contributions to the magnetothermoelectric power (MTEP) in Co/Pt layered structures — Axel Frauen, André Kobs, Tim Böhnert, Ann-Kathrin Michel, •Afsaneh Farhadi, Kornelius Nielsch, and Hans Peter Oepen — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11a, 20355 Hamburg, Germany

We report on the magnetothermoelectric power (MTEP) and magnetoresistance (MR) of Co/Pt films. Regarding the MR measurements, the in-plane rotation of magnetization **M** reveals the bulk-like anisotropic MR (AMR). The corresponding thermoelectric counterpart is observed in the Seebeck voltage U_S when an in-plane temperature gradient ∇T is applied. This is the conventional anisotropic MTEP effect, which is predicted to occur in the Seebeck coefficient $S = -U_S/\Delta T$ according to Mott's formula [1]: $S(\mathbf{M}) \propto [1/\rho(E,\mathbf{M}) \cdot \mathrm{d}\rho(E,\mathbf{M})/\mathrm{d}E]_{E=E_\mathrm{F}}$ (Fermi energy E_F). A linear $S(1/\rho)$ behavior is found revealing that $[\mathrm{d}\rho(E,\mathbf{M})/\mathrm{d}E]_{E=E_\mathrm{F}}$ does not depend on **M** in accordance with Ref. [1]. Moreover, we observe that U_S also depends on the orientation of **M** within the plane perpendicular to ∇T. This characteristic is the thermoelectric counterpart of the recently discoverd anisotropic interface MR (AIMR) [2]. Also for the AIMR and its thermoelectric counterpart a linear $S(1/\rho)$ curve is found. Interestingly, both $S(1/\rho)$ curves exhibits different slopes, which implies that $[\mathrm{d}\rho(E,\mathbf{M})/\mathrm{d}E]_{E=E_\mathrm{F}}$ and therefore the band structure is significantly different for Co/Pt interfaces compared to Co bulk. [1] Avery et al., PRB **86**, 184408 (2012), [2] Kobs et al., PRL **106**, 217207 (2011).

MA 20.44 Tue 9:30 Poster A

Field and temperature dependence of spin fluctuations in $ZrZn_2$ — •Pascal Reiss, Gilbert Lonzarich, and F Malte Grosche — Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

$ZrZn_2$ is a low temperature band ferromagnet ($T_c \approx 28$ K), which displays non-Fermi liquid transport properties over a wide temperature range: above $T_{FL} \approx 1K$ and even beyond T_c, the electrical resistivity follows a power-law temperature dependence with an exponent 5/3, whereas the electronic contribution to the thermal resistivity is linear in temperature. This has been explained in terms of a magnetic fluctuation model, which includes a self-consistent renormalisation for the magnetic susceptibility [1, 2]. Applied magnetic fields up to 9 T have been observed to increase the cross-over temperature T_{FL} to ≈ 7 K. Previous calculations did not include effects of magnetic fields.

We will present the results of an extended calculation which accounts for the role of applied field, allowing a comparison between high field resistivity measurements and the predictions of a magnetic fluctuation model. Furthermore we will show that the magnetic transition is expected to be continuous in this model. However this transition is characterised by a strongly temperature dependent coefficient $b(T)$ of the quartic term in a Landau-Ginzburg expansion. Moreover, $b(T)$ changes sign at T_c, with $b(T) < 0$ in the ordered phase.

[1] G. G. Lonzarich and L. Taillefer, J Phys C: Solid State Phys, **18**, 4339-4371 (1985)
[2] R. Smith et al., Nature, **455**, 1220-1223 (2008)

MA 20.45 Tue 9:30 Poster A

Capturing a Skyrmion with a Hole — •Jan Müller and Achim Rosch — Institut für Theoretische Physik, Universität zu Köln, Deutschland

Stable magnetic whirls in chiral magnets, so-called skyrmions, can be manipulated by ultrasmall current densities. We study both analytically and numerically the interactions of a single skyrmion in two dimensions with a small hole in the magnetic layer. Results from micromagnetic simulations are in good agreement with effective equations of motion obtained from a generalization of the Thiele approach. Skyrmion-defect interactions are described by an effective potential with both repulsive and attractive components.

For small current densities a previously pinned skyrmion stays pinned whereas an unpinned skyrmion moves around the impurities and never gets captured. For higher current densities, however, single holes are able to capture moving skyrmions. The maximal cross section is proportional to the skyrmion radius and to the square root of the Gilbert damping. For large currents all skyrmions are depinned. Small changes of the magnetic field strongly change the pinning properties, one can even reach a regime without pinning at all. We also show that a small density of holes can effectively accelerate the motion of the skyrmion and introduce a Hall effect for the skyrmion.

MA 20.46 Tue 9:30 Poster A

Dipole-Dipole Interactions in Skyrmionic Systems — •Lukas Heinen and Achim Rosch — Institut für theoretische Physik, Universität zu Köln, Deutschland

Chiral magnets exhibit vortex-like excitations of the magnetic structure, so-called skyrmions. These excitations carry an integer winding number and hence are stabilized by topological protection. Furthermore they can be manipulated with ultra-low current densities. Therefore skyrmions are a promising candidate for the development of spintronic devices.

Skyrmions in chiral magnets are mainly driven by Dzyaloshinksii-Moriya (DM) interactions. In typical skyrmion materials, like MnSi, dipole-dipole interactions are nominally of similar magnitude as DM interactions. However, they influence *static* skyrmion properties only weakly, due to the specific form of the magnetic structure of skyrmions. We study how the inclusion of the full dipole-dipole interactions changes the *dynamical* properties of skyrmions. Using micro-magnetic simulations of thin films, we compute the change in the phase diagram, the effective skyrmion-defect-interaction potential, and the excitation spectrum.

MA 20.47 Tue 9:30 Poster A

Current-induced effects in YIG/Pt heterostructures — •Johannes Mendil[1], Kevin Garello[1], Can Onur Avci[1], Morgan Trassin[2], Manfred Fiebig[2], and Pietro Gambardella[1] — [1]ETH Zurich, Department of Materials, Magnetism and Interface Physics, Hönggerbergring 64, CH-8093 Zürich, Switzerland — [2]ETH Zurich, Department of Materials, Multifunctional Ferroic Materials, Vladimir-Prelog-Weg 4, CH-8093 Zürich, Switzerland

Yttrium Iron Garnet (YIG)/heavy metal bilayers have attracted considerable interest in the field of spintronics due to the possibility of inducing spin currents by magnon excitation and vice versa. In this work, we report on current-induced effects that arise from the interplay of the magnetization in YIG and spin currents generated in Pt. YIG thin films have been prepared by pulsed laser deposition on Gadolinium Gallium Garnet (GGG) substrates followed by in-situ sputtering of 6 nm-thick Pt. We present results on the harmonic analysis of current-induced spin-orbit torques in YIG films of variable thickness.

MA 21: Focused Session on Ferroic Domain Walls III (DF with MA)

Part of the 3-days focus on ferroic domain walls:
Tutorial, Symposium (SYDW), three Focused Sessions, and Poster Session.
Organizers: Elisabeth Soergel (Universität Bonn) and Dennis Meier (ETH Zürich)

Time: Tuesday 14:00–16:00 Location: EB 107

MA 21.1 Tue 14:00 EB 107

STM imaging of ferroelectric domains of strained $BaTiO_3$ films at the thickness limit — •Maik Christl[1], Klaus Meinel[1], Stefan Förster[1,2], and Wolf Widdra[1,3] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [2]Department of Physics, University of Zurich, Zurich, Switzerland — [3]Max Planck Institute of Microstructure Physics, Halle, Germany

Ultrathin ferroelectric films are of increasing interest due to novel oxide based applications. In particular, the domain structure as well as the critical thickness are essential key aspects for ferroelectricity in thin films [1].
In this work, we report on in-situ STM and STS studies to image ferroelectric out-of-plane and in-plane nanodomain structures. $BaTiO_3$(100) ultrathin films have been grown pseudomorphically on Pt(100) and Au(100), which corresponds to 2% lateral compression and 2% expansion, respectively [2]. Films with a thickness of 2 unit cells (uc) show already ferroelectricity at room temperature as verified by reversible domain writing and reading using STM. On Pt(100), an irregular c^+/c^- nanodomain configuration is visible in dI/vV maps that are taken at domain sensitive voltages. With film thickness, the domain width increases from 2 nm for 2 uc to 6 nm for 25 uc. In contrast, for expanded $BaTiO_3$ films on Au(100) a regular structure with domain walls proceeding along [100] directions is observed which evidences an in-plane domain arrangement.

[1] Y. Wang *et al.*, *Materials 7*, 103390 **2014**
[2] S. Förster *et al.*, *J. Chem. Phys. 135*, 104701 **2011**

MA 21.2 Tue 14:20 EB 107

Microscopic perspective of magnetoelectric effect in multiferroic composites — •Harsh Trivedi[1], Vladimir V. Shvartsman[1], Doru C. Lupascu[1], Robert C. Pullar[2], Marcos S. A. Medeiros[2], Andrei L. Kholkin[2], Pavel Zelanovskiy[3], and Vladimir Ya. Shur[3] — [1]Institute for Materials Science and Centre for Nanointegration Duisburg-Essen (CeNIDE), University of Duisburg-Essen, 45141 Essen, Germany — [2]Department of Materials and Ceramic Engineering & CICECO, University of Aveiro, 3810193 Aveiro, Portugal — [3]Institute of Natural Sciences, Ural Federal University, 620002 Ekaterinburg, Russia

An extensive analysis of microscopic studies on bulk multiferroic composites is presented. Piezoresponse force microscopy (PFM) is used as a tool to study magnetoelectric effect in composites at local scale. Indirect influence of the stress, that mediates the ME effect, on the PFM response and local switching parameters is evaluated. Principal component analysis is utilized to extract the valuable data buried under noise and statistical inhomogeneity in order to create a spatial visualization of the effect. The spatial distribution of the intensity of the magnetoelectric coupling reveals interesting phenomena at the interface suggesting a resemblance to Eshelby's solution for elliptical inclusion in a matrix. Spatially resolved Raman spectroscopy mapping reveals a similar dominance of the stress at the interfaces corroborating the PFM findings. Finally, a simplified FEM based theoretical model simulating the realistic polycrystalline microstructure is presented, in order to compare the experimental findings.

MA 21.3 Tue 14:40 EB 107

Domain structure in anisotropically strained $K_{0.75}Na_{0.25}NbO_3$ thin films on $TbScO_3$ — •Dorothee Braun[1], Albert Kwasniewski[1], Philipp Müller[1], Martin Schmidbauer[1], Jan Sellmann[1], Michael Hanke[2], and Jutta Schwarzkopf[1] — [1]Leibniz-Institute for Crystal Growth, Berlin, Germany — [2]Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Understanding and controlling of domain formation in ferroelectric thin films at the nanoscale is essential for fundamental research as well as for potential applications. The incorporation of anisotropic in-plane lattice strain has a decisive impact on the stability of ferroelectric phases and is achieved by the deposition on lattice mismatched substrates. In this study 30 nm thick $K_{0.75}Na_{0.25}NbO_3$ films were epitaxially grown on $TbScO_3$ substrates by metal-organic chemical vapor deposition. They experience in average a slight compressive lattice strain of 0.47% and are $(100)_c$ oriented. Our PFM measurement revealed both a lateral and a vertical component of the polarization vector whereby the latter one is less pronounced. The lateral PFM shows regularly arranged 90° domains in two directions with domain walls running along <110> and a periodicity of 50 nm has been observed. According to x-ray measurements, the films are grown fully strained on the substrate. The film unit cell is monoclinically distorted in the vertical direction, but no in-plane monoclinic distortion has been detected. These results indicate the occurrence of monoclinic M_C domains which were not observed in (K,Na)NbO_3 thin films before.

MA 21.4 Tue 15:00 EB 107

Ferroelectric Domains of partially relaxed $NaNbO_3$ films under tensile strain — •Jan Sellmann, Dorothee Braun, Albert Kwasniewski, Martin Schmidbauer, and Jutta Schwarzkopf — Leibniz-Institute for Crystal Growth, Max-Born-Str. 12489, Berlin

Lead-free alkaline niobates have recently attracted much attention due to their promising piezoelectric properties like high Curie temperatures. In thin film form they exhibit large densities of ferroelectric domains so that the domain walls are expected to contribute significantly to electrical and electromechanical responses of the material. In the present work, epitaxial $NaNbO_3$ films have been grown by Pulsed Laser Deposition under optimized growth conditions yielding 2D growth and nearly stoichiometric films. Tensile lattice strain was induced by the use of $TbScO_3$ substrates. Increasing the film thickness above the critical thickness the formation of misfit dislocations resulted in partial plastic lattice relaxation and thus a reduction of the effective in plane strain. Concurrently, the ferroelectric domain pattern changes at the critical thickness from lateral 1D a1/a2/a1/a2 stripes domains with exclusive in-plane polarization to a periodic stripe domain pattern with both vertical and lateral polarization components. The latter can be described as a1c/a2c domains with head-to-head configuration in some cases possibly resulting in charged domain walls. Similar results with regard to the domain structure have been found for $NaNbO_3$ thin films on $DyScO_3$ substrates. However, it is in contrast to NaNbO3 thin films grown on DyScO3 and $TbScO_3$ by MOCVD where in-plane domains are exclusively found well beyond the onset of plastic strain relaxation.

MA 21.5 Tue 15:20 EB 107

Investigation of second order nonlinear susceptibility tensor elements at the transition of ferroelectric domains — •Alex Widhalm[1], Kai Spychala[1], Moritz Grothe[1], Gerhard Berth[1,2], and Artur Zrenner[1,2] — [1]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [2]Center for Optoelectronics and Photonics Paderborn (CeOPP), 33098 Paderborn, Germany

Second harmonic (SH) microscopy is an established method for characterizing periodically poled ferroelectric materials. This work focusses on mapping the second order susceptibility tensor elements in ferroelectric domain structures using spatially resolved second harmonic analysis with respect to a focused laser beam. Our novel nondestructive technique allows for a nonlinear confocal scanning probe microscopy as well as for a basic analysis of occurring point spread functions with respect to a fixed excitation point. The resulting complex distribution of polarization states of excitation and generated SH light, allows a prediction about the detectable nonlinear response of the whole system. Here the experimental results obtained by this method are in good agreement with the expected theoretical occurrence of the nonlinear field distributions. In our spatially resolved experiments we found, that in the transition region of contrarily poled domains and its immediate environment some susceptibility tensor elements disappear whereas other elements appear. This results strongly contribute to a deeper understanding of the occurring physics at domain walls and corresponding contrast mechanisms in ferroelectric domains respectively.

MA 21.6 Tue 15:40 EB 107

Visualization of ferroelectric domain structures in KTP by confocal Raman imaging — •Peter Mackwitz[1], Michael Rüsing[1], Gerhard Berth[1,2], and Artur Zrenner[1,2] — [1]Department Physik, Universität Paderborn, 33098 Paderborn, Germany — [2]Center for Optoelectronics and Photonics Paderborn (CeOPP), 33098 Paderborn, Germany

The nonlinear optical material Potassium titanyl phosphate (KTP) unifies several outstanding material properties. Its distinguished features contain a high damage threshold compared with the considerable well known further ferroelectrics, exalted electro-optical coefficients and especially high nonlinear coefficients. The achieving of periodically poled structures in this material represents one of the significant deployments of KTP in integrated optics. Within the common effects of nonlinear implementation frequency conversion is one of the central uses. In order to achieve a highly efficient frequency conversion it is required to supply a nearly ideal surrounding for quasi-phasematching. Periodically poled materials like PPKTP provide this condition. Confocal Raman imaging depicts a noninvasive technique for visualizations of poled structures which is the premise for a characterization. In this work the confocal Raman imaging was achieved in due consideration of different incident polarizations. The measurements were performed as well in y-cut geometry as in z-cut samples. For this purpose numerous phonon modes have been identified as a continuation of previous work. The fundamental result of this work can be outlined as the designation of PPKTP as a proper candidate for domain imaging.

MA 22: Multiferroics I (DF with DS/KR/MA/TT)

Time: Wednesday 9:30–13:00 Location: EB 107

MA 22.1 Wed 9:30 EB 107

Magnetoelectric domain control in multiferroic $TbMnO_3$ — •Sebastian Manz[1], Masakazu Matsubara[1,2], Masahito Mochizuki[3,4], Teresa Kubacka[1], Ayato Iyama[5], Nadir Aliouane[6], Tsuyoshi Kimura[5], Steven Johnson[1], Dennis Meier[1], and Manfred Fiebig[1] — [1]ETH Zürich — [2]Tohoku University — [3]Aoyama Gakuin University — [4]Japan Science and Technology Agency — [5]Osaka University — [6]Paul Scherrer Institute

Spin-spiral multiferroics exhibit a strong coupling between the electric and magnetic subsystems which is of potential interest for technological applications. Although these systems have been investigated for more than a decade, the magnetoelectric domain evolution under external fields is still largely unknown. Using optical second harmonic generation we resolve how electric and magnetic fields affect the multiferroic domains in the archetypal spin-spiral multiferroic $TbMnO_3$. In consecutive electric switching cycles, varying multi-domain patterns emerge before a single-domain state is obtained. This observation reflects that the domain walls can easily move without being pinned by, e.g., structural defects. In striking contrast to the electric-field response, multi-domain patterns persist when the polarization direction is flopped by applied magnetic fields. Here, a uniform polarization rotation is observed within all domains, which incorporates a transformation of neutral into nominally charged domain walls. Our results are explained based on numerical Landau-Lifshitz-Gilbert simulations and provide first evidence for the scalability of macroscopic magnetoelectric properties onto the level of domains.

MA 22.2 Wed 9:45 EB 107

Critical behavior at the order-disorder transition in multiferroic $DyMnO_3$ — •Markus Schiebl, Alexey Shuvaev, Anna Pimenov, Graeme Eoin Johnstone, Uladzislau Dziom, and Andrei Pimenov — Institute for Solid State Physics, Vienna University of Technology, 1040 Vienna Austria

We present the results of detailed dielectric investigations of the relaxation dynamics in $DyMnO_3$ multiferroic manganite. In addition to known domain wall relaxation a second strong mode is observed at low frequencies. We provide an experimental evidence that the new relaxation mode is coupled to the chirality switching of the spin cycloid.

We demonstrate that the relaxation dynamics in $DyMnO_3$ is typical for an order-disorder phase transition. Therefore, $DyMnO_3$ follows an order-disorder transition scenario implicating that a short range cycloidal order of Mn-spins exists above T_C. The results suggest that the paramagnetic sinusoidal phase should be explained as a dynamic equilibrium between the clockwise and counterclockwise cycloidal magnetic orders. The short range order in the paraelectric phase is transformed to a long range cycloid at the ferroelectric transition temperature.

MA 22.3 Wed 10:00 EB 107

Biquadratic and four-spin ring interactions in orthorhombic perovskite manganites — •Natalya Fedorova, Andrea Scaramucci, Claude Ederer, and Nicola A. Spaldin — ETH Zurich, Materials Theory, Wolfgang-Pauli-Strasse 27, CH-8093, Zurich, Switzerland

We use *ab initio* electronic structure calculations, based on DFT within the GGA+U approximation, to estimate the microscopic exchange interactions in the series of orthorhombic perovskite manganites (o-RMnO$_3$), in order to find a model Hamiltonian which can provide an accurate description of the magnetism in these materials. At low temperatures o-RMnO$_3$ with small radii of R cations (therefore, large octahedral tiltings) demonstrate a spiral or E-type antiferromagnetic orderings (E-AFM), which drive their multiferroic properties. Usually the establishment of such magnetic orderings is explained within the framework of a Heisenberg model with competing nearest-neighboring (NN) and next-nearest-neighboring exchange interactions. However, we find that the mapping the results of *ab initio* calculations onto the Heisenberg Hamiltonian for o-RMnO$_3$ show a clear deviation from the Heisenberg-like behavior. We demonstrate that this deviation can be explained only by the presence of biquadratic and four-spin ring exchange couplings and show that they have the strongest effect in compounds where NN exchange interactions are weakened, for example, due to large octahedral tiltings.

MA 22.4 Wed 10:15 EB 107

Time resolved polarized neutron scattering and dielectric spectroscopy reveal multiferroic domain dynamics in $MnWO_4$ and $TbMnO_3$ — •Jonas Stein[1], Daniel Niermann[1], Christoph Grams[1], Max Baum[1], Tobias Cronert[1], Jeannis Leist[2], Karin Schmalzl[3], A Agung Nugroho[4], Alexander C Komarek[5], Götz Eckold[2], Petra Becker[6], Ladislav Bohatý[6], Joachim Hemberger[1], and Markus Braden[1] — [1]II. Physikalisches Institut, Uni Köln — [2]Institut für Phys. Chemie, Uni Göttingen — [3]JCNS at ILL, France — [4]Institut Teknologi Bandung, Indonesia — [5]MPI Dresden — [6]Institut für Kristallographie, Uni Köln

Multiferroic materials are promising for future memory devices with low power consumption. The rise time between two states is a crucial parameter for a possible application and was investigated in the spin spiral multiferroics $TbMnO_3$ and $MnWO_4$. Polarized neutron diffraction is able to determine the ratio of chiral domains, which can be controlled by an electric field. Using the stroboscopic technique we follow the reversion of chiral domains in the timescale of a few hundred microseconds to hours. In $TbMnO_3$ we find a simple logarithmic relation between the rise time and temperature that is fulfilled over 5 decades. Broadband linear and nonlinear dielectric spectroscopy revealed the domain dynamics in the MF phase of $MnWO_4$. The rise time reaches values in the minute range in the middle of the multiferroic temperature regime at T≈10 K but unexpectedly decays again on approaching the lower, first-order phase boundary at T_{N1}≈7.6 K.

[1] Niermann et al. **PRB 89**,134412 [2] Baum et al. **PRB 89**,144406

MA 22.5 Wed 10:30 EB 107

Polarization control at spin-driven ferroelectric domain walls — •Naëmi Leo[1], Anders Bergmann[2], Andres Cano[3], Narayan Poudel[4], Bernd Lorenz[4], Manfred Fiebig[1], and Dennis Meier[1] — [1]ETH Zurich, Switzerland — [2]Uppsala University, Sweden — [3]University Bordeaux, France — [4]University of Houston, USA

As was recently demonstrated, domain walls in ferroelectric materials show emergent electronic properties, like enhanced conductivity tunable by the relative orientation of the polarisation in the adjacent domains. Here, multiferroic materials with a coexistence of magnetic and electric order offer a new route for the control of such localised functionalities at domain boundaries.

Using spatially-resolved optical second harmonic generation we demonstrate the magneto-electric-field control of the multiferroic domains in Co-doped $MnWO_4$. In particular, the obtained domain distribution remains unchanged upon the magnetic-field-induced continuous 90°-rotation of the ferroelectric polarization.

This stability implies that multiferroic domain walls can accommodate for varying local polarisation configurations leading to local charging and discharging. We discuss the microscopic structure of the domain walls using micro-magnetic simulations.

MA 22.6 Wed 10:45 EB 107

Tuning order-by-disorder multiferroicity in CuO by doping — •Johan Hellsvik[1,2], Marcello Balestieri[1], Tomoyasu Usui[3], Alessandro Stroppa[2], Anders Bergman[4], Lars Bergqvist[5], Dharmalingam Prabhakaran[6], Olle Eriksson[4], Silvia Picozzi[2], Tsuyoshi Kimura[3], and José Lorenzana[1,2] — [1]ISC-CNR, Rome, Italy — [2]CNR-SPIN, L'Aquila, Italy — [3]Osaka University, Osaka, Japan — [4]Uppsala University, Uppsala, Sweden — [5]KTH, Stockholm, Sweden — [6]University of Oxford, Oxford, United Kingdom

The high Curie temperature multiferroic compound CuO has a quasidegenerate magnetic ground state that makes it prone to manipulation by the so-called "order-by-disorder" mechanism. First principle computations supplemented with Monte Carlo simulations and experiments show that isovalent doping allows us to stabilize the multiferroic phase in nonferroelectric regions of the pristine material phase diagram with experiments reaching a 250% widening of the ferroelectric temperature window with 5% of Zn doping. Our results allow us to validate the importance of a quasidegenerate ground state on promoting multiferroicity on CuO at high temperatures and open a path to the material engineering of multiferroic materials. In addition we present a complete explanation of the CuO phase diagram and a computation on the incommensurability in excellent agreement with experiment without free parameters.

[1] J. Hellsvik et al., Phys. Rev. B 90, 014437 (2014) [2] T. Kimura et al., Nature Mat. 7, 291 (2008) [3] G. Giovannetti et al., Phys. Rev. Lett. 106, 026401 (2011)

MA 22.7 Wed 11:00 EB 107

Dielectric properties and electrical switching behavior of the spin-driven multiferroic $LiCuVO_4$ — •Alexander Ruff[1], Stephan Krohns[1], Peter Lunkenheimer[1], Andrey Prokofiev[2], and Alois Loidl[1] — [1]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Germany — [2]Solid State Physics, Vienna University of Technology, Austria

The spin-1/2 chain cuprate $LiCuVO_4$ exhibits both ferroelectric and magnetic order at low temperatures. This so-called multiferroic behavior is of great scientific interest due to the underlying complex physical mechanisms, especially in the case of strong magnetoelectric coupling. Here we thoroughly discuss the multiferroic properties of the prototypical spin-driven ferroelectric material $LiCuVO_4$. At temperatures below about 2.5 K, it exhibits a three dimensional helical spiral spin order, with propagation in the *b* direction and a spin helix in the *ab* plane, which induces via an inverse Dzyaloshinskii-Moriya interaction a ferroelectric polarization in the *a* direction. In an external magnetic field, the direction of the spin spiral and thus the direction of the electrical polarization can be switched. This switching behavior of the polarization was demonstrated via dielectric spectroscopy on a single crystalline sample oriented in two different directions in magnetic fields up to 9 T. Detailed magnetic-field and temperature-dependent ferroelectric hysteresis-loop measurements imply the electric control of the spin helicity [1]. This rarely documented feature indicates the close coupling of electric and magnetic order of $LiCuVO_4$.

[1] A. Ruff *et al.*, *J. Phys.: Condens. Matter*, **26**:485901 (2014).

15 min coffee break

MA 22.8 Wed 11:30 EB 107

Emergence of ferroelectricity in multiferroic h-$YMnO_3$ — •Martin Lilienblum[1], Thomas Lottermoser[1], Sebastian Manz[1], Sverre M. Selbach[2], Andres Cano[3] und Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich, Vladimir-Prelog-Weg 4, 8093 Zurich, Switzerland — [2]Department of Material Science and Engineering, NTNU, N-7491 Trondheim, Norway — [3]CNRS, Université de Bordeaux, ICMCB, UPR 9048, F-33600 Pessac, France

Universal scaling laws, interfacial nano-electronics, and topological defects are currently studied using hexagonal manganites $RMnO_3$ (R= Sc, Y, Dy-Lu) as model system. In spite of the remarkably broad interest in the system, surprisingly little is known about the origin of the ferroelectric state. Here we solve the controversy about the emergence of the spontaneous polarization and its coupling to the underlying structural distortion by applying scanning probe microscopy (SPM) and optical second harmonic generation (SHG). We trace the spontaneous polarization by SHG from 100 K to 1450 K directly and contact-free. We find that only a single transition exists in which the polarization arises slower than expected as by-product of the structural distortion. By thermal treatments close to the structural transition and subsequent SPM scans, we show that the exceptionally robust ferroelectric domain pattern is determined only by the structural distortion. In summary we reveal that the ferroelectric order results from an interplay of electric polarization, topological effects, and temperature.

MA 22.9 Wed 11:45 EB 107

Monte Carlo approach to the ferroelectric phase transition in hexagonal manganites — •Thomas Lottermoser[1], Martin Lilienblum[1], Andres Cano[2], and Manfred Fiebig[1] — [1]ETH Zurich, Zurich, Switzerland — [2]Université de Bordeaux, Pessac, France

Despite several experimental and theoretical efforts in recent years the nature of the structural high temperature phase transition in the hexagonal manganites and its relation to the occurrence of a ferroelectric polarization in this materials is still not fully understood. Experimental data give two contradicting answers to this problem. Some experiments indicate a simultaneous appearance of the polarization in a single structural phase transition while others hint to a second phase transition several hundred Kelvin below the structural transition. In order to clarify these contradictions we performed Monte Carlo simulations based on the so-called clock model. In this model the six trimerization states of the manganite crystal structure are represented by six clock vectors in the complex plane. From the simulation data we calculated the temperature dependence of the complex structural order parameter and the induced ferroelectric polarization. The results point to a single phase transition with a strongly suppressed polarization contribution at high temperatures. This is experimentally confirmed by direct measurements of the ferroelectric polarization using optical second harmonic generation. Contradictions with other experimental data can be explained as finite size effects depending on the length scale of the experimental probe.

MA 22.10 Wed 12:00 EB 107

Magon-phonon interactions in hexagonal multiferroic $YMnO_3$ — •Andreas Kreisel[1], Shantanu Mukherjee[1], Brian M. Andersen[1], Turi Schäffer[1], Sonja Holm[1], Kim Lefmann[1], Niels C.R. Momsen[1], Jacob Larsen[2], Amy Fennell[3], Uwe Stuhr[3], and Zahra Yamani[4] — [1]Niels Bohr Institute, University of Copenhagen, Denmark — [2]Institute of Physics, Technical University of Denmark — [3]Laboratory of Neutron Scattering, Paul Scherrer Institute, Switzerland — [4]Chalk River National Laboratory, Canada

The multiferroic material $YMnO_3$ is known to show a large spin lattice coupling such that the spin and lattice degrees of freedom influence various properties, as for example the thermal conductivity that is found to have an anomalous contribution. The magnetoelastic modes have been measured recently in neutron diffraction experiments and linked to certain spectral features in Raman signals. Starting from a Heisenberg model on a triangular lattice with single ion anisotropies, we investigate the spin-phonon coupling via the magnetostriction mechanism and derive a coupled magnon-phonon model valid in the entire Brillouin zone. Within a spin-wave approach, where the coupling yields a hybrid magnon-phonon mode, we calculate the dynamic structure factor and compare to recent experimental neutron results.

MA 22.11 Wed 12:15 EB 107

Stability of magnetic and electric domains against chemical doping in hexagonal manganites — •Ehsan Hassanpour Yesaghi, Viktor Wegmayr, Jakob Schaab, Dennis Meier, and Manfred Fiebig — Department of Materials, ETH Zürich, Zürich, Switzerland

The unique properties of magnetoelectric multiferroics are, to a large extent, determined by the coexistence and interaction of magnetic and electric domains. A major challenge towards future applications is to optimize the properties of these domains, such as their transport, without weakening or even losing the existing multiferroic order. Here, we present our study of ferroelectric and antiferromagnetic domains in chemically doped hexagonal manganites. We show that the electronic conductance of $ErMnO_3$ can be enhanced or suppressed by introducing either divalent (Ca^{2+}) or tetravalent (Zr^{4+}, Ti^{4+}) ions into the system. Using piezoresponse force microscopy (PFM) and optical second harmonic generation (SHG) we monitor the corresponding changes on the level of domains. We find that the $RMnO_3$-characteristic domain topography, as well as the multiferroic transition temperature, are robust against the applied ionic alteration, which demonstrates the usability of chemical doping for non-perturbative property-engineering of multiferroic domains.

MA 22.12 Wed 12:30 EB 107

Anisotropy study of multiferroicity in the pyroxene $NaFeGe_2O_6$ — •Lionel Andersen[1], Thomas Lorenz[1], Matthias Ackermann[2], Ladislav Bohatý[2], and Petra Becker[2] — [1]II. Physikalisches Institut - Universität zu Köln, Germany — [2]Institut für Kristallographie - Universität zu Köln, Germany

Since the mineral aegirine was found to be the first multiferroic member of the pyroxenes an intensive search for further related multiferroics was initiated [1]. In this contribution, we present a detailed study of the dielectric, magnetic and magnetoelastic properties of the pyroxene $NaFeGe_2O_6$ with special respect to the anisotropy. Unlike other investigations on $NaFeGe_2O_6$ [2] large single crystals where synthesized to examine pyroelectric currents, dielectric constants and magnetic susceptibilities as well as the thermal expansion and the magnetostriction. The spontaneous electric polarization detected below $T_C \simeq 11.6$ K in an antiferromagnetically ordered state ($T_N \simeq 13$ K) is mainly lying within the *ac* plane with a small component along *b*, indicating a triclinic symmetry of the multiferroic phase of $NaFeGe_2O_6$. The electric polarization can be strongly modified by applying magnetic fields along different directions. We derive detailed magnetic-field versus temperature phase diagrams and identify three multiferroic low-temperature phases, which are separated by a non-ferroelectric, antiferromagnetically ordered state from the paramagnetic high-temperature phase [3].

[1] S. Jodlauk *et al.* J. Phys.: Condens. Matter **19** (2007)
[2] I. Kim *et al.* J. Phys.: Condens. Matter **24** (2012)
[3] M. Ackermann *et al.* New J. Phys. (submitted, arXiv:1408.6772)

MA 22.13 Wed 12:45 EB 107

***Ab Initio* analysis of ferroelectric and magnetic properties of potentially multiferroic aurivillius phases** — •Axiel Yael Birenbaum, Jan van den Broek, and Claude Ederer — Materials Theory, ETH Zürich

A promising class of high temperature polar magnetic multiferroic materials are the Aurivillius family of layered-perovskites related compounds. They combine high temperature ferroelectric properties with a layered structure that allows for systematic introduction of magnetic ions. The simplest of such cases to have been studied is $Bi_5FeTi_3O_{15}$. However, no well-established value exists for its spontaneous electric polarization, and contradictory reports as to its magnetic states.

We perform Density Functional Theory calculations on $Bi_5FeTi_3O_{15}$, and conclude on a high spontaneous electric polarization. To better understand the mechanism for ferroelectricity, we examine 9 systems, based on $SrBi_2Ta_2O_9$ as reference. We find a high spontaneous polarization even in the case of with no nominally ferroelectrically-active cations. We discuss these results in light of the tri-linear coupling between soft and hard modes demonstrated for $SrBi_2Ta_2O_9$ and the general concept of "hybrid improper ferroelectricity". To clarify the range of temperatures expected for magnetic long range order despite a low concentration of magnetic ions and the short range of superexchange interactions, we perform Monte Carlo simulations. We discuss possible strategies to increase magnetic ordering temperatures.

MA 23: Spincaloric Transport I (jointly with TT)

Time: Wednesday 9:30–11:30 Location: H 0110

MA 23.1 Wed 9:30 H 0110

The Origin of spin Seebeck effect in Iron Garnet thin films — •Er-Jia Guo[1], Andreas Kehlberger[1], Gerhard Jakob[1], Matthias B. Jungfleisch[2], Burkard Hillebrands[2], Francesco D. Coletta[3], Hans Hübl[3], Stephan Geprägs[3], Sebastian Goennenwein[3], Rudolf Gross[3], and Mathias Kläui[1] — [1]Institute für Physics, Universität Mainz, 55099 Mainz, Germany — [2]Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [3]Walther-Meißner-Institut, Garching, Germany

The discovery of spin Seebeck effect (SSE) provides an exciting approach to generate spin currents, which are suggested to replace charge currents in order to reduce the power dissipation. However, the genuine origin of SSE is still under debate. Here, we present thickness and temperature dependences of SSE signals in Yttrium Iron Garnet (YIG) and Gadolinium Iron Garnet (GIG) films. Using Pt/YIG hybrid structures, the thickness dependence of the material shows that magnonic spin currents are the source of the SSE.[1] We find a thickness-dependent enhancement of the SSE at low temperatures, which agrees well with the thermal conductivity, implying the importance of the magnon-phonon drag. In contrast to YIG, the GIG films allow us to measure the SSE across the compensation point.[2] Two sign changes of the SSE are observed with temperature drop, revealing the SSE is not simply mirroring to the total magnetization but the magnons emitted from three interacting magnetic sub-lattices as well as the spin-mixing conductances depending on the atom type at the interface.[1]A.Kehlberger,et al.,arXiv:1306.0784 (2013)[2]S.Geprägs,et al.,arXiv:1405.4971(2014)

MA 23.2 Wed 9:45 H 0110

High tunnel magneto-Seebeck effect — •Alexander Boehnke[1], Marvin von der Ehe[2], Christian Sterwerf[1], Christian Franz[3], Michael Czerner[3], Karsten Rott[1], Andy Thomas[1], Christian Heiliger[3], Markus Münzenberg[2], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, Germany — [3]1. Physikalisches Institut, Justus-Liebig-Universität Gießen, Germany

Semiconducting materials are known to have large Seebeck coefficients. This is mainly attributed to the gap in their band structure and the asymmetric position of the Fermi-level with respect to this gap. Accordingly, half-metals with a band-gap for only one spin-channel may have very different Seebeck coefficients for the majority and minority charge carriers. The tunnel magneto-Seebeck effect (TMS) is a powerful tool to investigate such spin-dependent Seebeck coefficients because separate spin-channels can be defined in magnetic tunnel junctions (MTJs).

Here, we probe the spin-dependent Seebeck coefficients of half-metallic Heusler compounds in Heusler/MgO/CoFe MTJs. For Co_2FeSi we found a TMS ratio of 96%, which is much larger than that of CoFeB/MgO/CoFeB MTJs (4%). Furthermore, we found an increase in the mean Seebeck voltage from 30μV in CoFeB to 3mV in Co_2FeSi based MTJs, which agrees with *ab initio* calculations. We will explain these findings by a Julliere-like model, which also shows the importance of the asymmetric Fermi-level position.

MA 23.3 Wed 10:00 H 0110

How to control and determine the direction of thermal gradients in spin caloric measurements? — •Timo Kuschel, Tristan Matalla-Wagner, Michel Bovender, Oliver Reimer, Daniel Meier, Jan-Michael Schmalhorst und Günter Reiss — CSMD, Physics Department, Bielefeld University, Germany

In *longitudinal* spin Seebeck effect (LSSE) measurements in magnetic insulators like $NiFe_2O_4$ or $Y_3Fe_5O_{12}$ with an out-of-plane thermal gradient ∇T additional magnetic proximity effects in the adjacent spin detector material (e.g. Pt) have to be taken into account and can be identified or excluded by e.g. x-ray resonant magnetic reflectivity [1]. In *transverse* SSE experiments with in-plane ∇T unintended out-of-plane ∇T can induce additional contributions as mainly Nernst effects in magnetic metals [2] and primarily LSSE in magnetic insulators [3]. Therefore, the control and the determination of thermal gradient directions in spin Seebeck experiments should be investigated in detail. Here, we present a new spin caloric setup which allows the rotation of in-plane thermal gradients based on the vectorial superposition of $\nabla_x T$ and $\nabla_y T$. We check the in-plane direction of ∇T by an infrared camera and will use the setup to study established and new spin caloric effects for different ∇T directions. We further show exemplarily that linear and quadratic Nernst effects in CoFeTb thin films can be used to estimate the effective direction of ∇T in all three spatial directions.

[1] T. Kuschel et al., submitted 2014, arxiv: 1411.0113

[2] D. Meier et al., Phys. Rev. B 88, 184425 (2013)
[3] D. Meier et al., submitted 2014, arxiv: 1411.6790

MA 23.4 Wed 10:15 H 0110

Spincaloric properties of epitaxial $Co_2MnSi/MgO/Co_2MnSi$ magnetic tunnel junctions — •Benjamin Geisler and Peter Kratzer — Fakultät für Physik and Center for Nanointegration, Universität Duisburg-Essen, 47048 Duisburg, Germany

Magnetic tunnel junctions (MTJs) with ferromagnetic, half-metallic electrodes are interesting spintronics devices due to their high tunnel magnetoresistance ratio. If a thermal gradient is applied to such a MTJ, the relative electrode magnetization can be detected by measuring the induced voltage, i.e., by exploiting the magneto-Seebeck effect [Nat. Mater. 10, 472 (2011)].

Here we present an *ab initio* viewpoint on transport and spincaloric properties of epitaxial $Co_2MnSi/MgO(001)/Co_2MnSi$ MTJs. We compare results calculated with the conventional Sivan-Imry approach to results obtained from solving the Landauer-Büttiker equation directly. The latter procedure circumvents the linear response approximation inherent in the Seebeck coefficient and provides the response of the system (current or voltage) to arbitrary thermal gradients. Moreover, thermal variations of the chemical potential in the leads and finite-bias effects can be readily included in this method, but are found to be negligible for this specific MTJ. We show how the spincaloric properties of the MTJs depend on the interface atomic structure and that they can be tailored by a targeted growth control. Finally, we briefly comment on the perturbing influence of thermally activated electrode phonons and interface magnons on the tunneling transport.

MA 23.5 Wed 10:30 H 0110

Coherent spin wave scattering at defects and localization phenomena — •Martin Evers and Ulrich Nowak — University of Konstanz, 78457 Konstanz, Germany

From studies of transport of particles and waves it is known that there are different transport regimes. Under ideal conditions, like in vacuum or in a perfect crystal, transport will be ballistic. However, in reality one has usually to deal with some kind of imperfections that induce disorder in the system. If this disorder is strong enough the transport will become diffusive. As Anderson showed back in 1958 in case of phase coherent scattering disorder can also lead to completely suppressed transport, known as Anderson Localization [1]. For the case of spin waves this could lead to a vanishing magnon propagation length, even without any damping mechanism.

In the framework of a classical spin model the effect of disorder on magnonic transport is studied utilizing the Landau-Lifshitz-Gilbert equation. Numerical investigations of one and two dimensional systems give insight to scattering properties of the systems, e. g. the mean free scattering time. We show directly the existence of Anderson localization in 1D and weak localization, which is a precursor for strong localization, in 2D, showing the ubiquitousness of Anderson Localization in wave physics.

[1] P. W. Anderson, Phys. Rev. 109, 1492 (1958)

MA 23.6 Wed 10:45 H 0110

Spin-Phonon Interactions and Magnetoelastic Modes — •Matthias Assmann and Ulrich Nowak — University Konstanz, 78457 Konstanz, Germany

For modern spin-caloritronic applications in insulators the interactions between the magnonic and the phononic system play the decisive role. We developed a model, which allows a coupling between these two thermodynamic sub-systems under strict observance of energy and angular momentum conservation laws. For this model we perform spin-molecular dynamics simulations, which take into account the spatial as well as the spin degrees of freedom. The coupling between the spin and lattice degrees of freedom is achieved by pseudo dipolar forces. A temperature gradient is applied by appropriate boundary condition and the excitation of magneto-elastic modes in form of a coupled transport of magnons and phonons in the temperature gradient is studied.

MA 23.7 Wed 11:00 H 0110

Anisotropic magnetothermopower in Co-based trilayers: A comparison between Cu, Pd, and Pt as heterostructure partners — •Voicu Popescu and Peter Kratzer — Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany

Within the framework of the spin-polarized relativistic Korringa-Kohn-Rostoker Green's function method we investigate the magnetothermopower (MTP) in a series of M/Co/M (M = Cu, Pd, and Pt) trilayer systems. As thermoelectric analogue of the conventional anisotropic magnetoresistance (AMR), the amplitude of the MTP signal is shown to depend on the asymmetry of the AMR around the Fermi energy. This asymmetry is sizable even if the magnetic layer itself displays only a small AMR, thus providing a path towards an efficient spin read-out thermoelectric device based on a single ferromagnetic layer. Our calculations establish a direct correlation between the strength of the spin-orbit coupling, modulated by the heterostructure partner M, and the MTP. The role of Co/M interface related effects such as structural relaxation and interdiffusion is also discussed.

MA 23.8 Wed 11:15 H 0110

Anisotropic magneto-thermopower in (Ga,Mn)As thin films — •Sibylle Meyer[1,2], Matthias Althammer[1], Wladimir Schoch[3], Rudolf Gross[1,2,4], and Sebastian T. B. Goennenwein[1,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]Institut für Quantenmaterie, Universität Ulm, Ulm, Germany — [4]Nanosystems Initiative Munich, München, Germany

The resistance of ferromagnetic metals depends on the magnetization orientation. This is referred to as anisotropic magneto-resistance (AMR), and exploited in many applications. In close analogy, also the thermopower of magnetic metals depends on the magnetization orientation, i.e., the electrical field arising upon the application of a thermal gradient to the metal characteristically varies with the magnetization orientation (anisotropic magneto-thermopower AMTP). However, due to different symmetry restrictions, the evolution of AMR and AMTP with magnetization orientation is expected to be distinctly different. To experimentally test this conjecture, we measured the AMTP in (Ga,Mn)As single crystals. 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 quantitatively compare the AMTP with AMR data taken on the same (113)-oriented (Ga,Mn)As thin films and with corresponding model calculations.
Financial support by DFG via SPP 1538 is gratefully acknowledged.

MA 24: Magnetic Materials I

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

MA 24.1 Wed 9:30 H 0112

Excitations in the Skyrmion Lattice of the Molecular Magnet GaV_4S_8 — •Dieter Ehlers[1], Vladimir Tsurkan[1], Hans-Albrecht Krug von Nidda[1], István Kézsmárki[2], Ioannis Stasinopoulos[3], Dirk Grundler[3], and Alois Loidl[1] — [1]Experimentalphysik V, EKM, Universität Augsburg, 86135 Augsburg — [2]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Ungarn — [3]Physik-Department E10, TU München, 85747 Garching

The magnetic semiconductor GaV_4S_8 has the so-called lacunar spinel structure which can be derived from the normal spinel structure by removing every second Ga atom. On cooling, a Jahn-Teller instability lowers the symmetry from cubic to trigonal at 44 K, resulting in twinned crystals. Magnetism arises from V_4S_8 clusters[1,2] which carry an effective spin $\frac{1}{2}$, and leads, below 13 K, to a complex magnetic phase diagram consisting of cycloidal, skyrmion, and ferromagnetic regions. These are interpreted in terms of a competition of anisotropic exchange coupling as well as Zeeman interactions in the multi-domain phase. Electron spin resonance has been applied to get insight into the magetization dynamics. Fixed frequency measurements prove the assumed anisotropy model and provide information on the interaction strengths. Broadband microwave experiments at low temperatures show excitations at 5 GHz and above 15 GHz, indicating that the ferromagnetic phase is more complex than anticipated so far.

[1]R. Pocha et al., Chem. Mater. **12** (2000), 2882

[2]H. Nakamura et al., J. Phys.: Condens. Matter **17** (2005), 6015

MA 24.2 Wed 9:45 H 0112

Pressure and temperature dependent powder diffraction studies on magnetocaloric compounds of the series Mn5-xFexSi3 — •Paul Hering[1], Karen Friese[1], Thomas Brückel[1], Anatoliy Senyshin[2], Michael Hanfland[3], Andrzej Grzechnik[4], Mohammad Maswada[1], and Ye Cheng[1] — [1]JCNS-2/PGI4, Forschungszentrum Jülich GmbH — [2]MLZ, TUM, Garching — [3]Inst. of Crystallo., RWTH Aachen — [4]ESRF, Grenoble, France

Magnetic refrigeration based on the magnetocaloric effect hold a potential to replace conventional vapor compression cooling. Compared to other magnetocaloric materials, the compounds in the system Mn5-xFexSi3 have the advantage that they do not contain expensive rare earth elements like Gd, nor toxic elements like As. The compounds undergo a variety of magnetic phase transitions at different temperatures depending on the iron content [Songlin, et al., J. Alloys Comp. 334, 249-252 (2002)]. Therefore, this system is an ideal choice to gain a better understanding of the underlying mechanism of the MCE in multiple site driven magnetocaloric materials. We performed neutron and x-ray powder diffraction experiments as a function of temperature and could trace several magnetic and structural transitions through anomalies in the lattice parameter showing a close connection between lattice and spin degrees of freedom. Recent synchrotron powder experiments varying pressure and temperature simultaneously were performed to elucidate, -first- whether the influence of hydrostatic and 'chemical pressure' (i.e. through the variation of composition) is equivalent, and -second- to follow the magnetic and associated structural transitions.

MA 24.3 Wed 10:00 H 0112

Element-resolved thermodynamics of $LaFe_{13-x}Si_x$ — •Markus Ernst Gruner[1,2,3], Werner Keune[2,4], Beatriz Roldan Cuenya[5], Claudia Weis[2], Joachim Landers[2], Sergey I. Makarov[2], David Klar[2], Michael Y. Hu[6], Ercan E. Alp[6], Jiyong Zhao[6], Maria Krautz[1], Oliver Gutfleisch[7], and Heiko Wende[2] — [1]IFW Dresden — [2]Universität Duisburg-Essen — [3]Forschungs-Neutronenquelle FRM II, Garching — [4]MPI Halle — [5]Ruhr-Universität Bochum — [6]Argonne National Laboratory — [7]TU Darmstadt

By combination of two independent approaches, nuclear resonant inelastic X-ray scattering and first-principles calculations in the framework of density functional theory, we demonstrate an unusual and significant effect of the magnetic phase transition on the element-resolved vibrational density of states of $LaFe_{13-x}Si_x$. This comprises the disapperance of a high-energy peak in connection with an overall softening of phonons in the paramagnetic phase, which is unexpected due to the large volume decrease at the transition. The pronounced magnetoelastic effect originates from adiabatic electron phonon coupling caused by specific changes in the electronic density of states at the Fermi level arising from the itinerant electron metamagnetism of Fe. The increase in lattice entropy associated with the Fe subsystem is significant and contributes cooperatively with the magnetic and electronic entropy changes to the excellent magneto- and barocaloric properties.

MA 24.4 Wed 10:15 H 0112

The magnetocaloric effect in transition metal borides — •Maximilian Fries[1], Konstantin Skokov[1], Michael Kuzmin[2], Zsolt Gercsi[3], and Oliver Gutfleisch[1] — [1]Technische Universität Darmstadt — [2]Faculté des Sciences et Techniques Marseille — [3]Trinity College Dublin

Magnetic cooling is a thriving research topic because it may offer considerably higher energy efficiency compared to traditional vapor compression based machines. In a reverse process the magnetocaloric effect can also be utilized in a thermoelectric generator. In order to make these technologies viable, material compositions with highly tunable Curie Temperatures (T_C) in the range of 200-600K are needed.

The group of transition metal borides may be a good candidate especially for high temperature applications, as they are chemically inert and stable in air even at elevated temperatures. Many Borides exhibit high magnetic moments for example like pure MnB which exhibits the highest magnetization of all 3d metal monoborides with 158 emu/g.

Here we will report on transition metal borides based on Cobalt, Manganese and Iron. We will show and discuss the magnetic, magnetocaloric and structural properties including spontaneous magnetization, entropy change and lattice expansion. The results are complemented with insights from theory based on DFT calculations.

MA 24.5 Wed 10:30 H 0112

Direct measurements of the magnetocaloric effect in thin film and low volume samples — •Jago Döntgen[1], Jörg Rudolph[1], Tino Gottschall[2], Oliver Gutfleisch[2], Steffen Salomon[3], Alfred Ludwig[3], and Daniel Hägele[1] — [1]AG Spektroskopie der kondensierten Materie, Ruhr-Universität Bochum, Germany — [2]Functional Materials, TU Darmstadt, Germany — [3]Werkstoffe der Mikrotechnik, Ruhr-Universität, Bochum, Germany

We present the first temperature dependent measurements of the magnetocaloric effect in a Gd thin film with sub-mK resolution. The high sensitivity of our newly developed technique of magnetomodulation combined with detection of the sample's thermal radiation allows the systematic investigation of thin film material libraries grown on wafers and gives new insights into the low-field behaviour of the magnetocaloric effect, which is not accessible by traditional calorimetry.

At T_C, we find a quadratic magnetic field dependence of the magnetocaloric ΔT for low external fields, contradicting earlier predictions. The same behaviour is found in bulk Gd and the metamagnetic alloy $LaFe_{11.05}Co_{0.91}Si_{1.04}$, underlining the versatility of our approach. An analytic expression based on Landau theory is found, that describes the transition of ΔT from the H_{ext}^2 behaviour at low to the well-known $H_{ext}^{2/3}$ behaviour at high fields.

15 min. break

MA 24.6 Wed 11:00 H 0112

Enhancement of soft magnetic properties of FeCoBSiNb bulk glassy alloys — •Parthiban Ramasamy[1], Mihai ' Stoica[2], and Jürgen Eckert[3] — [1]IFW Dresden, Institute for Complex Materials,Dresden, Germany — [2]IFW Dresden, Institute for Complex Materials,Dresden, Germany — [3]IFW Dresden, Institute for Complex Materials,Dresden, Germany

Fe based bulk metallic glasses are gaining more importance in recent decades due to their high strength and excellent soft magnetic properties, combined with low materials cost. The effect of Zr addition on the glass forming ability (GFA) of FeCoBSiNb glassy alloys in [(Fe0.5Co0.5)B0.2Si0.05]96-xNb4Zrx and [(Fe0.5Co0.5)B0.2Si0.05]100-xZrx system is investigated. In this study effect of Zr addition is studied because of its mixing enthalpies between Zr and Fe, Co, B, or Si atomic pairs are-26, -41, -49, -56, and -67 kJ/mol, respectively, and they are larger than those between Nb and Fe, Co, B, or Si atomic pairs, which are -16, -25, -30, -39, and-39 kJ/mol, respectively. The addition of Zr instead of Nb decreases the liquidus temperature of the system around 100K (i.e. from 1475K to 1370K). Thought the formation of the ZrB2 slightly affects the glass forming ability of the alloy, the Zr helps in the precipitation of (Fe, Co) phase, which is magnetically softer than the Fe23B6 phase and also mechanical properties of the alloy is improved.

MA 24.7 Wed 11:15 H 0112

Effect of particle refinement and grain boundary diffusion process in hot-deformed Nd-Fe-B permanent magnets — •Simon Sawatzki[1], Christian Kübel[2], Semih Ener[1], Imants Dirba[1], and Oliver Gutfleisch[1,3] — [1]TU Darmstadt, Materialwissenschaft, Alarich-Weiß-Str. 16, 64287 Darmstadt, Germany — [2]KIT, institute of Nanotechnology INT, P.O. Box 3640, 76021 Karlsruhe, Germany — [3]IWKS Hanau, Fraunhofer-Projektgruppe für Wertstoffkreisläufe und Ressourcenstrategie, 63457 Hanau, Germany

The grain boundary diffusion process (GBDP) drastically increases the coercivity in sintered Nd-Fe-B magnets without losing much in remanent magnetization by using only a very small amount of Dy [1]. Here Nd-Fe-B melt-spun ribbons have been hot-compacted and die-upset together with low melting DyCu, DyNdCu and TbNdCu powders to enhance coercivity. In order to optimize the distribution of these eutectics within the sample, particle refinement has been applied by grinding as well as ball milling. For the ternary alloys a uniform distribution was observed with secondary electron microscopy, which was attributed to the lower melting point of DyNdCu and TbNdCu compared to DyCu. Additional annealing at 600°C leads to a diffusion of Dy or Tb into the Nd-Fe-B flakes, which was observed by transmission electron microscopy. This diffusion modifies the grain boundary phase and thus further enhances coercivity without decreasing remanence. The highest coercivity was observed for TbNdCu. Following this, hot-compacted magnets have been die-upset in order to prepare textured magnets. [1] Park et al. Proc. 16th REPM (Sendai, Japan) (2000) p.257

MA 24.8 Wed 11:30 H 0112

Computational search for rare-earth-free hard-magnetic materials — •Jose A. Flores Livas, S. Sharma, K. Dewhurst, and E. K. U. Gross — Max-Planck-Institut für Mikrostrukturphysik. Weinberg 2, 06120. Halle (Saale) Germany.

It is difficult to overstate the importance of hard magnets for human life in modern times; they enter every walk of our life from medical equipments (NMR) to transport (trains, planes, cars, etc) to electronic appliances (for house hold use to computers). All the known hard magnets in use today contain rare-earth elements, which are expensive and environmentally harmful. Rare-earths are also instrumental in tipping the balance of world economy as most of them are mined in limited specific parts of the world. Hence it would be ideal to have similar characteristics as a hard magnet but without or at least with reduced amount of rare-earths. This is the main goal of our work: search for rare-earth-free magnets.

To do so we employ a combination of cutting edged density-functional theory and advanced methods of crystal structure prediction. In our high-throughput scheme, the quantities that define a hard magnet are magnetic anisotropy energy (MAE) and saturation magnetization (M_s), which are the quantities we maximize in search for an ideal magnet.

In my talk I will present details of the computation search algorithm, the improved descriptor and the determination of anisotropy constants, together with some potential and newly discovered rare-earth free hard magnet.

MA 24.9 Wed 11:45 H 0112

Phase Formation and Hot Compaction of Mn-Ga L1$_0$ Hard Magnets — •Torsten Mix[1,2], Ludwig Schultz[1,2], and Thomas George Woodcock[2] — [1]IFW Dresden, Institute for Metallic Materials, PO Box 270116, 01171 Dresden, Germany — [2]Department of Physics, TU Dresden, Dresden, Germany

The Mn-Ga binary system contains phases with high magnetocrystalline anisotropy, which may be suitable candidates for rare earth free permanent magnets. Depending on the composition, L1$_0$ ($cP4$; $P4/mmm$) or D0$_{22}$ ($tI8$; $I4/mmm$) structured phases can be produced. The aim of this work is to understand the formation and stability of the L1$_0$ phase and to optimise both the intrinsic and extrinsic magnetic properties of the alloys. Mn-Ga binary alloys with compositions in the range 55-65 at.% Mn were produced by arc melting and annealing. Phase formation was studied using thermal analysis, x-ray diffraction and magnetometry. Measurements of the magnetocrystalline anisotropy constant and anisotropy field were performed in applied magnetic fields of 14 T. An improvement in the H$_c$ of the Mn-Ga alloys was obtained by producing powder from bulk L1$_0$ materials by mechanical milling. The L1$_0$ powder had a similar magnetisation but a fivefold higher H$_c$ compared to the bulk sample (cf. $Mn_{60}Ga_{40}$: powder: H$_c$ = 0.376 T, bulk: H$_c$ = 0.073 T). Partial alignment of the L1$_0$ powder in a magnetic field was possible, giving a possible route to the production of anisotropic magnets. Furthermore, fully dense, isotropic, hot compacts were produced in which the improved magnetic properties of the powders were retained.

MA 24.10 Wed 12:00 H 0112

Coercivity enhancement in HDDR based hot pressed and die-upset magnets by in situ grain boundary diffusion — •Christoph Schwöbel[1], Sandro Szabó[1], Simon Sawatzki[1], and Oliver Gutfleisch[1,2] — [1]TU Darmstadt, Deutschland — [2]Fraunhofer IWKS, Hanau, Deutschland

The hydrogenation, disproportionation, desorption, recombination (HDDR) process is a possibility to create submicron grains from Nd-FeB magnets. Hydrogen absorption at elevated temperatures leads to disproportionation followed by subsequent desorption and the formation of an ultrafine grained microstructure. Grain sizes are then close to the critical single domain size for NdFeB. These fine grained HDDR powders are then consolidated and textured by hot compaction and die-upsetting together with a dysprosium containing low melting compound. The applied heat treatment enables a diffusion of Dy along the grain boundaries. This grain boundary diffusion process (GBDP) leads to a further increase in coercivity.
In this study, different starting powders were treated by the HDDR process and mixed with different amounts of DyCu prior to the consolidation. The influence of the different process routes on magnetic properties and microstructure is investigated. Magnetometry and electron microscopy showed a significant increase in H_c after hot compaction if Dy is added. Die-Upsetting led to an increase in remanence due to texturing.

MA 24.11 Wed 12:15 H 0112

Development of Microstructure in Mn-Al-C Permanent Magnetic Materials — •Florian Bittner[1,2], Ludwig Schultz[1,2], and Thomas George Woodcock[1] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, 01171 Dresden, Germany — [2]Department of Materials Science, TU Dresden, Dresden, Germany

Mn-Al based materials have the potential for an application as rare earth free permanent magnets and could replace Nd-Fe-B in certain areas where the highest energy density is not required. The metastable τ phase in near equiatomic Mn-Al alloys is L1$_0$ structured and has high saturation magnetisation and magnetocrystalline anisotropy. Carbon atoms on interstitial sites increase the thermal stability of the τ phase, enabling processing at higher temperatures. In order to develop anisotropic magnetic properties, an easy axis texture must be induced by hot working. Coercivity strongly depends on microstructure and the presence of defects in the material is particularly important. In order to optimise the coercivity, it is therefore necessary to have detailed knowledge of the microstructural features which appear in these magnets, especially the type of defects, their formation mechanisms and the effect of processing on their fractions. Mn-Al-C magnets have therefore been studied in the as-cast, annealed and hot worked states using electron backscattered diffraction. Two different twinning systems were found to exist in the as-cast material, the fractions of which changed after hot working. These crystalline defects, other microstructural parameters and the magnetic properties will be discussed in terms of the various processing steps applied.

MA 25: Magnetic Imaging

Time: Wednesday 9:30–11:45 Location: H 1012

MA 25.1 Wed 9:30 H 1012

Detecting magnetic flux distributions in superconductors with magnetic scanning x-ray microscopy — •Claudia Stahl[1], Stephen Ruoss[1], Patrick Audehm[1], Markus Weigand[1], Gisela Schütz[1], and Joachim Albrecht[2] — [1]Max Planck Institut für Intelligente Systeme, Heisenbergstr. 3, 70569 Stuttgart — [2]Forschungsinstitut für Innovative Oberflächen, Hoschschule Aalen, Beethovenst. 1, 73430 Aalen

The magnetic flux distribution arising from a high-Tc superconductor is detected and visualized using polarized x rays. Therefore, we introduce a sensor layer, namely, an amorphous, soft-magnetic $Co_{40}Fe_{40}B_{20}$ cover layer, providing a large x-ray magnetic circular dichroism (XMCD). CoFeB is directly deposited on top of high-Tc superconducting YBCO structures [1]. The magnetic stray fields of the supercurrents lead to a local reorientation of the magnetic moments in the ferromagnet. Using polarized x-rays it is possible to measure the local magnetization via the XMCD effect.

We show that the XMCD contrast in the sensor layer corresponds to the in-plane magnetic flux distribution of the superconductor [2] and can hence be used to image magnetic structures in superconductors with high spatial resolution.

The measurements are carried out at our scanning x-ray microscope MAXYMUS and our own dedicated reflectometry endstation at Bessy II at HZB in Berlin.

[1] C. Stahl et al., EPL 106, 27002 (2014). [2] C. Stahl et al., PRB 90, 104515 (2014).

MA 25.2 Wed 9:45 H 1012

X-ray imaging of curved magnetic nanomembranes — •Denys Makarov[1], Robert Streubel[1], Peter Fischer[2], Florian Kronast[3], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, 01069 Dresden, Germany — [2]Center for X-ray Optics, Lawrence Berkeley National Laboratory, Berkeley

CA 94720, USA — [3]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, 12489 Berlin, Germany

Conventionally magnetic films and structures are fabricated on flat surfaces. The topology of curved surfaces has only recently started to be explored and leads to new fundamental physics and applied device ideas. Advancing in this field calls for the understanding of the magnetic responses of thin films on curved surfaces. Here, two basic geometries, i.e. hemi-spherical [1,2] and tubular [3-5], will be addressed. To enable the microscopic characterization of 3D architectures, we put forth the concept of magnetic soft x-ray tomography. This concept will be introduced and the angle- and layer-resolved imaging of 3D shaped tubular architectures [4,5] will be presented.

[1] T. C. Ulbrich et al., Phys. Rev. Lett. 96, 077202 (2006). [2] D. Makarov et al., Appl. Phys. Lett. 93, 153112 (2008). [3] E. J. Smith et al., Phys. Rev. Lett. 107, 097204 (2011). [4] R. Streubel et al., Nano Lett. 14, 3981 (2014). [5] R. Streubel et al., Adv. Mat. 26, 316 (2014).

MA 25.3 Wed 10:00 H 1012

High-Resolution Soft X-ray Holographic Microscope — Kai Bagschik[1], Judith Bach[1], Robert Frömter[1], •Jochen Wagner[1], Leonhard Müller[2], Stefan Schleitzer[2], Jens Viefhaus[2], Christian Weier[3], Roman Adam[3], Gerhard Grübel[2], Claus M. Schneider[3], and Hans Peter Oepen[1] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Germany — [2]DESY, Hamburg, Germany — [3]Peter Grünberg Institut, Forschungszentrum Jülich, Germany

X-ray Fourier transform holography has become a competitive technique to investigate magnetic samples with sub-20 nm spatial resolution exploiting the x-ray magnetic circular dichroism [1]. The obtainable resolution depends on the maximum recorded scattering angle and the size of the reference hole of the optics mask.

Our X-ray holographic microscope, equipped with a large-area CCD camera of 4k × 4k pixels, accepts scattering angle of up to 10°. This corresponds to a maximum $q = 0.66$ nm^{-1} for the L-edge of Cobalt (778 eV). Separated sample and optic mask allow a free movement across the sample [1]. A permanent-magnet assembly enables application of in- and out-of-plane magnetic fields of up to 140 mT [2].

We imaged the domain pattern of Co/Pt and Fe/Pd multilayer films and determined a spatial resolution of (16 ± 1) nm. With this resolution, we could successfully image Co/Pt nanodots with diameters between 30 - 100 nm.

[1] D. Stickler, et al., Appl. Phys. Lett. 96, 042501 (2010). [2] D. Nolle, et al., Rev. Sci. Instrum. 83, 046112 (2012).

MA 25.4 Wed 10:15 H 1012

Quantification of microscopic magnetic and/or electric fields by calibrated DPC measurements — •Felix Schwarzhuber, Johannes Wild, Ralph Schregle, and Josef Zweck — Institute of Experimental and Applied Physics, University of Regensburg

Differential phase contrast microscopy (DPC) in a scanning transmission electron microscope (STEM) allows to obtain detailed information about microscopic electric and/or magnetic field distributions within a specimen. The deflection of the electron beam due to those fields leads to a shift of the diffraction disk in the detector plane, which can be detected using a direction sensitive detector.

In order to retrieve quantitative information about those electric and/or magnetic fields a calibration of the beam deflection as a function of field strength is necessary. We present a simple calibration method which is based on the defined deflection of the convergent electron beam after passing the electric field of a parallel-plate capacitor that is built in a TEM holder. The diffraction disk shift caused by a well known capacitor field at a certain set of microscope parameters allows to derive device specific calibration factors. With this calibrated DPC system it is possible to quantitatively measure fields that cause deflections in the order of microradians.

MA 25.5 Wed 10:30 H 1012

Quantitative measurement of magnetic fields and magnetic moments of nanoparticles by off-axis electron holography — •Zi-An Li[1], Andras Kovcas[2], Alexandra Terwey[1], Rafal E. Dunin-Borkowski[2], and Michael Farle[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen, Germany — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Research Centre Jülich, Germany

The quantitative mapping of magnetic fields and the measurement of magnetic moments of individual nanoparticles is critically important, both for the fundamental understanding of nanoscale magnetism and for practical applications. Off-axis electron holography provides direct access to the magnetic field within and around an object of interest in the transmission electron microscope. Here, we use off-axis electron holography to map local variations in magnetic induction within and around individual nanoparticles with close to 2 nm spatial resolution. We apply a contour integration method developed by Beleggia et al. [1] to measure their magnetic moments with an estimated accuracy of better than 1%. The origins of possible statistical and systematic errors in such measurements are discussed [2].

References 1.*M. Beleggia, K. Takeshi, R. E. Dunin-Borkowski. Ultramicroscopy, 110, 425-432, (2010) 2.*Financial support by the European Research Council Grant *IMAGINE* is gratefully acknowledged.

MA 25.6 Wed 10:45 H 1012

Relaxometry imaging of superparamagnetic magnetite nanoparticles using a single qubit — •Dominik Schmid-Lorch[1], Thomas Häberle[1], Andrea Zappe[1], Friedemann Reinhard[1,2], Amit Finkler[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut und Forschungszentrum SCoPE, Universität Stuttgart, Germany — [2]Walter Schottky Insititut, Technische Universität München, Germany

We present a novel technique to image superparamagnetic iron oxide nanoparticles via their fluctuating magnetic fields. The detection is based on the nitrogen-vacancy (NV) color center in diamond, which allows optically detected magnetic resonance (ODMR) measurements on its electron spin structure. In combination with an atomic-force-microscope, this atomic-sized color center maps ambient magnetic fields in a wide frequency range from DC up to several GHz [1], while retaining a high spatial resolution in the sub-nanometer range [2].

We demonstrate imaging of single 10 nm sized magnetite nanoparticles using this spin noise detection technique. By fitting simulations (Ornstein-Uhlenbeck process) to the data, we are able to infer additional information on such a particle and its dynamics, like the attempt frequency and the anisotropy constant. This is of high interest to the proposed application of magnetite nanoparticles as an alternative MRI contrast agent or to the field of particle-aided tumor hyperthermia [3].

[1] E. Schäfer-Nolte et al., Phys. Rev. Lett. 113, 217204 (2014)
[2] P. Maletinsky et al., Nat. Nanotech. Vol. 7, 320-4 (2012)
[3] R. Hergt et al., J. Phys.: Condens. Matter 18 S2919-S2934 (2006)

MA 25.7 Wed 11:00 H 1012

Scanning probe magnetic resonance imaging with chemical contrast on the nanoscale — •Thomas Häberle[1], Dominik Schmid-Lorch[1], Friedemann Reinhard[1,2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut und Forschungszentrum SCoPE, Universität Stuttgart, Germany — [2]Walter Schottky Institut, TU München, Germany

We present a novel scanning probe imaging method that employs the nitrogen-vacancy (NV)-center in diamond as an atom-sized magnetic field sensor [1]. This technique extends the range of accessible quantities in scanning probe microscopy to nuclear magnetic spin noise imaging - on arbitrary samples and under ambient conditions. Moreover, the unique properties of different nuclear species allow chemical contrast imaging, while the sensitivity extends below the surface of a sample, thus revealing subsurface features.

We demonstrate NMR imaging with 20 nm resolution conducted on a benchmark sample. Furthermore, we present chemically specific contrast by separating fluorine from hydrogen rich regions, which additionally allows for the detection of subsurface features [2].

[1] Staudacher, T. et al. Science 339, 561-3 (2013)
[2] Häberle, T. et al. arXiv:1406.3324 [cond-mat] 25 (2014)

MA 25.8 Wed 11:15 H 1012

Simultaneous measurement of AMR and observation of magnetic domains with dual Kerr microscopy — •Julia Osten[1,2], Kilian Lenz[1], Jürgen Lindner[1], and Jürgen Fassbender[1,2] — [1]HZDR Institute of Ion-Beam Physics and Materials Research Bautzner Landstr.400 01328 Dresden, Germany — [2]TU Dresden , 01069 Dresden, Germany

Anisotropic magneto resistance (AMR) sensors are widely used in daily life. But the influence of magnetic domains on the AMR is still not fully understood. AMR depends on the direction of the magnetization. For the understanding of the AMR it is therefore important to know about the domain structure. Dual Kerr microscopy is used

for the observation of the magnetic domains while at the same time the AMR is measured. Dual Kerr microscopy means that it is possible to measure two magnetization directions at the same time. These two sensitivity directions make it possible to calculate quantitative Kerr images for a complete loop. The investigated samples were magnetic stripe patterned permalloy. The patterning was archived with Cr-Implantation. In addition to the measured resistance the AMR is calculated from the quantitative Kerr images. We also compare the field dependence of the AMR by variation of the magnetic field angle.Our measurements show a clear dependence of the AMR on the magnetic domain types.
This work is supported by DFG grant FA316/3-2.

Osten *et al.* Rev. Sci. Instrum. **85**(2014)

MA 25.9 Wed 11:30 H 1012

Investigation of magneto-optical anisotropy of epitaxial Bi-substituted rare-earth iron garnet films — •Rajkumar Patra[1], H. Richert[2], N. Du[1], M. Lindner[3], R. Holzhey[3], M. Rabung[4], J. McCord[5], M. Matczak[6], R. Schäfer[7], O. G. Schmidt[7], and H. Schmidt[1] — [1]TU Chemnitz — [2]MATESY GmbH — [3]INNOVENT e.V. — [4]IZFP Saarbrücken — [5]University of Kiel — [6]IFMPAN, Poland — [7]IFW Dresden

Bi-substituted rare-earth iron garnet films were grown by liquid phase epitaxy [1]. Magnetooptical (MO) anisotropy of different garnet films was studied by VMOGE with a 0.4T octupole magnet [2]. The MO response is strongest in the composition dependent band gap region and has been modeled with a wavelength dependent, complex MO coupling constant [3]. The MO anisotropy of different garnet films with out-of-plane or in-plane easy axis of magnetization has been studied in the corresponding band gap region by VMOGE measurements by orbiting the magnetic field out-of-plane and in-plane. The differences in the observed MO anisotropy have been confirmed by Kerr microscopy and by Barkhausen Noise and Eddy Current Microscopy (BEMI) measurements. By modeling the VMOGE rotation data we can easily determine the direction of the saturation magnetization in dependence on the direction and amplitude of applied magnetic field. [1] P. Capper et al. (2010) Magneto-Optic Garnet Sensor Films: Preparation, Characterization, Application, in Crystal Growth Technology: Semiconductors and Dielectrics, Wiley, [2] K. Mok, H.S. et al. Rev. Sci. Instr. 82 (2011), [3] K. Mok, H.S. et al., J. Appl. Phys. 110 (2011)

MA 26: Focus: Towards quantitative magnetic measurements at ultimate spatial resolution with electrons

Organizer: B. Rellinghaus (IFW Dresden)

The decreasing size of functional magnetic materials, the concurrently growing significance of surfaces and interfaces, and novel nanoscale magnetic phenomena (such as skyrmions) cause a steadily increasing demand for ultra-high resolution quantitative magnetic characterization if possible, with atomic resolution. While spin-polarized STM already provides this resolution for the characterization of surfaces, techniques that probe volume magnetic properties are still lacking behind. Here, transmission electron microscopy (TEM) based methods such as electron holography or Lorentz microscopy meanwhile offer significantly improved resolutions even in three dimensions or at low temperatures. The use of inelastically scattered electrons was claimed to even allow for local and element-specific measurements of the magnetic dichroism with up to atomic resolution. The session highlights the current status-quo, potentials and limitations of TEM-based quantitative magnetic measurement techniques with a particular focus on ultimate resolution.

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

Invited Talk MA 26.1 Wed 9:30 EB 202

Magnetic measurements at high resolution in an electron microscope: a review. — •Josef Zweck — University of Regensburg, 93040 Regensburg, Germany

This talk will introduce the various techniques which are today available in an electron microscope to yield highly resolved information of magnetic specimens.

While high resolution is usually associated with "high spatial resolution", this is nowadays only one aspect of (magnetic) electron microscopy, and certainly an important one. Beyond spatial resolution, and upon the advent of quantitative magnetic imaging, the second flavour of "high resolution", namely highly resolved measurements of local magnetic information, becomes more and more important.

Magnetic imaging in a TEM originated from the so-called Lorentz microscopy, which gave easy access to micromagnetic configurations on a local scale. It is tuneable in sensitivity, but suffers from being strongly non-linear. It is now complemented by other techniques such as electron holography, differential phase contrast (DPC) and the TIE reconstruction method which allow to exploit both meanings of "high resolution" at the same time.

The techniques will be presented, highlighting their specific advantages and disadvantages, examples of their use will be given.

Invited Talk MA 26.2 Wed 10:00 EB 202

Observation and Manipulation of Magnetic Skyrmions — •Shinichiro Seki — RIKEN Center for Emergent Matter Science (CEMS), Wako, Japan

Magnetic skyrmion is a topologically stable particle-like object, which appears as nanometer-scale vortex-like spin texture in a chiral-lattice magnet. In metallic materials (MnSi, FeGe, Fe1-xCoxSi etc), conduction electrons moving through skyrmion spin texture gain a nontrivial quantum Berry phase, which provides topological force to the underlying spin texture and enables the current-induced manipulation of magnetic skyrmion. Recently, we newly discovered that skyrmions appear also in an insulating chiral-lattice magnet Cu2OSeO3. We find that the skyrmions in insulator can magnetically induce electric polarization through the relativistic spin-orbit interaction, which implies possible manipulation of the skyrmion by external electric field without loss of Joule heating. Such electric controllability, as well as the particle nature and nanometric size, highlights skyrmion as a promising candidate of potential information carrior for next generation of magnetic storage device with high energy efficiency. In this talk, we discuss the imaging of skyrmions with Lorentz transmission electron microscopy (LTEM) technique and their dynamical response under various external stimuli.

15 min. break

Invited Talk MA 26.3 Wed 10:45 EB 202

Visualization Of Three Dimensional Magnetization Of Magnetic Nanostructures — •Charudatta Phatak — Argonne National Laboratory, Chicago, USA

Confinement of magnetic structures geometrically as well as energetically leads to novel and unexpected behavior. With advances in fabrication and lithography tools, magnetic structures can be made in complex, confined three-dimensional (3D) geometries at the nanoscale as well as patterned into a variety of interacting lattices. In order to control their behavior, it is necessary to understand the fundamental physics of such interactions along with the influence of physical shape of the nanostructures in 3D.

Lorentz transmission electron microscopy (LTEM) has been extensively used for characterizing magnetization and domains in magnetic structures as it offers a high spatial resolution along with direct visualization of the magnetization. LTEM combined with phase retrieval can be used to obtain quantitative information about the magnetization and interactions between nanostructures. In this work, we will present results using a dedicated Lorentz microscope equipped with a spherical aberration corrector which offers a highest spatial resolution of 0.5 nm while maintaining the sample in a field free region. In this work, we will present a brief introduction to the vector field tomography technique for 3D visualization of magnetization and demonstrate its application to various magnetic systems such as artificial spin ice lattices, shape memory alloys, and magnetic nanowires.

Invited Talk MA 26.4 Wed 11:15 EB 202

Utilizing chirality to explore local magnetic moments — •Peter Schattschneider — Institute of Solid State Physics, Vienna University of Technology, Vienna, Austria

Energy loss magnetic chiral dichroism (EMCD) is a rather new approach to study element specific magnetic moments with highest spatial resolution. EMCD is detected as an asymmetry in the transition probability to states with positive or negative magnetic quantum numbers (chiral transitions). The technique is similar to its well established relative, X-ray magnetic circular dichroism (XMCD) where the asymmetry appears in the fine structure of ionisation edges of magnetic materials. The observation that chiral electronic transitions break certain mirror symmetries in energy spectroscopic diffraction (ESD) led to the prediction that this breaking pertains in energy filtered high resolution imaging, thus opening the road to mapping spins of individual atomic columns under high resolution conditions in a conventional TEM. This was experimentally demonstrated on magnetite. An important advantage over XMCD is the site specificity, enabling the study of ferri- and antiferromagnets.

One of the intriguing consequences of EMCD is that the outgoing probe electrons have topological charge. Such electrons carry quantized orbital angular momentum, similar to the recently discovered vortex electrons. Vice versa, vortex electrons are a promising probe for atomic resolution spin mapping.

The author acknowledges funding from the Austrian Science Fund, project no. I543-N20

Invited Talk MA 26.5 Wed 11:45 EB 202

Linking magnetic properties to nanoscale spectral and spatial features — •Thomas Thersleff[1], Jan Rusz[2], Shunsuke Muto[3], and Klaus Leifer[1] — [1]Department of Engineering Sciences, Uppsala University, Box 534, 75121 Uppsala, Sweden — [2]Department of Physics and Astronomy, Uppsala University, Box 516, 75120 Uppsala, Sweden — [3]Division of Energy Science, EcoTopia Science Institute, Nagoya University, Chikusa-ku, 464-8603 Nagoya, Japan

The fundamental questions posed by the field of nanomagnetism demand characterization techniques that are both quantitative and capable of resolving nanoscale features. Electron Magnetic Circular Dichroism (EMCD) in the Transmission Electron Microscope (TEM) is a relatively young technique that promises to meet both of these criteria, and it has already demonstrated quantitative results with a spatial resolution superior to what can be achieved with x-rays. An additional advantage of EMCD is that the scattering geometry in the TEM permits the acquisition of an EMCD signal in parallel to a multitude of additional properties, such as composition, valence, strain, and crystallographic structure. In this talk, we describe an EMCD experimental design that enables these disparate property domains to be directly linked to magnetic behavior on the nanoscale. This allows us to quantitatively map the orbital to spin magnetic moment ratio (m_L/m_S) in real space and correlate it to nanoscale features such as interfaces and the presence of oxide. We also present our progress into the spectral segregation of overlapping EMCD signals from similar materials using blind-source separation techniques.

MA 26.6 Wed 12:15 EB 202

EMCD measurements on ferromagnetic nanoparticles using electron vortex probes — •Darius Pohl[1], Sebastian Schneider[1,2], Jan Rusz[3], Peter Tiemeijer[4], and Bernd Rellinghaus[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany — [2]TU Dresden, Institute for Solid State Physics, D-01062 Dresden, Germany — [3]Uppsala University, Department of Physics and Astronomy, SE-752 37 Uppsala, Sweden — [4]FEI Company, PO Box 8066, 5600 KA Eindhoven, The Netherlands

Recently discovered electron vortex beams, which carry a discrete orbital angular momentum (OAM) L, are predicted to reveal dichroic signals. Since electron beams can be easily focused down to subnanometer diameters, this novel technique provides the possibility to quantitatively determine local magnetic properties with unrivalled lateral resolution. As the spiralling wave front of the electron vortex beam has an azimutally growing phase shift of up to 2π and a phase singularity in its axial center, specially designed apertures are needed to generate such non-planar electron waves. We report on the preparation and successful implementation of spiral and dislocation apertures into the condenser lens system of an aberration-corrected FEI Titan^3 80-300 transmission electron microscope (TEM). This setup allows to perform scanning TEM (STEM) with vortex beams carrying user-selected OAM. First experiments and simulations on the interaction of vortex beams with ferromagnetic FePt nanoparticles reveal both the potential and present limitations of this technique.

MA 27: Magnetization / Demagnetization Dynamics I

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

MA 27.1 Wed 9:30 EB 301

Towards probing ultrafast magnetization dynamics with a table top XMCD setup — •Felix Willems[1], C T L Smeenk[2], Clemens von Korff Schmising[1], Oleg Kornilov[2], Marc Vrakking[2], and Stefan Eisebitt[1] — [1]TU Berlin, 10623 Berlin — [2]Max-Born-Institut, 12489 Berlin

The understanding of ultrafast demagnetization dynamics is of high interest for future applications such as ultrafast magnetic switches and magnetic data storage. Up today there is evidence that two mechanisms (spin-flips [1] and spin transport [2,3]) drive the magnetic dynamics on the femtosecond time scale. In order to isolate the two mechanisms, we need an experimental setup that provides ultrafast time resolution, a well-defined magnetic contrast and element specific sensitivity. We have set up a HHG source that generates circularly polarized x-rays in the energy range of the M-edges of transition metals (40-70 eV) using a four mirror reflection-polariser. We report on first measurements exploiting x-ray magnetic circular dichroism to measure transient magnetisation changes in tailored thin film multilayer sample systems. The advantage of our approach lies in the simultaneous quantitative probing of magnetization of different elements in the sample, enabling us to determine the timing of the dynamics in the adjacent layers with sub 40 fs accuracy. We expect to quantify transport of spin-polarized electrons between the layers vs. dynamics caused by electron-phonon spin flip processes and report on first experiments towards this goal. [1] Koopmans et al., Nat. Mat. 9, 259 (2010) [2] Battiato et al., PRL 105, 027203 (2010) [3] Pfau et al., Nat.Comm. 3, 1100 (2012)

MA 27.2 Wed 9:45 EB 301

Movement of magnetic domain walls induced by single femtosecond laser pulses — •Oliver Sandig[1], Yasser Shokr[1], Bin Zhang[1], Jan Vogel[2], Florian Kronast[3], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin, Germany — [2]CNRS, Institut Néel, 38042 Grenoble, France — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany

Controlling the movement of magnetic domain walls (DW) on ultrashort timescales is important to realize novel applications such as racetrack memories. Magnetic interactions between domain walls, magnetic anisotropy, and coupling between different layers may influence the DW motion. To explore the possibilities of ultra-short laser pulses as a means for ultrafast manipulation of DW's, we carried out lateral- and element-resolved x-ray magnetic circular dichroism (XMCD) photoelectron emission microscopy (PEEM) experiments at BESSY II. The experiments focused on the influence of laser pulses with a wavelength of 800 nm and a duration of 60 fs on the magnetic domains in single-crystalline Co/Cu/Ni trilayers on Cu(001). We observe that even single laser pulses can induce significant depinning and motion of domain walls. This can be considered as a laser-induced variant of thermal domain wall fluctuation, which in the quasi-static case leads to thermal melting of magnetic domains. The experiment shows that single laser pulses can switch individual magnetic domains, without demagnetizing the whole sample.

Funding by the DFG (Ku 1115/11-1) is gratefully acknowledged.

MA 27.3 Wed 10:00 EB 301

Laser-induced ultrafast demagnetization of Co_2MnGa Heusler alloy probed by femtosecond XMCD in reflection geometry — •Sergej Solopow[1], Alexander Kronenberg[2], Martin Jourdan[2], Loic Le Guyader[1], Niko Pontius[1], Torsten Kachel[1], Hans-Joachim Elmers[2], Ilie Radu[1], and Alexander Föhlisch[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Strasse 15, 12489 Berlin, Germany — [2]Institut für Physik Johannes Gutenberg Universität, Staudingerweg 7, 55128 Meinz, Germany

Being equally a science- and technologically-driven topic, the research on ultrafast demagnetization dynamics has witnessed an intense activity over the past decades. However, its microscopic origin remains highly elusive and equally debated. In this context, the half-metallic Heusler alloys are particularly interesting due to their peculiar band structure i.e. they are metallic for majority electrons while exhibiting a band gap for the minority ones. Here we report on ultrafast demagnetization investigations of the Co_2MnGa alloy using time-resolved XMCD in reflection geometry at the slicing facility of BESSY II Berlin. Upon tuning the pumping wavelength from visible to near-IR we were able to photo-excite k-specific and spin-selective electronic states and thus to trigger a band structure-specific demagnetization dynamics. The subsequent optical and magnetic responses of the alloy have been recorded for both Co and Mn elements, showing an intriguingly fast dynamics.

MA 27.4 Wed 10:15 EB 301

Constant spin polarization of the Gd(0001) surface state during laser-induced ultrafast demagnetization — •Beatrice Andres[1], Marko Wietstruk[1], Cornelius Gahl[1], Jürgen Kirschner[2], and Martin Weinelt[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle

Yet, there is no theory that is capable to completely describe the dynamics in the electronic structure during laser-induced ultrafast demagnetization. However, recent approaches can reproduce the observed electronic binding energies on Gd [1] by assuming a disordering either of the $4f$ [2] or the $5d$ spin orientation [3] after laser irradiation.

To test the validity of these models, we perform spin- and time-resolved photoemission spectroscopy on Gd/W(110) with our amplified Ti:Sa laser system. Using 4 mJ/cm^2 of the fundamental (1.5 eV) as pump and the 4th harmonic (6 eV) as probe pulse, we directly measure the spin polarization and binding energy of the majority surface-state.

We observe a shift in binding energy that is in accordance with the decreasing exchange splitting of the $5d$ bands in Ref. [1]. In parallel, the spin polarization remains constant before spins and lattice equilibrate after several tens of picoseconds. This is in clear contrast to thermal heating where the surface state's spin polarization decreases, while the exchange splitting remains finite even above the Curie temperature.

[1] Robert Carley *et al.*, Phys. Rev. Lett. **109**, 057401 (2012)
[2] Leonid M. Sandratskii, Phys. Rev. B **90**, 184406 (2014)
[3] Björn Frietsch *et al.*, submitted, (2014)

MA 27.5 Wed 10:30 EB 301

Ultrafast Generation of Magnetic Ordering in a First Order Phase Transition — •Robert Carley[1], Sebastian Carron[6], Tyler Chase[4], Bruce Clemens[4], Georgi Dakovski[6], Eric Fullerton[5], Patrick Granitzka[4], Alexander Gray[3], Stefan Günther[2], Daniel Higley[4], Manuel Izquierdo[1], Emmanuelle Jal[3], Loic Le Guyader[7], Joel Li[4], Serguei Molodtsov[1], Mike Minitti[6], Ankush Mitra[6], Alexander Reid[3], William Schlotter[6], Vojtech Uhlir[5], Joachim Stöhr[3], Hermann Dürr[3], Christian Back[2], and Andreas Scherz[1] — [1]European XFEL, Hamburg, Germany — [2]Universität Regensburg, Germany — [3]SIMES, Stanford, California, USA — [4]Stanford University, California, USA — [5]University of California San Diego, USA — [6]LCLS, Stanford, California, USA — [7]HZB, Berlin, Germany

We report on recent experimental studies of the laser-driven antiferromagnetic (AFM) to ferromagnetic (FM) phase transition in FeRh using the time-, element-, and spatially resolving technique of resonant x-ray diffraction (tr-RXD) at the Fe L3 edge. FeRh undergoes a prototypical first order phase transition where the magnetization is the order parameter. The AFM to FM transition is accompanied by an isotropic lattice expansion. Time-resolved magneto-optical Kerr effect measurements suggest FM generation on sub-picosecond time scales, indicating an electronic process. In contrast, monitoring the lattice with time-resolved hard x-ray diffraction reveals nucleation and growth of FM regions on 10ps time-scales. This work aims to establish if the electronic system or the lattice drives the phase transition.

MA 27.6 Wed 10:45 EB 301

Ultrafast demagnetization in rare-earth alloys: the role of spin-orbit coupling — •Loic Le Guyader[1], Sergej Solopow[1], Radu Abrudan[1,2], Florin Radu[1], Karsten Holldack[1], Rolf Mitzner[1], Torsten Kachel[1], Niko Pontius[1], Alexander Föhlisch[1], and Ilie Radu[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Strasse 15, 12489 Berlin, Germany — [2]Institut für Experimentalphysik/Festkörperphysik, Ruhr-Universität Bochum, D-44780 Bochum, Germany

Understanding the ultrafast demagnetization occurring upon femtosecond laser excitation of a magnetic material is a fundamental problem of modern magnetism and its microscopic origin remains highly elusive and intensely debated. Particularly, the spin-orbit coupling mediating the spin-lattice interaction is one of the key ingredients. An intriguing case of tunable parallel to anti-parallel LS coupling can be realized in rare-earth (RE) alloys. For instance, Gd60Sm40 and Gd60Dy40 alloys have similar absolute S and L, but exhibit opposite LS coupling while displaying the same ferromagnetic ordering temperature of 250 K. They constitute thus an ideal case to investigate the particular role of the LS coupling on the ultrafast demagnetization. Here we report on the properties of such RE thin film alloys using X-ray Magnetic Circular Dichroism (XMCD) with the spin and orbit sum rules at M5,4 edges. Femtosecond time-resolved transmission XMCD measurements performed at the slicing beamline reveal the element-specific demagnetization time constant in these alloys. Funding from European Union through FEMTOSPIN is gratefully acknowledged.

15 min. break

MA 27.7 Wed 11:15 EB 301

Magnetostriction in Dysprosium studied by Ultrafast X-Ray diffraction — •Alexander von Reppert, Jan-Etienne Pudell, Flavio Zamponi, and Matias Bargheer — Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany

We use ultrafast x-ray diffraction to study the lattice dynamics of thin film samples of dysprosium across a large temperature range with different magnetic ordering. Dysprosium has a phase transition from a paramagnetic to the antiferromagnetic phase at $T_{\mathrm{Neel}} = 179$ K and becomes ferromagnetic below $T_{\mathrm{C}} = 86$ K. A strong magnetostriction resulting from the RKKY - interaction in dysprosium leads to an anomalous increase of the interatomic distance with decreasing temperature. In our experiments, we study the behaviour of the dysprosium lattice after direct excitation of the electronic system in the dysprosium layer, as well as after an indirect excitation through electron and heat transfer from an excited adjacent yttrium layer. At temperatures below the phase transition hot electrons can not only couple to the phonon system, leading to an expansive stress but also interact with the magnetic system. Exciting the magnetic system affects the lattice potential so that we observe a contraction of the dysprosium lattice on the picosecond timescale on the order of 0.1%, which can be attributed to a partial removal of the repulsive RKKY interaction. From the fluence- and temperature-dependence we can study details of the coupling of electrons, phonons and magnetic excitation to extract relevant timescales.

MA 27.8 Wed 11:30 EB 301

Time-resolved X-ray diffraction on dysprosium thin films — •Azize Koc[1], Matthias Reinhardt[1], Peter Gaal[1,2], Wolfram Leitenberger[3], and Matias Bargheer[1,3] — [1]Helmholtz Zentrum Berlin, BESSY II, Germany — [2]Institute for Nanostructure and Solid State Physics, University of Hamburg, Germany — [3]Institute of Physics and Astronomy, University of Potsdam, Germany

Dysprosium is a rare earth metal with a ferromagnetic (FM) phase below 86K and an antiferromagnetic (AFM) phase with a helical spin structure below 178 K [1].An important property of the antiferromagnetic phase is the negative thermal expansion coefficient due to magnetostrictive forces [2]. To investigate the structural changes and the interactions between electronic, phononic and magnonic degrees of freedom we use time-resolved X-ray diffraction at the XPP-KMC3 beamline at BESSY II.We feed energy into the conduction band electron system by excitation with 250 fs laser pulses at a central wavelength of 1030 nm.The structural response of the Dy thin film is measured with 100 ps time-resolution at temperatures from 100 K to 300 K and at various fluences. Above the AFM phase transition a fast lattice expansion according to the excitation of the phonon occurs (thermal expansion).Below the AFM phase transition a lattice contraction due to the rapid loss of the RKKY interaction is detected.We observe that the phonon system approaches equilibrium by heat conduction faster than 100 ns required to reestablish the antiferromagnetic order of the magnon system. [1] F.J. Darnell,Phys. Rev.,130,5 (1963) [2] M. Doerr, M. Rotter and A.Lindbaum, Adv. in Phy.,54:1, 1-66 (2005)

MA 27.9 Wed 11:45 EB 301

Ultrafast optical tuning of ferromagnetism in EuO via the carrier density — •Manfred Fiebig — Department of Materials, ETH Zürich, Vladimir-Prelog-Weg 4, 8093 Zurich, Switzerland

The interest in manipulating magnetic order by ultrashort laser pulses has thrived since it was observed that such pulses can be used to alter magnetization on a sub-picosecond timescale. In many cases demagnetization by laser heating dominates the dynamics; this is well described by the classic three-temperature model — assuming energy exchange between thermalized reservoirs of electrons, spins, and the lattice. Here we demonstrate a mechanism that allows the magnetic order of a material to be enhanced or attenuated at will. This is possible in systems simultaneously possessing a low, tunable density of conduction band carriers and a high density of magnetic moments. In such systems the thermalization time can be set such that adiabatic processes dominate the photoinduced change of the magnetic order — the three-temperature model is bypassed. In ferromagnetic $Eu_{1-x}Gd_xO$ we thereby demonstrate strengthening as well as weakening of the magnetic order by ∼10% and within ≤3 ps by optically controlling the magnetic exchange interaction. A theory backing up and expanding our experimental results will be presented.

MA 27.10 Wed 12:00 EB 301

Ultrafast demagnetization of a ferrimagnetic insulator driven by selective phonon excitation — •Sebastian Mährlein[1], Ilie Radu[2], Pablo Maldonado[3], Alexander Paarmann[1], Michael Gensch[4], Alexandra Kalashnikova[5], Roman Pisarev[5], Peter Oppeneer[3], Martin Wolf[1], and Tobias Kampfrath[1] — [1]FHI der MPG, Berlin — [2]HZB, Berlin — [3]Uppsala University, Sweden — [4]HZDR, Dresden — [5]Ioffe Institute, St. Petersburg, Russia

We present a novel pathway for ultrafast demagnetization of spin-ordered solids by resonant excitation of their crystal lattice, while leaving the electronic orbital degrees of freedom in their ground state. More precisely, the oxygen-iron phonon modes (around 19 THz) of the insulating ferrimagnet $Y_3Fe_5O_{12}$ (YIG) are excited using intense THz pump pulses (absorbed fluence 4 mJ/cm^2) from a femtosecond laser source and, complementarily, a free-electron laser. The resulting spin dynamics are magneto-optically probed over a wide range of time scales from 100 fs to 1 ms. We find a quenching of the magnetization by 3 % with a time constant as short as (1.2±0.2) ps, which recovers very slowly with a time constant on the order of 0.3 ms. The phonon-driven demagnetization observed is surprisingly fast, orders of magnitude faster than spin-lattice relaxation times in YIG. These findings indicate a highly efficient nonequilibrium energy transfer between the optical phonons and spins. Supported by *ab initio* calculations, we discuss possible microscopic mechanisms of the magnetization dynamics observed.

MA 27.11 Wed 12:15 EB 301

Mechanisms of ultrafast phonon-driven demagnetization of a ferrimagnetic insulator — •Pablo Maldonado[1], Sebastian Mährlein[2], Ilie Radu[3], Alex Paarmann[2], Michael Gensch[4], Alexandra M. Kalashnikova[5], Roman V. Pisarev[5], Martin Wolf[2], Tobias Kampfrath[2], and Peter M. Oppeneer[1] — [1]Uppsala University, Sweden — [2]Fritz Haber Institute of the Max Planck Society, Berlin — [3]Helmholtz-Zentrum Berlin BESSY II, Berlin — [4]Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [5]A.F. Ioffe Physical Technical Institute, St. Petersburg, Russia

We observe that the magnetization of the insulating ferrimagnet Y3Fe5O12 (YIG) is quenched following a resonant phonon excitation by a THz electromagnetic pulse. As electronic degrees of freedom are not excited, we expect that the complexity of the subsequent dynamics is considerably reduced as compared to ultrafast demagnetization of ferromagnetic metals. To gain more insight into microscopic processes leading to a phonon-driven demagnetization in YIG, we perform an ab initio study of the electronic structure and phonon modes of the system. We discuss possible microscopic mechanisms leading to ultrafast demagnetization, by considering two fundamental processes that couple lattice and magnetic order: i) direct coupling, where phonons decay into magnons through the spin-orbit coupling, and ii) phonon anharmonicities driving the system into a metastable state in which the structural changes trigger a modification of the orbital angular momenta.

MA 27.12 Wed 12:30 EB 301

Ferromagnetic relaxation in yttrium iron garnet at small wave vectors — •Julian Hüser and Tilmann Kuhn — Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

Shortly after the discovery of yttrium iron garnet (YIG) in 1956, a lot of investigations have been performed on this unique magnetic material which to the present has the smallest known ferromagnetic resonance line width. Thereby, a problem occured in explaining the very fast thermalization of pumped magnons in recent experiments in the field of Bose-Einstein condensation of magnons. This fast thermalization is typically interpreted as a multi-stage four-magnon scattering process. However, according to the standard derivation, the contribution of the four-magnon scattering to the relaxation of low energy magnons vanishes in the limit of zero wave vector and therefore this process is far too weak in order to account for thermalization at very small wave vectors where the minimal energy state is located.

In this work, we study the intrinsic relaxation mechanisms and present an additional contribution which has been neglected so far. We show that this contribution is strong enough to explain the experimentally observed fast magnon thermalization.

MA 27.13 Wed 12:45 EB 301

Modelling of laser induced magnetization dynamics at very high magnetic fields — •Unai Atxitia — Zukunftskolleg and Department of Physics, Konstanz, Germany

Recently constructed high magnetic field labs connected to femtosecond laser pulse experiments will permit the measurement of the ultrafast magneto-optical properties of magnetic materials, allowing access to yet unexplored regimes of ultrafast non-equilibrium magnetisation dynamics. However, theoretical models of laser induced magnetisation dynamics assume applied magnetic fields as a second order effect, since it is usually very small in comparison to the strong exchange interactions present in ferromagnets. Thus, current models are not capable of adequately describing the magnetisation dynamics in the presence of high magnetic fields. Therefore further theoretical work is necessary in this line. Here, we present the extension to high fields of the widely used Landau-Lifshitz-Bloch equation of magnetisation dynamics. Within this model we compare the magnetisation dynamics induced by a laser pulse at different magnetic fields, from 0 to 50 Tesla. We show that very high magnetic fields can not only quantitatively but also qualitatively change the magnetisation dynamics after the laser pulse. It is expected that the predictions made within this model can be soon experimentally checked.

MA 28: Bio-Magnetism (Magnetoreception)

Time: Wednesday 11:30–12:15 Location: H 0110

Invited Talk MA 28.1 Wed 11:30 H 0110
The Future of Magnetoreception Research in Animals — •Erich Pascal Malkemper — University of Duisburg-Essen, Faculty of Biology, Department of General Biology, Essen, Germany

Magnetoreception, the ability to sense the Earth's magnetic field, is widespread within the animal kingdom. Even though the sense is behaviourally proven to exist in birds, amphibians and mammals, the transduction mechanism remains a mystery. Two basic mechanisms have been proposed: A magnetic particle based mechanism (MPM) and a chemical mechanism based on radical pairs (RPM). In birds, both mechanisms seem to exist, perhaps complementing each other, while mammals seem to have either one or the other type. This has been concluded from a variety of straight forward behavioural experiments specifically addressed to narrow down the mode of magnetoreception. On the other side, histological evidence is ambiguous and often key findings are challenged several years later. Therefore, unravelling the magnetic sense is still a highly motivating field of research. In this talk, I will give an overview of the methods and findings regarding the mechanisms of magnetoreception in animals. I will discuss current problems, show up to date techniques and upcoming research directions.

MA 28.2 Wed 12:00 H 0110
Cattle under power lines - ELF MFs disturb magnetic alignment — •Sabine Begall[1], Pavel Němec[2], Erich Pascal Malkemper[1], and Hynek Burda[1] — [1]University of Duisburg-Essen, Dept. General Zoology, Essen, Germany — [2]Charles University in Prague, Faculty of Science, Prague, Czech Republic

Resting and grazing cattle tend to align their body axes in the geomagnetic North-South (NS) direction when being on flat pastures with no high-voltage power lines. In a follow-up study, we used aerial images provided by Google Earth to show that extremely low-frequency magnetic fields (ELFMFs) generated by high-voltage power lines disrupt alignment of the bodies of these animals with the geomagnetic field. Body orientation of cattle was random on pastures under or near power lines. Cattle exposed to alternating magnetic fields (AMF) directly under East-West trending power lines, exhibited a preference to orient their body axes parallel to the power lines and perpendicular to the resultant magnetic field, that oscillates between two intensity values (and two inclination values) but without changes in azimuth. In contrast, the alternating magnetic field vector of NS-oriented power lines is perpendicular to the horizontal component of the Earth's magnetic field lines, so that mainly the azimuth of the EMF is affected by the AMF, while intensity and inclination remain nearly constant. Under NS power lines, cattle tended to align their body axes along the NS axis, showing much higher scatter than controls (cattle on pastures without power lines). The disturbing effect of ELFMFs on body alignment attenuated with the distance from conductors.

MA 29: Spincaloric Transport II (jointly with TT)

Time: Wednesday 15:00–17:00 Location: H 0110

MA 29.1 Wed 15:00 H 0110
Interface spin polarization in FM/Pt bilayers investigated by XRMR — •Christoph Klewe[1], Timo Kuschel[1], Jan-Michael Schmalhorst[1], Markus Meinert[1], Florian Bertram[2], Olga Schuckmann[3], Joachim Wollschläger[3], Matthias Opel[4], Francesco Della Coletta[4], Stephan Geprägs[4], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Division of Synchrotron Radiation Research, Lund University, Sweden — [3]Physics Department, Osnabrück University, Germany — [4]Walther-Meißner-Institut, BAdW, Garching, Germany

We demonstrate the suitability of x-ray resonant magnetic reflectivity (XRMR) for investigations of proximity induced interface spin polarizations. This technique was currently used to exclude magnetic proximity effects in $NiFe_2O_4$/Pt bilayers [1] in order to confirm the longitudinal spin Seebeck effect in this system, free from Nernst effects.

Here, we present photon energy dependent XRMR measurements (P09, PETRA III, DESY; ID12, ESRF) at the Pt L_3-absorption edge on Fe/Pt, and further investigations on the systems $Ni_{0.33}Fe_{0.66}$/Pt, $Ni_{80}Fe_{20}$/Pt, Ni/Pt, Fe_3O_4/Pt, and $Y_3Fe_5O_{12}$/Pt. A detailed analysis of the observed reflectivity curves based on varying magnetic profiles at the Pt interface and a comparison with ab initio calculations provides an accurate spatial distribution and quantitative values of the induced magnetic moments per Pt atom. We find a correlation of the Pt spin polarization and the Fe content of the adjacent ferromagnet, while we see no evidence for proximity effects in $Y_3Fe_5O_{12}$/Pt.

[1] T. Kuschel et al., submitted 2014, arxiv: 1411.0113

MA 29.2 Wed 15:15 H 0110
Bias-enhanced tunnel magneto-Seebeck effect in Co-Fe-B/MgO-based magnetic tunnel junctions — •Marvin von der Ehe[1], Alexander Boehnke[2], Marius Milnikel[1], Ulrike Martens[1], Vladyslav Zbarsky[1], Karsten Rott[2], Andy Thomas[2], Michael Czerner[3], Günter Reiss[2], Christian Heiliger[3], and Markus Münzenberg[1] — [1]Inst. f. Phys., Universität Greifswald, Germany — [2]CSMD, Physics Dep., Bielefeld University, Germany — [3]I. Phys. Inst., Universität Giessen, Germany

In recent spincaloritronic research, several groups have observed the tunnel magneto-Seebeck effect (TMS) in magnetic tunnel junctions (MTJs) incorporating CoFe electrodes and MgO tunnel barriers [1,2].

Here, we present an approach of tuning the TMS effect by applying a DC bias voltage to the MTJ while a temperature gradient is generated by laser heating. We prepared Co-Fe-B/MgO/Co-Fe-B magnetic tunnel junctions that show high TMR ratios and observed Seebeck voltages of several microvolt, generated locally in the MTJ layers. Our experiments show that the resulting thermocurrent can be tuned to exhibit an on/off- switching when the magnetization configuration of the electrodes is changed from parallel to antiparallel and vice versa. Consequently, very high bias-enhanced TMS ratios are obtained. This behavior can be understood by the interplay of the TMS effect and the ohmic properties of the MTJs for small voltages. Funding by DFG SPP 1538 is acknowledged.

[1] Walter, M., et al. Nature Mater. 10, 742 (2011)
[2] Liebing, N., et al. Phys. Rev. Lett. 107, 177201 (2011)

MA 29.3 Wed 15:30 H 0110
Magnonic spin currents in ferro- and antiferromagnetic materials — •Denise Hinzke, Severin Selzer, Ulrike Ritzmann, Frank Schlieckeiser, and Ulrich Nowak — Fachbereich Physik, Universität Konstanz, 78457 Konstanz

Recent experiments show that applied temperature gradients can excite magnonic spin currents in ferromagnetic (FM) materials [1]. These experiments have raised the question of the role of the relevant length scales for these spin currents. We perform atomistic spin model simulations using the Landau-Lifshitz-Gilbert equation to calculate these characteristic length scales of magnon propagation in the vicinity of temperatures gradients. Our numerical findings are supported by analytical descriptions [2]. Extending our investigations to antiferromagnetic (AFM) materials we determined the frequency dependent magnon propagation length and also simulate magnon propagation due to thermal excitation. One of our findings is that an applied temperature gradient can excite magnons still transporting heat even if the expected spin current is zero. Furthermore, it was shown that the maximisation of entropy drives FM domain walls (DW) in temperature gradients [3]. We extend our former numerical and analytical investigations of DW motion caused by magnon excitation to AFM materials and compare with FM materials [3]. We acknowledge financial support by the DFG through SFB 767 and through SPP "Spin Caloric Transport". [1] K. Uchida et al, Appl. Phys. Lett. 97, 122505 (2010) [2] U. Ritzmann et al. Phys. Rev. B 89, 024409 (2014) [3] D. Hinzke and U. Nowak, Phys. Rev. Lett. 107, 027205 (2011)

MA 29.4 Wed 15:45 H 0110

Spin-wave propagation through a magnonic crystal in a thermal gradient — •Thomas Langner, Andrii V. Chumak, Alexander A. Serga, Burkard Hillebrands, and Vitaliy I. Vasyuchka — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern

Spin waves show a high potential to transport information in form of spin angular momentum. Magnonic crystals (MC), spin-wave waveguides with a periodic modulation of the magnetic properties, provide possibilities to code and process data in manifold ways. For the application of MC-based spin-wave devices it is of crucial importance to understand their behavior in thermally inhomogeneous surroundings since local heating might appear in real devices. We present studies on the dynamics of coherently excited spin waves in thermal gradients applied to a MC in form of an yttrium iron garnet (YIG) waveguide of varied thickness. We observe a broadening of the frequency bandgaps, the regions where spin-wave propagation is forbidden, as well as a decrease in the transmitted signal compared to the equilibrium temperature case. The mechanisms leading to these effects are discussed. The experimental results are accompanied by numerical calculations. A T-matrix formalism that includes the changes of the magnetic parameters induced by thermal gradients is used. We acknowledge financial support by the Deutsche Forschungsgemeinschaft (DFG) within priority program 1538 “Spin Caloric Transport“.

MA 29.5 Wed 16:00 H 0110

Magnetic field dependence of magnon accumulation in ferromagnets — •Ulrike Ritzmann, Denise Hinzke, and Ulrich Nowak — Universität Konstanz, Konstanz, Germany

In the last years it was shown that in a magnetic material spin currents are created by applying temperature gradients. This spin currents are due to a net magnon current that propagates from the hotter towards to cooler region of the magnetic material [1].

We perform atomistic spin model simulation with the stochastic Landau-Lifshitz-Gilbert equation for different temperature profiles to study magnon accumulation and magnonic spin currents and its characteristic lengthscales in ferromagnetic insulators [2]. Furthermore, we present simulations regarding the magnetic field dependence of the magnon propagation in linear temperature gradients, which allow to control the excited spin current and tune the frequency spectra of the involved magnons. The results show an increasing signal with increasing length of the system with a saturating behavior in agreement with experimental measurements [3]. On the other hand, we study the magnetic field dependence of the magnon accumulation and find a decreasing accumulation for increasing magnetic field. Both effects can be explained with the frequency distribution of the propagating magnons that are excited in the temperature gradient and its dependence on the system parameters. We acknowledge financial support by the DFG through SFB 767 and through SPP "Spin Caloric Transport".

[1] K. Uchida et al., APL 97, 172505(2010); [2] Ritzmann et al., PRB 89, 024409 (2014); [3] Kehlberger et al., arXiv:1306.0784

MA 29.6 Wed 16:15 H 0110

Longitudinal spin Seebeck effect contribution in transverse spin Seebeck effect experiments in Pt/YIG and Pt/NFO — •Daniel Meier[1], Daniel Reinhardt[1], Michael van Straaten[1], Christoph Klewe[1], Matthias Althammer[2], Michael Schreier[2], Sebastian T. B. Goennenwein[2], Arunava Gupta[3], Maximilian Schmid[4], Christian H. Back[4], Jan-Michael Schmalhorst[1], Timo Kuschel[1], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Walther-Meißner-Institut, BAdW, Germany — [3]MINT Center, University of Alabama, USA — [4]Department of Physics, University of Regensburg, Germany

We investigated the inverse spin Hall voltage generated in a 10 nm thin Pt strip deposited on the magnetic insulators $Y_3Fe_5O_{12}$ (YIG) and $NiFe_2O_4$ (NFO) with a temperature gradient in the film plane. We observed characteristics typical of the spin Seebeck effect (SSE), although we did not observe a change of sign of the voltage at the Pt strip when the direction of the heat flow was reversed, which is believed to be the most striking feature of the *transverse* SSE. Therefore, we relate the observed signals to the *longitudinal* SSE generated by a parasitic out-of-plane temperature gradient, which can be simulated by contact tips of different material and heat conductivities and by tip heating [1]. This work [2] gives new insights into the interpretation of transverse spin Seebeck effect experiments, which are still under discussion.

[1] D. Meier et al., Phys. Rev. B 88, 184425 (2013)
[2] D. Meier et al., arXiv:1411.6790 (2014)

MA 29.7 Wed 16:30 H 0110

Thickness and temperature dependent thin film thermal conductance of YIG — •Christoph Euler[1], Paulina Holuj[1,2], Andreas Kehlberger[1,2], Mathias Kläui[1,2], and Gerhard Jakob[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität mainz, Staudinger Weg 7, 55128 Mainz — [2]Graduate School of Excellence 'Materials Science in Mainz', Staudinger Weg 8, 55128 Mainz

Thin film YIG ($Y_3Fe_5O_{12}$) is commonly used in spin-caloritronics, as it is a prototype material for experiments on thermally generated pure spin currents and the spin Seebeck effect. However, bulk values of the thermal conductance are often used to determine temperature gradients even if the actual experimental geometry employs thin films. The 3ω method is an established technique to measure the cross-plane thermal conductance of thin films, but it is inapplicable in YIG/GGG ($Ga_3Gd_5O_{12}$) systems in its standard form. We use two-dimensional modeling of heat transport and introduce a technique based on Bayesian statistics to evaluate measurement data obtained from the 3ω method. This allows us to extract the temperature dependent thermal conductance of thin film YIG between room temperature and 10 K even for films in the hundreds of nanometer thickness range, which are of major importance for experiments in the field of spin-caloritronics. Moreover, our developed generic data evaluation scheme is suitable to analyze all thin film 3ω measurements, which have so far not been accessible for analysis using the 3ω method. We gratefully acknowledge financial support by DFG (Ja821/7-1) and (GSC 266).

MA 29.8 Wed 16:45 H 0110

Optically-Reconfigurable Dynamic Magnetic Materials for the Control of Spin Waves — •Marc Vogel[1], Andrii V. Chumak[1], Erik H. Waller[1], Thomas Langner[1], Vitaliy I. Vasyuchka[1], Burkard Hillebrands[1], and Georg von Freymann[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Str. 56, 67663 Kaiserslautern, Germany — [2]Fraunhofer-Institute for Physical Measurement Techniques IPM, Erwin-Schroedinger-Str. 56, 67663 Kaiserslautern, Germany

Spin waves - eigen excitations of the electrons' spin system - are of special importance nowadays due to the large potential for applications (e.g. processing, filtering or short-time storage of data). While all these applications rely on pre-defined constant structures, a dynamic variation of the structures opens access to novel physical phenomena and to novel applications. Here, we present the realization of such dynamic two-dimensional magnetic materials. By using laser light and a spatial light modulator, we reconstruct computer generated holograms on a ferrimagnetic yttrium iron garnet spin-wave waveguide. A black absorber (including carbon black nanoparticles) absorbs the light and creates thermal landscapes in the magnetic medium. The local change in temperature results in landscapes of the saturation magnetization. An acousto-optical modulator controls the temporal heating. Thus, the spin-wave characteristics can be controlled both in space and in time. The proposed fully-reconfigurable magnetic material is demonstrated using examples of one- and two-dimensional magnonic crystals.

MA 30: Magnetic Materials II

Time: Wednesday 15:00–17:00 Location: H 0112

MA 30.1 Wed 15:00 H 0112

Pure spin thermocurrents in Permalloy at high Temperatures
— •Marco Di Gennaro[1], Bin Xu[2], and Matthieu Verstraete[1] — [1]Department of Physics, University of Liege, B4000 Liege — [2]Physics Department and Institute for Nanoscience and Engineering, University of Arkansas, Fayetteville, Arkansas 72701, USA

We present a method for the calculation of spin dependent transport quantities in ferromagnetic metals based on an variational resolution of the semi-classical Boltzmann equation. The electron-phonon coupling is calculated ab-initio [1], explicitly considering two different spin channels and thermal expansion. The calculated Seebeck coefficient for magnetic Permalloy agrees with experimental data measured within a large temperature range. We also calculate the spin dependent Seebeck coefficient describing a build up of spin chemical potential under application of a temperature gradient. We find that a thermal gradient can produce a pure spin current in Permalloy at high temperatures.

[1] B. Xu and M. J. Verstraete, Phys. Rev. Lett. 112, 196603 (2014).

MA 30.2 Wed 15:15 H 0112

Finite-temperature magnetism and transport properties of FeRh
— •Sergiy Mankovsky[1], Svitlana Polesya[1], Kristina Chadova[1], Diemo Ködderitzsch[1], Jan Minar[1], Julie B. Staunton[2], and Hubert Ebert[1] — [1]Dept. Chemie/Physikalische Chemie, Universität München, Butenandtstr. 5-13, D-81377 München, Deutschland — [2]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom

The finite temperature magnetic properties of the FeRh compound with B2 structure have been investigated by performing first-principles electronic structure calculations in combination with Monte Carlo simulations. The central role of the temperature dependence of the interatomic exchange interactions for the AFM-FM phase transition at $\approx 340K$ is demonstrated, where the $J_{ij}(T)$ dependence is determined by the degree of magnetic order in the system. The finite temperature electric conductivity has been calculated using the scheme based on the alloy analogy model. Investigation of separate contributions to the electric conductivity shows explicitly the strongly dominating role of thermal spin fluctuations. The influence of impurities and intermixing between Fe and Rh sub-lattices on the magnetic and transport properties is investigated. The results are compared with the experimental data showing rather good agreement.

MA 30.3 Wed 15:30 H 0112

Effect of annealing on the magnetic state in Ni-doped FeRh alloys
— •Alisa Chirkova[1,2,3], Alexander Funk[1], Anja Waske[1], Konstantin Nenkov[1], Ludwig Schultz[1], Nikolai Baranov[2,3], and Thomas George Woodcock[1] — [1]IFW Dresden, Dresden, Germany — [2]Institute of Metal Physics, Yekaterinburg — [3]Ural Federal University, Yekaterinburg

FeRh alloys are known for the antiferromagnetic (AF) - ferromagnetic (FM) phase transition which takes place at about 360 K on heating; the crystal symmetry of CsCl-type (α') is retained. The transition temperature T_t can be changed by additions of other d-metals [1]; Ni shifts T_t down to about 150 K and at 2 at. % Ni only the FM state exists. Hydrostatic pressure raises T_t and in Ni-doped samples the effect is stronger. Depending on the cooling rate after long term annealing, either AF or FM states were produced in $(Fe_{0.965}Ni_{0.035})_{49}Rh_{51}$ samples at 2 K. Quenching produced the AF state, whereas cooling at 1 K/min resulted in the FM state. Microstructural analysis revealed the presence of retained high temperature γ phase. The γ phase is paramagnetic, Rh-rich (60 at.%) and contains twice as much Ni as α'. The quenched (AF) sample has 0.070 volume fraction of the γ phase against 0.035 in the slow-cooled (FM) sample which indicates that Ni content of the α' phase differs between the samples, thus explaining the different magnetic state. The possible additional effect of strain on the phase boundaries will also be considered.

[1] N.V. Baranov, E.A. Barabanova, J. Alloys Compd. 219 (1995) 139.

MA 30.4 Wed 15:45 H 0112

Structural and magnetic properties of $Fe_{11-x}Co_xTiCe$ intermetallic compounds
— •Dagmar Goll, Ralf Loeffler, Roland Stein, Ulrich Pflanz, Susanne Goeb, Roman Karimi, and Gerhard Schneider — Aalen University, Materials Research Institute (IMFAA), Aalen

Ce-based hard magnetic intermetallic compounds are currently undergoing a revival for potential low-cost permanent magnet applications due to the better abundance of Ce in the earth crust compared to Nd or Dy. One of these compounds is $Fe_{11}MCe$ (M: Ti, Mo, V, Cr) with tetragonal $Mn_{12}Th$ (12:1) structure and uniaxial anisotropy. The novel quaternary compound $Fe_{11-x}Co_xTiCe$ with Co content $x = 0$ to 3.25 (0 at% to 25 at%) has been fabricated by arc melting. The samples have been analyzed concerning their crystallographic structure and intrinsic magnetic properties as function of temperature using x-ray diffraction, domain pattern analysis and magnetometry. With increasing Co content the lattice structure becomes contracted and the Curie temperature T_C continuously increases from 468 K (0 at% Co) to 725 K (25 at% Co). The maximum values of the anisotropy constant K_1 and saturation polarization J_s are observed for a Co content of 15 at%. For about $x = 1.95$ (about 15 at% Co) K_1 and J_s are 2.15 MJ/m^3 and 1.27 T at room temperature and 1.22 MJ/m^3 and 1.05 T at 200 °C, respectively.

MA 30.5 Wed 16:00 H 0112

Electron-electron interaction strength in ferromagnetic nickel determined by spin-polarized positron annihilation
— •Hubert Ceeh[1], Josef-Andreas Weber[1], Michael Leitner[1], Liviu Chioncel[2], Dieter Vollhardt[2], Diana Benea[3], Peter Böni[1], Hubert Ebert[3], Jan Jan Minár[3], and Christoph Hugenschmidt[1] — [1]Technische Universität München, Physik Department, Lehrstuhl E21, James-Franck-Straße, D-85748 Garching, Germany — [2]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D-86135 Augsburg, Germany — [3]Chemistry Department, University Munich, Butenandstraße 5-13, D-81377 München, Germany

Spin resolved positron annihilation measurements using the angular correlation of annihilation radiation technique have been performed on ferromagnetic Ni. The analysis is based on a direct comparison of the experimentally obtained projections of the momentum density and state-of-the-art dynamic mean-field calculations. The experimental data were best described for a value of 2.0 eV for the on-site repulsion term U in the Hubbard model. We show that spin-polarized 2D-ACAR, where probe effects of the positron can be avoided, is a powerful tool to investigate the electronic structure of ferromagnetic systems.

MA 30.6 Wed 16:15 H 0112

Large magnetic anisotropy in $LaCo_{5-x}$
— •Christoph Schwöbel[1], Konstantin Skokov[1], Michael Kuzmin[2], and Oliver Gutfleisch[1,3] — [1]TU Darmstadt, Germany — [2]IM2NP, Marseille, France — [3]Fraunhofer IWKS, Hanau, Germany

One focus in the search for new hard magnetic materials are compounds which exhibit a large magneto-crystalline anisotropy as the anisotropy field represents the upper limit for the potential coercive field in a permanent magnet. Materials which crystallize in a hexagonal structure like the $CaZn_5$-structure can exhibit an easy axis along the c-direction with a relatively high anisotropy field. The investigated $LaCo_5$ system is particularly interesting as the magnetic moment comes solely from the Co atoms. Therefore it is possible to gain further insight on the magnetism of this 3d element.
Single crystals with a substoichiometric composition of $LaCo_{5-x}$ were grown and investigated. The measurements were performed up to 14 T at different temperatures. Anisotropy fields larger than 20 T were extrapolated.

MA 30.7 Wed 16:30 H 0112

Giant magnetic anisotropy and quantum tunneling of the magnetization in $Li_2(Li_{1-x}Fe_x)N$
— •Anton Jesche[1] and Paul C. Canfield[2] — [1]Zentrum für Elektronische Korrelationen und Magnetismus, Universität Augsburg, 86135 Augsburg, Germany — [2]Ames Laboratory, Iowa State University, Ames, Iowa 50011, USA

The magnetic anisotropy of 3d transition metals is usually considered to be weak. Main reason is the widely known paradigm of orbital quenching. However, a rare interplay of crystal electric field effects and spin-orbit coupling causes a large orbital contribution to the magnetic moment of iron in $Li_2(Li_{1-x}Fe_x)N$. This leads not only to large magnetic moments of $\sim 5\,\mu_B$ per iron atom but also to an enormous magnetic anisotropy field that extrapolates to more than 200 Tesla [1]. Magnetic hysteresis emerges for $T < 50$ K and the coercivity fields of more than 11 Tesla exceed even the hardest 4f electron based ferromagnets.

$Li_2(Li_{1-x}Fe_x)N$ not only has a clear and remarkable anisotropy, generally not associated with iron moments, but also shows time-dependence more consistent with molecular magnets. In particular for low iron concentrations $x \ll 1$ the spin-inversion is dominated by a macroscopic tunneling process rather than by thermal excitations.

It is shown that the huge magnetic anisotropy makes $Li_2(Li_{1-x}Fe_x)N$ (i) an ideal model system to study macroscopic quantum effects at elevated temperatures and (ii) a basis for novel magnetic functional materials.

[1] A. Jesche *et al.* Nature Commun. 5:3333 (2014)

MA 30.8 Wed 16:45 H 0112

Magnetic anisotropy manipulation in Ni nanostructures fabricated on VO_2 (100) thin films imaged by time-resolved high resolution x-ray microscopy across the phase transition — •Simone Finizio[1], Mehran V. Khanjani[1], Andrea Fantini[1,2], Michael Foerster[3], Simone Altendorf[2,4], Donata Passarello[2], Lucia Aballe[3], Stuart S.P. Parkin[2], and Mathias Kläui[1] — [1]Institut für Physik, Universität Mainz, Mainz, Germany — [2]IBM Almaden Research Center, San Jose, CA, USA — [3]ALBA Synchrotron Light Source, Cerdanyola del Valles, Spain — [4]Max Planck Institute for Microstructure Physics, Halle, Germany

Due to the possibility to generate strain variations on ultra-short timescales, the metal-insulator-transition (MIT) in VO_2 is of particular interest for the study of the dynamics involved in the magnetostrictive coupling. In particular, strain can be manipulated in conventional piezoelectric materials only on slow timescales (<GHz), while here fast strain variations result from the MIT, which occurs on the ps timescale.

In this contribution, we will present x-ray magnetic microscopy imaging of Ni nanostructures fabricated on VO_2 (100) thin films deposited by pulsed-laser-deposition on TiO_2 (100) substrates upon crossing the MIT of the VO_2. Due to strain change when crossing the MIT, strong changes in the magnetic anisotropy of the Ni nanostructures were observed, which changed from a low temperature uniaxial-anisotropy dominated state to a high temperature shape-anisotropy dominated state.

MA 31: Focus: Ultra-fast magnetism under electronic nonequilibrium conditions

Organizers: U. Bovensiepen (U. Duisburg-Essen), Martin Eckstein (U. Hamburg), M. I. Katsnelson (U. Nijmegen)

Rapid control of magnetism is of high technological relevance for ultra-fast magnetic storage [Kirilyuk et al., RMP 82, 2731 (2010)]. Because the magnetic order emerges from electronic correlations, magnetism control can be pushed to the extreme time limit with ultra-short laser pulses that bring the electronic state out of equilibrium. For example, recent photoemission studies resolve the dynamics of the exchange splitting in ferromagnetic Gadolinium [Carley et al., PRL 109, 057401 (2012)], and photo-induced phase transitions are possible in materials with coupled orbital and spin order [Wall et al., PRL 103, 097402 (2009)]. When electrons are driven out of equilibrium, the magnetic exchange interaction itself can be manipulated by ultrafast carrier (photo) doping or by dressing the electronic states with light. On the theory side, recent developments like nonequilibrium dynamical mean-field theory [Aoki et al., RMP 86, 779 (2014)] allow to investigate electronic correlations in magnetically ordered systems out of equilibrum. This session will highlight recent experimental and theoretical developments which provide an understanding for the dynamics of magnetism in a regime where separation of slow spin and fast electron dynamics is no longer valid.

Time: Wednesday 15:00–17:45 Location: H 1012

Invited Talk MA 31.1 Wed 15:00 H 1012

Ultrafast optical tuning of ferromagnetism in EuO via the carrier density — •Manfred Fiebig — ETH Zürich, Department of Materials, Vladimir-Prelog-Weg 4, 8093 Zurich, Switzerland

The interest in manipulating magnetic order by ultrashort laser pulses has thrived since it was observed that such pulses can be used to alter magnetization on a sub-picosecond timescale. In many cases demagnetization by laser heating dominates the dynamics; this is well described by the classic three-temperature model — assuming energy exchange between thermalized reservoirs of electrons, spins, and the lattice. Here we demonstrate a mechanism that allows the magnetic order of a material to be enhanced or attenuated at will. This is possible in systems simultaneously possessing a low, tunable density of conduction band carriers and a high density of magnetic moments. In such systems the thermalization time can be set such that adiabatic processes dominate the photoinduced change of the magnetic order — the three-temperature model is bypassed. In ferromagnetic $Eu_{1-x}Gd_xO$ we thereby demonstrate strengthening as well as weakening of the magnetic order by $\sim$10% and within $\leq$3 ps by optically controlling the magnetic exchange interaction. A theory backing up and expanding our experimental results will be presented.

Invited Talk MA 31.2 Wed 15:30 H 1012

Intra-atomic exchange in ultrafast magnetism — •Martin Weinelt — Freie Universität Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin, Germany

The exchange interaction is the defining element in the formation of magnetic order in atoms and solids. Therefore the role of intra- and interatomic exchange during ultrafast magnetization dynamics needs to be explored. In the atomic magnetism of lanthanide metals localized $4f$ and itinerant $5d$ orbitals contribute to the overall magnetic moment. In general it is assumed that the intra-atomic exchange coupling is fast enough to be treated as an instantaneous process. We studied the magnetization dynamics of the lanthanide metals gadolinium [1] and terbium by time-resolved photoemission employing femtosecond higher-order harmonic vacuum-ultraviolet pulses. Recording in parallel $4f$ magnetic linear dichroism and $5d$ exchange splitting we observe distinct spin dynamics in Gd, which show the breakdown of the intra-atomic exchange upon femtosecond laser excitation. An orbital-resolved Heisenberg model [2] explains well the state-dependent two timescales of magnetization dynamics in Gd metal, which differ by one order of magnitude. Due to its much stronger spin-lattice coupling, Tb shows a distinctly different magnetization dynamics.

[1] Robert Carley *et al.*, Phys. Rev. Lett. **109** (2012) 057401.
[2] Soenke Wienholdt *et al.*, Phys. Rev. B **88** (2013) 020406(R).

15 min. break

Invited Talk MA 31.3 Wed 16:15 H 1012

Laser induced ultrafast demagnetization in solids: a time-dependent density functional theory perspective — •Sangeeta Sharma, J. K. Dewhurst, K. Krieger, P. Elliott, and E. K. U. Gross — Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany.

Ultrafast manipulation of spins in a controlled manner is a milestone of solid state physics. The motivation for this is to use electronic spin for storing binary data, which can then be optically manipulated using lasers. Recent experiments have demonstrated that demagnetization or spin-reorientation processes can be induced by femtosecond laser pulses. However, we are still far from achieving optimally controlled manipulation of spins required for production of devices. One of the reasons behind this is the lack of full understanding of the phenomena leading to demagnetization.

Time-dependent density functional theory (TDDFT) is a formally exact method for describing the real-time dynamics of electrons under the influence of an external field – for example vector potential of the intense laser pulse. We use spin-resolved TDDFT to study of the process of optical demagnetization. The advantage of such a technique is clear from the fact that it is fully ab-initio in nature. Our analysis shows that the demagnetization occurs as a two step process where first the electrons make transitions to excited states, followed by spin-orbit-mediated spin-flip transitions which lead to a loss of moment. Non-collinearity of the spins does not play significant role in the demagnetization process.

Invited Talk MA 31.4 Wed 16:45 H 1012

Ultrafast control of the exchange interaction with electric fields — •Johan H. Mentink — Max Planck Research Department for Structural Dynamics, University of Hamburg-CFEL, 22761 Hamburg, Germany — Radboud University Nijmegen, Institute for Molecules and Materials, Heyendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

The strongest interaction between microscopic spins in magnetic materials is the exchange interaction $J_{\rm ex}$. Therefore, ultrafast control of $J_{\rm ex}$ keeps the promise to control spins on ultimately fast timescales, potentially bypassing fundamental speed limits for the control of magnetism with magnetic fields. In this talk we provide theoretical evidence that the exchange interaction can be manipulated on ultrashort timescales by strong electric field pulses. Focusing on the prototype Mott-Hubbard insulator, we find very different effects for resonant and off-resonant photo-excitation. In the former case, the electron distribution is changed and the subsequent relaxation of photo-excited carriers causes an ultrafast reduction of $J_{\rm ex}$. Conversely, off-resonant driving allows for an ultrafast and reversible control of $J_{\rm ex}$, *i.e.*, it is active while the field is on, but leaves the electronic state unexcited after the pulse is switched off. In the regime of weak-driving strength the modification of $J_{\rm ex}$ is proportional to the intensity of the electric field and we find that $J_{\rm ex}$ can be enhanced and reduced for frequencies below and above gap, respectively. Furthermore, for strong driving even the sign of the exchange interaction can be reversed and we show that this causes time reversal of the associated quantum spin dynamics.

Invited Talk MA 31.5 Wed 17:15 H 1012

Controlling, probing and harnessing the strongest force in magnetism — •Alexey Kimel — Radboud University Nijmegen, Institute for Molecules and Materials, 6525 AJ Nijmegen, The Netherlands

The idea to change magnetic properties of media with the help of light has long intrigued people in physics and chemistry. Naturally, this raises the question about the speed limit of the optical control of magnetism. Fundamentally, magnetic order is a macroscopic manifestation of a quantum mechanical exchange coupling between spins. This exchange coupling represents the largest interaction in magnetism. It can be associated with an effective magnetic field of 100-1000 T. The strength can be appreciated from the fact that magnetic order in condensed matter survives well above room temperature. Obviously, harnessing the exchange interaction is the way to achieve the ultimately fastest magnetic switching. How can we control, probe and harness the exchange interaction for ultrafast magnetic switching? Here we demonstrate that the exchange interaction can be manipulated through ultrafast laser excitation in a large class of transition metal oxides. We show that using ultrashort laser pulses one can monitor laser-induced dynamics of the energy of the exchange interaction with subpicosecond temporal resolution. Finally, we suggest a scenario in which the strength of the exchange interaction is employed to achieve the fastest possible magnetic switching.

MA 32: Spin Structures and Magnetic Phase Transitions

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

MA 32.1 Wed 15:00 EB 202

Magnetic phase transition and anisotropy in Mn_3GaC — •Moritz Riebisch, Mehmet Acet, Ralf Meckenstock, Horst Zähres, and Michael Farle — Universität Duisburg-Essen, Fakultät für Physik, AG Farle

A new setup for temperature and frequency dependent magnetic resonance measurements at high magnetic fields up to 12 T was built to study the field-induced magnetic phase transition and transitional hysteresis of the antiperovskite compound Mn_3GaC. The magnetic phase transition at $T_t \approx 165$ K of a powdered sample of Mn_3GaC was studied with temperature dependent FMR at 9.2 GHz. A field-hysteresis between 160 and 145 K in the FMR measurements indicates the field-induced transition between the antiferromagnetic ground state and the ferromagnetic phase. In the ferromagnetic phase, aligned and non-aligned resonance modes are measured as a function of temperature and frequency. Frequency dependent measurements yield an estimation of the magnetocrystalline anisotropy. The value of K4 is in the order of $-100\mathrm{kJ/m^3}$ at $T = 176\,\mathrm{K}$.
Financial support by DFG is acknowledged.

MA 32.2 Wed 15:15 EB 202

Spin freezing and spin dynamics in the re-entrant spin glass $Cr_{1-x}Fe_x$ — •Steffen Säubert[1,3], Georg Benka[1], Jonas Kindervater[1], Andreas Bauer[1], Julia N. Wagner[4], Wolfgang Häussler[3], Olaf Holderer[3], Stephen M. Shapiro[5], Christian Pfleiderer[1], and Peter Böni[2] — [1]Lehrstuhl für Topologie korrelierter Systeme, Technische Universität München, Garching, Germany — [2]Lehrstuhl für Neutronenstreuung, Technische Universität München, Garching, Germany — [3]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Garching, Germany — [4]Karlsruher Institute for Technology, IAM-WK, Eggenstein-Leopoldshafen, Germany — [5]Brookhaven National Laboratory, Department of Physics, Upton, USA

$Cr_{1-x}Fe_x$ shows reentrant spin glass behaviour as the ground state changes from antiferromagnetic to ferromagnetic order with increasing iron concentration x [1, 2]. We report magnetisation measurements, neutron depolarisation imaging (NDI) and neutron resonance spin-echo (NRSE) spectroscopy for a wide range of concentrations x. Our measurements provide an unprecedented combination of microscopic information on the spin dynamics and spin freezing on multiple length and time scales.

[1] S. K. Burke et al., J. Phys. F: Met. Phys. **13** (1983) 45 1-470
[2] S. M. Shapiro et al., Phys. Rev. B **24** (1981), 6661

MA 32.3 Wed 15:30 EB 202

Quantum-mechanical study of clean and segregated Σ5(210) grain boundaries in Ni_3Al — •Martin Friák[1,2], Monika Všianská[2,1], and Mojmír Šob[2,1,3] — [1]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Brno, Czech Republic — [2]Central European Institute of Technology, CEITEC MU, Masaryk University, Brno, Czech Republic — [3]Department of Chemistry, Faculty of Science, Masaryk University, Brno, Czech Republic

Grain boundaries (GBs) represent an important class of two-dimensional extended defects and macroscopic strength of polycrystalline materials depends strongly on their cohesion. It is known that impurities in ppm concentration can drastically change material properties. After our previous study of segregation trends of sp elements in Ni [1], we extend our research to a binary intermetallic compound, Ni_3Al. We employ quantum-mechanical methods to study the energetics, magnetism, segregation and strengthening/embrittling tendencies at the Σ5(210) GB. We simulate two different interface stoichiometries of the clean Ni_3Al Σ5(210) GB and that one with both Ni and Al atoms present at the interface is found to have a lower energy than that with only Ni atoms. For Si, Ga, Ge, As, Se, In, Sn, Sb and Te segregated to Ni_3Al Σ5(210) GB and free (210) surfaces, we perform the relaxation of the geometric configurations with and without impurities and analyze the effect of impurities on the distribution of magnetic moments.
[1] M. Všianská and M. Šob, Prog. Mat. Sci. 56 (2011) 817, and Phys. Rev. B 84 (2011) 014418.

MA 32.4 Wed 15:45 EB 202

Neutron study of the field-dependant spin structure of nanocrystalline and coarse-grained holmium — •Daniel Kaiser[1], Philipp Szary[1], Jens-Peter Bick[1], Andre Heinemann[2], Charles Dewhurst[3], and Andreas Michels[1] — [1]Physics and Materials Science Research Unit, University of Luxemburg — [2]HZG, Geesthacht, Germany — [3]Institute Laue-Langevin, Grenoble, France

We present the results of magnetic-field-dependant small-angle neutron scattering (SANS) measurements on nanocrystalline (nc) and coarse-grained (cg) polycrystalline holmium. At 50 K, single-crystalline holmium exhibits a series of complicated spin structures with increasing applied magnetic field, ranging from a simple antiferromagnetic helix, to a helifan-3/2, to a fan, and finally to a ferromagnetic structure. While the transitions between these different structures are discrete in the defect-free single-crystalline case, we observe for nc and cg holmium the emergence of periodic structures with a continuously changing wavelength. Moreover, a superposition of several structures at the same field was found for both materials.

MA 32.5 Wed 16:00 EB 202

Structural, magnetic and magneto-optical properties of Mn2NiSn and Fe-Ni-Sn compounds — Michaela Tomíčková[1], Lukáš Beran[2], Petr Cejpek[2], Jaromír Kopeček[3], Oleg Heczko[3], Dominik Legut[1], Rastislav Varga[4], Václav Holý[2], Martin Veis[2], and •Jaroslav Hamrle[1] — [1]VSB-Technical University of Ostrava, Czech Republic — [2]Charles University in Prague, Czech Republic — [3]Institute of Physics, ASCR, Prague, Czech Republic — [4]UPJŠ Košice, Slovakia

Heusler compounds are well-known as exceptionally tunable materials by suitable element substitution. Here we present study of structural (XRD, SEM, EDX), magnetic (SQUID) optical and magneto-optical (ellipsometry, MOKE spectroscopy) properties of Mn_2NiSn cubic Heusler and Fe-Ni-Sn hexagonal compounds. Physical properties were studied with respect to the material composition and post deposition treatment. The samples were prepared by repeated arc melting of stoichiometric amounts of high-purity elements in argon atmosphere. Selected alloys were then subsequently annealed at 1200°C, however effect of annealing was found negligible. In case of Fe-Ni-Sn, only hexagonal ($P6_3/mmc$) $Fe_2Ni_3Sn_3$ was found to exhibit ternary phase. Spectral dependencies of complete permittivity tensor of studied materials in the photon energy range from 1.5 to 5 eV were deduced from ellipsometric and MOKE measurements. These dependencies were confronted with ab-initio calculations to obtain the information about the electronic structure of studied compounds. Supported by Grant Agency of Czech Republic 13-30397S.

15 min. break

MA 32.6 Wed 16:30 EB 202

Reversible processes in minor loop hysteresis at the first-order magnetostructural transition in NiMn*X* (*X*=In, Sn) — •Franziska Scheibel[1], Tino Gottschall[2], Michael Farle[1], and Mehmet Acet[1] — [1]Faculty of Physics and CENIDE Universität Duisburg-Essen, Duisburg, Germany — [2]Material Science Technische Universität Darmstadt, Darmstadt, Germany

One key factor for efficient magnetic refrigeration is the reversibility of the adiabatic temperature-change ΔT when the external magnetic field is reversed. Even if ΔT is large in the range of a first-order magnetostructural transition (FOMST), the thermal hysteresis of the transition can limit its reversibility [1-2]. Materials with sufficiently narrow thermal hysteresis shows a reversible ΔT in a minor loop of the transition. NiMnX (X=Sn, In) Heusler alloys show a FOMST from a low temperature martensite state with low magnetization to a high temperature austenite state with a higher magnetization. The transition temperatures are around room temperature and the hysteresis is smaller than 10 K. To understand the reversible processes in the minor loops adiabatic ΔT and magnetostriction been measured simultaneously in an externally applied field up to 5 T. The magnetostriction behavior of the material is directly related to the volume ratio of matrensite- to austenite phase.

Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).

[1] I. Titov et al., J. Appl. Phys. **112**, 073914 (2012)
[2] J. Liu et al., Nature Materials **11**, 620-626 (2012)

MA 32.7 Wed 16:45 EB 202

Hydrostatic Pressure Investigation on the Magnetic and Structural Properties of the Quantum-Spin-Chain CuAs2O4 — •Kevin Caslin[1], Reinhard Kremer[1], Karl Syassen[1], Fereidoon Razavi[2], Michael Hanfland[3], Mike Whangbo[4], and Elijah Gordon[4] — [1]Max Planck Institute Stuttgart — [2]Brock University — [3]ESRF — [4]North Carolina State University

$CuAs_2O_4$ (Trippkeite) is a S =1/2 quantum-spin-chain system with competing ferromagnetic nearest-neighbor (NN) and antiferromagnetic next-nearest-neighbor (NNN) spin-exchange interactions which undergoes long-range ferromagnetic ordering below 7.4 K. We have investigated the pressure dependence of the magnetic and structural properties of the $CuAs_2O_4$ by single-crystal synchrotron x-ray diffraction, Raman spectroscopy and SQUID magnetometry under hydrostatic pressure. Precise structural parameters gained from the single crystal x-ray structure determination under hydrostatic pressure have been used for detailed density functional calculations of the spin-exchange interactions. Furthermore, we have correlated the spin-exchange constants to the magnetic properties measured under hydrostatic pressure. Up to approximately 9 GPa we observe a significant reduction of the Jahn-Teller elongations of the distorted CuO_6 octahedra. Above approximately 9 GPa a structural phase transition occurs which leads to modifications of the crystals structure driving both NN and NNN spin-exchange constants to the ferromagnetic regime, thus, removing the magnetic frustration.

MA 32.8 Wed 17:00 EB 202

Photoluminescence monitoring of magnetic phase transitions in CuB_2O_4 — •Dennis Kudlacik[1], Jörg Debus[1], Roman V. Pisarev[2], Dmitri R. Yakovlev[1,2], and Manfred Bayer[1,2] — [1]Experimentelle Physik 2, TU Dortmund, Dortmund, Germany — [2]Ioffe Physical-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia

Copper metaborate CuB_2O_4 comprises two sublattices with different magnetic orderings. At low temperatures below $T_N = 21K$, CuB_2O_4 demonstrates an antiferromagnetic ordering and a rich magnetic phase diagram with several phase transitions [1]. Commensurate and incommensurate magnetic orderings are observed as a result of intra-sublattice and inter-sublattice mutual interactions. The study of these interactions for the various magnetic phases of the sublattices shall provide highly promising insights into properties of different kinds of collective spin interactions. In that context, we report on the monitoring of the magnetic phase transitions via photoluminescence (PL). The intensity, linewidth as well as energy of the sublattice PL indicate changes in the magnetic ordering. Hereby, not only the ambient temperature but also the optical pumping intensity can induce a magnetic phase transition. During the decay time of the 4b-sublattice PL of several hundreds of μs, the magnetic phase transitions could be followed in the time domain highlighting the dynamics between the spin, electron and phonon systems.

[1] R. V. Pisarev et al., Phys. Rev. B 88, 024301 (2013).

MA 32.9 Wed 17:15 EB 202

High-frequency electron spin resonance studies on the antiferromagnetic phase of $A_3Ni_2SbO_6$ (A = Li, Na) — Jaena Park[1], •Changhyun Koo[1], Michael Tzschoppe[1], Maria A. Evstigneeva[2], Vladimir B. Nalbandyan[2], Elena A. Zvereva[3], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Heidelberg, Germany. — [2]Chemistry Faculty, Southern Federal University, Rostov-na-Donu, Russia. — [3]Faculty of Physics, Moscow State University, Moscow, Russia.

High-frequency electron spin resonance (HF-ESR) and static magnetization studies have been used to study the antiferromagnetically ordered phase in the layered honeycomb antimonates $A_3Ni_2SbO_6$ (A = Li, Na). Antiferromagnetic resonance (AFMR) branches are observed below Neel temperature of both compounds, 15 K and 17 K, respectively, and the frequency-magnetic field phase diagram of the AFMRs is constructed. Above the Neel temperature, all AFMR branches merge to a single resonance mode. The frequency field diagram allows reading off the zero-field splitting which amounts to about 200 GHz and 360 GHz, respectively. The spin-flop field is extracted both from the static magnetization and the AFMR data. Analyzing the AFMR modes by means of spin wave theory provides estimates of the exchange field and of the magnetic anisotropy in the antiferromagnetic phase of both compounds.

MA 32.10 Wed 17:30 EB 202

Magnetic properties of a new phase of $MnSb_2O_6$ — •Johannes

Werner[1], Michael Tzschoppe[1], Changhyun Koo[1], Vladimir B. Nalbandyan[2], Alexey Yu. Nikulin[2], Elena A. Zvereva[3], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg University, Heidelberg, Germany — [2]Chemistry Faculty, Southern Federal University, Rostov-na-Donu, Russia — [3]Moscow State University, Moscow, Russia

Magnetic properties of a new, layered, trigonal ($P\overline{3}1m$) form of $MnSb_2O_6$ were investigated by means of magnetic susceptibility and high-frequency electron spin resonance (HF-ESR) measurements. The magnetic susceptibility at high temperatures follows the Curie-Weiss law, with a Weiss temperature of $\Theta = -17$K, indicating antiferromagnetic interactions. Indeed, long range antiferromagnetic order appears at T_N = 9K. In addition, the data imply weak ferromagnetism below T_1 = 41.5K. Based on the magnetic susceptibility and specific heat data the magnetic phase diagram of the new $MnSb_2O_6$ form is constructed. The spin-flop field of 1T in the antiferromagnetically ordered phase signals only a small anisotropy which is confirmed by our HF-ESR data. In addition, there is a phase boundary in the non-spin-flopped phase separating two regions of antiferromagnetic order. At this boundary, there are only negligible entropy changes. In HF-ESR, the antiferromagnetic resonance mode is observed and spin wave theory is applied to model the results.

MA 33: Multiferroics II (DF with DS/KR/MA/TT)

Time: Wednesday 15:00–18:50 Location: EB 107

Invited Talk MA 33.1 Wed 15:00 EB 107

Low energy consumption spintronics using multiferroic heterostructures — •Morgan Trassin — ETH Zurich, Zurich, Switzerland

Magnetization reversal in spintronics applications requires either an externally applied magnetic field or a large current density, which is accompanied by significant energy dissipation. A reversal of magnetization induced only by the application of an electric field would lead to low-power devices. Using multiferroics, previous approaches have seen limited success by only achieving rotations of the magnetization or a change in anisotropy by applying an electric field. To pave the way to new low-power devices, the more desirable electric-field driven magnetization reversal must be achieved and read out with a small current. In multiferroic heterostructures, ferromagnetic domains can be moved and switched using different charge states, strain configurations or magnetoelectric coupling. Ferroelectric domain engineering using epitaxial strain is critical towards the achievement of deterministic switchings. A combination of scanning probe microscopy and optical second harmonic generation were used to characterize multiferroic thin films strain state. Using electron microscopy and transport based techniques, a room temperature magnetization reversal of a CoFe thin layer solely induced by the application of a few volts to the heterostructure will be described.

MA 33.2 Wed 15:30 EB 107

Probing ferroic order in thin film heterostructures with optical second harmonic generation — •Gabriele De Luca, Manfred Fiebig, and Morgan Trassin — ETH Zurich, Switzerland

The evidence of the electric field control on the antiferromagnetic ordering in multiferroic bismuth ferrite ($BiFeO_3$) [1] increased interest in low energy consumption logic and memory devices. However, to exploit such functionality for devices it is essential to attain deterministic control of ferromagnetism at the single domain scale. Therefore a ferromagnet/multiferroic heterostructure has been designed based on the combination of magnetoelectric coupling in $BiFeO_3$ (BFO) and exchange coupling between magnetic materials thus offering a new pathway for the electrical control of magnetism [2,3]. Here we show that second harmonic generation (SHG), can detect the distribution of ferroelectric domains in BFO thin films non-invasively and unimpeded by transport properties. We use epitaxial strain for engineering different types of BFO domain patterns that are characterized by SHG, showing a unique relation between the domain distribution and the film symmetry. We then manipulate the BFO film by voltage poling and demonstrate the sensitivity of the SHG process to this manipulation. The concept applied to BFO is transferable to other multiferroics compounds thus indicating the general feasibility of SHG as a characterization technique for heterostructures in which buried ferroelectricity plays a key role in the emergence of magnetoelectric coupling. 1.Zhao et al., Nat. Mat. 5, 823 (2006) 2.Heron et al., Phys. Rev. Lett. 107, 217202 (2011) 3.Trassin et al., Phys. Rev. B 87, 134426 (2013)

MA 33.3 Wed 15:45 EB 107

Investigation of the antiferromagnetic coupling at $SrRuO_3$ / $La_{0.7}Sr_{0.3}MnO_3$ interfaces — •Sujit Das[1,2], Diana Rata[1], Andreas Herklotz[3], Er Jia Guo[4], Robert Roth[1], and Kathrin Dörr[1,2] — [1]Institute for Physics, MLU Halle-Wittenberg, 06099 Halle, Germany — [2]IFW Dresden, Postfach 270116, 01171 Dresden, Germany — [3]Oak Ridge National Lab., Oak Ridge, 37830 TN, USA — [4]Affiliation: Institute for Physics, Johannes-Gutenberg University Mainz, 55128 Mainz, Germany

$La_{0.7}Sr_{0.3}MnO_3/SrRuO_3$ superlattices grown on piezoelectric substrates show large antiferromagnetic coupling of the two ferromagnetic components and a significant strain effect on interfacial coupling [1]. Here we present a systematic investigation of the antiferromagnetic interface coupling in bilayers of $SrRuO_3$ (SRO) and $La_{0.7}Sr_{0.3}MnO_3$ (LSMO), grown by pulsed laser deposition (PLD) on (100)- oriented $SrTiO_3$ substrates. Epitaxial and coherent growth of the bilayers was confirmed by in-situ RHEED and ex-situ x-ray diffraction (XRD). Magnetic characterization was performed by SQUID magnetometry. We observed a strong dependence of the AFM coupling on the layer sequence and the thickness of the individual layers. The bilayers exhibit exchange bias, with the magnitude and sign of the exchange field strongly dependent on cooling field. Results of this study and ongoing work will be discussed. [1] Sujit Das et al, arXiv:1411.0411

MA 33.4 Wed 16:00 EB 107

Massive magnetoelectric modulation of the magnetic anisotropy in an epitaxial $La_{0.7}Sr_{0.3}MnO_3$/PMN-PT heterostructure — •Martin Wahler[1], Sujit Das[1], Kathrin Dörr[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany

We use ferromagnetic resonance (FMR) to investigate the strain induced change of the in-plane magnetic anisotropy of an epitaxial ferromagnetic oxide layer on a piezoelectric substrate. The samples consist of 20 nm thick $La_{0.7}Sr_{0.3}MnO_3$ layers on two different substrates, namely $Pb(Mg_{1/3}Nb_{2/3})_{0.72}Ti_{0.28}O_3$ (PMN-PT) (001) and (110) single crystals. The two substrates induce either isotropic or anisotropic in-plane strain, respectively. For $La_{0.7}Sr_{0.3}MnO_3$ on (001) PMN-PT substrate, it has already been demonstrated by SQUID magnetometry that the Curie-temperature and saturation magnetization can be changed by applying an electric field normal to the sample plane [1]. Here we show that for the same substrate orientation there is a small but significant change in FMR resonance fields along the directions of the magnetic easy axes. For the (110) substrate, however, a massive shift of the resonance fields is observed, resulting in a change of the uniaxial anisotropy of more than 0.5 kOe for an applied electric field of 12 kV cm^{-1}. All measurements are carried out at a temperature of 120 K.

[1] C. Thiele et al., Phys. Rev. B, **75** 054408 (2007)

MA 33.5 Wed 16:15 EB 107

Inverse TMR effect in multiferroic tunnel junctions studied from first principles — •Vladislav Borisov[1,2], Sergey Ostanin[2], and Ingrid Mertig[1,2] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg — [2]Max Planck Institute of Microstructure Physics

The spin-polarized electronic transport in multiferroic tunnel junctions (MTJ): Co/PTO/Co and LSMO/PTO/Co was computed from first principles. We confirm that the so-called four-state tunnelling magnetoresistance (TMR) may be detected for each MTJ when its TMR and TER are controlled by the reversible barrier polarization as well as reversible magnetization of the leads. The *ab initio* based results are directly compared to the experimental features of the inverse TMR recently reported for LSMO/PZT/Co [1]. We show how the observed effect originates from the magnetoelectric coupling seen at both interfaces of the MTJ [2]. The role of half-metallic LSMO as well as the effect of Zr substitutes in PTO are analysed in the context of the inversion of the TMR signal [1]. Another important issue of TMR discussed here concerns the functional (insulating) barrier thickness, which is always less than the nominal thickness and which depends on the polarization direction. We found that the functional barrier thickness is systematically reduced when the polarization is directed toward the Co electrode due to charge transfer at the Co/PTO interface.

[1] D. Pantel *et al.*, *Nat. Mater.* **11**, 289 (2012).
[2] V. S. Borisov *et al.*, *Phys. Rev. B* **89**, 054436 (2014).

MA 33.6 Wed 16:30 EB 107

Origin of superstructures in (double) perovskite thin films — •Vikas Shabadi, Marton Major, Philipp Komissinskiy, Aldin Radetinac, Mehran Vafaee, Wolfgang Donner, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Alarich-Weiss-Strasse 2, 64287 Darmstadt, Germany

We have investigated the origin of superstructure peaks as observed by X-ray diffraction of multiferroic $Bi(Fe_{0.5}Cr_{0.5})O_3$ thin films grown by pulsed laser deposition on single crystal $SrTiO_3$ substrates. The photon energy dependence of the contrast between the atomic scattering factors of Fe and Cr is used to rule out a chemically ordered double perovskite Bi_2FeCrO_6 (BFCO). Structural calculations suggest that the experimentally observed superstructure occurs due to unequal cation displacements along the pseudo-cubic [111] direction that mimic the unit cell of the chemically ordered compound [1]. This result helps to clarify discrepancies in the correlations of structural and magnetic order reported for Bi_2FeCrO_6. The observation of a superstructure in itself is not a sufficient proof of chemical order in double perovskites.

[1] V. Shabadi, M. Major, P. Komissinskiy, M. Vafaee, A. Radetinac, M. Baghaie Yazdi, W. Donner, and L. Alff, J. Appl. Phys. **116**, 114901 (2014).

MA 33.7 Wed 16:45 EB 107

Using multiferroic systems as a spin filter - an ab initio study — •Stephan Borek[1], Jürgen Braun[1], Hubert Ebert[1], Angelika Chassé[2], Gerd Schönhense[3], Hans-Joachim Elmers[3], Dmytro Kutnyakhov[3], and Ján Minár[1,4] — [1]Ludwig-Maximilians-Universität München — [2]Martin-Luther-Universität Halle-Wittenberg — [3]Johannes-Gutenberg-Universität Mainz — [4]University of West Bohemia, Pilsen

Multiferroic heterostructures such as ultrathin $Fe/BaTiO_3(001)$ films are of high interest for technical applications giving the opportunity to control the ferromagnetic state with an electric field or vice versa. In our theoretical study we investigated the effect of changing the electric polarization of the ferroelectric substrate $BaTiO_3$ on the ferromagnetic state of Fe and Co thin films using the method of Spin Polarized Low Energy Electron Diffraction (SPLEED). This method has been shown to be an effective tool for the investigation of surface properties like the determination of surface magnetic moments and the local crystal structure. The possibility of an application of the multiferroic heterostructures Fe/BTO(001) and Co/BTO(001) as a spin filter is discussed. It will be shown that a change of the polarisation of the $BaTiO_3$ results in a significant change of the exchange asymmetry giving the possibility to control the diffraction of electrons using the exchange interaction at the Fe (Co) surface. We focus on the systems of 1 ML, 2 ML and 3 ML Fe (Co) on $BaTiO_3$ because their electronic and magnetic structure as well as the coupling mechanism between the ferroic phases have been intensively discussed in the literature.

20 min coffee break

MA 33.8 Wed 17:20 EB 107

Optical investigation of ferroic domains beyond the resolution limit — •Christoph Wetli, Viktor Wegmayr, Thomas Lottermoser, and Manfred Fiebig — Department of Materials, ETH Zurich, Zurich, Switzerland

In recent years optical second harmonic generation (SHG) has been shown to be a versatile, non-destructive tool to investigate the often complex domain structures of ferroic and multiferroic materials. Ferroic domains vary broadly in structure and size, depending on the nature of the ferroic ordering. So far, however SHG was restricted to domains larger than the optical resolution limit of 1 μm. Here we present a method by applying a numerical model and simulation to overcome this limitation and to analyze ferroic domain structures some orders of magnitude smaller than the optical resolution limit. The method is based on the relation between the orientation of the ferroic order parameter and the phase of the nonlinear optical signal. It gives a relation between domain size and density, optical resolution and the intensity of the SHG signal. To show the reliability of the model, we applied it to several simulated domain structures. The simulation of the domain structures is based on an iterative geometrical algorithm, which allows us to generate complex domain patterns like the ferroelectric vortex structures or the irregular bubble like antiferromagnetic domains in hexagonal $YMnO_3$. The numerical calculations were compared with experimental data and found to be in excellent agreement.

MA 33.9 Wed 17:35 EB 107

Multiferroicity in $DyMnO_3$ thin films — •Chengliang Lu[1,2], Hakan Deniz[2], and Jun-Ming Liu[3] — [1]School of Physics, Huazhong University of Science and Technology, Wuhan 430074, China — [2]Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle(Saale), Germany — [3]Laboratory of Solid State Microstructures, Nanjing University, Nanjing 210093, China

The mutual control of ferroelectricity and magnetism is stepping towards practical applications proposed for quite a few promising devices in which multiferroic thin films are involved. Although ferroelectricity stemming from specific spiral spin ordering has been reported in highly distorted bulk perovskite manganites, the existence of magnetically induced ferroelectricity in the corresponding thin films remains an unresolved issue, which unfortunately halts this step. Here we report magnetically induced electric polarization and its gigantic response to magnetic field (an enhancement of 800% upon a field of 2 Tesla at 2 K) in $DyMnO_3$ thin films grown on Nb-$SrTiO_3$ substrates. Interestingly, we found a consecutive control of the polarization under a rotating magnetic field by detailed multiferroic response measurements. This is distinct to the standard polarization-flop process which results in a sudden change in polarization in multiferroics with spiral-spin-ordering state. The cooperative action of dual multiferroic mechanisms (the inverse Dzyaloshinskii-Moriya interaction among Mn moments and the exchange striction working between Dy and Mn moments) and phase coexistence associated with a twin-like structure was proposed as the origin of this phenomenon.

MA 33.10 Wed 17:50 EB 107

Observation of direct and converse local magnetoelectric switching at room-temperature in modified single-phase bismuth ferrite — •Leonard Frederic Henrichs[1], Oscar Cespedes[1], James Bennett[1], Joachim Landers[2], Wolfgang Kleemann[2], Heiko Wende[2], Doru Lupascu[2], and Andrew Bell[1] — [1]University of Leeds, Leeds, GB — [2]Universität Duisburg/Essen, Duisburd/Essen, Germany

Multiferroics are promising for applications in sensors and memory. However, no single-phase material with both ferroelectric and ferro- or ferrimagnetic order at room-temperature has been reported to date. Here, we observe very large local magnetoelectric coupling in the novel single-phase multiferroic $(BiFeCo_{0.1}O_3)_{0.4}$-$(K_{1/2}Bi_{1/2}TiO_3)_{0.6}$ at room-temperature. On ceramic samples, both direct and converse magnetoelectric switching was observed using piezoresponse force-microscopy and magnetic force-microscopy respectively. Areas where converse switching occurred, incorporate both a ferroelectric and magnetic domain-like cluster and thus appear to be (relaxor) ferroelectric and ferrimagnetic at room-temperature. The direct coupling-coefficient estimated from the experiments is 1.0×10^{-5} s/m, and thus extremely large. The locally observed converse meangetoelectric effect has a similar of magnitude. we propose that the material can be interpreted as a pseudo-nanocomposite with an ideal strain-mediated coupling due to congruent polar and magnetic nanoregions which are related to the relaxor ferroelectric and superparamagnetic nature of the material.

MA 33.11 Wed 18:05 EB 107

Tiny cause with large effects: the origin of the large magnetoelectric and magnetoelastic effect in $EuTiO_3$ — •Annette Bussmann-Holder — MPI-FKF, Heisenbergstr. 1, D-70569 Stuttgart, Germany

The magnetoelectric coupling in the perovskite $EuTiO_3$ is analyzed within a spin-phonon coupled Hamiltonian. It is shown that the tiny magnetostriction which accompanies the onset of antiferromagnetic order at $T_N = 5.7$ K induces a substantial hardening in the soft optic mode and a drop in the dielectric constant. The reduction of magnetostriction with increasing magnetic field reverses this behavior. While for small fields ferromagnetic order rapidly sets in accompanied by a volume expansion, this is destroyed with increasing fields and a strange paramagnetic state obtained. This exotic observation can be understood as stemming from the interplay between the enhanced oxygen p Ti d dynamical covalency which alters the crystal field at the Eu site and inhibits the virtual transition from $4f7$ to $4f65d$ responsible for ferromagnetic order.

MA 33.12 Wed 18:20 EB 107

First principles calculations on the effect of inner cationic site disorder, single and multiple cation and anion doping on the magnetic properties of $GaFeO_3$ — •Jacqueline Atanelov, Wernfried Mayr-Schmölzer, and Peter Mohn — Institute of Applied Physics - Computational Materials Science, Vienna University of Technology, Austria

$GaFeO_3$ is a promising multiferroic suitable for a wide range of applications in electronic devices. Motivated by that we investigate the influence of single and multiple cation and anion doping on the electronic and magnetic properties of gallium ferrite. Further we consider the well known fact of innner cation site disorder in $GaFeO_3$. In terms of cation doping we replace Ga atoms by Fe atoms and vice versa so that in total a concentration range of $0.9 \leq x \leq 2.0$ in $Ga_2-xFe_xO_3$ is investigated. In addtion to that we substitute oxygen by B, C, N and S atoms. GFO is also known to show magnetic anisotropy for different cristallographic directions and sublattices. Beside changes in the total net magnetic moment induced by cation and anion doping, the magnetic anisotropy energy (MAE) can be affected as well. Doping therefore can lead to an enhancement or reduction of the MAE. First principles density functional theory (DFT) calculations performed by the Vienna ab Initio Simulation Package (VASP) are used to predict and analyze the ground state electronic structure of the investigated systems.

MA 33.13 Wed 18:35 EB 107

Mechanism of interfacial magnetoelectric coupling in composite multiferroics — Chenglong Jia[1], Tongli Wei[1], Changjun Jiang[1], Desheng Xue[1], •Alexander Sukhov[2], and Jamal Berakdar[2] — [1]Key Laboratory for Magnetism and Magnetic Materials of MOE, Lanzhou University, Lanzhou 730000, China — [2]Institut für Physik, Martin-Luther-Universität, Halle-Wittenberg, 06099 Halle (Saale), Germany

We present a mechanism for the magnetoelectric coupling at ferroelectric/ferromagnetic interfaces based on screening via interfacial spin-rearrangement [1]. We find an electric-polarization-driven, noncollinear spin region extending over the spin-diffusion length in the ferromagnet. The orbital motion of the carriers in the ferromagnet is affected by the gauge field associated with the non-collinear spin order and hence indirectly by the electric polarization. Changing the latter, e.g., via an electric field influences the interfacial magnetic order and hence the spin-orbital coupled motion of the carriers. This allows for tuning the interfacial spin-dependent transport via electric fields. The resulting coupling is robust at room temperature and can be well approximated by a linear polarization- magnetization coupling, whose strength estimate for the composite Co(40 nm)/(tetragonal)$BaTiO_3$ is in line with recent experiments [2].

[1] C.-L. Jia, T.-L. Wei, C.-J. Jiang, D.-S. Xue, A. Sukhov, J. Berakdar, Phys. Rev. B **90**, 054423 (2014). [2] N. Jedrecy, H.J. von Bardeleben, V. Badjeck, D. Demaille, D. Stanescu, H. Magnan, A. Barbier, Phys. Rev. B **88**, 121409(R) (2013).

MA 34: Topological insulators: Theory (HL with DS/MA/O/TT)

Time: Wednesday 9:30–11:30 Location: ER 270

MA 34.1 Wed 9:30 ER 270

Weyl and Dirac semimetals: A platform for new interface phenomena — •Adolfo G. Grushin[1], Jorn W. F. Venderbos[2], and Jens H. Bardarson[3] — [1]Max Planck Institute for the physics of Complex Systems, Dresden, Germany — [2]Massachusetts Institute of Technology, Cambridge, MA, USA — [3]Max Planck Institute for the physics of Complex Systems, Dresden, Germany

The Weyl semimetal (WSM) state is sometimes loosely referred to as the three-dimensional cousin of graphene since its low energy theory is described by an even number of copies of the Weyl Hamiltonian. Closely related to WSM, the Dirac semimetals hosts the Weyl nodes at the same point in the Brillouin Zone and it is realised in Cd_3As_2 and Na_3Bi compounds. In this talk I will explore the rich surface state physics that these states can host and how can it be probed, including coexistence of Dirac and Fermi arc states at the topological insulator-weyl semimetal interfaces as well as signatures of the chiral anomaly.

MA 34.2 Wed 9:45 ER 270

Spin chirality tuning and Weyl semimetal in strained $HgS_{1-x}Te_x$ — •Tomáš Rauch[1], Steven Achilles[1], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06099 Halle (Saale), Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle (Saale), Germany

We have theoretically investigated the phase diagram of $HgS_{1-x}Te_x$. The parameters which have been varied are the concentration x and the in-plane strain, which could be applied by an appropriate substrate in an experiment. In the topological phase diagram we found a normal metallic phase, two topological insulator phases with different spin chiralities of the surface states and a Weyl semi-metal phase. The phases have been probed by calculating topological invariants and the dispersion of the surface states for both crystal terminations of the (001) surface by an *ab-initio* based tight-binding model.

MA 34.3 Wed 10:00 ER 270

Topological phases in (interfacial) phase-change materials — •Peter Schmitz, Wei Zhang, and Riccardo Mazzarello — Institute for Theoretical Solid State Physics, RWTH Aachen University

We investigate the topological, spectral and structural properties of $[Sb_2Te_3]_x[GeTe]_y$ (GST) compounds, some of which are interfacial phase change materials (IPCMs), as a function of strain and stacking sequence by performing a DFT study of bulk and slab models and discuss the relevance of a 3D (topological) Dirac semimetal phase ((T)DSM), eg. to GST225.

IPCMs can perform fast reversible transitions, induced by electric fields or heat, between crystalline states of different stacking. Since they also possess strong spin-orbit coupling and a strong topological insulator (STI) + normal insulator(NI) layering, they are a promising platform to investigate nontrivial interface states and direct applications to data storage in terms of switching topological phases. Until now they were shown to exhibit STIs and *unstable* DSM-like critical states corresponding to STI/NI transitions [1]. Then recently [2] a *robust* TDSM phase was predicted for crystals having certain rotational symmetries: The STI/NI transition point can be extended to a line and 2 Dirac points appear in the bulk spectrum.

Analyzing whether such phases can be obtained in GST compounds is also interesting since the problem of a TDSM in a multilayer structure has not yet been discussed.

[1] J. Tominaga et al, Adv. Mat. Inter. 1 (2014);
[2] B. Yang and N. Nagaosa, Nature Commun. 5, 4898 (2014)

MA 34.4 Wed 10:15 ER 270

Effect of Bi bilayers on the topological states of Bi_2Se_3: A first-principles study — Kirsten Govaerts[1], Kyungwha Park[2], Christophe De Beule[1], Dirk Lamoen[1], and •Bart Partoens[1] — [1]CMT-group and EMAT, University of Antwerp, Belgium — [2]Virginia Tech, Department of Physics, USA

Bi_2Se_3 and vice versa, has not been explored much. Bi bilayers are often present between the quintuple layers of Bi_2Se_3, since $(Bi_2)_n(Bi_2Se_3)_m$ form stable ground-state structures. Moreover, Bi_2Se_3 is a good substrate for growing ultrathin Bi bilayers. By first-principles techniques, we first show that there is no preferable surface termination by either Bi or Se. Next, we investigate the electronic structure of Bi bilayers on top of, or inside a Bi_2Se_3 slab. If the Bi bilayers are on top, we observe a charge transfer to the quintuple layers that increases the binding energy of the surface Dirac cones. The extra states, originating from the Bi bilayers, were declared to form a topological Dirac cone, but here we show that these are ordinary

Rashba-split states. This result, together with the appearance of a new Dirac cone that is localized slightly deeper, might necessitate the reinterpretation of several experimental results. When the Bi bilayers are located inside the Bi_2Se_3 slab, they tend to split the slab into two topological insulators with clear surface states. Interface states can also be observed, but an energy gap persists because of strong coupling between the neighboring quintuple layers and the Bi bilayers.

MA 34.5 Wed 10:30 ER 270

Topological states in α-Sn and HgTe quantum wells: a comparison of ab-initio results — •Sebastian Küfner and Friedhelm Bechstedt — Friedrich Schiller Universität Jena

Quantum well (QW) structures based on HgTe are theroretically predicted and experimentally verified to exhibit the quantum-spin Hall phase. Despite the similarities of the bulk band structures, studies of α-Sn QW structures are missing. We compare the properties of QW structures made by the different zero-gap semiconductors α-Sn and HgTe, but both sandwiched in nearly lattice-matched CdTe barriers by means of first-principles calculations including quasiparticle corrections and spin-orbit interaction. The two well materials possess different space groups O_h^7 (diamond structure) and T_d^2 (zinc-blende structure). The spin-orbit interaction, in particular that in the p-derived valence states, is different due to the contribution of both atoms in the unit cell (α-Sn) and mainly the anion (HgTe) to the states at the top of the valence bands, and the different local electrostatic properties due to the different bonding character in the QW layers and their interfaces with the CdTe barrier material. We investigate the similarities and differences of the two embedded zero-gap semiconductors on the formation of quantum-well, edge and interface states in detail.

MA 34.6 Wed 10:45 ER 270

Quasiparticle band structure of the topological insulator Bi_2Se_3 — •Tobias Förster, Peter Krüger, and Michael Rohlfing — Institut für Festkörpertheorie, Westfälische Wilhelms-Universität, 48149 Münster, Germany

Bi_2Se_3 is a prototype topological insulator. Its simple surface band structure with only one Dirac point makes it an ideal system for exploring the properties of topological surface states. Up to now, the vast majority of theoretical investigations of the electronic structure of Bi_2Se_3 has utilized DFT calculations. In Bi_2Se_3 and related compounds, however, many body perturbation theory in the GW approximation yields both quantitative and qualitative quasiparticle corrections of the DFT bulk band structures [1].

Here we discuss results for bulk Bi_2Se_3 from GW calculations employing a localized basis as well as from a perturbative LDA+GdW approach [2]. The latter provides a numerically very efficient method for the calculation of quasiparticle corrections with only slightly reduced precision compared to GW. The applicability of the LDA+GdW formalism to the Bi_2Se_3 surface with the Dirac state will also be addressed.

[1] I. Aguilera *et al.*, Phys. Rev. B **88**, 045206 (2013)

[2] M. Rohlfing, Phys. Rev. B **82**, 205127 (2010)

MA 34.7 Wed 11:00 ER 270

Calculation of topological invariants from a maximally localized Wannier functions derived model Hamiltonian — •Patrick M. Buhl, Chengwang Niu, Yuriy Mokrousov, Daniel Wortmann, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Using density-functional methods it is possible to provide an accurate description of topological phases in complex materials. We demonstrate how topological characterization can be performed in a unified manner based on Wannier functions generated from the full-potential linearized augmented plane-wave method as implemented in the `FLEUR` code [1]. Taking as examples bcc Fe, Na_3Bi and PbTe we compute various topological invariants and identify topologically non-trivial points in the electronic structure of these materials in bulk and their close relation to the surface electronic structure. In particular, we focus on the Weyl semimetallic phase as a transitional phase between various topological phases in the same material and on the role of the Weyl points in the electronic structure for topological properties. Financial support by the HGF-YIG Programme VH-NG-513 and SPP 1666 of the DFG is gratefully acknowledged.

[1] F. Freimuth *et al.*, Phys. Rev. B **78**, 035120 (2008)

MA 34.8 Wed 11:15 ER 270

Functionalized Bismuth Films: Giant Gap Quantum Spin Hall and Valley-Polarized Quantum Anomalous Hall States — •Chengwang Niu, Gustav Bihlmayer, Hongbin Zhang, Daniel Wortmann, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The search for new large band gap quantum spin Hall (QSH) and quantum anomalous Hall (QAH) insulators is critical for their realistic applications at room temperature [1,2]. Here we predict, based on first principles calculations, that the band gap of QSH and QAH states can be as large as 1.01 eV and 0.35 eV in an H-decorated Bi(111) film [3]. The origin of this giant band gap lies both in the large spin-orbit interaction of Bi and the H-mediated exceptional electronic and structural properties. Moreover, we find that the QAH state also possesses the properties of quantum valley Hall state, thus intrinsically realising the so-called valley-polarized QAH effect. We further investigate the realization of large gap QSH and QAH states in an H-decorated Bi($\bar{1}10$) film and X-decorated (X=F, Cl, Br, and I) Bi(111) films.

This work was supported by the Priority Program 1666 of the DFG and project VH-NG-513 of the HGF.

[1]M. Hasan and C. Kane, Rev. Mod. Phys. **82**, 3045 (2010).

[2]X.-L. Qi and S.-C. Zhang, Rev. Mod. Phys. **83**, 1057 (2011).

[3]Chengwang Niu, Gustav Bihlmayer, Hongbin Zhang, Daniel Wortmann, Stefan Blügel, and Yuriy Mokrousov, submitted.

MA 35: Magnetization / Demagnetization Dynamics II

Time: Wednesday 15:00–18:45 Location: EB 301

MA 35.1 Wed 15:00 EB 301

***Ab initio* calculations of laser-induced magnetism in materials** — •Marco Berritta[1], Ritwik Mondal[1], Karel Carva[1,2], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Charles University, Prague, Czech Republic

An intensive femtosecond laser pulse can induce a short-lived magnetization in materials through the inverse Faraday effect. This effect can be described quantum-mechanically as a quadratic order response to the perturbing circularly polarized laser pulse. The magnitude of the light-imparted opto-magnetic field is thus far unknown; speculatively, it could be responsible for the recently demonstrated all-optical switching in magnetic recording materials [1]. We report *ab initio* calculations of the light-induced magnetization in typical ferromagnetic materials, Fe, Ni, and FePt. Results of full quantum quadratic response calculations are compared with results based on classical electron gas theory by Pitaevskii and an extension within the Drude-Lorentz theory. Support from the EU (under grant No. 281043, FemtoSpin) is acknowledged.

[1] C.-H. Lambert *et al.*, *All-optical control of ferromagnetic thin films and nanostructures.* Science **345**, 1337 (2014).

MA 35.2 Wed 15:15 EB 301

Element-specific investigation of photo-induced ultrafast demagnetization with light in the visible spectral range — •David Weder, Felix Willems, Oliver Gückstock, Clemens von Korff Schmising, and Stefan Eisebitt — Technische Universität Berlin

A promising approach to control magnetic properties and their subpicosecond dynamics is photo-induced ultrafast demagnetization which was measured for the first time in 1996 [Beaurepaire1996]. But even after almost 20 years of research the theoretically background about the fundamental microscopic processes has remained unclear. Several competing models describing the underlying mechanisms of laser-induced "femtomagnetism" have been put forward, one of which focuses on spin-polarized superdiffusive electron transport [Battiato2012]. Here, an ultrashort laser pulse triggers non-equilibrium superdiffusive electrons and gives rise to ultrafast transfer of magnetization on a nanometer length scale.

We have established a time-resolved, high-repetition, low-noise optical Kerr setup with micrometer spatial and 100 fs temporal resolution for ultrafast magnetic spectroscopy [KorffSchmising2014]. By nonlinear interaction of the light pulses in a photonic crystal fiber we generate a femtosecond white light continuum which allows us to disentangle the distinct ultrafast transient response of 3d-4f metallic magnetic multilayers and alloys (e.g. CoTb) [Khorsand2013]. We present first results on element specific magnetization dynamics in engineered sample geometries and discuss the influence of spin-polarized electron transport.

MA 35.3 Wed 15:30 EB 301

Electron kinetics in ultrafast magnetization dynamics — •Benedikt Y. Mueller[1], Bärbel Rethfeld[2], and Manfred Fähnle[1] — [1]Max-Planck-Institute for Intelligent Systems, Heisenbergstrasse 3, 70569 Stuttgart, Germany — [2]Technical University of Kaiserslautern, Germany

When a ferromagnetic metal is excited by an ultrashort laser pulse, a demagnetization within less than one picosecond is observed [1]. Up to now, no microscopic theory explains the large variety of this effect [1-3] on equal footing. As a step towards this goal, we investigate the ultrafast demagnetization by a kinetic approach, applying Boltzmann collision integrals [4-8] to trace the dynamics of the electrons [6,7]. For Nickel, we investigate the contribution of electron-electron and electron-phonon spin-flip scattering to the total demagnetization effect. Moreover, we illustrate the thermalization and relaxation processes after laser irradiation. As a result, we find that a dynamic electron band structure is essential for describing ultrafast demagnetization [6].

[1] Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996)
[2] Roth et al., Phys. Rev. X 2, 021006 (2012)
[3] Koopmans, B. et al., Nature Materials 9, 259 (2010)
[4] Rethfeld et al., Phys. Rev. B 65, 214303 (2002)
[5] Mueller and Rethfeld, Phys. Rev. B 87, 035139 (2013)
[6] Mueller et al., Phys. Rev. Lett. 111, 167204 (2013)
[7] Illg et al., Phys. Rev. B 88, 214404 (2013)
[8] Essert and Schneider, Phys. Rev. B 84, 224405 (2011)

MA 35.4 Wed 15:45 EB 301

Transfer of angular momentum from the electrons to the lattice during ultrafast demagnetization — •Thodoris Tsatsoulis, Michael Haag, Christian Illg, and Manfred Faehnle — Max-Planck-Institute for Intelligent Systems, Heisenbergstrasse 3, 70569 Stuttgart, Germany

After irradiation of a magnetic film with a femtosecond (fs) optical laser pulse there is an ultrafast demagnetization of the film on a timescale of few 100 fs. For a theoretical explanation it is often assumed (see [1] and references therein) that the electrons excited by the beam are scattered at phonons and that thereby in systems with spin-orbit coupling the spin- and orbital-angular momentum of these electrons, which are related to magnetic moments, change. In all these theories only the change of the electronic magnetic moment is calculated explicitly, whereas it is implicitly assumed that the lattice acts as a perfect sink for the angular momentum. The reason is that for the construction of the electron-phonon scattering operator the lattice dynamics is represented in terms of linearly polarized phonons, which do not have a well-defined angular momentum. Therefore the change of the angular momentum of the lattice cannot be calculated from the change of the phononic occupation numbers. We calculate the modification of the angular momentum of the lattice explicitly by representing the lattice dynamics in terms of the magnetoelastic eigenmodes of a ferromagnetic system which carry a well-defined angular momentum [2], respectively.

[1] C.Illg, M. Haag and M. Faehnle, Phys. Rev. B 88, 214404 (2013).
[2] L. Zhang and Q. Niu, Phys. Rev. Letters 112, 085503 (2014).

MA 35.5 Wed 16:00 EB 301

Spin oscillations triggered by strongly correlated t_{2g} electrons at the timescale of electron-electron interactions — •Malte Behrmann and Frank Lechermann — I. Institut für Theoretische Physik, Universität Hamburg, 20355 Hamburg, Germany

Laser-induced ultrafast (fs) magnetization experiments in antiferromagnets have recently attracted large attention, paving the road for inherently fast spin dynamics in the THz regime without invoking stray fields. The technical importance is emphasized by the rising new research field of antiferromagnetic (AFM) spintronics, where superexchange-dominated strongly correlated compounds provide an interesting materials playground. Then an intriguing question is, whether the Coulomb interaction may be a key to control AFM order on ultrafast timescales. Therefore we here study (de)magnetization processes in a time-dependent multi-orbital Hubbard model, focusing on t_{2g} electrons in a wider doping range. We reveal novel filling-dependent stable/transient spin oscillations via interaction quenches from the antiferro- or paramagnetic state. Non-equilibrium ultrafast spin-orientation effects in prominent correlated transition-metal oxides are therefrom predicted, which could be detected by THz emission spectroscopy.

MA 35.6 Wed 16:15 EB 301

Ultrafast changes in crystal field during the demagnetization of antiferromagnetic Cr2O3 — •Vera Giulia Sala[1], Timothy Miller[1], Stefano Dal Conte[2], Valérie Véniard[3], Giulio Cerullo[2], and Simon Wall[1] — [1]ICFO - The Institute of Photonic Sciences, Av. Carl Friedrich Gauss 3, 08860 Castelldefels, Spain — [2]Politecnico di Milano, Piazza L. da Vinci 32, I-20133 Milano, Italy — [3]École Polytechnique, 91128 Palaiseau cedex, France

While magnetization dynamics in ferro- and ferri-magnetic materials has received significant experimental attention, dynamics in antiferromagnetic systems has been less studied. This is because most optical techniques used to probe magnetism require a net magnetic moment for a signal to be observed, but antiferromagnets have no net magnetization. To overcome this issue we use time-resolved resonant second harmonic spectroscopy which is sensitive to the magnetic order in the room temperature antiferromagnet Cr2O3. Exciting the system with visible light causes charge transfer excitations which modify both the magnetic state and the resonance condition of the second harmonic process. By performing polarization analysis we can separate the dynamics of the magnetic state and the crystal field which sets the resonant conditions. By tuning the pump wavelength, we can control how strongly we drive the crystal field and find that the crystal field contribution can be reduced whilst still demagnetizing the system by the same amount. This opens the way to more efficient control of the magnetic state, where energy is coupled more selectively into the magnetic system than other degrees of freedom.

15 min. break

MA 35.7 Wed 16:45 EB 301

Sublattice Magnetization Orientation Dependence of All-Optical Magnetic Switching in Tb-Fe Thin Films — •Alexander Hassdenteufel[1], Christian Schubert[1,2], Johannes Schmidt[3,4], Peter Richter[1], Dietrich R. T. Zahn[1], Georgeta Salvan[1], Manfred Helm[3,4], Rudolf Bratschitsch[5], and Manfred Albrecht[2] — [1]Institute of Physics, Technische Universität Chemnitz, D-09107 Chemnitz, Germany — [2]Institute of Physics, University of Augsburg, D-86159 Augsburg, Germany — [3]Helmholtz Zentrum Dresden Rossendorf, P.O. Box 510119, D-01314 Dresden, Germany — [4]Technische Universität Dresden, D-01062 Dresden, Germany — [5]Institute of Physics, University of Münster, D-48149 Münster, Germany

All-optical switching (AOS), first witnessed with GdFeCo [1], attracted growing attention for future data storage devices as well as from the fundamentals point of view. Here we demonstrate that the direction of AOS in rare-earth transition-metal (RE-TM) alloy Tb-Fe thin films depends on the orientation of the sublattice magnetization and not on the direction of the resulting net magnetization[2]. This finding of the sublattice dependence of AOS contributes to the understanding of switching in RE-TM multilayered thin films [3] and heterostructures [4]. [1] C. D. Stanciu et al. Phys. Rev. Lett 99, 047601 (2007). [2] A. Hassdenteufel et al. Appl. Phys. Lett. 105, 112403 (2014). [3] S. Mangin et al. Nature Mater. 13, 286-292 (2014). [4] C. Schubert et al. Appl. Phys. Lett. 104, 082406 (2014).

MA 35.8 Wed 17:00 EB 301

Ultrafast Spin dynamics in tunnel-magneto resistance junctions — •Jakob Walowski[1], Marvin von der Ehe[1], Ulrike Martens[1], Vladyslav Zbarsky[1,2], Markus Münzenberg[1], Andy Thomas[3], Jia Zhang[4], Christian Franz[4], Michael Czerner[4], and Christain Heiliger[4] — [1]Institut für Physik, Ernst-Moritz-Arndt Universität, Greifswald, Germany — [2]Fakultät für Physik, Georg-August Universität, Göttingen, Germany — [3]CSMD, Physics Department, Bielefeld University, Germany — [4]I. Physikalisches Institut, Justus Liebig Universität, Gießen

We investigate the spin transport and ultrafast spin dynamics in the magnetic layers of tunnel-magneto resistance junctions (MTJs) with out-of-plane magnetic anisotropy PMA. Both effects are induced by the excitation of the electron and spin system by ultra-short laser pulses.

The processes causing the spin dynamics and the spin transport depend on the properties of the magnetic electrodes and the tunnel barrier. Therefore the thickness of the CoFeB electrodes is varied within the range of permendicular magnetic anisotropy from 0.9 nm up to 1.3 nm. By studying the ultrafast dynamics, we disentangle the mechanisms and processes causing spin transfer between the electrodes through the tunnel barrier on femtosecond time scales.

Financial funding by the DFG SPP 1538 SpinCaT is acknowledged.

MA 35.9 Wed 17:15 EB 301

Ultrafast Electron Spin Dynamics at the Fermi Level in Fe3O4 Thin Films — C Cacho[1], M Battiato[2], J-M Mariot[3], •M C Richter[4], O Heckmann[4], F Parmigiani[5], H Ebert[6], J Minar[6], and K Hricovini[4] — [1]Central Laser Facility, STFC, RAL, Harwell, United Kingdom — [2]Institute of Solid State Physics, Vienna University of Technology, Austria — [3]LCP-MR, Univ. Paris 6/CNRS, France — [4]LPMS, Univ. de Cergy-Pontoise, France — [5]Elettra - Sincrotrone Trieste, Italy — [6]LMU Münich, Germany

Magnetite, Fe3O4 (FO), belongs to the family of half-metals characterized by an insulating gap for one spin state resulting in a fully spin-polarised transport at the Fermi level, which attracts a high interest for spintronic devices. In spite of intensive theoretical and experimental studies, the magnetic and electronic properties of FO remain controversial. We studied the demagnetisation process in FO by spin- and time-resolved pump-probe photoemission experiments using the third harmonic (4.65 eV) of a Ti-Saphire laser with a repetition rate of 250 kHz. For the maximum of the photoexcitation we observe a clear reduction of the spin polarisation in a region of ~200 meV around the Fermi level. At higher binding energy no variation is observed up to a 1000 fs delay indicating that the spin polarisation reduction observed comes from the electron dynamics and not from the demagnetization. The Boltzmann equation for out-of-equilibrium dynamics combined with the calculated spin-resolved electronic density-of-states fully describes the decay of the excited electrons as well as the variation of the spin polarisation.

MA 35.10 Wed 17:30 EB 301

Competition between ultrafast spin transport and spin-flip scattering investigated by complex femtosecond time-resolved MOKE — Jens Wieczorek[1], •Andrea Eschenlohr[1], Boris Weidtmann[1], Malte Rösner[2], Andreas Duvenbeck[1], Nicolas Bergeard[1], Alexander Tarasevitch[1], Tim O. Wehling[2], and Uwe Bovensiepen[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen — [2]Institute for Theoretical Physics, University of Bremen, and Bremen Center for Computational Materials Science

We analyze femtosecond laser-induced magnetization dynamics of epitaxial Co/Cu(001) films via ultrafast changes in the polarization rotation and ellipticity of the complex magneto-optical Kerr effect (MOKE). By exploiting the effective depth sensitivity of this experimental method, we conclude on a time- and depth-dependent magnetization profile, which is qualitatively different for ultrafast spin transport and spin-flip scattering. We find that before hot electron thermalization ($<$100 fs) the ultrafast demagnetization of Co/Cu(001) is dominated by spin-dependent transport, while local spin-flip processes govern the magnetization dynamics after thermalization.

We acknowledge funding from the DFG through SFB 616, the BMBF through Grant 05K10PG2 FemtospeX, and the Mercator Research Center Ruhr through Grant PR-2011-0003.

MA 35.11 Wed 17:45 EB 301

Interplay of spin scattering and spin transport in the complex demagnetization of Ni — •Oliver Schmitt, Moritz Barkowski, Sakshath S, Daniel Steil, Mirko Cinchetti, Stefan Mathias, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

We use femtosecond time-resolved MOKE to study ultrafast demagnetization in a variety of different Ni films. With this approach, we aim to investigate and quantify the interplay of spin-flipping and spin-transport in the demagnetization process [1][2]. To exclude one of each possible channel, we performed measurements on Ni films that are fabricated into various different multilayer compositions. For our investigations, we than extended our MOKE setup by an advanced Kerr method, which enables us to measure a distinct depth or layer of the sample system [3].

[1] B. Koopmans et al., Nature Materials 9, 259-265 (2010)
[2] E. Turgut et al., PRL 110, 197201 (2013)
[3] A. J. Schellekens et al., PR B 90, 104429 (2014)

MA 35.12 Wed 18:00 EB 301

Ultrafast demagnetization dynamics in Ni/Ru/FePt/MgO(100) films — •Sadashivaiah Sakshath[1], Oliver Schmitt[1], Moritz Barkowski[1], Patrick Matthes[2], Manfred Albrecht[2,3], Mirko Cinchetti[1], Stefan Mathias[1], and Martin Aeschlimann[1] — [1]Technische Universität Kaiserslautern, Germany — [2]Technische Universität Chemnitz, Germany — [3]Universität Augsburg, Germany

Non-collinear magnetic layers allow us to study the influence of one ferromagnetic layer on the ultrafast dynamics of the non-collinear ferromagnet, primarily due to a spin current through the spacer layer [1,2]. We follow the dynamics of the in-plane magnetized Ni layer, as influenced by the perpendicularly magnetized FePt, using Ni/Ru/FePt/MgO(100) films. By changing the thickness of the Ru layer, we tune the amount of spin currents flowing between the magnetic layers [3]. When the thickness of Ru is low, Ni is observed to demagnetize faster in the non-collinear than in the collinear configuration. At high Ru thickness, the rate of demagnetization is the identical in both configurations, since the ultrafast spin currents do not reach the Ni layer. Additionally, at high Ru thickness, the observed magneto-optic signal shows a transient change of sign.

[1] A. J. Schellekens *et al.*, Nat. Comm. **5**, 4333 (2014)
[2] G-M. Choi *et al.*, Nat. Comm. **5**, 4334 (2014)
[3] E. Turgut *et al.*, Phys. Rev. Lett. **110**, 197201 (2013)

MA 35.13 Wed 18:15 EB 301

The fate of the transient ferromagnetic-like state in ferrimagnetic GdFe alloys — •Ilie Radu[1], Loic LeGuyader[1], Ilya Radzolsky[2], Raja Medapalli[2,3], Christian Stamm[1,4], Torsten Kachel[1], Rolf Mitzner[1], Karsten Holldack[1], Arata Tsukamoto[5], Alexey Kimel[2], and Theo Rasing[2] — [1]Helmholtz-Zentrum Berlin, BESSY II, Germany — [2]Radboud University Nijmegen, Netherlands — [3]University of California, San Diego, USA — [4]ETH Zürich, Switzerland — [5]Nihon University, Chiba, Japan

Recent femtosecond time-resolved XMCD investigations of ferrimagnetic GdFeCo alloys revealed the existence of a transient ferromagnetic state [1] mediating the ultrafast magnetization switching of antiferromagnetically coupled Fe and Gd spins [2]. Here we present a two-fold strategy on the control of the transient state's lifetime and onset by either changing the alloy stoichiometry or upon varying the laser excitation density. Possible implications for the magnetic switching phenomena in ferrimagnetic alloys and heterostructures will be discussed.

We acknowledge funding from European Union through FEMTOSPIN program and from BMBF through FEMTOSPEX grant No. 05K10PG2.

[1] I. Radu et al., Nature 472, 205 (2011) [2] T. Ostler et al., Nature Commun. 3, 666 (2012)

MA 35.14 Wed 18:30 EB 301

Monitoring of spin-polarized hot carrier currents by time-resolved magneto-induced SHG in metallic multi-layers — Alexandr Alekhin[1], Nikita Ilin[1], Damian Bürstel[2], Detlef Diesing[2], Tim O. Wehling[3], Ivan Rungger[4], Maria Stamenova[4], Stefano Sanvito[4], Vladimir Roddatis[5], Uwe Bovensiepen[6], and •Alexey Melnikov[1] — [1]Fritz-Haber-Institut der MPG, Abt. Phys. Chemie — [2]Universität Duisburg-Essen, Institut für Phys. Chemie — [3]Universität Bremen, Theor. Phys. Institut — [4]Trinity College Dublin, School of Physics and CRANN — [5]Universität Göttingen, Institut für Materialphysik — [6]Universität Duisburg-Essen, Fakultät für Physik

In metals, spin dynamics is non-local and determined by the transport of spin-polarized hot carriers (HC). We monitor resulting ultrafast variations of the magnetization in ferro- and the appearance of transient magnetization in paramagnetic layers by time-resolved MOKE. To get deeper insight in complex dynamics of the excited state, we complement MOKE by magneto-induced second harmonic generation (mSHG) which is sensitive to electron and magnetization dynamics at interfaces. In addition, it contains terms proportional (i.e. giving a direct access) to electric and spin currents in the bulk of metallic layers. Analyzing the response of Au/Fe/MgO(001) and Fe/Au/Fe/MgO(001) structures with varying layer thicknesses, we observe contributions from both charge/particle and spin components of HC currents within

300 fs after the excitation. The underlying mechanisms and related details of mSHG diagnostics are discussed. DFG (ME 3570/1, Sfb 616) and EU 7-th framework program (CRONOS) are acknowledged.

MA 36: Topological insulators: Transport (HL with DS/MA/O/TT)

Time: Wednesday 11:45–13:00 Location: ER 270

MA 36.1 Wed 11:45 ER 270

Surface Transport on a Bulk Topological Insulator — •Frederik Edler[1], Lisa Kühnemund[1], Marco Bianchi[2], Ellen M.J. Hedegaard[3], Martin Bremholm[3], Bo B. Iversen[3], Philip Hofmann[2], and Christoph Tegenkamp[1] — [1]Inst. f. Festkörperphysik, Uni. Hannover — [2]Dep. of Physics and Astronomy, Uni. Aarhus — [3]CMC, Dep. of Chemistry and iNANO, Uni. Aarhus

Topological insulators are guaranteed to support metallic surface states on an insulating bulk, and one should thus expect that the electronic transport in these materials is dominated by the surfaces states. Alas, due to the high remaining bulk conductivity, surface contributions to transport have mainly only been singled out indirectly via quantum oscillations, or for devices based on gated and doped topological insulator thin films, a situation in which the surface carrier mobility could be limited by defect and interface scattering. This issue was first overcome for Bi_2Te_2Se where compensation of defects leads to low bulk conductivity and surface-dominated transport could directly be observed [1]. Here we present a direct measurement of surface-dominated conduction on atomically clean surfaces of Bi_2Te_3. Using a four tip STM for nano-scale four point transport measurements with variable contact distance we show that the transport at 30 K is again two-dimensional rather than three-dimensional. The sheet conductivity is $7.9(3)\times10^{-4}\Omega^{-1}$ corresponding to a mobility of 505 cm^2/Vs. Besides, results regarding the temperature dependence of the conductivity and the influence of structural defects, e.g steps, present after cleavage will be discussed. [1] Barreto et al., Nano Lett. **14**, 3755 (2014)

MA 36.2 Wed 12:00 ER 270

Aharonov-Bohm oscillations in quantum wire of topological insulator — •Louis Veyrat[1], Joseph Dufouleur[1], Romain Giraud[1], Emmanouil Xypakis[2], Jens Bardarson[2], Christian Nowka[1], Silke Hampel[1], and Bernd Büchner[1] — [1]IFW-Dresden — [2]MPIPKS

Studying Aharonov-Bohm (AB) effect in a nanowire of topological insulator is a convenient way to reveal the specific properties of the topological surface states (SS), which are spin-chiral Dirac fermions. In the short perimeter limit, we evidenced in a previous work the ballistic transport of the SS in the perimeter of the nanowire, revealed by the temperature dependance of the phase coherence length [1] and showing the weak scattering effect of disorder on Dirac fermions. The quantum transverse confinement of SS is further revealed by the observation of non-universal conductance fluctuations. In the longer perimeter limit, we surprisingly find that the transport remains ballistic in the perimeter, despite the presence of disorder. The interaction with disorder is revealed by specific phase-jump of the AB oscillations under transverse magnetic field.

[1] Dufouleur et al., Phys. Rev. Lett. 110, 186806 (2013)

MA 36.3 Wed 12:15 ER 270

The effect of strain on the two-dimensional topological insulator HgTe — •Philipp Leubner, Andreas Budewitz, Christoph Brüne, Hartmut Buhmann, and Laurens Molenkamp — Experimentelle Physik III, Fakultät für Physik, Universität Würzburg, Germany

In the past years, HgTe quantum wells have been used extensively to study the magnetotransport signature of two-dimensional topological insulators, namely the quantum spin Hall effect. It has been shown that the band structure of those systems strongly depends on the thickness of the quantum well, and that, in particular, the topology changes from trivial to nontrivial at a critical thickness of 6.3 nm.

As an additional degree of freedom, the influence of strain on the band structure is investigated in this work. By using different CdTe-ZnTe superlattices grown on GaAs as virtual substrates, we are able to tune the strain of the HgTe quantum well layer from tensile to compressive, and thus modify the shape of the valence band.

Depending on strain, temperature dependent transport measurements on nominally identical wells reveal either features of topological insulators or semimetals, with the obtained fitting parameters nicely agreeing with band structure calculations. Further experiments focus on the correlation between the magnitude of the inverted bandgap and stability of the quantum spin Hall edge states.

MA 36.4 Wed 12:30 ER 270

Transport measurements on Mn-doped HgTe quantum wells — •Andreas Budewitz, Kalle Bendias, Philipp Leubner, Christoph Brüne, Hartmut Buhmann, and Laurens W. Molenkamp — Universität Würzburg, Lehrstuhl für experimentelle Physik III

In 2007 HgTe quantum wells have been experimental identified as a quantum spin Hall system [1]. One open question is how quantum spin Hall states interplay with magnetic impurities. Especially the formation of the anomalous quantum Hall effect raises a lot of interest [2, 3]. Since Mn-doped HgTe is a paramagnetic topological insulator it is important to investigate the onset of the ν = -1 plateau at low fields. Here we present transport measurements on Mn-doped HgTe quantum wells. Therefore we show results on different temperatures, magnetic fields, Mn concentration and quantum well width. We discuss our results in comparison to undoped HgTe quantum wells.

[1] M. König, S. Wiedmann, C. Brüne, A. Roth, H. Buhmann, L. W. Molenkamp, X.-L. Qi and S.-C. Zhang, Science 318, 766 (2007)

[2] Chao-Xing Liu, Xiao-Lang Qi, Xi Dang, Zhong Fang and Shou-Cheng Zhang, PRL 101, 14682 (2008)

[3] Hsiu-Chang Hsu, Xin Liu and Chao-Xing Liu, Phys. Rev. B 88, 085315 (2013)

MA 36.5 Wed 12:45 ER 270

Quantum hall states equilibration in lateral heterojunctions on inverted HgTe quantum wells — •M. Reyes Calvo[1,2], Christoph Brüne[3], Christopher Ames[3], Philipp Leubner[3], Hartmut Buhmann[3], Laurens W. Molenkamp[3], and David Goldhaber-Gordon[1] — [1]Department of Physics, Stanford Universtiy, Stanford, U.S.A. — [2]C.I.C. Nanogune, San Sebastián, Spain — [3]Physikalisches Institut (EP3), Universität Würzburg, Würzburg, Germany

We study lateral heterojunctions on HgTe quantum wells with inverted band structure. At high densities and fields, we can explore the equilibration between Quantum Hall (QH) states with different filling factor. The resulting resistance plateaus are particularly clear in the n-n'-n quadrant and fit the expected values for a 2D electron gas heterojunction. The low density and moderate magnetic field regime is of more interest, since due to the inverted band structure of HgTe, Quantum Spin Hall (QSH) edge states could be present. In this regime, we observe unexpected features in the Hall resistance, which could be associated with the interplay between chiral QH edge modes and helical QSH edge modes.

MA 37: Topological insulators: Structure and electronic structure (HL with DS/MA/O/TT)

Time: Wednesday 15:00–16:30 Location: ER 270

MA 37.1 Wed 15:00 ER 270

New electron states at the Bi/InAs(111) interface — K Hricovini[1,2], J-M Mariot[3], •L Nicolaï[1,2,7], U Djukic[1], M C Richter[1,2], O Heckmann[1,2], T Balasubramanian[4], M Leandersson[4], J Sadowski[4], J Denlinger[5], I Vobornik[6], J Braun[7], H Ebert[7], and J Minár[7,8] — [1]LPMS, UCP,Cergy, France — [2]DSM-IRAMIS, SPEC, CEA-Saclay, France — [3]LCP-MR, UPMC Univ. Paris 06/CNRS, France — [4]MAX-lab, Lund Univ., Sweden — [5]ALS, Berkeley, USA — [6]EST, Trieste, Italy — [7]LMU München, Germany — [8]Univ. of West Bohemia, Plzeň, Czech Republic

The Bi(111) surface is a prototype system to study Rashba-split surface states. Theoretical studies [1] predicted non-trivial topological surface states appearing on a single bi-layer of Bi(111) and a more complex behaviour was suggested for a variable film thickness as a function of layer thickness [2]. This clearly indicates that the electronic properties of thin films of this material are far from being understood. Here we present combined theoretical and ARPES studies of the electronic structure of Bi(111) films grown on InAs(111). Bi growth is epitaxial and a monocrystal of very high quality is obtained after depositing several monolayers. The ARPES experiments on these samples show several new types of electronic states. It is shown that a part of these new states corresponds to novel bulk-like features. These features are well reproduced by the one-step model of photoemission as implemented in the SPR-KKR package [3].[1] M. Wada et al., Phys. Rev. B 83, 121310 (2011). [2] Z. Liu et al., Phys. Rev. Lett. 107, 136805 (2011). [3] H. Ebert, D. Ködderitzsch, J. Minár, Rep. Prog. Phys. 74, 096501 (2011).

MA 37.2 Wed 15:15 ER 270

Ultrafast currents at the surface of the topological insulator Bi_2Se_3 — •Lukas Braun[1], Luca Perfetti[2], Gregor Mussler[3], Markus Münzenberg[4], Martin Wolf[1], and Tobias Kampfrath[1] — [1]Fritz-Haber-Institut Berlin (MPG) — [2]Ecole Polytechnique Palaiseau — [3]Forschungszentrum Jülich — [4]Universität Greifswald

Optical excitation of topological insulators (TIs) can launch electron currents along the TI surface whose direction can be controlled by varying the polarization of the driving light [J. W. McIver *et al.*, Nat. Nanotech. **7**, 96]. So far, photocurrents have been detected with a time resolution from DC to picoseconds [C. W. Luo *et al.*, Adv. Opt. Mat. **1**, 804]. Since electrons moving through a solid typically undergo scattering on a 100fs time scale, it is highly desirable to generate and detect TI photocurrents with femtosecond time resolution in a contact-free manner. For this purpose, we excite n-doped Bi_2Se_3 (Fermi energy at 300meV) crystals with a femtosecond laser pulse (10fs, 1.55eV). The resulting photocurrent gives rise to the emission of a broadband terahertz (THz) electromagnetic pulse (1 to 20THz) whose transient electric field is detected by means of electro-optic sampling. We present a method that allows us to extract the transient current $j(t)$ from the measured field $E(t)$. The AC photocurrents are found to be dominated by shift currents along the surface and photo-Dember injection currents into the bulk. We finally discuss the origin of $j(t)$ and implications for the dynamics of photoexcited TI electrons.

MA 37.3 Wed 15:30 ER 270

Observation of the photon drag effect in epitaxially grown $(Bi_{1-x}Sb_x)_2Te_3$ based topological insulators — •H. Plank[1], L. E. Golub[2], P. Olbrich[1], T. Herrmann[1], S. Bauer[1], V. V. Bel'kov[2], G. Mussler[3], J. Kampmeier[3], D. Grützmacher[3], and S. D. Ganichev[1] — [1]University of Regensburg, Regensburg, Germany — [2]Ioffe Institute, St. Petersburg, Russia — [3]Jülich Aachen Research Alliance (JARA-FIT), Jülich, Germany

We report on the observation of a terahertz (THz) radiation induced photon drag effect in epitaxially grown $(Bi_{1-x}Sb_x)_2Te_3$ three-dimensional topological insulators. We demonstrate that the excitation with polarized radiation results in a dc electric photocurrent. While at normal incidence a current arises due to the photogalvanic effect in the surface states, caused by asymmetrical scattering of Dirac fermions [1], at oblique incidence it is overweighted by the trigonal photon drag effect. The currents are generated in n- and p-type $(Bi_{1-x}Sb_x)_2Te_3$ samples with various composition applying linearly and circularly polarized THz radiation. Results are analysed in terms of phenomenological theory and microscopic model based on transfer of photon momentum to free carriers resulting in an asymmetric distribution of electrons (holes) in k-space. Our analysis describes well all experimental findings including e.g. variation of the angle of incidence, radiation polarization and frequency. The observed trigonal photon drag and photogalvanic effect provide an opto-electronic method to study high frequency transport of Dirac fermions even at room temperature.

[1] P. Olbrich *et al.*, Phys. Rev. Lett. **113**, 096601(2014)

MA 37.4 Wed 15:45 ER 270

Cyclotron Resonance Induced Spin Polarized Photocurrents in Surface States of a 3D Topological Insulator — •K.-M. Dantscher[1], D.A. Kozlov[2], Z.D. Kvon[2], P. Faltermeier[1], M. Lindner[1], P. Olbrich[1], C. Zoth[1], G.V. Budkin[3], S.A. Tarasenko[3], V.V. Bel'kov[3], N.N. Mikhailov[2], S.A. Dvoretskii[2], D. Weiss[1], and S.D. Ganichev[1] — [1]University of Regensburg, Regensburg, Germany — [2]Institute of Semiconductor Physics, Novosibirsk, Russia — [3]Ioffe Institute, St. Petersburg, Russia

We report on the observation of cyclotron resonance (CR) induced photocurrents excited by cw radiation, with frequencies of 2.54, 1.62 and 0.69 THz in a 3D topological insulator based on 80 nm strained HgTe films. To support the complex study, including optical, opto-electronic and electron transport experiments, various sample designs have been used. The measurements were done in a wide range of temperatures (1.6 to 120 K). We demonstrate that the photocurrent is generated in the topologically protected surface states. Studying the resonance response in the gated samples we examined the behaviour of the photocurrent and Dirac fermions cyclotron mass upon variation of Fermi energy. For large gate voltages we also detected CR in the bulk HgTe with the mass about two times larger than that obtained for the surface states. Based on this data we develop a microscopic theory of the effects and show that the asymmetry of light-matter coupling in the system of Dirac fermions subjected to an external magnetic field causes the electric current to flow. We show that the current is spin polarized.

MA 37.5 Wed 16:00 ER 270

Response of the topological surface state to surface disorder in $TlBiSe_2$ — Florian Pielmeier[1], •Andreas Eich[2], Gabriel Landolt[3,4], Bartosz Slomski[3,4], Julian Berwanger[1], Alexander A. Khajetoorians[5], Jens Wiebe[2], Roland Wiesendanger[2], Jürg Osterwalder[3], Franz J. Giessibl[1], and J. Hugo Dil[3,4,6] — [1]Institute of Experimental and Applied Physics, Universität Regensburg, D-93040 Regensburg, Germany — [2]Department of Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany — [3]Physik-Institut, Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland — [4]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen, Switzerland — [5]Institute of Molecules and Materials, Radboud University, 6500 GL Nijmegen, Netherlands — [6]Institut de Physique de la Matière Condensée, Ecole Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

By a combination of experimental techniques we show that the topmost layer of the topological insulator $TlBiSe_2$ as prepared by cleavage is formed by irregularly shaped Tl islands. No trivial surface states are observed in photoemission, which suggests that these islands can not be regarded as a clear surface termination. The topological surface state is, however, clearly resolved in photoemission experiments. This is interpreted as a direct evidence of its topological self-protection and shows the robust nature of the Dirac cone like surface state.

MA 37.6 Wed 16:15 ER 270

Wet etch process for HgTe nanostructure fabrication — •Kalle Bendias[1], Erwann Bocquillon[1], Alex Hughes[2], Christoph Brüne[1], Hartmut Buhmann[1], and Laurens W. Molenkamp[1] — [1]EP3, Physikalisches Institut, Universität Würzburg — [2]Department of Physics, Stanford University

Topological insulators (TI) are a new class of material with outstanding spin properties. Grown in 2d quantum wells HgTe does not only host Quantum Spin Hall edge channels [1][2], but also a giant Rashba splitting [3]. Both could lead to numerous applications in spintronic devices. In order to perform experiments such as spininjection, -probing

[3] or quantum point contact collimation [4] a high carrier mobility and i.e. a long ballistic mean free path is essential.

The conventional processing method using ion milling to define the structure strongly affects these surface properties on small microstructures. In this talk the development and results of an alternative lithography etch method using KI:I:HBr as wet etchant are presented. Measurements on microstructures will be shown, indicating comparable mobilities on big and small structures.

[1] Markus König et al., Journal of the Physical Society of Japan 77.3 (2008), S. 031007.
[2] C. Brüne et al., Nature Physics 6.6 (2010), S. 448-454.
[3] J. Hinz et al., Semiconductor science and Technology 21.4 (2006), S 501-506.
[4] L.W. Molenkamp et al., Phys. Rev. B 41, 1274 (1990)

MA 38: Magnetic Nanoparticles

Time: Thursday 9:30–12:45 Location: H 0110

MA 38.1 Thu 9:30 H 0110

Tuning the magnetic properties of granular FePt media by seed layer conditioning — •S. Wicht[1,2], V. Neu[1], L. Schultz[1,2], O. Mosendz[3], V. Mehta[3], S. Jain[3], J. Reiner[3], O. Hellwig[3], D. Weller[3], and B. Rellinghaus[1] — [1]IFW Dresden, Hemholtzstr. 20, D-01069 Dresden, Germany — [2]TU Dresden, IFWW, D-0162 Dresden, Germany — [3]HGST, 3403 Yerba Buena Rd, San Jose, CA-95135, USA.

In the course of the steadily increasing amount of digitized information reliable data storage at ultimate storage densities is mandatory. Accordingly, areal densities in future storage media will soon cross the 1TB/in^2 border. For such media, L1$_0$ ordered, granular FePt-X films, grown on highly textured MgO, are promising materials candidates. The present work aims at a better understanding of the influence of the MgO seed layer roughness on the structure and the magnetic performance of the granular media. Therefore, the MgO was subjected to Ar$^+$ ion irradiation prior to the deposition of the magnetic material. Aberration-corrected high-resolution transmission electron microscopy (HRTEM) and vibrating sample magnetometry (VSM) are used to correlate the structure with the magnetic properties. We find that decreasing the surface roughness of the oxide seed layer results in a change of the morphology of the grains from spherical over cylindrical to island-type shapes. This modification is accompanied by an enhanced fraction of small second layer particles and an increasing degree of coalescences of the primarily deposited grains. Concerning the magnetic properties, this results in a reduction of the coercivity from 5 to 2.6 T.

MA 38.2 Thu 9:45 H 0110

Experimental investigation and modeling of the spin structure in MnO nanoparticles — •Xiao Sun[1], Alice Klapper[1], Yixi Su[2], Kirill Nemkovski[2], Oskar Köhler[3], Heiko Bauer[3], Anna Schilmann[3], Wolfgang Tremel[3], Oleg Petracic[1], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich — [2]Jülich Centre for Neutron Science JCNS, Forschungszentrum Jülich GmbH, Outstation at MLZ, Garching — [3]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz, Mainz

The spin structure of antiferromagnetic (AF) MnO nanoparticles (NPs) has been investigated for various NP diameters (5-20nm) using both magnetometry and polarized neutron scattering. Magnetization curves show a peculiar peak at low temperatures (ca. 25K) instead at the Néel temperature of 120K. However, the AF order parameter of MnO shows the expected behavior from polarized neutron scattering studies. In MnO powder, features at both the low temperature (ca. 25K) and the Néel temperature can be found. To understand the observed behavior further magnetometry studies using hysteresis curves, memory effect and susceptibility measurements were employed. We conclude that the magnetic behavior of MnO NPs can be explained by a superposition of superparamagnetic-like thermal fluctuations of the AF Néel vector inside an AF core and a strong magnetic coupling to a FM shell. Moreover, we employed Monte-Carlo simulations of the spin structure to model the observed behavior.

MA 38.3 Thu 10:00 H 0110

Magnetic Properties of FePt and FePt@MnO Heterodimer Nanoparticles — •Alice Klapper[1], Sabrina Disch[2], Xiao Sun[1], Oskar Köhler[3], Heiko Bauer[3], Wolfgang Tremel[3], Oleg Petracic[1], 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]Department Chemie, Universität zu Köln, 50939 Köln, GERMANY — [3]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz, 55099 Mainz, GERMANY

For particles with characteristic length scales of a few nanometers, surface and interface effects compared to bulk systems play an important role and can drastically alter the magnetic behavior of nanoparticles (NP). In this work we investigate the magnetic properties of FePt NP and the change of these properties due to an exchange interaction with an attached antiferromagnetic NP, i.e. FePt@MnO heterodimer NP. The epitaxial intergrowth of the two NP leads to an increase of the blocking temperature compared to the FePt NP proven by ZFC curves obtained from SQUID measurements. Polarized small angle neutron scattering (SANS) measurements in a magnetic field have been performed to measure the magnetic form factor of the NP.

MA 38.4 Thu 10:15 H 0110

A unique multiple-twinned, chemically ordered FePt nanocrystal observed by transmission electron microscopy — •Zi-An Li[1], Marina Spasova[1], Quentin Ramasse[2], Markus Gruner[1], Christian Kisielowski[3], and Michael Farle[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CeNIDE), University Duisburg-Essen, Germany — [2]SuperSTEM Laboratory, STFC Daresbury Campus, United Kingdom — [3]National Center for Electron Microscopy, Lawrence Berkeley National Laboratory, University of California, USA

Using a combination of high-resolution transmission electron microscopy (HRTEM) and high angle annular dark field (HAADF) imaging in scanning transmission electron microscopy (STEM), we characterize the crystal structure of multiple-twinned FePt nanocrystals produced by gas-phase condensation. These FePt nanocrystals are found to be chemically ordered, decahedral or icosahedral shaped, and Pt enriched at the surfaces. [1,2] The experimentally determined crystallographic lattice constants and distribution of Fe and Pt atoms are compared with first-principles calculations of FePt nanocrystals to confirm the discovery of a unique multiple-twinned structure with Fe/Pt ordering and Pt surface segregation. References: 1. Zi-An Li, et al. Phys. Rev. B 89, 161406(R) (2014). 2. Financial support by ERC-Grant *IMAGINE* is acknowledged.

MA 38.5 Thu 10:30 H 0110

The effect of segregation on the magnetic properties of RE-TM nanoparticles — •Frank Schmidt[1,2], Darius Pohl[1], Ludwig Schultz[1], and Bernd Rellinghaus[1] — [1]IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany. — [2]TU Dresden, IFWW, D-01062 Dresden, Germany.

Rare earth transition metal compounds like $Nd_2Fe_{14}B$ or $SmCo_5$ are among the magnets with the highest energy product and coercive field. Nonetheless, there is still demand further to improve the magnetic properties of these alloys. The present study reveals the investigation on the formation and phase stability of RE-TM nanoparticles from the gas phase which could serve as a model system for their bulk counterparts. Particular attention is paid to the question, if the intermetallic $Nd_2Fe_{14}B$ and $SmCo_5$ phase form in particles with only a few nanometers in size, which grow without contact to any solid or liquid matrix in a low pressure Ar atmosphere. It also addresses the possibility of segregation that goes along with the phase formation and how this possibly affect the magnetic properties. Aberration-corrected transmission electron microscopy was used in combination with spectroscopic methods to determine the local atomic structure and the chemical composition, and it was found that in both cases, the RE element segregates to the particle surface. The magnetic properties of Nd-Fe-B and Sm-Co nanoparticles ensembles as determined from VSM measurements are correlated with the resulting core-shell structure of these RE-TM particles.

MA 38.6 Thu 10:45 H 0110

Interface strain mediated magnetoelectric coupling in BaTiO3 /Iron oxide nanoparticle composites — •Li-Ming Wang, Oleg Petracic, Emmanuel Kentzinger, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, Jülich

We demonstrate strain mediated magnetoelectric coupling in a composite consisting of ferrimagnetic iron oxide nanoparticles coupled to a BaTiO3 (BTO) ferroelectric single crystal substrate. We performed measurements of the magnetization as function of the magnetic and electric field and measurements of the magneto-electric AC susceptibility (MEACS) as function of temperature and field. We find jumps in the magnetization at the BTO phase transition temperatures and corresponding peaks in the MEACS signal. An interface strain coupling model is proposed to understand the observed effects. Up to 8%magnetization change is achieved upon the BTO phase transition between orthorhombic and rhombohedral phase. Moreover, an electric field controlled magnetic "hardening effect" is observed from magnetization hysteresis loops. The self-assembly of the nanoparticles on top of the BTO substrate is investigated using grazing incidence small angle X-ray scattering (GISAXS).

15 min. break

MA 38.7 Thu 11:15 H 0110

Magnetic trapping of a superparamagnetic particle by a single micro-ring conductor — •Benjamin Riedmüller, Meng Li, and Ulrich Herr — Institut für Mikro- und Nanomaterialien, Ulm, Deutschland

In this work we present a magnetic trap for superparamagnetic particles, consisting of a single ring-shaped current conductor, which allows to transport and trap magnetic particles to a defined position with an accuracy of ≈ 1 um. The functionality of the device can be understood on the magnetic force caused by the superposition of a magnetic field gradient (generated by a static current through the conductor ring) and a superimposed, homogeneous magnetic field perpendicular to the plane of the substrate. The tracking of a single trapped Dynabead M-280 particle allows to determine the viscosity of the surrounding medium (here water was used) with an accuracy of < 10 %. By applying the fluctuation-dissipation-theorem the stiffness constant of the trap, which is a measure for the remaining particle fluctuation around the energy minimum caused by Brownian motion, can be extracted. The stiffness constant is then systematically changed by applying different static currents and by changing the externally applied field. We find a good correlation between the experimentally extracted stiffness constants to the values which are predicted from numerically modeling the energy landscape near the energy minimum with a simple spring model.

MA 38.8 Thu 11:30 H 0110

On the statistical nature of intermetallic nanoparticle assemblies — •Markus Gellesch[1], Franziska Hammerath[1,2], Silke Hampel[1], Sabine Wurmehl[1,2], and Bernd Büchner[1,2] — [1]Institut für Festkörperforschung, IFW Dresden — [2]Institut für Festkörperphysik, TU Dresden

It is well known, that the synthesis of nanoparticles usually results in the formation of particles with a certain distribution of geometries (e.g. diameter, shape). Since, especially at the nanoscale, shape and size govern the physical properties including the occurence of magnetic phenomena, one of the challenges in magnetic nanoparticle synthesis is to create monodisperse particle assemblies.

Here, we raise the issue of an additional challenge since we report about distributed chemical compositions in intermetallic nanoparticle assemblies with ternary precursor conditions. Our results were obtained by an extensive TEM-EDX study of a larger number of individual particles. In order to crosscheck and to validate our results obtained with TEM we successfully applied the solid state NMR technique where the local environments of all particles in the sample are observed.

We are confident, that our results guide the way to establish NMR as a powerfull tool to characterize complex multi-element magnetic nanoparticle assemblies.

MA 38.9 Thu 11:45 H 0110

Phase formation in colloidal systems with tunable interaction — •Hauke Carstensen, Vassilios Kapaklis, and Max Wolff — Dept of Physics & Astronomy, Box 516, SE-751 20 Uppsala, Sweden

Self assembly is one of the most fascinating phenomena in nature and one key component in the formation of hierarchic structures forming the basis for living organisms. The formation of structure depends critically on the interaction between the different constituents. We have realized a two dimensional system of colloidal particles with tunable magnetic dipole forces. Particles with a diameter in the micrometer range are embedded in a magnetic medium, which is composed of nanometer sized magnetic particles dispersed in water. The result is an effective magnetic susceptibility of the embedded particles which can be altered by the concentration of nanoparticles. The phase formation and diagram of the micrometer particles are studied by transmission optical microscopy. For in-plane magnetic fields we report a phase transition from hexagonal to cubic, when tuning the magnetic interaction between the individual particles from antiferromagnetic to ferrimagnetic. Quantitatively information is extracted from the pair correlation function and explained by the dipolar particle interaction. For out-of plane fields the phase diagram is more rich and is mapped for different particle ratios and concentrations.

MA 38.10 Thu 12:00 H 0110

Superparamagnetische Partikel als Bausteine für komplexe Mikrostrukturen? — •Claus Fütterer — Translational Centre of Regenerative Medicine, Leipzig & Biophysical Tools GmbH, Leipzig

Superparamagnetische Partikel zeigen auch auf makroskopischer Skala ungewöhnliche Strukturbildung und unterscheiden sich wesentlich von elektrostatisch selbstorganisierenden Partikel (z.B. Moleküle). Der Grund ist die Form des Potentials sowie die starke Abhängigkeit der Wechselwirkung von der relativen Partikel-Orientierung in Konkurrenz zur Diffusion und weiteren Kräften. Diese Kräfte, die zeitliche Dynamik und die Möglichkeit 2D- oder sogar 3D-Strukturen gezielt zu erzeugen allein basierend auf Selbstorganisation werden diskutiert und durch Simulationen gestützt. Vereinfachte Ausdrücke erlauben die Interpretation der ebenfalls gezeigten Experimente. Die möglichen Anwendungen sind vor allem wichtig für die Biotechnologie, aber möglicherweise auch für Metamaterialien.

MA 38.11 Thu 12:15 H 0110

X-ray magnetic circular dichroism of free iron and cobalt dimer cations — •Vicente Zamudio-Bayer[1,2], Konstantin Hirsch[2], Arkadiusz Ławicki[2], Andreas Langeberg[2], Akira Terasaki[3,4], Bernd von Issendorff[1], and Tobias Lau[2] — [1]Physikalisches Institut, Universität Freiburg, Stefan-Meier-Straße 21, 79104 Freiburg, Germany — [2]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [3]Cluster Research Laboratory, Toyota Technological Institute, 717-86 Futamata, Ichikawa, Chiba 272-0001, Japan — [4]Department of Chemistry, Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan

Only recently was it possible for the first time to measure the x-ray magnetic circular dichroism (XMCD) of small, free, size selected clusters. This achievement opens up new possibilities to better understand how spin coupling and orbital magnetic moment in $3d$ transition metals develop from the isolated atom to the bulk material. With this in mind, we have now measured the XMCD of free iron and cobalt dimer cations. The high complexity of the electronic structure of these smallest molecules is evidenced by the numerous attempts in the literature to theoretically describe their electronic ground states. By applying the XMCD sum rules it is possible to resolve spin and orbital contributions to the total magnetic moment in these molecules and to therefore determine their electronic ground state. Experimental results and possible trends in trimers and larger clusters will be discussed.

MA 38.12 Thu 12:30 H 0110

Magnetism of free Rh clusters via ab-initio calculations: which intuitive concepts can or cannot be used — •Ondřej Šipr[1], Hubert Ebert[2], Sergey Mankovsky[2], and Ján Minár[2,3] — [1]Institute of Physics ASCR, Praha, Czech Republic — [2]Universität München, München, Germany — [3]University of West Bohemia, Plzeň, Czech Republic

A fully relativistic ab-initio study on free Rh clusters of 13-135 atoms is performed to identify general trends concerning their magnetism and to check whether concepts which proved to be useful in interpreting magnetism of 3d metals are applicable to magnetism of 4d systems. Some important intuitive concepts which proved to be useful in interpreting magnetism of 3d metals are not applicable to magnetism of 4d systems (such as Rh clusters). In particular, there is no systematic relation between local magnetic moments and coordination numbers. On the other hand, the Stoner model appears to be well-suited as a criterion for the onset of magnetism of Rh clusters and, on the top of that, it can serve as a guide for the dependence of local magnetic moments on the local density of states at the Fermi level.

Fully-relativistic calculations indicate that in some cases there can be large orbital magnetic moments antiparallel to the spin magnetic moments. The intra-atomic magnetic dipole T_z term can be quite large at certain sites, however, as a whole it is unlikely to affect the interpretation of x-ray magnetic circular dichroism (XMCD) experiments based on the sum rules.

MA 39: Spin-dependent Transport Phenomena I

Time: Thursday 9:30–11:30 Location: H 0112

MA 39.1 Thu 9:30 H 0112

Unified theory for charge, spin and angular momentum excitations — •Filipe Souza Mendes Guimaraes[1,2], Antonio Tavares da Costa Jr[1], Roberto Bechara Muniz[1], Manuel dos Santos Dias[2], and Samir Lounis[2] — [1]Instituto de Física, Universidade Federal Fluminense, Niterói, Brazil — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The investigation of phenomena involving the spin and charge of the electron, called spintronics, has the potential to generate and enhance tools for the development of devices with low power consumption and fast switching speeds, as well as technologies that may be mass-produced. Polarized currents and angular momentum currents may be used to transfer information more efficiently than the conventional charge currents. We have developed a fully quantum mechanical approach that allows us to study charge, spin and angular momentum excitations. This method takes into account realistic electronic structures obtained from first principles calculations. We show that spin, charge and angular momentum currents and disturbances can be expressed in terms of generalized susceptibilities. Results on static and dynamic quantities related to the Spin Hall Effect and Inverse Spin Hall Effect for ultrathin films of Pt and Co/Pt will be presented.

MA 39.2 Thu 9:45 H 0112

Enhancement of the anomalous Hall effect in ternary alloys — •Katarina Tauber[1], Albert Hönemann[1], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg — [2]Max Planck Institute of Microstructure Physics, Halle — [3]University of Bristol

We present our results for the anomalous Hall effect (AHE) in ternary alloys of the form $\mathrm{Cu(Mn_{1-w}T_w)}$ with T as nonmagnetic Au, Bi, Ir, Lu, Sb, or Ta impurities. As was shown experimentally [1], Mn causes negligible skew scattering in copper and therefore a very weak AHE is observed in the Cu(Mn) binary alloys. In contrast, the systems Cu(T) have a strong skew scattering, but only provide a spin Hall effect (SHE) instead of an AHE, since the systems are nonmagnetic. Fert *et al.* [1] found that the AHE can be strongly enhanced in the Cu(Mn) alloys via the co-doping of 5d-impurities. Furthermore, they showed that it is possible to describe the SHE in the Cu(T) alloy via measurements of the AHE in the $\mathrm{Cu(Mn_{1-w}T_w)}$ alloys. Here, a theoretical study via Matthiessen's rule is presented with focus on the connection between the AHE in the ternary alloy and the SHE in the related Cu(T) alloy. Our formalism provides the conditions for a maximal enhancement of the AHE with respect to the weighting factor w. This is underpinned by first-principles calculations using a relativistic Korringa-Kohn-Rostoker method and Boltzmann transport theory [2].

[1] A. Fert et al., JMMM **24**, 231 (1981).
[2] K. Tauber et al., Phys. Rev. B **87**, 161114(R) (2013).

MA 39.3 Thu 10:00 H 0112

Anomalous Hall Effect at Terahertz Frequencies — Tom Seifert[1], Frank Freimuth[2], Lukas Braun[1], Florin Radu[3], Ulrike Martens[4], Markus Münzenberg[4], Ilie Radu[3], Yuriy Mokrousov[2], Martin Wolf[1], and •Tobias Kampfrath[1] — [1]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Faradayweg 4-6, 14195 Berlin, Germany — [2]Forschungszentrum Jülich, Peter Grünberg Institut, 52425 Jülich, Germany — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, BESSY II, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [4]Ernst-Moritz-Arndt Universität, Institut für Physik, Felix-Hausdorff-Str. 6, 17489 Greifswald, Germany

Spin-orbit interaction (SOI) is expected to be of central importance in future spin-based electronics (spintronics) as it permits, for example, the conversion of charge into spin currents. It is highly interesting to study SOI-based effects at terahertz (THz) frequencies because (i) spintronic devices should eventually operate at THz rates and since (ii) the THz photon energy (4 meV at 1 THz) is comparable to the SOI energy in magnetically ordered solids. Here, we employ broadband THz time-domain ellipsometry [1] to measure the complex conductivity tensor of various magnetic metals from 1 to 40 THz. Supported by *ab initio* calculations [2], we discuss spectral features of the spin Hall angle in terms of SOI.

[1] A. Rubano, L. Braun, M. Wolf, and T. Kampfrath, Appl. Phys. Lett. **101**, 081103 (2012).
[2] F. Freimuth, S. Blügel, and Y. Mokrousov, Phys. Rev. Lett. **105**, 246602 (2010).

MA 39.4 Thu 10:15 H 0112

Separation of different contributions to the spin Hall effect in dilute alloys based on the Kubo-Středa approach — •Kristina Chadova[1], Dmitry Fedorov[2,3], Christian Herschbach[2], Martin Gradhand[4], Ingrid Mertig[2,3], Diemo Ködderitzsch[1], and Hubert Ebert[1] — [1]Department of Chemistry, Physical Chemistry, Ludwig-Maximilians University Munich, Germany — [2]Institute of Physics, Martin-Luther University Halle-Weinberg, 06099 Halle, Germany — [3]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany — [4]H.H. Wills Physics Laboratory, University of Bristol, Bristol BS8 1TL, United Kingdom

In recent years several first-principles approaches have been established to describe transverse electron transport phenomena as e.g. the anomalous Hall and spin Hall effects. Starting from an earlier decomposition scheme [1] we extract the coherent part of the SHC as well as the extrinsic vertex-correction (vc) based skew-scattering and the side jump (sj) contributions. Further using insight from Boltzmann transport theory we separate the sj into a sum of a term being exclusively caused by the vc and a term that does not depend on the vc. The proposed procedure was applied within first-principles fully relativistic KKR transport framework (Kubo-Středa) to dilute alloys based on Cu, Au and Pt hosts [2].

[1] S Lowitzer, D Ködderitzsch, H Ebert, PRL **105**, 266604 (2010)
[2] K Chadova, D Fedorov, C Herschbach, M Gradhand, I Mertig, D Ködderitzsch, H Ebert (to be published)

MA 39.5 Thu 10:30 H 0112

Higher dimensional Wannier functions for a description of multi-parameter ab initio Hamiltonians — •Jan-Philipp Hanke, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Maximally localized Wannier functions (MLWFs) have become a widely applied tool in understanding the electronic structure [1]. Here, we present higher dimensional Wannier functions (HDWFs), which provide a minimal and accurate description of multi-parameter Hamiltonians $H^{(\mathbf{k},\boldsymbol{\lambda})}$ carrying a dependence on the crystal momentum $\mathbf{k}$ and an additional periodic parameter $\boldsymbol{\lambda}$. We derive a generalized interpolation scheme and emphasize the essential conceptual and computational simplifications in using the formalism for instance in the evaluation of linear response coefficients. The necessary machinery to construct HDWFs from *ab initio* is implemented within the full-potential linearized augmented plane-wave method (FLAPW) as realized in the `FLEUR` code [2]. We further apply our implementation to accurately interpolate the Hamiltonian of a one-dimensional magnetic chain of Mn atoms with spin-spiral texture in a composite space of Bloch and spin-spiral vectors, and thereby extract efficiently Heisenberg exchange constants.

Financial support by the HGF-YIG programme VH-NG-513 and SPP 1538 of DFG is gratefully acknowledged.

[1] N. Marzari and D. Vanderbilt, Phys. Rev. B **65**, 12847 (1997).
[2] See http://www.flapw.de

MA 39.6 Thu 10:45 H 0112

Description of electron transport in multilayer systems using Boltzmann approach — •Ondřej Stejskal[1], André Thiaville[2], Shunsuke Fukami[3], Hideo Ohno[3], and Jaroslav Hamrle[1] — [1]IF, VSB-Technical University of Ostrava, Czech Republic — [2]LPS, Univ. Paris-Sud, Orsay, France — [3]CSIS/RIEC/WPI-AIMR, Tohoku University, Sendai, Japan

Recent discoveries of spin current, spin Hall effect and Rashba effect have attracted a new interest in transport phenomena in multilayer systems. The Fuchs-Sondheimer theory that is based on the Boltzmann transport equation covers the transport phenomena in thin films. Though the paper was released in 1952, the theory is still being used with great success and is in a great agreement with experiments. We use this theory for the description of an in-plane current density in a multilayer system Ta/Pt/[Co/Ni]/Pt/Ta. The resistance of the multilayer is measured as the function of the thicknesses of individual layers. Using the Fuchs-Sondheimer model, we obtain the material and interface parameters of the layers and the current distribution in the sample. This is of a great importance for multilayers, as the spin phenomena, like spin Hall effect and spin-transfer torque, are proportional to current densities in the vicinity of the interface with ferromagnetic material. This work is partly supported by R&D Project for ICT Key Technology to Realize Future Society of MEXT.

[1] E. Sondheimer, Advances in Physics 1, 1 (1952)
[2] P. M. Haney, H.-W. Lee, K.-J. Lee, A. Manchon, M. D. Stiles, Physical Review B., 87, 174411 (2013)

MA 39.7 Thu 11:00 H 0112

Higher order contributions to Anisotropic Interface Magnetoresistance (AIMR) in Ni/Pt thin films — •Afsaneh Farhadi, André Kobs, Gerrit Winkler, Carsten Thönnissen, and Hans Peter Oepen — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11a, 20355 Hamburg, Germany

The influence of interfaces on the magnetotransport in systems with one ferromagnetic layer has attracted much attention. In Pt/Co/Pt the resistivity behaves as $\rho(\varphi,\theta) = \rho_t + \Delta\rho_{ip}\cos^2\varphi\sin^2\theta + \Delta\rho_{op}\cos^2\theta$ where φ/θ is the angle between magnetization and current direction/film normal [1]. While $\Delta\rho_{ip}$ is caused by the conventional AMR (bulk effect) a $\Delta\rho_{op} \propto 1/t$ behavior was found for Pt(5nm)/Co(t)/Pt(3nm) sandwiches revealing that $\Delta\rho_{op}$ originates at the Co/Pt interfaces (anisotropic interface magnetoresistance (AIMR)). So far the AIMR was observed also for Py/Pt and Co/Pd [2,3]. In order to answer the question if interfacial MR contributions also exist when stacking isoelectronic materials we investigated Ni/Pt systems. We prepared Pt(5nm)/Ni(t)/Pt(3nm) sandwiches with Ni thicknesses of $1-50$ nm by dc magnetron sputtering on Si_3N_4 substrate. As a result, in contrast to previous findings, the $\rho(\theta)$ behavior can only be satisfactorily described when considering higher orders in the expansion of the MR up to $n=3$: $\rho(\theta) = \rho_t + \sum_n \Delta\rho_{op,2n}\cos^{2n}\theta$. The thickness dependence of the amplitudes $\Delta\rho_{op,2n}$ behaves according to $1/t$ revealing that also the higher orders have their origin at the Ni/Pt interfaces.

[1] A. Kobs et al., PRB **90**, 016401 (2014), [2] Y.M. Lu et al., PRB **87**, 220409 (2013), [3] J.-C. Lee et al., JAP **113**, 17C714 (2013).

MA 39.8 Thu 11:15 H 0112

Lattice strain accompanying the colossal magnetoresistance effect in EuB_6 — •Rudra Sekhar Manna[1,2], Pintu Das[1], Mariano de Souza[1], Frank Schnelle[1], Michael Lang[1], Stephan von Molnár[3], Zachary Fisk[4], and Jens Müller[1] — [1]Phys. Inst., Goethe-University Frankfurt, 60438 Frankfurt (Main), SFB/TR49, Germany — [2]EP VI, EKM, Augsburg University, 86159 Augsburg, Germany — [3]Phys. Dept., FSU, Tallahassee, Florida 32306, USA — [4]Phys. Dept., UC Irvine, California 92697, USA

Semimetallic EuB_6 shows a complex ferromagnetic order and a colossal magnetoresistance effect due to the interplay of magnetic, electronic and lattice degrees of freedom. EuB_6 may be viewed as a model system, where pure magnetism-tuned transport and the response of the crystal lattice can be studied in a comparatively simple environment, i.e., not influenced by strong crystal-electric field effects and Jahn-Teller distortions. We performed thermal expansion and magnetostriction measurements and find a large lattice response when the system enters the ferromagnetic region. Our analysis reveals that a significant part of these lattice effects - quantified by the large magnetic Grüneisen parameter and spontaneous strain when entering the ferromagnetic region - originates in the magnetically driven delocalization of charge carriers, consistent with the scenario of percolating magnetic polarons. A strong effect of the formation and dynamics of local magnetic clusters on the lattice parameters is suggested to be a general feature of colossal magnetoresistance materials [1].

[1] R. S. Manna *et al.*, PRL **113**, 067202 (2014)

MA 40: Spintronics: Mobile electrons and holes (HL with MA/TT)

Time: Thursday 10:00–12:30 Location: ER 164

MA 40.1 Thu 10:00 ER 164

Conserved Spin Quantity in Strained Hole Systems with Rashba and Dresselhaus Spin-Orbit Coupling — •Michael Kammermeier[1], Paul Wenk[1], John Schliemann[1], Klaus Richter[1], and Roland Winkler[2] — [1]Universität Regensburg, D-93040 Regensburg, Germany — [2]Northern Illinois University, IL 60115 DeKalb, US

We investigate conditions for the existence of a conserved spin quantity in two-dimensional hole gases in zincblende type semiconductor heterostructures. It is shown that in the presence of shear stress, a symmetric in-plane strain, and both Rashba and Dresselhaus spin-orbit coupling one can find such a conserved quantity. The found optimal parameter-space, for strain and spin-orbit coupling strength, gives the possibility to an experimental access. This is in contrast to previous works which require restrictions on the band model parameters (here the Luttinger parameters) which are either difficult to realize in real materials or even singular ($\gamma_3 = 0$).

* * *

[1] Schliemann *et al.*, PRL **90** 146801 (2003)
[2] Bernevig *et al.*, PRL **97** 236601 (2006)
[3] Kohda *et al.*, PRB **86** 081306 (2012)
[4] Dollinger *et al.* Phys. Rev. B **90**, 115306 (2014)

MA 40.2 Thu 10:15 ER 164

Quantum transport and response with spin-orbit coupling in magnetic fields — •Klaus Morawetz — Münster University of Applied Sciences, Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics (IIP) Av. Odilon Gomes de Lima 1722, 59078-400 Natal, Brazil — Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany

Electronic transport in spin-polarized systems with impurity interactions and spin-dependent meanfields is discussed. The coupled quantum kinetic equations for the scalar and spin components for SU(2) are derived with special consideration of spin-orbit coupling and magnetic fields. Linearizing, the RPA spin and density dynamical responses to electric fields (polarized light) are preseented for arbitrary magnetic fields, Several known effects are described: spin-Hall, anomalous Hall and optical Hall effect, spin-heat coupling. New transport coefficients occur due to the selfconsistent precession direction. Clarifying the relative importance of meanfield and scattering correlations, new modes due to magnetic fields and spin-orbit coupling are found. (EPL, 104 (2013) 2700)

MA 40.3 Thu 10:30 ER 164

Spin injection through Fe/GaAs Schottky contacts — •Lennart-Knud Liefeith, Rajkiran Tholapi, Max Hänze, Ann-Kathrin Michel, Taras Slobodskyy, and Wolfgang Hansen — Institut für Festkörper- und Nanostrukturphysik, Hamburg, Hamburg

The understanding of the dominant mechanism of spin injection through the Fe/GaAs interface is crucial for spintronics applications. It was suggested that the spin injection process is controlled by thermal activation of surface states at the ferromagnet/semiconductor interface [1]. To test this theory we investigated the bias dependence of the spin injection efficiency as well as the electrical properties of the interface. The measurements were carried out using non-local spin detection devices at liquid helium temperatures and backed up by magneto optical Kerr effect and magnetic force microscopy measurements on the electrodes. We found that the post growth annealing strongly influences the spin injection efficiency and a notable asymmetry of the spin injection efficiency depending on the applied bias was observed.

[1] Q. U. Hu et. al., „Spin accumulation near Fe/GaAs(001) interfaces: The role of semiconductor band structure“, Physical Review B 84, 085306 (2011)

MA 40.4 Thu 10:45 ER 164

Electric control of spin transport in GaAs (111)B quantum wells — •Alberto Hernández-Mínguez, Klaus Biermann, and Paulo Santos — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

The main challenge towards the use of electron spins in semiconductors is the control of the dephasing mechanisms that reduce the spin lifetime below the spin manipulation time. In III-V semiconductors, the main relaxation processes are related to the spin-orbit interaction (SOI). In the case of GaAs(111) quantum wells (QWs), the SOI can be efficiently suppressed for out-of-plane spins by applying an electric field, E_z, transverse to the QW plane. In this case, the contribution to the SOI induced by E_z compensates the intrinsic SOI due to the zinc-blende lattice and spin lifetimes of tenths of ns are observed.

In this contribution, we show experimental studies of both carrier and spin diffusion in a GaAs(111) QW under the effect of vertical electric fields. Spin polarized electron-hole pairs are optically generated in the QW by a tightly focused laser beam. The carrier and spin dynamics are studied by spatially and time-resolved photoluminescence. We show that the enhancement of the spin lifetime due to SOI compensation allows the transport of out-of-plane electron spins over distances exceeding 10 μm. In addition to the spin lifetime, the spin diffusion coefficient D_s also depends on E_z. For the carrier densities and temperatures studied, D_s shows a maximum of approx. 50 cm^2/s at SOI compensation, where it approaches the values observed for the carrier diffusion coefficient under the same experimental conditions.

MA 40.5 Thu 11:00 ER 164

Time and space resolved visualization of spin diffusion and drift in GaAs based two-dimensional electron gases — •Markus Schwemmer[1], Roland Völkl[1], Tobias Korn[1], Sergey Tarasenko[2], Dieter Schuh[1], Dominique Bougeard[1], Mariusz Ciorga[1], Werner Wegscheider[3], and Christian Schüller[1] — [1]Institute of Experimental and Applied Physics, Faculty of Physics, University of Regensburg, Germany — [2]A. F. Ioffe Physical-Technical Institute, Russian Academy of Sciences, St. Petersburg, Russia — [3]ETH Zurich, Switzerland

The combination of a femtosecond pulsed TiSa-Laser system with a magneto-optical Kerr effect microscope setup allows us to study time and space resolved propagation of an optically injected electron spin packet in a resident two-dimensional electron gas based on a modulation-doped AlGaAs/GaAs quantum well. The interplay between the Dresselhaus and Rashba fields according to crystallographic orientation and layer structure of the sample determines the electron spin dynamics. On one hand we present diffusive and current-driven motion of a spin packet in a sample in which the orientation of the optically injected spins point along the effective spin orbit field. Therefore D'yakonov-Perel spin dephasing is suppresed and a long spin coherence time can be attained. On the other hand the diffusive spreading of the initial spin packet in a sample with a spin-orbit interaction close to the spin helix regime is monitored, whereby a direct visualization of the helix pattern is achieved. Financial support by the DFG via SFB 689 and SPP 1285 is gratefully acknowledged.

Coffee break

MA 40.6 Thu 11:30 ER 164

Hole spin coherence in coupled GaAs/AlAs quantum wells — •Christian Gradl, Johannes Holler, Michael Kempf, Dieter Schuh, Dominique Bougeard, Christian Schüller, and Tobias Korn — Universität Regensburg, D-93040 Regensburg, Germany

We performed time-resolved Kerr rotation (TRKR) measurements on an undoped [113]-grown double quantum well (QW) structure to resolve the spin dynamics of hole ensembles at low temperatures. Our gated system consists of two QWs with different well widths, which we use for the spatial separation of the optically excited electron-hole pairs. Thus, we are able to create hole ensembles with spin dephasing times of several hundreds of picoseconds in the broader QW without any doping.

This allowed an unexpected observation of a non-precessing component in the TRKR signal in the presence of an applied magnetic field perpendicular to the spin polarization. These measurements also show the non-precessing component to be a part of the optically generated hole spin polarization. This effect might arise from a tilting of the quantization axis with respect to the applied magnetic field due to a large anisotropy between the in- and out-of-plane hole g factor.

MA 40.7 Thu 11:45 ER 164

Inelastic light scattering in a two-dimensional electron gas under external magnetic fields — •Christoph Schönhuber, Dieter Schuh, Dominique Bougeard, Tobias Korn, and Christian Schüller — Universität Regensburg, 93040 Regensburg, Germany

We present inelastic light scattering measurements of a 12-nm-wide (001)-oriented GaAs/AlGaAs QW under external magnetic fields. The investigated system is single-side Si doped to reach a balanced Rashba and Dresselhaus SOI contribution.

The performed measurements on intrasubband transitions of the conduction band reveal for B=0 a double peak structure for the [1-1] direction due to spin splitting, while the [11] direction features only a single peak. For small magnetic fields, the wave vector appears to be conserved in the scattering process while both directions aim to assimilate the excitation with increasing field strength. At higher perpendicular magnetic fields, the anisotropic behaviour has vanished and the spectra are characterized by inter-Landau excitations.

MA 40.8 Thu 12:00 ER 164

Impurity band spin dynamics in GaAs directly above the metal-to-insulator transition — •Jan Gerrit Lonnemann[1], Eddy Patrick Rugeramigabo[2], Jens Hübner[1], and Michael Oestreich[1] — [1]Institute for Solid State Physics, Leibniz Universität Hannover, Appelstr. 2, D-30167 Hannover, Germany — [2]Laboratory of Nano and Quantum Engineering, Leibniz Universität Hannover, Schneiderberg 39, D-30167 Hannover, Germany

Several theoretical works treat the spin dynamics in zinc-blende semiconductors. We present extremely low excitation Hanle depolarization measurements on well characterized n-doped MBE grown GaAs in the vicinity of the metal-to-insulator transition (MIT). The doping concentrations range from the MIT at $2 * 10^{16}$ cm^{-3}, where extremely long spin lifetimes are experimentally observed [1], up to the merging of impurity and conduction band at $8 * 10^{16}$ cm^{-3}, where for conduction band electrons the spin relaxation is typically dominated by the Dyakonov-Perel mechanism (DP). We conclude from our measurements that DP is also dominating the impurity band regime in slightly metallic samples. Furthermore the measurements show no indication of spin relaxation by hopping transport (HT) that has recently been predicted as the main mechanism of relaxation for the impurity band regime [2]. In contrast our measurements of the spin dynamics indicate a metal-like behavior of the electrons in the impurity band.

[1] M. Römer et al.; *Phys. Rev. B*, **81**, 075216 (2010).
[2] G.A. Intronati et al.; *Phys. Rev. Lett.*, **108**, 016601 (2012).

MA 40.9 Thu 12:15 ER 164

Boundary dependent spin manipulation via Rashba-SOC — •Phillipp Reck and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany

Besides spin injection, controlled spin manipulation is a major aspect of active spintronic devices such as spin transistors. In a two dimensional electron gas (2DEG), this manipulation is often achieved by Rashba spin orbit coupling (SOC).

We study numerically the effects of a non-trivial deformation of a wire (quasi 1DEG) on the spin evolution of an initially spin polarized wave packet exposed to Rashba SOC. To make sure that the wave packet follows the deformation, we apply additionally a magnetic field to get edge states, which are resistant to impurity scattering. The benefit of the deformation is the higher variability of the spin state: Without the deformation, the spin precesses on the Bloch sphere around one fixed axis, whereas the deformation changes continuously the orientation of the precession axis leading to a more complex spin evolution. Thus, it is possible, e. g., to create either a x-, y- or z-spin polarization by only changing the Rashba SOC, but not the geometry.

A generalization is a wire with a periodic deformation. Because of the constant out-of-plane magnetic field and an in-plane rotating effective magnetic field due to SOC, one could engineer spin resonance effects.

MA 41: Focus: All-optical magnetic switching

Organizers: M. Aeschlimann (U. Kaiserslautern), M. Albrecht (U. Augsburg)

Since the discovery of all-optical switching (AOS) in ferrimagnetic rare-earth transition metal (RE-TM) alloy films the question arose if a manipulation of magnetic order by light without applying magnetic fields is specific for 3d-4f systems or a more general phenomena. After years of research, all-optical magnetic switching was indeed observed in various other systems, including multilayer structures, synthetic ferrimagnetic heterostructures and even in ferromagnetic Co/Pt layered films. These very recent new findings open up a broad range of additional exciting applications based on AOS, but also restart the discussions about the fundamental physics involved in AOS. This focus session shall give an overview of novel experimental and theoretical developments in this exciting research field.

Time: Thursday 9:30–12:30 Location: H 1012

Invited Talk MA 41.1 Thu 9:30 H 1012

Optically-induced magnetisation switching: Experiments and models — •Hans Christian Schneider — Physics Department, University of Kaiserslautern, Germany

This talk will present a general overview of optically induced magnetic switching in multi-sublattice magnets. Apart from reviewing experimental results, it will try to set the stage for the following talks by giving an introduction to the different mechanisms that contribute to optically induced magnetization dynamics in general. The different models that are nowadays applied to explain magnetization dynamics (or its crucial mechanism) during optical switching will be reviewed with a particular focus on the angular-momentum balance, and an attempt will be made to identify the remaining “mysteries” connected with all-optical switching. For the inverse Faraday effect the basic concepts that have been originally developed for semiconductors will be compared with more recent theoretical approaches.

Finally, we characterize conditions for heat-induced magnetic switching, and discuss its physical mechanism in a generic two-sublattice toy model, which includes dynamical exchange and electron-phonon scattering in the band picture.

Invited Talk MA 41.2 Thu 10:15 H 1012

All optical control of magnetic thin films and nanostructures — •Eric Fullerton — University of California San Diego, La Jolla, CA 92093-0401 USA

The possibilities of manipulating magnetization without applied magnetic fields have attracted growing attention over the last fifteen years with implications for future magnetic information memory and storage technologies. I will discuss recent experiments on the optical manipulation of the magnetization of engineered materials and devices using 100-fs to 10-ns optical pulses. We demonstrate that all optical switching can be observed in a broad range of materials and not limited to selected rare-earth transition-metal alloy films as had been previously observed. We observe all optical switching in a variety of engineered materials, including ferrimagnetic alloys, multilayers, heterostructures and rare-earth-free Co-Ir-based synthetic ferrimagnets [1] and most recently observe optical control of ferromagnetic films and nanostructures [2]. The latter discovery could potentially enable breakthroughs for numerous applications since it exploits materials that are currently used in magnetic data storage, memories and logic technologies. This work is supported, in part, by the ONR MURI program and is in collaboration with M. Gottwald, R. Medapalli, C.-H. Lambert, R. Tolley, V. Uhlir, and Y. Fainman at UCSD, S. Alebrand, D. Steil, M. Cinchetti and M. Aeschlimann at University of Kaiserslautern, M. Hehn, D. Lacour and S. Mangin at Université de Lorraine and Y. Takahashi and K. Hono at NIMS in Japan. [1]. Mangin et al., Nature Materials 13, 286, (2014). [2]. Lambert et al., Science 345, 1337 (2014).

15. min. break

Invited Talk MA 41.3 Thu 11:00 H 1012

All-optical switching: a challenge for its theoretical description — •Ulrich Nowak[1], Sönke Wienholdt[1], Steffen Sievering[1], Denise Hinzke[1], Karel Carva[2], and Peter Oppeneer[2] — [1]Fachbereich Physik, Universität Konstanz, D-78457 Konstanz — [2]Department of Physics, Uppsala University, SE-751 20 Uppsala

The term all-optical switching (AOS) refers to the fact that some magnetic materials can be switched solely by the effect of an ultrafast laser pulse, without any applied magnetic field. First, this effect was shown for ferrimagnets [1-3] but later also for layered, synthetic ferrimagnets [4] and recently even for ferromagnets [6]. Two different kinds of AOS have to be distinguished, namely helicity dependent AOS [1,4,5], where the new magnetic orientation is defined by the helicity of the laser light, and thermally driven swiching with linearly polarized light which cannot define the new orientation but always switches the initial state to the reversed one. In this talk an overview over the current status of the understanding and the remaining open questions is given.

Supported by the EC under Contract No. 281043, FemtoSpin

[1] K. Vahaplar et al. Phys. Rev. Lett. **103**, 117201 (2009) [2] I. Radu et al., Nature **472**, 205 (2011) [3] S. Wienholdt et al., Phys. Rev. B, **88**, 020406(R) (2013) [4] S. Mangin et al., Nature Mater. **13**, 286 (2014) [5] C.-H. Lambert et al., Science **345**, 1337 (2014)

Invited Talk MA 41.4 Thu 11:30 H 1012

All-optical helicity-dependent magnetic switching in Tb-Fe — •Rudolf Bratschitsch — Physikalisches Institut, Westfälische Wilhelms-Universität Münster

Ferrimagnets such as GdFeCo can be switched all-optically by circularly polarized femtosecond laser pulses, opening the door to ultrafast magnetic data storage. We reveal all-optical switching (AOS) in the ferrimagnet Tb-Fe [1]. We demonstrate that AOS also occurs in a tailored artificial zero moment magnet consisting of two TbFe layers, which exhibit no AOS as single layers [2]. Finally, we show that expensive and bulky laser amplifier systems are not necessary to induce AOS and present AOS with a laser oscillator [3].

[1] A. Hassdenteufel et al., Adv. Mat. 25, 3122 (2013)
[2] C. Schubert et al., Appl. Phys. Lett. 104, 082406 (2014)
[3] A. Hassdenteufel et al., Opt. Expr. 22, 10017 (2014)

Invited Talk MA 41.5 Thu 12:00 H 1012

Ultrafast magnetization dynamics of thin films showing helicity dependent magnetization switching — •Grégory Malinowski — Institut Jean Lamour, Département P2M Université de Lorraine - CNRS UMR 7198 Boulevard des Aiguillettes, BP 239 54506 VANDOEUVRE LES NANCY Cedex (France)

The interplay of light and magnetism has been a topic of interest since the original observations of Faraday and Kerr where magnetic materials affect the light polarization. While these effects have historically been exploited to use light as a probe of magnetic materials there is increasing research on using polarized light to alter or manipulate magnetism. For instance deterministic magnetic switching without any applied magnetic fields using laser pulses of the circular polarized light has been observed for specific ferrimagnetic materials [1,2]. More recently, optical control of ferromagnetic materials ranging from magnetic thin films to multilayers and even granular films have been shown to present helicity dependent magnetization reversal [3,4]. In this presentation, we will focus on ultrafast magnetization dynamics of thin films multilayers and alloys showing helicity dependent all-optical switching. [1] C.D. Stanciu et al., Physical Review Letters 99(4), 047601 (2007). [2] S. Alebrand et al., Applied Physics Letters 101(16), 162408 (2012). [3] S. Manginet al., Nat Mat ,3864 (2013). [4] C. Lambert et al., Science 345, 1337 (2014)

MA 42: Topological Insulators I (jointly with DS, HL, O, TT)

Time: Thursday 9:30–12:00 Location: EB 202

MA 42.1 Thu 9:30 EB 202

DETECTION OF SURFACE SPIN CURRENT IN 3-DIMENSIONAL TOPOLOGICAL INSULATOR, BiSbTeSe — •Masashi Shiraishi[1], Yuichiro Ando[1], Takahiro Hamasaki[1], Kohji Segawa[2], Satoshi Sasaki[2], Feng Yang[2], Mario Novak[2], and Yoichi Ando[2] — [1]Kyoto Univ., Japan — [2]ISIR, Osaka Univ., Japan

Topological insulators (TIs) attract tremendous attention in recent years, since topologically-protected edge current is a persistent pure spin current. The first detection of the edge current was achieved by using 2-dimensional TI, HgTe quantum well [1], and the next challenge is to detect the edge current in 3-dimensional TIs, because a number of spin channel can be dramatically increased. Whereas Li et al. claimed that they successfully detected the surface spin current in Bi2Se3 by using an electrical spin accumulation method [2], the polarity of the spin signals is not accordance with the direction of magnetization of a detector ferromagnet. Thus, there is still open for discussion how to detect the edge spin current. Here, we present the detection of the edge spin current of BiSbTeSe, which is a bulk insulative TI [3]. The spin signal due to the spin accumulation was detected electrically, and was observed up to 150 K [4].

[1] M. Koenig et al., Science 318, 766 (2007). [2] C. Li et al., Nature Nanotech. 9, 218 (2014). [3] T. Arakane, Yo. Ando et al., Nature Commun. 3, 636 (2011). [4] Yu. Ando, M. Shiraishi et al., Nano Lett., in press.

MA 42.2 Thu 9:45 EB 202

First-principles calculation of quasiparticle spin interference and scattering processes on 3D topological insulators — •Philipp Rüssmann, Phivos Mavropoulos, Nguyen H. Long, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

We present density-functional calculations of the quasiparticle interference (QPI) due to scattering of electrons off magnetic and non-magnetic impurities at the surface of the strong topological insulator Bi_2Te_3. The focus of our work is the calculation and analysis of possible spin-dependent scattering processes and their relation to the QPI pattern observed in experiment. The presence of an impurity magnetic moment leads to broken time-reversal symmetry and the protection against back-scattering is lifted. Therefore, we investigate magnetic transition-metal adatoms as well as non-magnetic Bi and Te adatoms on Bi_2Te_3. Finally, we compare the QPI pattern and scattering processes at different energies around the Fermi energy and discuss the importance of the hexagonal warping of the constant energy contours.

The electronic structure calculations are carried out with our KKR-Green function method for scattering properties at defects [1]. We acknowledge financial support from the DFG (SPP-1666), from the VITI project of the Helmholtz Association and computational support from the JARA-HPC Centre at the RWTH Aachen University.

[1] N. H. Long, P. Mavropoulos, B. Zimmermann, D. S. G. Bauer, S. Blügel, and Y. Mokrousov, Phys. Rev. B **90**, 064406 (2014).

MA 42.3 Thu 10:00 EB 202

Momentum resolved spin dynamics of bulk and surface excited states in the topological insulator Bi_2Se_3 — C Cacho[1], A Crepaldi[2], M Battiato[3], J Braun[5], H Ebert[5], K Hricovini[4], •Jan Minar[5,6], and F Parmigiani[2] — [1]Central Laser Facility, STFC Rutherford Appleton Laboratory, Harwell, United Kingdom — [2]Elettra - Sincrotrone Trieste, Italy — [3]Institute of Solid State Physics, Vienna University of Technology — [4]Universite de Cergy-Pontoise, France — [5]LMU München, Germany — [6]University of West Bohemia, Plzen, Czech Rep.

The prospective of optically inducing a spin polarized current for spintronic devices has generated a vast interest in the out-of-equilibrium electronic and spin structure of topological insulators (TIs). In this presentation we prove that only by measuring the spin intensity signal over several order of magnitude in spin, time and angle resolved photoemission spectroscopy (STAR-PES) experiments is it possible to comprehensively describe the optically excited electronic states in TIs materials. The experiments performed on Bi2Se3 reveal the existence of a Surface-Resonance-State in the 2nd bulk band gap interpreted on the basis of fully relativistic ab-initio spin resolved photoemission calculations. Remarkably, the spin dependent relaxation of the hot carriers is well reproduced by a spin dynamics model considering two non-interacting electronic systems, derived from the excited surface and bulk states, with different electronic temperatures. For more details see: Cacho et all.,
http://arxiv.org/abs/1409.5018

MA 42.4 Thu 10:15 EB 202

Spin structure of the Dirac state of the topological insulator Bi_2Te_3(0001) — •Christoph Seibel[1], Henriette Maass[1], Hendrik Bentmann[1], Jürgen Braun[2], Jan Minár[2], Taichi Okuda[3], and Friedrich Reinert[1] — [1]Experimentelle Physik VII, Universität Würzburg, D-97074 Würzburg — [2]Department Chemie, Physikalische Chemie, Universität München, Butenandtstrasse 5-13, D-81337 München — [3]Hiroshima Synchrotron Radiation Center, Hiroshima University, Higashi-Hiroshima 739-0046, Japan

Three-dimensional topological insulators feature non-trivial surface states in the fundamental band gap of the bulk. In particular, the spin texture of these topological surface states (TSS) attracts attention in the context of possible applications in spintronics. We have performed angle- and spin-resolved photoemission measurements to analyze the three-dimensional spin texture of the TSS of the topological insulator Bi_2Te_3. The measured photoelectron spin-polarization is found to significantly deviate from the anticipated ground-state spin texture of the TSS, as derived e.g. on the basis of first-principles calculations. Possible origins of our observations are discussed in terms of the influence of spin-orbit coupling on the photoemission process. We compare our experimental data to the results of fully relativistic one-step photoemission calculations.

MA 42.5 Thu 10:30 EB 202

Atomic relaxations in Bi_2Se_3 (0001) — Sumalay Roy[1], •Holger L. Meyerheim[1], Katayoon Mohseni[1], Arthur Ernst[1], Mikhail Otrokov[2,3], Maia G. Vergniory[1,2], Gregor Mussler[4], Christian Tusche[1], Evgueni Chulkov[2,3], and Jürgen Kirschner[1,5] — [1]MPI f. Mikrostrukturphysik, D-06120 Halle, Germany — [2]DIPC, San Sebastian, Spain — [3]Tomsk St. Univ. , Russia — [4]FZ Jülich, Germany — [5]MLU Halle-Wittenberg, Germany

Surface x-ray diffraction analysis of the Bi_2Se_3(0001) surface reveals an expansion of the top Se-Bi interlayer spacing in the range between 2 and 17% relative to the bulk. It is directly related to the concentration of surface contaminants like carbon and is observed in both, single crystals and MBE grown ultrathin films. Deeper layers and the first van der Waals gap remain unrelaxed. Ab-initio calculations which are in agreement with angular resolved photoemission experiments reveal that carbon acts as an n-dopant, while the top layer expansion induces a shift of the Dirac point towards the bulk conduction band of Bi_2Se_3 [1,2].

[1] S. Roy, H.L. Meyerheim, A. Ernst et al., PRL **113**, 116802 (2014);
[2] S. Roy, H.L. Meyerheim, K. Mohseni et al., PRB **90**, 155456 (2014)

This work is supported by SPP1666 (Topological Insulators) of the DFG.

MA 42.6 Thu 10:45 EB 202

Spin resolved momentum microscopy of the topological insulator Bi_2Se_3 — •Christian Tusche[1], Martin Ellguth[1], Shigemasa Suga[1,2], Holger L. Meyerheim[1], and Jürgen Kirschner[1,3] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [2]Institute of Scientific and Industrial Research, Osaka, Japan — [3]Institut für Physik, Martin-Luther-Universität, Halle, Germany

Topological insulators are a new class of materials that attracted wide interest by their electronic structure with unusual relations of electron spin and momentum, leading to highly spin polarized "Dirac-cone" surface states. Recently, comprehensive experimental access to such band structures became feasible by spin resolved momentum microscopy. This novel concept combines high resolution imaging of photoelectrons in two-dimensional (k_x, k_y) sections with a highly efficient imaging spin filter. Electron reflection at a Au/Ir(100) mirror allows us to measure 5000 spin-resolved points in the surface Brillouin zone, simultaneously.

We show that the band-structure of Bi_2Se_3 is characterized by highly spin polarized states within the complete Brillouin zone, beyond the "Dirac cone" surface state. For the latter we find that the spin polarization of photoelectrons can reach up to 90%, the highest value reported so far. A direct conclusion on the ground state polarization in these systems is complicated by the peculiar interplay between spin- and light-polarization in the photoemission, as directly observed in spin-resolved (k_x, k_y) images.

This work is supported by SPP1666 (Topological Insulators) of the DFG. M.E. acknowledges support by the BMBF (05K12EF1).

MA 42.7 Thu 11:00 EB 202

The magnetism of Ni adatoms adsorbed on the TI Bi_2Te_2Se — Jan Honolka[1], Martin Vondráček[1], •Lasse Cornils[2], Malte Schüler[3], Markus Dunst[4], Jonas Warmuth[2], Lihui Zhou[2], Anand Kamlapure[2], Alexander Ako Khajetoorians[2,5], Matteo Michiardi[6], Lucas Barreto[6], Philip Hofmann[6], Jian-Li Mi[6], Martin Bremholm[6], Bo B. Iversen[6], Cinthia Piamonteze[7], Hubert Ebert[4], Jan Minar[4,8], Tim Wehling[3], Roland Wiesendanger[2], and Jens Wiebe[2] — [1]Inst. of Physics ASCR, Prague, Czech Republic — [2]INF, University of Hamburg, Germany — [3]Inst. of Theo. Physics, University of Bremen, Germany — [4]LMU München, Germany — [5]IMM, Radboud University Nijmegen, The Netherlands — [6]iNano, Aarhus University, Denmark — [7]PSI, Switzerland — [8]New Technologies-Research Center, University of West Bohemia, Pilsen, Czech Republic

The predicted gap opening in the surface state of topological insulators (TIs) induced by surface magnetic doping, and the associated novel electron phases, have recently caught strong interest of the scientific community. However, the experimental evidence of an induced gap opening is still controversial [1] and calls for a detailed investigation of the magnetism of different adatoms. Here, we show by a combined XMCD, ARPES and STS study, that Ni adatoms on the TI Bi_2Te_2Se reveal a surprising behaviour: While there is no detectable XMCD signal at the Ni $L_{2,3}$-edges, the XAS spectrum unveils a considerable resonant absorption of the d-shell. The results are analyzed by *ab-initio* calculations. [1] J. Honolka *et al.*, PRL **108**, 256811 (2012).

MA 42.8 Thu 11:15 EB 202

Fe-induced stress on *Bi_2Se_3*(0001) — •Kenia Novakoski Fischer, Safia Ouazi, Dirk Sander, and Jürgen Kirschner — Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle

The topological insulator Bi_2Se_3 has attracted intense research activity since its discovery 5 years ago [1]. Here we present the first experimental study of the stress change induced by sub-monolayer deposition of Fe on Bi_2Se_3. Deposition of 0.2 ML Fe at 300 K induces a stress change of -2.3 N/m. On the contrary, deposition of Fe at 150 K leads to negligible stress change of less than -0.2 N/m. The growth of Fe at 473 K induces a stress of -3.4 N/m. LEED reveals that the hexagonal diffraction pattern of the substrate gets blurred for deposition at 150 K, whereas deposition at higher temperature induces faint diffraction spots indicative of precursor of possible FeSe formation. We discuss these results in view of a recent STM study [2], where the authors suggest thermally activated sub-surface doping of Bi_2Se_3 by Fe.

[1] H. Zhang, C.X. Liu, X.L. Qi, X. Dai, Z. Fang, and S. C. Zhang, Nat. Phys. 5 (2009) 438; W. Zhang, R. Yu, H.J. Zhang, X. Dai, and Z. Fang, New Journal of Physics 12 (2010) 065013. [2] T. Schlenk, M. Bianchi, M. Koleini, A. Eich, O. Pietzsch, T. O. Wehling, T. Frauenheim, A. Balatsky, J.-L. Mi, B. B. Iversen, J. Wiebe, A. A. Khajetoorians, Ph. Hofmann, and R. Wiesendanger, Phys. Rev. Lett. 110 (2013) 126804

MA 42.9 Thu 11:30 EB 202

Atomic structure and magnetism of Fe on Bi_2Se_3 — •Andrey Polyakov[1], Holger L. Meyerheim[1], E. Daryl Crozier[2], Robert A. Gordon[3], Maia G. Vergniory[4], Arthur Ernst[1], Evgueni V. Chulkov[4], and Jürgen Kirschner[1,5] — [1]MPI f. Mikrostrukturphysik, D-06120 Halle, Germany — [2]SFU, Burnaby, V5A 1S6 BC, Canada — [3]CLS at APS Sector 20, Argonne, IL, USA — [4]DIPC, San Sebastian, Spain — [5]MLU Halle-Wittenberg, Germany

We have carried out extended x-ray absorption fine structure (EXAFS) and surface x-ray diffraction (SXRD) experiments in combination with ab-initio calculations to investigate the geometric and magnetic properties of iron deposited on the (0001) surface of the topological insulator Bi_2Se_3 in the coverage range between about 0.2 and 1.5 monolayers (ML). For iron deposited at T=170 K in the low coverage limit no polarization dependence of the EXAFS amplitude (electric field vector parallel vs. perpendicular to the surface of the bulk crystal) could be observed. In combination with the nearest neighbor distance of 2.42 Å this suggests that Fe atoms substitute bismuth atoms involving a local relaxation of the neighboring selenium atoms. Ab-initio calculations support this structural model and predict antiferromagnetic ordering of iron [1]. SXRD data collected at 1.5 ML indicate that iron atoms also occupy threefold hollow surface sites. Mild annealing leads to the formation of a bulk FeSe like structure. [1] M. G. Vergniory et al. PRB 89, 165202 (2014); This work is supported by SPP 1666 (Topological Insulators). Work at APS sector 20 is supported by the CLS and by US DOE under Contract No. DE-AC02-06CH11357

MA 42.10 Thu 11:45 EB 202

Signatures of Dirac fermion-mediated magnetic order — •Paolo Sessi[1], Felix Reis[1], Thomas Bathon[1], Konstantin Kokh[2], Oleg Tereshchenko[2], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Novosibirsk State University, 630090 Novosibirsk, Russia

The spin-momentum locking of topological states offers an ideal platform to explore novel magneto-electric effects. These intimately depend on the ability to manipulate the spin texture in a controlled way. Although numerous studies aimed to shed light on the role played by magnetic perturbations, contradictory results have been obtained and a clear picture is still missing. The interaction of surface magnetic moments with topological states has predominantly been performed by using spatial averaging techniques such as angle-resolved photoemission spectroscopy and x-ray magnetic circular dichroism. Here, we combine low-temperature scanning tunneling microscopy with single-adatom deposition to directly map the evolution of the electronic properties of topological states under the influence of different magnetic perturbations. By analyzing energy-resolved quasi-particle interfer- ence maps, we reveal signatures of Dirac fermion-mediated surface magnetic order for extremely dilute adatom concentrations. By using different magnetic elements and coverages, we find that this striking observation crucially depends on two parameters: single adatoms mag- netic anisotropy direction and energy-level alignment [1].

[1] P. Sessi et al., Nature Comm. 5, 5349 (2014).

MA 43: Magnetization / Demagnetization Dynamics III

Time: Thursday 9:30–12:00 Location: EB 301

MA 43.1 Thu 9:30 EB 301

Control of the effective damping in Heusler/Pt microstructures via the spin-transfer torque effect — •Thomas Meyer[1], Thomas Brächer[1], Philipp Pirro[1], Tobias Fischer[1], Alexander Serga[1], Hiroshi Naganuma[2], Koki Mukaiyama[2], Mikihiko Oogane[2], Yasuo Ando[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Applied Physics, Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan

We present the control of the effective spin-wave damping by the spin-transfer torque exerted by a pure spin current injected into Heusler compound microstructures. In this work, the pure spin current is generated by a DC current in a Pt layer adjacent to the magnetic layer via the spin-Hall effect. Especially, the used cobalt-based Heusler compound $Co_2Mn_{0.6}Fe_{0.4}Si$ used in this work already provides a comparably low Gilbert damping. Thus, this class of materials is very promising for the usage in any devices based on spin waves as only very low currents for the control of the effective damping are needed. The obtained results show a strong influence of an applied DC current on the spin-wave properties. Investigations using only thermally excited spin waves exhibit a strongly increased spin-wave intensity due to a decreased effective damping. The measurements show the feasibility of using the spin-transfer torque effect to control the effective spin-wave damping in waveguides which is very promising for future applications using propagating spin waves to transfer information.

MA 43.2 Thu 9:45 EB 301

Full electric detection of a Bose-Einstein condensate via the spin-pumping effect — •Dmytro A. Bozhko[1,2], Akihiro Kirihara[3], Andrii V. Chumak[1], Gennadii A. Melkov[4], Yaroslav Tserkovnyak[5], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany — [3]Smart Energy Research Laboratories, NEC Corporation, Japan — [4]Faculty of Radiophysics, Taras Shevchenko National University of Kyiv, Ukraine — [5]Department of Physics and Astronomy, University of California, USA

It is well known, that magnons excited in an insulating magnetic medium can transfer their angular momenta to free electrons in an adjacent non-magnetic metal layer, and thus generate a spin current via the spin-pumping effect. Due to the inverse spin Hall effect (ISHE) this current is transformed into a charge current and is measured as an electric voltage. It is commonly believed that the magnitude of the ISHE voltage increases with the total number of magnons in a spin-wave system as well as with the energy of these magnons. However, the electric signal, which corresponds to the formation of a magnon Bose-Einstein condensate (BEC) by a freely evolving magnon gas after the termination of an external pumping, breaks with this rule: The transition of the thermalized gaseous magnons to the lowest energy states leads to a pronounced upward jump of the voltage magnitude. This unusual behaviour can be understood as a result of a rectification of a coherent microwave current induced by the coherence of the BEC.

MA 43.3 Thu 10:00 EB 301

Spin-transfer Torque Magnetisation Switching in Multilayered System from Atomistic Spin Dynamics — •Fan Pan[1], Anders Bergman[2], and Lars Bergqvist[1] — [1]Department of Material and Nano Physics, School of ICT, KTH Royal Institute of Technology, Electrum 229, 164 40, Kista, Sweden — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 20, Uppsala, Sweden

The magnetization dynamics of a synthetic layered magnetic materials, prototype for a magnetic random access memory device, has been investigated through first-principles and atomistic spin dynamics simulations (ASD). It is found that the magnetization dynamics driven by the spin-transfer torque (STT) is of nonlinear character and the roles of adiabatic and non-adiabatic STT are still not clear. Therefore, our study aims to gather a deeper understanding of these intrinsic properties. We have compared two different system geometries, both with an applied current flowing perpendicular to the plane of the layers. If no restriction is imposed to the magnetisation of the both outer layers, a steady-state processing motion is found. A more complicated switching behaviour is found if the magnetization of one layer is fixed and the other is free to rotate. In the latter case, the critical current density of the magnetization reversal is described both analytically and numerically. In addition, the optimal conditions of STT induced switching are suggested. Finally, we have performed calculations of experimental available systems using material parameters from electronic structure calculations based on density functional theory.

MA 43.4 Thu 10:15 EB 301

Phonon-affected Gilbert damping tensor within the breathing Fermi-surface model — •Danny Thonig[1], Nicki F. Hinsche[2], Jürgen Henk[2], and Olle Eriksson[1] — [1]Department of Material Theory, Uppsala University, Sweden — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

Concerning magnetic switching, an essential property of magnetic devices is the relaxation rate which depends strongly on the damping α in the magnetization dynamics. This angular-momentum dissipation was predicted to be dominated by the coupling between the magnon and the phonon reservoir [1]. Especially in the high-temperature regime, discrepancies between theory and experiment call for deeper understanding of the phonon-mediated damping, for example by means of a model.

We apply the breathing Fermi-surface model [2] in the framework of a Green-function tight-binding approach [3] and transition matrix theory. For bulk Stoner magnets, the spatial disorder (phonons) is considered either as gaussian-distributed around the equilibrium positions or as a self-energy. We compare these two approaches with each other, with other *ab initio* methods as well as with experiment.

[1] H. Ebert, S. Mankovsky, D. Ködderitzsch, and P. J. Kelly., Phys. Rev. Lett, **107** (2011) 066603

[2] V. Kamberský, Cz. Journal of Physics B, **34** (1984) 1111

[3] D. A. Papaconstantopoulos and M. J. Mehl, J. Phys.: Condens. Matter, **15** (2003) R413-R440

MA 43.5 Thu 10:30 EB 301

Optically Induced Ferromagnetic Resonance in Magnetic Iron Garnets — •Manuel Jäckl[1], Ilya A. Akimov[1], Vladimir I. Belotelov[2,3,4], Anatoly K. Zvezdin[3,4], and Manfred Bayer[1] — [1]Experimentelle Physik 2, TU Dortmund, D-44221 Dortmund, Germany — [2]Lomonosov Moscow State University, 119991 Moscow, Russia — [3]Russian Quantum Center, Novaya St. 100, Skolkovo, Moscow Region, 143025, Russia — [4]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia

We use the inverse Faraday effect in order to influence the magnetization of a ferromagnetic bismuth iron garnet (BIG) film by means of circularly polarized femtosecond laser pulses. Optical excitation modifies the magnetization and triggers its precession around the equilibrium position with a lifetime of several nanoseconds and a frequency of 2 – 7 GHz in transverse magnetic fields of 70 – 250 mT, respectively. The phase of the precession changes by 180 degrees when the helicity of the exciting laser pulses is switched from σ^+ to σ^-. Optically induced ferromagnetic resonance is achieved using a sequence of optical pulses with low pulse energy of 50 pJ and high repetition rate of $F_{\rm Rep} = 1$ GHz which is larger than the decay rate of the oscillation. We observe an amplification of the laser induced Faraday rotation signal by 60 % when the precession frequency corresponds to the resonance condition ($F = nF_{\rm Rep}$, n is integer).

15 min. break

MA 43.6 Thu 11:00 EB 301

Gilbert damping from nonperturbative partial summation — •David Vincent Altwein, Elena Y. Vedmedenko, and Roland Wiesendanger — University of Hamburg, Hamburg, Germany

We devise an exact way to recover the concept of Rayleigh-dissipation from the framework of quantum field theory (QFT) which is illustrated for magnetization dynamics. Initially, an effective hamiltonian for a subsystem is obtained by employing the inequivalent sets of canonical operators, generated by the system-bath-interactions, causing vacuum polarization which gives rise to a geometric expansion in a complexe quantity. The latter's imaginary part is intimately connected to the irreducible polarization and self-energy operators of the problem and appears as a damping parameter which contains nonperturbative information. Remarkably, we obtain the Landau-Lifshitz-Gilbert-Equation with its correct scaling of the gyromagnetic ratio γ, stemming directly from the renormalization of charge e and mass m of the problem whilst lowest order perturbation theory in the interaction strength was used to derive the Landau-Lifshitz-Equation microscopically. Conceptually, our approach shares certain similarities with the known truncation schemes, employed in the QFT framework for dissipation and it uses a smaller set of assumptions than many popular system-bath-approaches in the literature.

MA 43.7 Thu 11:15 EB 301

Spin precession mapping at ferromagnetic resonance via nuclear resonant — •Lars Bocklage[1,2], Christian Swoboda[3], Kai Schlage[1], Hans-Christian Wille[1], Liudmila Dzemiantsova[1,2], Guido Meier[4,2,3], and Ralf Röhlsberger[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany — [3]Institut für Angewandte Physik, Universität Hamburg, Germany — [4]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany

We employed nuclear resonant scattering (NRS) to study spin dynamics at ferromagnetic resonance. NRS measures the temporal decay of nuclear transitions of Mössbauer isotopes, the 14.4 keV transition of iron-57 in our case. The inherent sensitivity to dynamical effects, its isotope sensitivity, and its combinability with diffraction techniques makes NRS a perfect candidate to investigate magnetization dynamics on nanometer length scales. We present NRS results measured on a ferromagnetic film excited at its ferromagnetic resonance in the GHz-regime. At ferromagnetic resonance the NRS time spectra of the nuclear decay are altered. The reduction of the effective hyperfinefield due to the spin precession is identified as source for the changes in the time spectra. We are able to determine the precession trajectory of the magnetic moments from the measured time spectra. The method provides a new way to study magnetization dynamics with high precision.

MA 43.8 Thu 11:30 EB 301

Gilbert-like damping mediated by time retardation in atomistic magnetization dynamics — •Danny Thonig[1], Jürgen Henk[2], and Olle Eriksson[1] — [1]Department of Material Theory, Uppsala University, Sweden — [2]Martin Luther University Halle-Wittenberg, Halle, Germany

The switching dynamics of atomic magnetic moments is determined by the loss of angular momentum. This damping in the equation of motion correlates a magnetic moment at a time t to its very recent value at a time $t - \delta t$. However, physical events are time retarded; that is, magnetic moments are linked to their state at any $t' < t$. This raises two questions: 1. How does time retardation affect the evolution of magnetic moments? 2. Could time retardation motivate a damping mechanism proportional to the Gilbert damping?

We consider the time-retarded form of the atomistic Landau-Lifshitz-Gilbert equation that accounts for momentum length conservation. More precisely, various retardation functions are applied to the equation of motion without Gilbert damping. We consider a macrospin model as well as realistic materials, like Fe bulk.

From an analytical model as well as from numerical simulations we establish a damping mechanism proportional to the Gilbert damping. On top of this, we also find higher-order effects, like nutation. Our model and results suggest that the origin of damping and inertia in magnetic systems could be due to time retardation.

MA 43.9 Thu 11:45 EB 301

Microscopic theory of Gilbert damping in metallic ferromagnets — •Antonio Costa and Roberto Muniz — Universidade Federal Fluminense, Niteroi, RJ, Brazil

We present a microscopic theory for magnetization relaxation in metallic ferromagnets of nanoscopic dimensions that is based on the dynamic response function in the presence of spin-orbit coupling. Our approach allows the calculation of the Gilbert damping parameter even in perfectly crystalline systems, where other approaches fail. We demonstrate that the relaxation properties are not completely determined by the transverse susceptibility alone, and that the damping rate has a non-negligible frequency dependency in experimentally relevant situations.

MA 44: Surface Magnetism (Joint Session with O) - Adatoms on surfaces

Time: Thursday 15:00–17:30 Location: H 0110

MA 44.1 Thu 15:00 H 0110

Magnetism of Ho and Er Atoms on Close-Packed Metal Surfaces — •Fabio Donati[1], Aparajita Singha[1], Sebastian Stepanow[2], Christan Wäckerlin[1], Jan Dreiser[1,3], Pietro Gambardella[2], Stefano Rusponi[1], and Harald Brune[1] — [1]Institute of Condensed Matter Physics (ICMP), École Polytechnique Fédérale de Lausanne (EPFL), Switzerland — [2]Department of Materials, ETH Zürich, Switzerland — [3]Swiss Light Source (SLS), Paul Scherrer Institute (PSI), Switzerland

Single atoms on a surface represent a paradigm for investigating the ultimate size limit of nanomagnets. By combining x-ray magnetic circular dichroism measurements with multiplet calculations, we performed a comparative study of the ground state and magnetic anisotropy of single Ho and Er atoms on Pt(111) and Cu(111). Our results emphasize the different interaction of the $4f$ orbitals with the substrate electrons, showing that the s- or d- character of the substrate states plays a major role in determining the hierarchy of the magnetic quantum states [Donati et al., Phys. Rev. Lett., in press]. In particular, Er atoms display a rotation of the magnetization easy axis from out-of-plane on Pt(111) to in-plane on Cu(111), whereas Ho atoms on Pt(111) present a ground state that is incompatible with the long spin relaxation times reported by a recent scanning tunneling microscopy study of the same system [Miyamachi et al., Nature **503**, 242 (2013)].

MA 44.2 Thu 15:15 H 0110

Impact of spin-fluctuations on the magnetic properties of 4d adatoms on metal substrates — •julen ibañez-azpiroz, manuel dos santos dias, stefan blügel, and samir lounis — Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

We present a theoretical analysis of the effect of spin-fluctuations on the magnetic properties of 4d adatoms deposited on metallic substrates. These systems have been long predicted to develop a large local magnetic moment by theoretical calculations based on density functional theory (DFT) [1], but experiments have measured negligible magnetic signals so far (see e.g. [2]). Our aim is to clarify the role of the spin-fluctuations, which tend to destabilize the magnetic moment and are not included into the standard DFT. We make use of the fluctuation-dissipation theorem, which relates the magnitude of the spin-fluctuations to the interacting spin-susceptibility as calculated in linear response theory. We access the latter quantity using a fully ab-initio approach based on the Korringa Kohn Rostoker (KKR) Green function formalism within time-dependent DFT [3,4].

We would like to acknowledge support from the Helmholtz Gemeinschaft Deutscher-Young Investigators Group Program No. VH-NG-717 (Functional Nanoscale Structure and Probe Simulation Laboratory).

[1] K.Wildberger etal., Physical Review Letters, **75** 509 (1995)
[2] J. Honolka etal., Physical Review B, **76** 144412 (2007)
[3] S. Lounis etal., Physical Review B, **83** 035109 (2011)
[4] S. Lounis etal., Physical Review Letters, **105** 187205 (2010)

MA 44.3 Thu 15:30 H 0110

Magnetic linear dichroism of 3d metal thin films — •Torsten Veltum[1], Tobias Löffler[1], Mathias Gehlmann[2], Sven Döring[2], Lukasz Plucinski[2], Stephan Borek[3], Jan Minar[3], Jürgen Braun[3], Hubert Ebert[3], and Mathias Getzlaff[1] — [1]Institut für Angewandte Physik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf — [2]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52428 Jülich — [3]Department Chemie, Ludwig-Maximilians-Universität München, 81377 München

Magnetic linear dichroism in the angular distribution of photoelectrons (MLDAD) is a technique that allows the study of both the electronic band structure and the magnetic properties of thin films and single crystals. We are looking for a deeper understanding of the magnetic linear dichroism of 3d metals. We study epitaxially grown Co(0001) and Fe(110) thin films on a W(110) surface.

In this study linearly polarized synchrotron radiation (Beamline 5, DELTA Dortmund) in the VUV regime is used to gain experimental data. Theoretical calculations for these systems are carried out with local spin density approximation (LSDA) and dynamical mean field theory (DMFT).

The electronic structure of the valence band is measured by variation of the photon energy. At excitation energies above 20 eV, dichroism measurements are reconfirmed and extended to angle-resolved spectra in off-normal geometry. The resonance between the 3d core-levels and the valence band of these materials shows an influence on the dichroism.

MA 44.4 Thu 15:45 H 0110

Magnetic properties of Cobalt nanodot arrays on rare-earth-Au$_2$ surface compounds — •Frederik Schiller[1,2], Laura Fernández[2,3], Maxim Ilyn[1], Ana Magaña[4], and Enrique Ortega[4] — [1]Centro de Física de Materiales, San Sebastian, Spain — [2]Fachbereich Physik, Phillips Universität Marburg, Germany — [3]Donostia International Physics Center, San Sebastian, Spain — [4]Universidad del País Vasco (UPV/EHU), San Sebastian,Spain

Cobalt deposition on prepatterned rare-earth (RE)Au$_2$/Au(111) substrates leads to self-organization into very dense hexagonal structures of Co nanodots. Depending on the substrate surface RE material one can achieve different interactions that determine the magnetic properties of the dots. In order to investigate in detail such effects, a combined study involving X-ray Circular Magnetic Dichroism and Scanning Tunneling Microscopy will be presented. Several substrates will be analyzed (SmAu$_2$, GdAu$_2$, and YbAu$_2$) that have the same RE-Au$_2$ surface structure and lattice but reveal ferromagnetic, anti-ferromagnetic [1], and non-magnetic interaction with the Co nanodot array, respectively. These interactions not only determine the magnetic properties below the Curie temperature T_C of the substrate but also far above T_C and lead to enhancements of the magnetic anisotropy and blocking temperature of the Co nanodot array.

[1] L.Fernandez *et al.*, Nano Letters **14**, 2977 (2014).

MA 44.5 Thu 16:00 H 0110

Magnetism of Fe/Pt surface alloys and Fe/Pt nanostructures embedded in Pt(111) via ab initio calculations — •Saleem Ayaz Khan[1], Ján Minár[1,2], and Ondřej Šipr[3] — [1]University of West Bohemia, Plzeň, Czech Republic — [2]Universität München, Germany — [3]Institute of Physics ASCR, Praha, Czech Republic

Embedding Fe atoms in the surface layer of Pt (111) creates low dimensional materials with complex magnetic behavior. To understand the combined effect of coordination and disorder, a systematic theoretical study of spin and orbital magnetic moments and of density of states for a series of embedded Fe/Pt nanostructures was performed within the ab initio density functional theory framework, using the FLAPW method (WIEN2K code) and the KKR-Green's function method (SPRKKR code). Different ways of including relativistic effects were tested. We find that increasing the Pt content in Fe/Pt nanostructures generally results in enhancement of magnetic moments. The effect of hybridization of Fe 3d and Pt 5d electrons in the presence of a surface is discussed in detail.

15 min. break

MA 44.6 Thu 16:30 H 0110

Modifying the magnetic exchange coupling of hybrid organic-ferromagnetic interfaces — •Rico Friedrich, Vasile Caciuc, Nikolay S. Kiselev, Nicolae Atodiresei, and Stefan Blügel — Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

In molecular spintronics the properties of hybrid organic/ferromagnetic interfaces are of crucial importance [1]. Recently, it has been demonstrated by experimental and theoretical means [2] that an organic layer made of phenalenyl-based molecules on top of a cobalt contact can significantly modify the electronic and magnetic properties of the metal surface.

In this talk we outline a systematic study of this effect by investigating the influence of hetero-atoms within the organic molecules on the magnetic exchange coupling constant J between the surface Fe atoms below the molecule. Our results demonstrate, that a magnetic hardening can be specifically tuned when atoms like boron, carbon or nitrogen influence the magnetic exchange coupling. Moreover, a magnetic softening effect can be realized when either oxygen or a boron-carbon bond mediate the coupling between surface Fe atoms. Furthermore, we demonstrate that the most important contribution to the modification of the coupling constants is due to the hybridization between the electronic states of the molecule and those of the substrate.

[1] N. Atodiresei et al., Physical Review Letters **105**, 066601 (2010).
[2] K. V. Raman et al., Nature **493**, 509 (2013).

MA 44.7 Thu 16:45 H 0110

Unexpected antiferromagnetic coupling of Cr-porphyrin to bare cobalt thin film — •Jan Girovsky[1], Kartick Tarafder[2,3], Jan Nowakowski[1], Christian Wäckerlin[4], Milos Baljozovic[1], Dorota Siewert[5], Aneliia Wäckerlin[5], Armin Kleibert[6], Nirmalya Ballav[7], Thomas A. Jung[1], and Peter M. Oppeneer[2] — [1]LMN, PSI, Villigen, Switzerland — [2]Uppsala University, Uppsala, Sweden — [3]BITS, Shameerpet, Andhra Pradesh, India — [4]LNS, EPFL, Lausanne, Switzerland — [5]University of Basel, Basel, Switzerland — [6]SLS, PSI,Villigen, Switzerland — [7]IISER, Pune, India

Spin bearing square-planar metallo-organic complexes interact magnetically with ferromagnetic (FM) substrates even up to room temperature[1]. So far, exclusively FM ordering has been reported for such molecules adsorbed on bare metallic ferromagnets [2,3]. Here, we present a combined experimental and theoretical study on CrTPP molecules antiferromagnetically (AFM) coupled to bare cobalt substrate. The observed AFM interaction is confirmed by DFT+U calculations and alternatively described within the framework of Goodenough-Kanamori-Anderson (GKA) rules. In the GKA model, the less than half-filled 3d shell of the Chromium ion interacts with the out-of-plane orbitals of the cobalt atoms via indirect 90 degree exchange coupling mediated by the porphyrins' nitrogen atoms[4].

[1] A. Scheybal et al, Chem Phys Lett 411, 214 (2005).
[2] N. Ballav et al, JPCL 4, 2303 (2013).
[3] A. Lodi Rizzini et al, Surface Science 630, 361 (2014).
[4] J. Girovsky et al, PRB (R), in press

MA 44.8 Thu 17:00 H 0110

Molecular-driven magnetism on reactive metal surfaces — •Amilcar Bedoya-Pinto[1], Stefan Lach[2], Christiane Ziegler[2], Mats Fahlman[3], Eugenio Coronado[4], and Luis Hueso[1] — [1]CIC nanoGUNE, San Sebastián, Spain — [2]Department of Physics, University of Kaiserslautern — [3]Department of Physics, Chemistry and Biology, Linköping University, Sweden — [4]ICMOL, Valencia, Spain

The fascinating properties of molecules, due to their wide-ranging chemical functionalities that can be tailored on purpose, are currently opening new pathways in many fields connected to solid-state physics. As for molecular-based spintronics, the interaction strength between ferromagnetic metals and adsorbed molecules have been found to be determinant to engineer spin-dependent interface properties. Here, with a multi-method study (IR,UPS,XPS,EELS,XMCD,SQUID), we show that the adsorption of high-spin molecules (Tb3q9) on non-magnetic reactive metals induces the formation of room-temperature magnetically active phases, even without the presence of any ferromagnet. This approach relies on a strong chemical reaction at the metal-molecule interface, which dramatically alters the structure and stoichiometry of the molecular species and generates a new phase involving both the high-spin metal atom present in the molecule (Tb) and the metallic surface atoms (Cu). The fact that these purpose-made molecules are able to trigger the creation of a new inorganic phase with robust magnetic properties at a non-magnetic surface underlines the importance and role of interfacial chemistry to crucially modify surface properties and thus design building blocks for spintronic applications.

MA 44.9 Thu 17:15 H 0110

Uncompensated antiferromagnets for artificial magnetic semiconductors — •Michalis Charilaou[1,2,3], Simca Bouma[2,3], Catherine Bordel[2,3], and Frances Hellman[2,3] — [1]Department of Materials, ETH Zurich, Zurich, Switzerland — [2]Department of Physics, University of California Berkeley, Berkeley, California, USA — [3]Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California, USA

Like ferromagnets (FM), antiferromagnets (AFM) exhibit spontaneous long-range spin ordering below a transition temperature. The net magnetization of a perfect AFM is zero, however; defects such as vacancies, grain boundaries, or surfaces can create an uncompensated net magnetization. As a specific example we consider AFM CoO, which consists of AFM-coupled FM (111) planes; (111)-oriented epitaxial films with an odd number of planes will exhibit a non-zero net magnetization due to uncompensated surfaces. These uncompensated surfaces have been used to produce an artificially-structured FM semiconductor using epitaxial layers of AFM CoO with a doped semiconductor Al:ZnO (AZO). Both M(T) and the anomalous Hall effect show oscillatory behavior with thickness of either CoO (compensated vs uncompensated) or AZO (RKKY-type oscillations related to the AZO Fermi wavevector due to electron-induced coupling between Co moments at its two CoO surfaces). The experimental results are complemented by theoretical calculations, which show that the thermodynamic behavior of the magnetization in uncompensated AFM is highly versatile, and is dominated by the exchange coupling on the surface.

MA 45: Spin-dependent Transport Phenomena II

Time: Thursday 15:00–18:00 Location: H 0112

MA 45.1 Thu 15:00 H 0112

D'yakonov-Perel' spin dephasing in metallic films — •N. H. Long, P. Mavropoulos, D. S. G. Bauer, B. Zimmermann, Y. Mokrousov, and S. Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The D'yakonov-Perel' mechanism for spin dephasing of conduction electrons is prominent in systems with broken space-inversion symmetry, where spin-orbit coupling induces a $\mathbf{k}$-dependent Zeeman-type field, the *spin-orbit field* $\mathbf{\Omega_k}$. The electron spin precesses around $\mathbf{\Omega_k}$, while momentum scattering into a different state $\mathbf{k}'$ results in a new precession axis $\mathbf{\Omega_{k'}}$, eventually leading to spin dephasing. The mechanism is well-studied in semiconductors but not in metals that usually have inversion symmetry, which is, however, lifted in metallic films deposited on a substrate.

In this work we employ density-functional theory and a linear response approach for the calculation of the spin-orbit fields in supported metallic films typically used in spintronics, such as Au(111) or Pt(111). A kinetic equation is applied to derive the dephasing time that is found to be smaller than the Elliott-Yafet spin-relaxation time, e.g., 100 ns in 24-layer Au(111) films with self-adatom impurities. We discuss the importance of the mechanism in systems of varying film thickness and impurity concentration.

We acknowledge funding from the DFG SPP-1538 SpinCaT and HGF-YIG Programme VH-NG-513.

MA 45.2 Thu 15:15 H 0112

Description of magneto-optics of disordered alloys from first principles — •Kristina Chadova[1], Rudolf Sykora[2], Dominik Legut[2], Diemo Ködderitzsch[1], Hubert Ebert[1], and Jan Minár[1,3] — [1]Department of Chemistry, Physical Chemistry, Ludwig-Maximilians University Munich, Germany — [2]Nanotechnology Centre VSB - Technical University of Ostrava, 17. Listopadu 15/2172, 708 33 Ostrava-Poruba, Czech Republic — [3]NewTechnologies-Research Center, University of West Bohemia, Pilsen, Czech Republic

The optical properties of pure - as well as disordered - alloys have received a lot of interest as they play an important role, for example in storage applications. We present a first-principle approach to calculate magneto-optical properties based on the Kubo formula implemented within the fully relativistic KKR (Korringa-Kohn-Rostoker) formalism in combination with coherent potential approximation accounting for chemical disorder in substitutional random alloys. The implemented formalism allows to calculate the full frequency dependent conductivity tensor and to discuss on this basis the magneto-optical effects. The first results will be presented for ferromagnetic transition metal alloys.

MA 45.3 Thu 15:30 H 0112

Compton profiles of random $Fe_{0.5}Ni_{0.5}$ alloy, evidence for the interplay of disorder and correlation in momentum space — •Liviu Chioncel[1,2], Diana Benea[3,4], Hubert Ebert[4], and Jan Minar[4,5] — [1]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D - 86135 Augsburg, Germany — [2]Augsburg Center for Innovative Technologies, University of Augsburg, D-86135 Augsburg, Germany — [3]Faculty of Physics, Babes-Bolyai University, Kogalniceanustr 1, Ro-400084 Cluj-Napoca, Romania — [4]Chemistry Department, University Munich, Butenandstr. 5-13, D-81377 München, Germany — [5]New Technologies - Research Center, University of West Bohemia, Univerzitni 8, 306 14 Pilsen, Czech Republic

We study the magnetic Compton profile of the disordered $Fe_{50}Ni_{50}$ alloy and discuss the interplay between structural disorder and electronic correlations. The disorder distribution is described within the Coherent Potential Approximation while local electronic correlations are captured with the Dynamical Mean Field Theory. The disorder induced changes in the experimental magnetic Compton profiles are well described by the theoretical calculations only when both components Fe and Ni are subject to considerable electronic correlations.

MA 45.4 Thu 15:45 H 0112

Current Induced Domain Wall Depinning in Non-Local Spin Valve Half Ring Structures — •Alexander Pfeiffer[1], William Savero Torres[2], Nils Richter[1], Laurent Vila[2], Jean Philippe Attané[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Institut Nanosciences et Cryogénie, Université Grenoble Alpes & CEA, France

We demonstrate current induced domain wall depinning and phase transitions in non-local spin valve Permalloy/Aluminium half ring structures. With our optimized geometry by patterning a notch acting as a pinning center in one half ring, we are to able study the influence of Oersted fields, Joule heating and the spin transfer torque. We find a complete depinning event at zero applied external field for a charge current density of 600 GA/m^2, showing that our geometry can be used for low power domain wall manipulation.

MA 45.5 Thu 16:00 H 0112

Electronic transport from ab-inito linear response – a generalized Kubo-Bastin approach — •Diemo Ködderitzsch, Kristina Chadova, and Hubert Ebert — Department Chemie, Ludwig-Maximilians-Universität, 81377 München, Germany

Starting from a Kubo-Bastin like linear response expression we present a general approach to describe various linear response phenomena from ab-inito. Within a fully relativistic KKR framework in a spin-density functional formulation we treat among other things the full (spin-) conductivity tensor including its antisymmetric components and thereby spin-orbit induced transverse transport phenomena like the spin- and anomalous Hall effects. Both Fermi-sea and Fermi-surface terms are described on the same footing. Employing the coherent potential approximation allows to treat, besides pure systems, disordered alloys through the whole concentration range. Within this approach intrinsic as well as extrinsic contributions are fully accounted for without any model assumptions. In this context the role of vertex corrections and their importance will be discussed. Applications to transition-metals and their alloys will be presented.

15 min. break

MA 45.6 Thu 16:30 H 0112

Transverse transport and magneto-optical properties of noncollinear antiferromagnets — •Sebastian Wimmer, Ján Minár, Sergiy Mankovsky, Diemo Ködderitzsch, and Hubert Ebert — Ludwig-Maximilians-Universität München, München, Deutschland

Recently, a number of investigations on the anomalous Hall effect (AHE) in materials having nontrivial spin structures, such as noncollinear antiferromagnets, have been performed [1-4]. One especially striking result is the prediction of the AHE for a system with zero net magnetization [3]. We revisit and extend these studies employing a combined group theoretical and first principles approach.

Based exclusively on symmetry considerations the occurence of transverse transport and related optical effects for a given magnetic order of a solid can be predicted. Numerical studies using a first principles electronic structure method in the framework of Korringa-Kohn-Rostoker (KKR) multiple scattering theory and subsequent calculation of response quantities using a Kubo-type linear response formalism are performed to independently cross-check the group theoretical predictions. Our results in part confirm previous findings and furthermore give first numerical estimates of the magnitude of magneto-optical properties experimentally not observed so far.

[1] S. Yoshii, S. Iikubo, T. Kageyama, K. Oda, Y. Kondo, K. Murata, and M. Sato, JPSJ **69**, 3777 (2000). [2] T. Tomizawa and H. Kontani, PRB **82**, 104412 (2010). [3] H. Chen, Q. Niu, and A. H. MacDonald, PRL **112**, 017205 (2014). [4] J. Kübler and C. Felser, arXiv:1410.5985 [cond-mat.mtrl-sci] (2014).

MA 45.7 Thu 16:45 H 0112

Sign change in tunnel magnetoresistance of Fe_3O_4/MgO/CoFeB magnetic tunnel junctions depending on annealing temperature and interface treatment — Luca Marnitz[1], Karsten Rott[1], Stefan Niehörster[1], Christoph Klewe[1], Daniel Meier[1], Savio Fabretti[1], Matthäus Witziok[2], Andreas Krampf[2], Olga Schuckmann[2], Tobias Schemme[2], Karsten Kuepper[2], Joachim Wollschläger[2], Andy Thomas[1], Günter Reiss[1], and •Timo Kuschel[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Physics Department, Osnabrück University, Germany

Magnetite (Fe_3O_4) is a promising candidate for magnetic tunnel junctions (MTJs) since it shows a high spin polarization at the Fermi level as well as a high Curie temperature of 585°C. However, MTJs with magnetite electrodes have not shown a large tunnel magnetoresistance (TMR) so far. It is reported in literature for magnetite on MgO that Mg^{2+} ions diffuses into the magnetite at growth temperatures above 250°C, replacing parts of the Fe^{2+} ions. In typical magnetite MTJs MgO is used both as substrate as well as barrier material.
In this study, a sign change in the TMR of Fe_3O_4/MgO/CoFeB MTJs is observed after annealing at temperatures between 200°C and 280°C which can be explained by Mg interdiffusion from the MgO barrier into the magnetite. Additionally, different treatments of the magnetite interface during the preparation of the MTJs have been studied regarding their effect on the performance of the MTJs. A maximum TMR of up to -12% was observed despite exposing the magnetite surface to atmospheric conditions prior to the deposition of the MgO barrier.

MA 45.8 Thu 17:00 H 0112

Tunneling Anisotropic Magnetoresistance in oxide heterostructures — •Nico Homonnay[1], Johannes Lotze[1], Robert Göckeritz[1], Alexander Müller[1], Tim Richter[1], and Georg Schmidt[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany

We have investigated tunneling anisotropic magnetoresistance (TAMR) [1] in hybrid structures consisting of an epitaxial stack of a ferromagnetic oxide ($La_{0.7}Sr_{0.3}MnO_3$, LSMO) and an oxide tunnel barrier ($SrTiO_3$, STO) fitted with a non-magnetic metal contact. The oxide stack was deposited by pulsed laser deposition and metallization was done without breaking UHV conditions using various metals for different samples. The layers were processed to vertical tunneling devices with lateral dimensions of approx. 10 μm and the devices were investigated at low temperature in a 4He bath cryostate equipped with a 3D vector magnet. In all devices we observe TAMR which strongly depends on temperature, bias voltage and thickness of the tunnel barrier. The TAMR signal can be larger than 50 % which is more than 10 times bigger than reported for inorganic systems [1]. The magnetoresistance is clearly identified as TAMR by in-plane magnetic field sweeps at different angles. The TAMR signal persists up to a bias voltage of approx. 1 V and up to a temperature of 240 K which is well below the Curie temperature of the LSMO. [1] Gould et al., Phys. Rev. Lett. 93, 117203 (2004)

MA 45.9 Thu 17:15 H 0112

Spin-dependent Fano effect and two-stage Kondo effect in T-shaped double quantum dots with ferromagnetic leads — •Krzysztof P. Wójcik and Ireneusz Weymann — Faculty of Physics, Adam Mickiewicz University, Umultowska 85, 61-614 Poznań, Poland

We analyze the influence of ferromagnetism of the leads on the transport properties of T-shaped double quantum dots. The calculations are performed by using the numerical renormalization group method. We focus on two particularly interesting phenomena occurring in such systems: the Fano-like interference causing a strong antiresonance in the dependence of the linear conductance on the gate voltage, and the two-stage Kondo effect. The latter effect is related with a nonmonotonic dependence of the linear conductance on temperature T: with lowering T below the Kondo temperature the conductance is first enhanced, but then at the second stage it becomes suppressed due to the formation of spin singlet state between two singly occupied quantum dots. We find that spin-resolved tunneling can suppress the second stage of the Kondo effect for appropriately chosen dots' energy levels. Moreover, we show that the presence of ferromagnets results in spin-dependent conditions for the Fano destructive interference, which gives the possibility of tuning the spin polarization of the linear conductance in the range $[-1, +1]$.

MA 45.10 Thu 17:30 H 0112

The influence of Coulomb interactions on spin-dependent thermoelectric transport through double quantum dot system with Rashba spin-orbit coupling — •Łukasz Karwacki and Piotr Trocha — Faculty of Physics, Adam Mickiewicz University, Poznań, Poland

We investigate theoretically a double quantum dot system embedded into an Aharonov-Bohm ring and coupled to two electronic reservoirs. The magnetic potential present in the system due to the Aharonov-Bohm device leads to spin-independent phase factors in terms related to coupling between the dots and the electrodes. Furthermore, we assume additional spin-dependent phase factors arising from Rashba spin-orbit interaction. We show the influence of the aforementioned phases and that of the Coulomb blockade on the dots on such basic thermoelectric parameters as charge and spin conductances, electronic contribution to heat conductance, charge and spin thermopower and the resulting thermoelectric effectiveness factor.

In our approach we focus on the linear response regime, where the thermoelectric parameters are functions of transmission coefficient. To derive this coefficient we employ equation of motion for non-equilibrium Green's function method.

The results indicate a possibility for an efficient spin-dependent Seebeck generator. Tuning the Rashba spin-orbit interaction leads to pure spin current through the system. In both cases Coulomb blockade leads to enhancement of thermoelectric transport.

MA 45.11 Thu 17:45 H 0112

Tunable Thermoelectric Power Factors of Magnetoresistive Nanowires — •Anna Niemann[1], Tim Böhnert[1], Ann-Kathrin Michel[1], Svenja Bässler[1], Johannes Gooth[1], Bence G. Tóth[2], Katalin Neuróhr[2], László Péter[2], Imre Bakonyi[2], Victor Vega[3], Victor M. Prida[3], and Kornelius Nielsch[1] — [1]Universität Hamburg, Hamburg, Germany — [2]Hungarian Academy of Sciences, Budapest, Hungary — [3]Universidad de Oviedo, Oviedo, Spain

We present spin-caloric transport in single Co-Ni alloy and multilayered Co-Ni/Cu nanowires, including magnetoresistance (MR) and magneto-thermopower (MTP) measurements. Co-Ni alloy nanowires show anisotropic MR while multilayered nanowires show predominant giant MR. MTP and MR are studied in a temperature range between 50 K and 325 K leading to effect sizes up to 6 % for Co-Ni alloy samples and up to 15 % for multilayered samples at room temperature. While the thermopower describes a material's ability to convert temperature gradients into electrical voltage, thermoelectric power factors (PFs) give a measure of the electrical power generated from thermoelectric effects. The PFs of our nanowires can compete with common thermoelectric bulk materials like Bi_2Te_3. Additionally, a magnetic field-dependence of the nanowires' PFs can be observed. PFs of Co-Ni nanowires increase by 24 % in an external magnetic field, while PFs of multilayered nanowires can be increased by up to 40 %. This magnetic field dependence opens interesting opportunities to tune electrical power output according to applicational needs.

MA 46: Magnetic Thin Films I

Time: Thursday 15:00–18:30 Location: H 1012

MA 46.1 Thu 15:00 H 1012

Microscopic analysis of the composition driven spin-reorientation transition in Ni_xPd_{1-x}/Cu(001) — •Daniel M. Gottlob[1], Hatice Doğanay[1], Florian Nickel[1], Stefan Cramm[1], Ingo P. Krug[1,2], Slavomír Nemšák[1], and Claus M. Schneider[1,3] — [1]Peter Grünberg Institut 6, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Institut für Optik und Atomare Physik, Technische Universität Berlin, 10623 Berlin, Germany — [3]Fakultät für Physik and Center for Nanointegration Duisburg-Essen (CeNIDE), Universität Duisburg-Essen, 47048 Duisburg, Germany

The composition driven spin-reorientation transition (SRT) has been investigated in the thin film system Ni_xPd_{1-x}/Cu(001) by photoemission microscopy (PEEM) utilizing the x-ray magnetic circular dichroisim (XMCD) effect at the Ni $L_{2,3}$ edge. The magnetic domain structure and its development has been investigated on microwedges grown in the integrated preparation chamber by molecular beam epitaxy and characterized in-situ. By alloying palladium into nickel the epitaxial strain of a thin film may be varied and the critical film thickness at which an SRT occurs can be controlled. A composition driven SRT could be identified between 37 ML and 60 ML film thickness and 0 to 38 atomic % of Pd. The domain structure in the vicinity of the SRT shows comparable behavior to ultrathin film SRTs, however, additional influences of magnetic in-plane anisotropies could be observed, resulting in a domain alignment along the in-plane easy axis. The SRT is found to take place by a continuous canting of the magnetization axis.

MA 46.2 Thu 15:15 H 1012

Topological defect evolution and transverse instability in magnetic stripe domain patterns — •Michael Zimmermann, Thomas Meier, Matthias Kronseder, and Christian Back — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Deutschland

Magnetic phase transitions in ultra thin films have long been the subject of extensive studies. Particular interest has been dedicated to the spin reorientation transition found in some ultra thin magnetic films with perpendicular anisotropy. Here, the evolution of stripe domain patterns into less ordered phases (i.e. disordered phase) is investigated. Emphasis is placed on the development of topological defects within single stripe domains when heated. The generation of topological defects is closely related to the effect of transverse instability. To quantitatively describe the domain state, numerical order parameters are used. Besides heating, also cooling experiments have been conducted. Thereby the inverse effect of transverse instability could be observed. We use a laboratory based imaging technique with high spatial resolution, which is threshold photoemission magnetic circular dichroism (TP-MCD) in combination with photoemission electron microscopy (PEEM). All measurements were conducted on ultra thin Ni/Fe/Cu(001) and Fe/Ni/Cu(001) samples, since both offer an out-of-plane magnetization direction if the layer thicknesses are chosen properly.

MA 46.3 Thu 15:30 H 1012

Quantification of fluctuations of domain patterns in ultrathin ferromagnetic films — •Thomas Meier, Michael Zimmermann, Matthias Kronseder, and Christian Back — Institut für experimentelle und angewandte Physik, Universität Regensburg, Deutschland

Magnetic phase transitions in ultrathin ferromagnetic films have been subject to intensive studies in the last decades. If the magnetic film exhibits a perpendicular magnetic anisotropy either caused by surface and interface effects or magnetoelastic anisotropy due to a lattice mismatch in epitaxial growth, a spin-reorientation transition (SRT) may take place. Here the SRT of epitaxially grown Fe/Ni/Cu(001) or Ni/Fe/Cu(001) ultrathin films is investigated. We use a laboratory based imaging technique based on the threshold photoemission magnetic circular dichroism (TP-MCD) effect in combination with photoemission electron microscopy (PEEM). This technique provides a high spatial as well as high temporal resolution allowing for the observation of fluctuations of the domain pattern in real time. We quantify fluctuations of the domain pattern in the vicinity of the SRT using the magnetic susceptibility as well as the variance of the total domain wall length calculated on a sequence of images recorded at the PEEM-setup and analyzed via an automatized image processing approach. The fluctuations of the domain pattern are investigated depending on temperature and external out-of-plane magnetic fields.

MA 46.4 Thu 15:45 H 1012

Correlation of magnetic moment and lattice expansion in γ'-Fe_4N thin films — •Dominik Gölden, Imants Dirba, Erwin Hildebrandt, Philipp Komissinskiy, Oliver Gutfleisch, and Lambert Alff — Institute of Materials Science, Technische Universität Darmstadt, Germany

γ'-Fe_4N is the most stable phase among the iron nitrides and can be grown in a wide temperature range. It has been in the focus of research for several decades due to its physical properties such as low electrical resistance, low coercivity, and relatively high saturation magnetization, making it interesting for application in magnetic tunnel junctions. We report on the correlation of the lattice expansion and the magnetic moment of γ'-Fe_4N thin films grown by molecular beam epitaxy on single crystal MgO(100) substrates and give an estimate of the Curie temperature. In addition, the electronic properties were studied by X-ray photoelectron spectroscopy to show the influence of the interstitial nitrogen on the electronic structure in the γ-Fe lattice. By changing the nitridation conditions using a nitrogen radical source, the lattice constant of γ'-Fe_4N could be varied in a wide range. We have correlated nitridation parameters during thin film growth with the structural and magnetic properties using X-ray diffractometry and SQUID magnetometry.

MA 46.5 Thu 16:00 H 1012

Increased magnetic moment induced by lattice expansion from α-Fe to α'-Fe_8N — Imants Dirba[1], Philipp Komissinskiy[1], Dominik Gölden[1], Oliver Gutfleisch[1,2], and •Lambert Alff[1] — [1]Institute of Materials Science, Technische Universität Darmstadt, 64287 Darmstadt — [2]Fraunhofer-Projektgruppe für Wertstoffkreisläufe und Ressourcenstrategie IWKS, 63457 Hanau

We have grown buffer-free and epitaxial α-Fe and α'-Fe_8N_x thin films by RF magnetron sputtering and molecular beam epitaxy onto MgO (100) substrates. The film thicknesses and densities have been determined with high accuracy by evaluating the Kiessig fringes of X-ray reflectometry measurements allowing a precise volume estimation. A gradual increase of the nitrogen content in the plasma led to an expansion of the iron bcc unit cell along the [001] direction resulting finally in a tetragonal distortion of about 10% corresponding to the formation of α'-Fe_8N. The α-Fe lattice expansion was accompanied by an increase in magnetic moment to $2.61 \pm 0.06\,\mu_B$ per Fe atom, and an increase in anisotropy of around 6000 Oe. Our experiments show that - without requiring any additional ordering of the nitrogen atoms - the lattice expansion of α-Fe itself is the origin of the increased magnetic moment in α'-Fe_8N.

MA 46.6 Thu 16:15 H 1012

Strain induced magneto-optical anisotropy in epitaxial hcp Co-films — •Jon Ander Arregi, Juan Bautista González-Díaz, Olatz Idigoras, and Andreas Berger — CIC nanoGUNE Consolider, Donostia San Sebastian, Spain

In nearly all magneto-optical Kerr effect (MOKE) studies, it is assumed for the sake of simplicity that the strength of the magneto-optical coupling factor Q is independent from the magnetization orientation. This is generally understood to be a reasonable assumption for metallic systems, and very few experimental studies have observed only modest deviations from this assumption [1,2].

Here, we investigate the existence and origin of magneto-optical anisotropy in epitaxial hcp Co-films. By employing the generalized magneto-optical ellipsometry (GME) technique [3], we find that the amplitude of magneto-optical anisotropy is strongly correlated with the growth induced crystallographic strain, observing that this anisotropy is very much reduced upon structural relaxation towards the bulk for the thicker films. In addition, we find that the strain state variation produces a redistribution of the first- and second-order magnetic anisotropy fields, while the total saturation field of the films remains basically unaltered. The possibility to tune the magneto-optical anisotropy of the Co-films by engineering their strain state is briefly discussed.

[1] D. Weller *et al.*, *Phys. Rev. Lett.* **72**, 2097 (1994)
[2] D. Schmidt *et al.*, *Appl. Phys. Lett.* **102**, 123109 (2013)
[3] J. A. Arregi *et al.*, *J. Appl. Phys.* **111**, 103912 (2012)

15 min. break

MA 46.7 Thu 16:45 H 1012

Evidenceof Antiferromagnetic Exchange Interaction in Fe Films on Rh(001) — •Yang Meng[1], Khalil Zakeri Lori[1], Arthur Ernst[1,2], Tzu-Hung Chuang[1], Huajun Qin[1], Ying-Jiun Chen[1], and Jürgen Kirschner[1,3] — [1]Max-Planck-Institut für Mikrostrukturphysik, Weinberg 2, 06120 Halle, Germany — [2]Wilhelm Ostwald Institut für Physikalische und Theoretische Chemie, Universität Leipzig, Linnéstr. 2, 04103 Leipzig, Germany — [3]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06120 Halle, Germany

Magnetic properties and high-energy magnon excitations in ultrathin Fe films on Rh(001) are studied by means of magneto-optical Kerr effect and spin polarized high resolution electron energy loss spectroscopy, respectively. The magnon dispersion relation is probed over a large region of the surface Brillouin zone. A strong magnon softening is observed at the high symmetry $\bar{\mathrm{M}}$–point, indicating a large antiferromagnetic (AFM) exchange interaction in the films. First-principles calculations showed that this unusual AFM exchange interaction has its origin not only in the strong interfacial electronic hybridizations between the Fe film and the Rh substrate but also in the tetragonal distortion of the film, caused by the film epitaxy. Our results shed light on the long standing question regarding the possibility of having an AFM exchange interaction in Fe films.

MA 46.8 Thu 17:00 H 1012

Thickness-dependent magnetic domain structure of Fe films on Rh(001) — •Stefan Wilfert, Jeannette Kemmer, Pin-Jui Hsu, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

We have investigated the thickness-dependent magnetic domain structure of epitaxial Fe films on Rh(001) by means of spin-polarized scanning tunneling microscopy (SP-STM) at low-temperature ($T = 5$ K). In agreement with earlier density functional theory calculations [1,2] we find a first atomic layer (AL) that exhibits a perpendicular antiferromagnetic spin structure equivalent to a c(2×2) checkerboard pattern. In the Fe thickness range between 1 AL and 3.5 AL the film consists of out-of-plane ferromagnetic domains, as proposed by Takada *et al.* [3]. We find that the domain size quickly decreases with increasing thickness. The data will be discussed in terms of competing contributions to the magnetic anisotropy.

[1] D. Spišák and J. Hafner, Phys. Rev. B **73**, 155428 (2006).
[2] A. Al-Zubi *et al.*, Phys. Rev. B **83**, 024407 (2011).
[3] M. Takada *et al.*, J. Magn. Magn. Mater. **329**, 95 (2013).

MA 46.9 Thu 17:15 H 1012

Layer-resolved in-situ ^{57}Fe conversion electron Mössbauer spectroscopy (CEMS) on 4 ML Fe(001)/Ir(001) at 30 K — •Sergey Makarov[1,2], Werner Keune[1,2], Heiko Wende[1], and Jürgen Kirschner[2] — [1]Faculty of Physics and CeNIDE, University of Duisburg-Essen — [2]Max Planck Institute of Microstructure Physics

Our recent in-situ ^{57}Fe Mössbauer spectroscopy (CEMS) measurements in UHV on the Fe(001)/Ir(001) system have provided experimental prove of magnetic order in Fe(001)/Ir(001) ultrathin films below four atomic Fe monolayers (< 4 ML) at 30 K, and the average spin canting angle $<\Theta>$ (rel. to the surface normal direction) was extracted. The result is consistent with a ground state helical spin configuration in 2 ML and 3 ML Fe(001)/Ir(001) [1]. Moreover, the existence of two inequivalent Fe sites in terms of fct and bct Fe was discussed [2].

In the present work we focus on in-situ ^{57}Fe CEMS measurements of layer-dependent magnetic ordering in homogeneous 4 ML Fe(001)/Ir(001) films resolved by a 2 ML ^{57}Fe probe layer placed at different positions with respect to Ir(001). We conclude that site 1 of fct Fe has a higher abundance near the Fe/Ir interface than in the rest of the film (the opposite is valid for site 2 of bct Fe). We observe a weak tendency for a layer-dependence of the angle $<\Theta>$. The sum spectrum of all tracer layers agrees well with the spectrum of a homogeneous 4 ML ^{57}Fe(001)/Ir(001) film.

[1] A. Deák et al., Phys. Rev. B **84** (2011) 224413
[2] V. Martin et al., Phys. Rev. B **76** (2007) 205418

MA 46.10 Thu 17:30 H 1012

Non bulk-like magnetoelastic coupling in Fe monolayers on Ag (001) — •Kenia Novakoski Fischer, Dirk Sander, and Jürgen Kirschner — Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle

Film strain contributes significantly to the magnetic anisotropy of atomic layers via the magnetoelastic coupling B_i [1]. The magnetoelastic coupling coefficient B_1 is experimentally accessible from measurements of the magnetoelastic stress change upon a magnetization reorientation along the <100> film directions. We present results of magnetoelastic stress measurements of 30 layers of Fe on Ag (001). We find that a reduced growth temperature of 150 K as compared to 300 K influences both epitaxial film stress and magnetoelastic stress. For growth at 300 K we find $B_1 = +25MJ/m^3$ and for growth at 150 K $B_1 = +3.8MJ/m^3$. This differs in sign and magnitude from the respective bulk value $B_1^{bulk} = -3.4MJ/m^3$. This result in conjunction with previous studies [2,3] indicates that intermixing at the Fe-Ag interface needs to be considered for growth at 300 K. Our results shed fresh light on the role of lattice strain and intermixing on the resulting magnetoelastic coupling.

[1] D. Sander, Rep. Prog. Phys. 62 (1999) 809. [2] R.J. Hicken, S.J. Gray, A. Ercole, C. Daboo, D.J. Freeland, E. Gu, E. Ahmad, J.A.C. Bland, Phys. Rev. B 55 (1997) 5898. [3] M. Canepa, P. Cantini, O. Ricciardi, S. Terreni, and L. Mattera, Surface Science 429 (1999) 34.

MA 46.11 Thu 17:45 H 1012

Magnetic properties of iron nanostructures fabricated with electron beam induced deposition — •Fan Tu, Martin Drost, Florian Vollnhals, Esther Carrasco, Andreas Späth, Rainer Fink, Hans-Peter Steinrück, and Hubertus Marbach — Physikalische Chemie II, Universität Erlangen-Nürnberg, Egerlandstr.3, D91058, Germany

In the mask-less, "direct writing" technique, electron beam induced deposition(EBID), a focused electron beam is used to locally decompose precursor molecules on a surface. The non-volatile decomposition products form a deposit, while the volatile fragments are pumped off. With iron pentacarbonyl, we are able to fabricate ferromagnetic iron nanostructures with controlled shape and high purity (>95%) in our ultra high vacuum system. By controlling the electron dose and the autocatalytic growth time, we can fabricate clean nanostructures with arbitrary thickness [1,2]. The nanostructures have been investigated at the PoILux beamline at the Swiss Light Source with Scanning Transmission X-ray Microscopy. X-ray Magnetic Circular Dichroism contrast enables to image magnetic domains of the individual deposits while applying a variable magnetic field. The corresponding magnetic properties can be quantified.

Supported by the DFG through grant MA 4246/1-2, research unit FOR 1878/funCOS; and the Excellence Cluster Engineering of Advanced Materials of the FAU Erlangen-Nürnberg.

[1] F. Vollnhals, et al., Beilstein J. Nanotech., 5 (2014) 1175.
[2] H. Marbach, Appl. Phys. A., 117 (2014) 987.

MA 46.12 Thu 18:00 H 1012

Fe_3Si/Ge thin film stacks on GaAs(001) subtrates: An annealing study — •Jochen Kalt, Bernd Jenichen, and Jens Herfort — Paul-Drude-Institut für Festkörperelektronik, Berlin, Germany

Multilayer stacks consisting of ferromagnetic metals and semiconductors are promising candidates for the realisation of spintronic device concepts. Implemantable structures feature highly orderd interfaces as well as semiconductor thin films of high crystal quality. Due to considerably different growth temperatures and chemical reactions at the interface, the overgrowth of a metal by a semiconductor requires sophisticated methods in order to achieve both of these features.

This report presents recent results in processing MBE grown Fe_3Si/Ge thin film stacks with a post-growth in-situ annealing step. 9 nm of amorphous Germanium were grown at $T_G = 150\,°$C on top of stochiometric Fe_3Si/Ge on GaAs(001) subtrates. Subsequent annealing with temperatures ranging from 240 °C to 380 °C was done in order to crystallize the film, where the crystallisation process was in-situ monitored by RHEED. AFM measurements show an optimally smooth Germanium surface for an annealing temperature of $T_A = 320\,°$C and an annealing time of 10 min. For $T_A \geq 330\,°$C rough surface structures emerge, while for $T_A \leq 330\,°$C rather smooth surfaces form, with thin bars dominating the surface morphology. XRR measurements reveal a high interface quality up to $T_A = 330\,^\circ$C. XRD analysis indicates a new phase for $T_A \geq 330\,^\circ$C, namely Fe_3Si. Analysis of the in plane magnetic properties of the Fe_3Si/Ge-layer shows that with increasing T_A saturation magnetization and remanence decrease.

MA 46.13 Thu 18:15 H 1012

Reversible control of magnetism in Fe and FePt/Fe films by voltage induced phase changes — •Kenny Duschek[1,2], Sebastian Fähler[1], Heike Schlörb[1], Margitta Uhlemann[1], and Karin Leistner[1] — [1]Leibniz Institute for Solid State and Materials Research, Dresden, Germany — [2]Hochschule für Technik und Wirtschaft, Dresden, Germany

Voltage control of magnetism in thin films is of key interest for microelectromechanical systems, like sensors or actuators. In FePt and CoPt films, voltage induced faradaic reactions in the native iron oxide layer result in changes in anisotropy and magnetization [1]. As a model system promising even larger magnetization changes we here investigate 2 - 10 nm Fe films charged in 1 M KOH electrolyte. Depending on the applied potential we reversibly reduce the surface layer to Fe or oxidize it to iron oxide. This way we achieve a voltage induced change of saturation magnetization of 23 % for 10 nm, 40 % for 5 nm and 64 % for 2 nm Fe films. Combining this functional Fe layer with an underlying hard magnetic L10-FePt (001) layer, a significant voltage induced change of perpendicular anisotropy is achieved. The results show that electrochemical reactions can be used to tune surface magnetic properties in a large manner, to even switch magnetism on or off or induce a spin reorientation.

[1] K. Leistner, J. Wunderwald, N. Lange, S. Oswald, M. Richter, H. Zhang, L. Schultz, and S. Fähler, Phys. Rev. B 87 (2013) 224411

MA 47: Topological Insulators II (jointly with DS, HL, O, TT)

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

MA 47.1 Thu 15:00 EB 202

Topological surface states of Heusler-type topological insulators — •Shu-Chun Wu[1], Binghai Yan[1,2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Max Planck Institute for Physics of the Complex Systems, Dresden, Germany

Some promising half-Heusler compounds, RPtBi (R = La, Lu, Y), are demonstrated experimentally to be superconductors and are predicted to be topological insulators. The topological feature of bulk is band inversion and the s orbital of Pt atom is the main clue. However, their topological surface states (TSSs) remain unclear. In this work, we use *ab initio* method to investigate the TSSs. In experiment, they are found at the Γ point inside the valence bands. Spin texture is also calculated to confirm the topologically nontrivial surface states. External strain can push the TSSs from the valence bands up into gap.

MA 47.2 Thu 15:15 EB 202

Topological surface states on NaBaBi with two opposite spin textures — •Yan Sun[1], Shu-Chun Wu[1], Claudia Felser[1], and Binghai Yan[1,2] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany. — [2]Max Planck Institute for the Physics of Complex Systems, 01187 Dresden, Germany.

By breaking the inversion symmetry of the 3D Dirac metal Na_3Bi, we realize topological insulator (TI) phases in a known compound NaBaBi using $ab-initio$ calculations. Two distinct TI phases emerge: one phase is due to the band inversion between $Bi-p$ and $Na-s$ bands, and the other phase (under pressure) is induced by the inverted $Bi-p$ and $Ba-d$ bands. Both phases exhibit Dirac-cone-type surface states, but opposite spin textures. In the upper cone, a left-hand spin texture exists for the s-p inverted phase (similar to a common TI, e.g. Bi_2Se_3) while a right-hand spin texture appears for the $p-d$ inverted phase. NaBaBi presents a prototype model for TIs that exhibit different spin textures in the same material.

MA 47.3 Thu 15:30 EB 202

Indirect exchange interaction through topological surface states in crystalline topological insulators of a SnTe class — •Nicolas Klier, Sam Shallcross, and Oleg Pankratov — Theoretische Festkörperphysik, Universität Erlangen-Nürnberg, Staudtstr. 7B2, 91058 Erlangen

As predicted theoretically [1,2] and confirmed experimentally [2,3] the interface of SnTe and vacuum (i.e. the material's surface) hosts topologically stable Dirac states. We investigate the properties of this state within a **k**.**p** model that includes a full account of the bulk band structure [4]. An essential advantage of an analytical band model [4] is that it allows to unequivocally trace the two key degrees of freedom that this system possesses: spin and pseudospin. The indirect exchange interaction between magnetic impurities is a perfect probe for the surface Dirac states, especially for their spin structure. We revealed explicitly the dependence of this interaction on the properties of the bulk band states, in particular on the spin orbit coupling strength and on the crystal field splitting parameters. Depending on these parameters, the interaction may be either of Ising type or of a novel anisotropic XY type with the spin direction aligned with the connection vector between the two impurities.

[1] B.A. Volkov, and O.A. Pankratov, JETP Lett. **42**, 178, 1985.
[2] T.H. Hsieh *et al.*, Nature Comm. **3**, 982, 2012.
[3] Y. Tanaka *et al.*, Nature Phys. **8**, 800, 2012.
[4] B.A. Volkov, and O.A. Pankratov, Zh.Eksp. Theor. Fiz. **75**, 1362, 1978.

MA 47.4 Thu 15:45 EB 202

Edge states in topological magnon insulators — Alexander Mook[1], •Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle (Saale), Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany

For magnons, the Dzyaloshinskii-Moriya interaction accounts for spin-orbit interaction and causes a nontrivial topology that allows for topological magnon insulators. In this theoretical investigation [1] we present the bulk-boundary correspondence for magnonic kagome lattices by studying the edge magnons calculated by a Green function renormalization technique. Our analysis explains the sign of the transverse thermal conductivity of the magnon Hall effect in terms of topological edge modes and their propagation direction. The hybridization of topologically trivial with nontrivial edge modes enlarges the period in reciprocal space of the latter, which is explained by the topology of the involved modes.

[1] Phys. Rev. B **90** (2014) 024412.

MA 47.5 Thu 16:00 EB 202

Magnon waveguides from topological magnon insulators — •Alexander Mook[1], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle

Topological magnon insulators exhibit a nontrivial topology due to the Dzyaloshinskii-Moriya interaction. They host topologically nontrivial edge magnons and, consequently, energy as well as spin currents along their edges [1,2].

Bringing two topological magnon insulators into contact results in topologically protected unidirectional interface magnons. As these interface modes decay toward both bulk regions, their currents are confined to a few nanometer wide strip around the interface. Owing to the topological nature of the edge states, the edge currents follow any geometry.

We address theoretically the formation of interface edge magnons and their currents. On top of this, we propose recipes to compose magnon waveguides with nano-scale confinement.

[1] L. Zhang et al., PRB **87**, 144101 (2013).
[2] A. Mook et al., PRB **90**, 024412 (2014).

MA 47.6 Thu 16:15 EB 202

Probing the Electronic Properties of Individual MnPc Molecules Coupled to Topological States — •Thomas Bathon[1], Paolo Sessi[1], Konstantin Kokh[2], Oleg Tereshchenko[2], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik 2, Universitaet Wuerzburg, Am Hubland, 97074 Wuerzburg, Germany — [2]Novosibirsk State University, 630090 Novosibirsk, Russia

Hybrid organic-inorganic interfaces have been widely reported to host emergent properties that go beyond those of their single constituents. Coupling molecules to the recently discovered topological insulators, which possess linearly dispersing and spin-momentum-locked Dirac fermions, may offer a promising platform towards new functionalities.

Here, we report a scanning tunneling microscopy and spectroscopy study of the prototypical interface between MnPc molecules and a Bi_2Te_3 surface. MnPc is found to bind stably to the substrate through its central Mn atom. The adsorption process is only accompanied by a minor charge transfer across the interface, resulting in a moderately n-doped Bi_2Te_3 surface. More remarkably, topological states remain completely unaffected by the presence of the molecules, as evidenced by the absence of scattering patterns around adsorption sites. Interestingly, we show that, while the HOMO and LUMO orbitals closely resemble those of MnPc in the gas phase, a new hybrid state emerges through interaction with the substrate.

MA 47.7 Thu 16:30 EB 202

first principle study of structural, electronic and magnetic properties of graphene nanoribbons deposited on the topological insulator Sb2Te3 — wei zhang[1,2], •farideh hajiheidari[1], yan li[1,3], manuel j. schmidt[1], and riccardo mazzarello[1,4] — [1]Institute for Theoretical Solid State Physics, RWTH Aachen University, D-52074 Aachen, Germany — [2]Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany — [3]IEK-6, Forschungszentrum Jülich, D-52425 Jülich, Germany — [4]JARA-FIT and JARA-HPC, RWTH Aachen University, D-52074 Aachen, Germany

Magnetic perturbations are known to affect the surface properties of a topological insulator (TI) dramatically. According to mean-field calculations, zigzag graphene nanoribbons (zGNRs) possess spin-polarized edge states. Hence, zGNRs deposited on a TI could be a promising candidate for an experimental investigation of proximity effects between a magnetic system and a TI. In this work, we carry out a first-principles investigation based on density functional theory of zGNRs on the Sb2Te3 (001) surface. We use gradient-corrected density functionals in combination with semi-empirical van der Waals corrections. Both H-free and H-terminated zGNRs are considered. In the case of H-free zGNRs, the strong interaction between the edge atoms and the TI surface is shown to lead to the bending of the zGNRs , however, the edge magnetism is preserved. Moreover, the magnetic anisotropy axis is perpendicular to the surface of the substrate. In the H-terminated case, on the other hand, the interaction is less significant and edge magnetism is fully preserved.

MA 47.8 Thu 16:45 EB 202

WSe_2 Synthesis, Characterization and Properties — •Catherine R Rajamathi, Binghai Yan, Marcus Schmidt, Kumari Gaurav Rana, Chandra Shekhar, Siham Ouardi, Guido Kreiner, and Claudia Felser — Max-Planck Institute for Chemical Physics of Solids, Dresden

Layered transition metal dichalcogenides (TMDs) are widely studied systems as they are chemically versatile and technologically enthralling. The facile tunability of their electronic structure by varying certain parameters - carrier type (n- or p-type), composition, structure or sample size expand their applications from catalysis to topological insulators. Single crystals were synthesized from its polycrystalline components using $SeCl_4$ as the transport agent. Mono- or few-layered tungsten selenide obtained by the scotch-tape technique discussed in this talk are direct-gap semiconductors. FET devices fabricated from a few-layered sample of WSe_2 show ambipolar transistor behavior. In addition, hybrid materials such as $WSe_{2-x}Te_x$ may be promising due to high magnetoresistance and surface states on WTe_2 single crystals.

MA 47.9 Thu 17:00 EB 202

Classification of spin liquids on the square lattice with strong spin-orbit coupling — •Johannes Reuther[1,2], Shu-Ping Lee[3], and Jason Alicea[3] — [1]Freie Universität Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie — [3]California Institute of Technology

The investigation of spin liquids is a fascinating field in condensed matter physics that is increasingly motivated by experiments. Exhaustive classifications of spin liquids have been carried out in several systems, particularly when full SU(2) spin-rotation symmetry is present. Systematic studies that explore strongly spin-orbit-coupled magnetic compounds (for which there are many experimental examples) are, however, relatively scarce. We report on a classification of Z_2 spin liquids on the square lattice when SU(2) spin symmetry is maximally lifted. Using projective symmetry group methods, we find that, surprisingly, the lifting of spin symmetry yields vastly more spin liquid states compared to SU(2)-invariant systems. A generic feature of the SU(2)-broken case is that the spinons naturally undergo $p + ip$ pairing; consequently, many of these Z_2 spin liquids feature a topologically nontrivial spinon band structure supporting gapless Majorana edge states. These boundary modes are often protected by a combination of time reversal and lattice symmetries and hence resemble recently proposed topological crystalline superconductors.

MA 47.10 Thu 17:15 EB 202

Fate of the 1/3 magnetization plateau in quantum triangular antiferromagnets with various anisotropies — •Fedor Simkovic[1], Natasha Perkins[2], and Andrey Chubukov[2] — [1]King's College, London, England — [2]University of Minnesota, Minneapolis, United States

The triangular Heisenberg lattice is investigated by means of semi-classical 1/S expansion. Although classically the up-up-down phase with 1/3 magnetisation exists only at one magnitude of the field, it is stabilised by quantum fluctuations and forms a magnetisation plateau around this point. We investigate into three types of anisotropies for the triangular lattice, and access the stability of the aforementioned phase towards the limits of decoupled chains, the square, honeycomb, Kagome, rhombille and scaled triangular lattices.

MA 47.11 Thu 17:30 EB 202

Matrix product operators: Local equivalences and topological order in 2D — •Oliver Buerschaper — Freie Universität Berlin

Projected entangled pair states (PEPS), which naturally generalize matrix product states (MPS) to higher dimensions, describe the low energy properties of local quantum Hamiltonians with an energy gap very well. For this reason they are increasingly used as a valuable tool in both analytical and numerical studies of strongly correlated 2D quantum systems. Some of the most interesting such systems exhibit topological order, i.e. patterns of long-range entanglement which cannot be detected by any local order parameter. At the same time, excitations in these systems typically exhibit fractional statistics and may be used, for instance, as a resource for topological quantum computation.

For both fundamental and practical reasons, it is thus of the utmost importance to understand and classify PEPS in 2D, especially those with topological order. Recently it was found that symmetries defined in terms of certain matrix product operators (MPO) provide a mechanism for the emergence of topological order in PEPS. Furthermore, the kind of topological order was seen to depend on the algebraic properties of the given MPO symmetry. Here we show that many, seemingly distinct MPO symmetries are, in fact, locally equivalent and characterize PEPS with the *same* kind of topological order. We discuss interesting ramifications for the classification of 2D quantum systems.

MA 48: Magnetization / Demagnetization Dynamics IV

Time: Thursday 15:00–17:15 Location: EB 301

MA 48.1 Thu 15:00 EB 301

Magnetic reversal and magnetization dynamics in artificial ferromagnetic quasicrystals — •Vinayak Bhat[1,2], Barry Farmer[2], Lance DeLong[2], Joseph Sklenar[3], John Ketterson[3], and Justin Woods[2] — [1]Technical University of Munich, Munich, Germany — [2]University of Kentucky, Lexington, USA — [3]Northwestern University, Evanston, USA

Studies on ferromagnetic (FM) antidot arrays, i.e. arrays of nonmagnetic regions in an otherwise continuous FM thin film, so far have been restricted to periodic lattices [1]. We have fabricated artificial FM quasicrystals (AFQs) in the form of connected networks of nanostructured Permalloy segments on five-fold rotationally symmetric (but aperiodic) Penrose P2 tilings (P2Ts) [2]. Low-field DC magnetization curves M(H,T) indicate abrupt transitions between ordered magnetization textures, and novel "asymmetric" ferromagnetic resonance modes are found to exist on only one side of the field origin accompanying "knee" anomalies in M(H,T). We argue that AFQs behave also as novel artificial spin ice systems that exhibit non-stochastic switching, pinned Dirac monopoles, and Dirac strings due to their aperiodicity and inequivalent pattern vertices.

We acknowledge support by the Custer of Excellence Nanosystems Initiative Munich.

[1] S. Neusser et al., Adv. Mater. 21, 2927 (2009). [2] V. S. Bhat et al., Phys. Rev. Lett. 111, 077201 (2013).

MA 48.2 Thu 15:15 EB 301

Fokker-Planck approach to the theory of magnon-driven spin Seebeck effect — •Levan Chotorlishvili and Jamal Berakdar — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Str. 4, 06120 Halle, Germany

Considering the spin Seebeck effect we calculate the mean value of the total spin current flowing through a normal-metal/ferromagnet interface. The spin current emitted from the ferromagnet to the normal metal is evaluated in the framework of the Fokker-Planck approach for the stochastic Landau-Lifshitz-Gilbert equation. We show that the total spin current depends not only on the temperature difference between the electron and the magnon baths, but also on the external magnetic field and the magnetic anisotropy. In addition, the spin current is shown to saturate with an increasing magnon temperature, and the saturation temperature increases with increasing the magnetic field and/or the magnetic anisotropy. Based on the solution of the stochastic Landau-Lifshitz-Gilbert equation which is discretized for a ferromagnetic chain subject to a uniform temperature gradient, we performed a detailed numerical study of the spin dynamics with a focusing particularly on finite-size effects. Our particular aim was to study the spin Seebeck effect beyond the linear response regime. We find that within our model the microscopic mechanism of the spin Seebeck current is the magnon accumulation effect quantified in terms of the exchange spin torque. // Ref: S. R. Etesami et al Phys. Rev. B 90, 014410 (2014); L. Chotorlishvili et al Phys. Rev. B 88, 144429 (2013).

MA 48.3 Thu 15:30 EB 301

Hybridisation of azimuthal spin waves with higher order gyromodes in magnetic vortex structures — •M. Noske[1], G. Dieterle[1], M. Weigand[1], J. Förster[1], M. Fähnle[1], H. Stoll[1], A. Gangwar[1,2], G. Woltersdorf[3], A. Slavin[4], C.H. Back[2], and G. Schütz[1] — [1]Max Planck Institute for Intelligent Systems, Stuttgart — [2]Department of Physics, University of Regensburg — [3]Department of Physics, Martin Luther University Halle — [4]Department of Physics, Oakland University, Rochester, MI, USA

Hybridization with the fundamental gyromode (G0) in magnetic vortex structures results in the well known frequency splitting of CW and CCW rotating azimuthal spin waves. Here we focus on the higher order gyromodes G1 and G2, characterized by a strong z dependence of their magnetization with one or two nodes in z direction. We demonstrate that hybridizations exist, not only between the fundamental gyromode G0 and azimuthal spin waves, but also between these spin waves and higher order gyromodes. Three-dimensional micromagnetic simulations have been performed in Permalloy discs, diameter 500 nm, with thicknesses varying from 5 nm to 100 nm. At small sample thicknesses, hybridisation with higher order gyromodes does not play a role. With increasing sample thicknesses the z dependence of the magnetization of azimuthal spin waves is significantly altered by a hybridisation with the G1 gyromode (in a medium thickness range) and the G2 mode (at larger sample thicknesses). However, hybridisation with these higher gyromode is only observed at those spin waves where their senses of rotation correspond with that of the gyromodes.

MA 48.4 Thu 15:45 EB 301

Electrical determination of vortex state in sub-micron magnetic elements — •Ajay Gangwar[1,2], Hans G. Bauer[1], Jean-Yves Chauleau[1], Matthias Noske[2], Markus Weigand[2], Hermann Stoll[2], Gisela Schütz[2], and Christian H. Back[1] — [1]Institut für Experimentelle Physik, Universität Regensburg, Germany — [2]Max-Planck-Institut für Intelligente Systeme, Stuttgart, Germany

Magnetic vortices, characterized by two boolean topological quantities: chirality (c) and polarity (p), are currently under close scrutiny [1]. We have studied vortex dynamics excited by spin transfer torque and found that the vortex states can be detected electrically by analyzing homodyne voltage signals generated by the anisotropic magneto-resistance (AMR) effect [2]. An in-plane external dc magnetic field is required to rectify the homodyne signal which can be measured with a nanovoltmeter. The sign of this DC voltage changes with the handedness (+cp or -cp) of the vortex state which makes the AMR effect a promising technique to investigate vortex states electrically. In addition, the vortex dynamics was also observed by direct imaging in a Scanning Transmission X-ray Microscope in order to verify the measured AMR signal, in particular its correct range of power and frequency. Our experimental results have found to be consistent with micromagnetic simulations which gives us a better understanding of the experimental outcome and proofs the validity of the AMR technique. [1] M. Kammerer et al., Nature Commun. 2, 279 (2011). [2] M. Goto et al., PRB 84, 064406 (2011).

MA 48.5 Thu 16:00 EB 301

Parametric amplification of spin waves in a microstructured magnonic waveguide — •Thomas Brächer, Frank Heussner, Philipp Pirro, Tobias Fischer, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Parallel parametric amplification has proven to be a useful means of spin-wave excitation and amplification in microstructured magnonic waveguides. Therefore, it is a very versatile tool for the field of magnonics, where the limited lifetime of magnons still constitutes a major limitation for, e.g., the construction of microstructured magnonic circuits.

Here, we report on some of the perspectives and limitations of the this technique. In particular, we focus on the velocity and the range of spin waves which are amplified throughout their propagation along a magnonic waveguide. We show that, for the use of a single amplification pulse, one has to find a trade-off between a fast signal propagation and a large range of the amplified spin waves. Here, the latter is limited by the amplification of the thermal noise.

MA 48.6 Thu 16:15 EB 301

Spin-wave propagation within domain-walls — •Kai Wagner, Thomas Sebastian, Attila Kákay, and Helmut Schultheiss — Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Research efforts to deploy spin waves as information carriers in micro- and nano-structured ferromagnetic materials have increased tremendously over the recent years. However, tailoring guided spin-wave propagation in two dimensions still remains a delicate challenge. Here we demonstrate spin-wave transport inside a domain-wall. For this, we perform micromagnetic simulations for thin film elements in a Landau state. To excite spin-wave resonances inside the domain-wall we apply pulsed as well as cw-excitation in a constricted area at the domain-wall-edge. We find several spin-wave modes of different energies with well distinguished wave vectors. They exhibit a positive dispersion and propagate along the domain-wall towards the vortex core. Domain-walls, thus, open the perspective for reprogrammable and yet non-volatile spin-wave waveguides of nanometer width. Financial support

by the Deutsche Forschungsgemeinschaft within project SCHU2922/1-1 is gratefully acknowledged.

MA 48.7 Thu 16:30 EB 301

Design of a fully functional spin-wave majority gate — •Stefan Klingler, Philipp Pirro, Thomas Brächer, Britta Leven, Burkard Hillebrands, and Andrii V. Chumak — Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Magnon-Spintronics aims to replace the electron charge as information carrier by the transport of spin via the fundamental excitations of the magnetization - spin waves and their quanta the magnons - in order to utilize novel methods and effects in the solid state for future information technology. Information can then be stored in the spin-waves' phase, and thus the data processing occures by the interference of different spin waves.

One important step towards the application of spin-wave devices is the realization of a majority gate, due to its configurability and functionality. It allows to evaluate the majority of an odd number of input signals, and can be used to rebuild multiple logic operations with a single gate like AND-, OR-, NAND- and NOR-operations.

Here, we present the microstructure design and numerical simulations of a fully functional three-input spin-wave majority gate, as well as a spin-wave mode section process, which allows for a single-mode operation therein. For this, we use the material parameters of YIG and spatial dimensions which ensure an easy fabrication. By superimposing the different input waves in the gates, the resulting interference patterns in the output signal will have the same phase, as the majority of the incoming spin waves. With this, the full majority operation is processed and the truth table of the function is reproduced.

MA 48.8 Thu 16:45 EB 301

Evolution of Spin Wave Modes in Periodically Perturbed Thin Films — •Manuel Langer[1,2], Rodolfo A. Gallardo[3], Anja Banholzer[1], Tobias Schneider[1,2], Kai Wagner[1], Pedro Landeros[3], Kilian Lenz[1], Jürgen Lindner[1], and Jürgen Fassbender[1,2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [2]Technical University Dresden, 01069 Dresden — [3]Technical University Valparaíso, Valparaíso, Chile

The transition from a continuous thin film to a magnonic crystal is studied by ferromagnetic resonance (FMR).
Ion irradiation as well as reactive ion beam etching were used to realize a periodic modulation of the sample surface after patterning by electron beam lithography.
Mode-splitting in the FMR spectra has been investigated dependent on the size of the perturbations and compared to available analytical perturbation theory. Numerical simulations have been carried out to identify the spin waves corresponding to the mode spectra as well as to understand deviations between measurement and analytical theory for large perturbations.
This work is supported by DFG grant LE2443/5-1.

MA 48.9 Thu 17:00 EB 301

A scenario for dynamic magnonic spin-wave traps — Frederik Busse[1], •Maria Mansurova[1], Benjamin Lenk[1], Marvin von der Ehe[2], and Markus Münzenberg[2] — [1]I. Physikalisches Institut, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Institut für Physik, Greifswald University, Felix-Hausdorff-Straße 6, 17489 Greifswald, Germany

This work contributes to the understanding of spin waves behavior in periodically structured magnetic materials [1,2] subject to a heat gradient. We use an all-optical approach to both excite and detect spin waves using short (femtosecond) pulses. The femosecond laser pulse is used twofold: It allows generating spin-waves locally, and as we demonstrate in this work, the same pulse can be used to create defined thermal gradient in a periodic array of antidots. The saturation magnetization varies as a function of temperature due to the spatial thermal profile induced by the femtosecond pump pulse that persists for up to one nanosecond. We consistently observe a shift of 0.5 GHz of the excited spin waves towards higher frequencies as we perform spatially-resolved measurements. Moreover, no spin waves are detected outside the excitation spot. This is explained by considering that a temperature gradient imposes additional scattering as spin waves are continuously reflected when entering a colder region with higher saturation magnetization and can be used as a dynamic trap for the femtosecond laser driven spin-wave excitations.

[1] H. Ulrichs, et al. Applied Physics Letters 97, 092506 (2010)
[2] B. Lenk, et al. Physics Reports 507, 107 (2011)

MA 49: Poster II

Time: Thursday 15:00–18:00 Location: Poster A

MA 49.1 Thu 15:00 Poster A

Effects of the DM-interaction on thermodynamic properties of molecular spin systems — •Christian Heesing and Jürgen Schnack — Universitätsstr. 25, 33739 Bielefeld

The magnetism of many magnetic molecules is dominated by isotropic Heisenberg exchange interactions. For 3d elements anisotropic contributions are usually small. Nevertheless, they can have drastic consequences at low temperatures as for instance on bistability and quantum tunnelling in the case of easy-axis anisotropies.
In this contribution we investigate the effect of the Dzyaloshinskii-Moriya (DM) interaction [1,2] on thermodynamic magnetic observables such as the low-temperature magnetization. The full Hamiltonian contains Heisenberg exchange, Zeeman term, and Dzyaloshinskii-Moriya interaction. Thermodynamic observables are systematically compared for various ratios of DM and Heisenberg interaction strength.

[1] T. Moriya, Phys. Rev., 1960, 120, 90-98
[2] I. Dzyaloshinskii, J. Phys. Chem. Solids, 1958, 4, 241-255

MA 49.2 Thu 15:00 Poster A

Thermodynamic properties of deposited spin clusters — •Felix Kaiser, Henning-Timm Langwald, and Jürgen Schnack — Bielefeld University, Bielefeld, Germany

With regard to future technological applications magnetic clusters have attracted significant interest. Magnetic molecules or other structures of interacting magnetic centers may be deposited on a substrate to utilize the resulting increased addressability. However the resulting coupling to the substrate may also influence the (magnetic) properties of the deposited clusters. Thus the characterization of magnetic clusters deposited on a substrate is of significant importance to their future usage. One may be especially interested in comparing the properties of free and of deposited clusters.

On our poster we present theoretical results for deposited magnetic clusters on a metallic substrate. To describe the magnetic clusters we utilize the Heisenberg Hamiltonian with and without anisotropy while the metallic substrate is described via a band of conduction electrons which is exchange coupled to the magnetic cluster. The calculations are performed by means of the Numerical Renormalization Group method (NRG) which allows us to characterize thermodynamic properties for a wide range of temperatures and in dependence to a magnetic field.

MA 49.3 Thu 15:00 Poster A

XAS Study of the Spin-Crossover Molecules $Fe(bpz)_2phen$ and $Fe(bpz)_2bipy$ on Surfaces — •Lalminthang Kipgen[1], Holger Naggert[2], Matthias Bernien[1], Fabian Nickel[1], Jens Kopprasch[1], Qingyu Xu[1,3], Felix Tuczek[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin, Germany — [2]Institut für Anorganische Chemie, Christian-Albrechts Universität zu Kiel, 24098 Kiel, Germany — [3]Department of Physics, Southeast University, 211189 Nanjing, P.R. China

The Spin-crossover molecules $Fe(bpz)_2phen$ and $Fe(bpz)_2bipy$ (bpz=dihydrobis(pyrazolyl)borate, phen = 1,10-phenanthroline, bipy = 2,2-bipyridine) have recently attracted a lot of attention due to their suitability for vacuum deposition. Thin films and even single molecules on surfaces have been studied. However, if the molecules are in direct contact with another material, their spin-crossover properties may be altered or even suppressed. We have investigated submonolayers of $Fe(bpz)_2phen$ and $Fe(bpz)_2bipy$ on Au(111), Bi(111) and HOPG surfaces by means of X-ray absorption spectroscopy (XAS). We find that submonolayers of $Fe(bpz)_2bipy$ on Au(111) do not exhibit thermal spin-crossover behavior. On HOPG, in contrast, these molecules show complete spin-state switching as a function of temperature. Submonolayers of $Fe(bpz)_2phen$ on Bi(111) show a partial conversion of about 40 percent as a function of temperature and illumination with green light at T = 5 K. Financial support by the DFG (Sfb's 658 and 677) is gratefully acknowledged.

MA 49.4 Thu 15:00 Poster A

Giant magnetoresistance effects in gel-like matrices: comparing theoretical and experimental data — •Thomas Rempel[1], Judith Meyer[1], Lisa Teich[2], Martin Gottschalk[1], Karsten Rott[1], Christian Schröder[2], and Andreas Hütten[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, PB 100131, D-33501 Bielefeld, Germany — [2]Bielefeld Institute of Applied Materials Research, University of Applied Sciences Bielefeld, PB 101113, D-33511 Bielefeld, Germany

High GMR effects of up to 260% have been shown by Meyer et al. by dispersing carbon coated cobalt nanoparticles into non-magnetic, conductive, water-based gel matrices. While these gels tend to dry out and lack reproducibility due to low gel viscosity, gels with a liquid-solid transition such as agarose gel showed high and reproducible GMR effects of up to 60% over a long period of time. Therefore, they represent a promising candidate for future, low cost printable GMR sensor devices. To investigate the influence of magnetic coupling and particle superstructures on the magnetoresistance for agarose based gel systems, we compare transport measurements with theoretical calculations, which indicate a collective behavior of the nanoparticles due to dipole-dipole interactions. By the use of a dual beam system consisting of a focused ion beam and a scanning electron microscope, the particle arrangement for different particle superstructures has been explored. The information about the particle arrangement was used to perform stochastic spin dynamics simulations based on a point-dipole approach to compare the results with the experimental data.

MA 49.5 Thu 15:00 Poster A

DNA origami as a microstructural tool for magnetic nanoparticle ordering — •Marianne Bartke and Andreas Hütten — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Superparamagnetic beads have numerous applications within microfluidic systems, i.e. as mobile substrates, binds or magnetic labels, as well as to transport and separate analytes. Recently, the use of beads as self-assembling matter has attracted attention. Due to rotating homogeneous magnetic field, beads rapidly form ordered monolayers. If there is no magnetic field, the cluster structures rapidly disassemble. This work presents a method to prevent the decay of monolayers in the absence of a magnetic field employing DNA double strand *bridges* that connect adjacent particles. DNA with biotin can be linked to streptavidin coated magnetic beads, thus resulting in a DNA layer around these beads. These strands are complementary to a linker-DNA which induces a hybridization into DNA double strands. This hybridization between the linker strands and the oligonucleotides leads to a solidification of the monolayer that originally has been produced and stabilized by the external rotating magnetic field. The DNA bridges can be broken through controlled temperature change. Futhermore, DNA strands can also facilitate the creation of blocks of superparamagnetic cobalt nanoparticles by means of DNA origami. These new DNA stabilized superparamagnetic structures are auspicious innovations for DNA analysis and production of photonic crystal.

MA 49.6 Thu 15:00 Poster A

Structural and magnetic properties of self-assembled 3D nanoparticle macrocrystals — •Michael Smik, Elisa Volkmann, Genevieve Wilbs, Emmanuel Kentzinger, Jörg Persson, Ulrich Rücker, Oleg Petracic, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich

We have refined self-assembly methods for the fabrication of 3D nanoparticle 'macrocrystals' composed of spherical iron oxide nanoparticles with 15 nm diameter. The macrocrystals were prepared using centrifuge assisted sedimentation with optimized temperature, centrifugation length and post-centrifugation procedures. Fabrication of macrocrystals up to 300 μm in size was possible. The samples were characterized using scanning electron microscopy (SEM) and grazing incidence small angle x-ray scattering (GISAXS) on single macrocrystals. The GISAXS experiments were performed at the new in-house instrument 'GALAXI' (Gallium Anode Low-Angle X-ray Instrument) and reveal close-packed hexagonal ordering with very large coherence lengths. Zero field cooled (ZFC) and field cooled (FC) magnetization curves have been recorded. They show pronounced inter-particle collective ordering due to dipole-dipole interactions.

MA 49.7 Thu 15:00 Poster A

Stabilization of $L1_0$ phase and suppression of twin structures in FePt-Cu nanoparticles — •Anna Elsukova, Marina Spasova, Mehmet Acet, and Michael Farle — Experimental Physics, Faculty of Physics and CENIDE, University of Duisburg - Essen, 47057 Duisburg, Germany

FePt alloy has a high value of magnetic anisotropy energy in the thermodynamically stable ordered $L1_0$ phase and, therefore, the FePt nanoparticles are expected to remain ferromagnetic at small sizes, which makes them a potential candidate for manufacturing magnetic storage devices with high areal density. However, due to the fact that particles' preparation methods are kinetically controlled, the disordered magnetically soft A1 phase is stabilized instead and formation of metastable multi-twinned structures is observed.

In this work we report on the influence of Cu addition to the FePt on the stabilization of $L1_0$ phase and suppression of multi-twinned structures in small (around 6 nm) FePt-(Cu) gas-phase nanoparticles.

FePt-Cu nanoparticles with various concentrations of Cu were prepared by DC magnetron sputtering. The sputtering setup incorporates the furnace in order to anneal the particles in-flight prior to their deposition on a substrate. We have found that addition of Cu combined with in-flight annealing at 1273 K promotes the formation of single-crystalline $L1_0$ FePt-Cu particles in the gas-phase.

MA 49.8 Thu 15:00 Poster A

Characterization of Single and Clustered Nanoparticles — •Martin Gottschalk, Nadine Mill, Karsten Rott, and Andreas Hütten — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Nanoparticles of all kinds of shapes and material properties receive increasing attention due to their widely spread applications possible. As a consequence there is the need for characterization of the properties of not just nanoparticle clusters but also single nanoparticles. By exploiting the features of a dual beam system, consisting of a SEM and a FIB-microscope, it is possible to apply an electrical contact to single cobalt nanoparticles. The particles are connected by gas deposited platinum lines to e-beam-lithographed, conductive gold paths. These paths are the teeth of a comb whose shaft is a contact pad that can be used for GMR- or TMR-measurements of the particles outside the dual beam system. To attain a current running through just the connected particle, the other gold paths, which are now dispensable, are to be cut by the ion beam. Otherwise there would be a short circuit caused by larger clusters of particles, lying on several gold paths of the two combs, whose occurrence cannot be avoided in the course of the dropping down. Evidently this procedure is also suitable for clusters, if the spacing between the gold paths is respectively adjusted. With this setup it is possible to investigate single and clustered particle properties like magnetoresistive effects.

MA 49.9 Thu 15:00 Poster A

Validation of high brilliant moderators for cold neutrons — •Tobias Cronert[1], Jan Philipp Dabruck[2], Paul Emanuel Döge[2], Yannik Bessler[1], Ulrich Rücker[1], Carsten Lange[3], Michael Butzek[1], Wolfgang Hansen[3], Rahim Nabbi[2], and Thomas Brückel[1] — [1]JCNS/ZEA1 - Forschungszentrum Jülich — [2]NET - RWTH Aachen — [3]TU Dresden

Investigation of magnetic phenomenons like chiral spin-density waves (SDW) and skyrmions requires a high flux of cold neutrons for polarized neutron spectroscopy and similar advanced applications. While neutron optics have evolved greatly during the last years, the moderator itself leaves much options for improvement. Using MCNPX, sophisticated moderator configurations are developed allowing for high neutron yields and a high beam brilliance. Calculations propose flat, so called 2-dimensional pancake moderators, of supercritical para hydrogen for the upcoming European Spallation Source. Validation of the calculations however is challenging, since neutron energy spectra from several MeV down to 0.1meV need very high levels of measurement equipment and easily accessible neutron sources. Highly specialized cold moderators, optimized to the energy and time structure of the future neutron sources will yield higher brilliance and available flux at the sample to improve the performance of magnetic scattering methods and neutron applications in Chemistry and Biology.

MA 49.10 Thu 15:00 Poster A

A High-Resolution Confocal Scanning Polarizing Microscope for Low-Temperature Magneto-Optical Imaging — •Matthias Lange, Stefan Guénon, Reinhold Kleiner, and Dieter Koelle — Physikalisches Institut and Center for Collective Quantum Phenomena in LISA$^+$, Universität Tübingen, Auf der Morgenstelle 14, D-72076 Tübingen, Germany

The magneto-optical Kerr effect (MOKE) is widely used for the investigation of magnetic materials. We present a confocal laser scanning microscopy setup that is capable of simultaneously imaging the surface's reflectivity (conventional image), the in-plane and out-of-plane magnetization components, and electric transport characteristics of the sample. The magnetization components are imaged exploiting the longitudinal and polar MOKE. Information on the electric transport characteristics can be gained from local laser heating, combined with the detection of beam-induced changes of the voltage across current-biased samples, which yields a spatial resolution of $\sim 1\,\mu$m. Through the use of a high numerical aperture microscope objective, an optical resolution of about 220 nm at a wavelength of 405 nm is achieved. The sample is mounted on a continuous flow cryostat providing a temperature range between 5 K and 300 K. An electromagnet is used to apply magnetic fields of up to 800 mT with variable in-plane orientation.

MA 49.11 Thu 15:00 Poster A

Enhancement of the Magneto-optical Kerr effect using Si capping layers — •Nicolas David Mueglich 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

Investigations on the enhancement of the longitudinal Magneto-optical Kerr effect with amorphous silicon capping layers[1] are shown for different exchange bias multilayer systems. The Kerr Amplitude, as the fundamental material property defining the achievable signal-to-noise ratio in magneto-optical readout measurements, was measured for the magnetic materials $Ni_{80}Fe_{20}$, $Co_{70}Fe_{30}$ and Co in dependence of angle and polarization of the incident light and the thickness of the silicon capping layer. The results were compared to calculations using the 4x4 transfer matrix method. Strong enhancement of the Kerr Amplitude for certain combinations of the silicon layer thickness and the angle of incidence can be achieved and may be used to tailor magnetic layer systems with maximized contrast in magneto-optical read out measurements.

[1] Nakamura, K.; Asaka, T.; Asari, S.; Ota, Y.; Itoh, A., Enhancement of Kerr rotation with amorphous Si film, Magnetics, IEEE Transactions on , vol.21, no.5, pp.1654,1656, Sep 1985, doi: 10.1109/TMAG.1985.1063911

MA 49.12 Thu 15:00 Poster A

Laser-Induced Modifications of Co/Pt Multilayer Films Studied with Tabletop Resonant Magnetic Scattering — •Christian Weier[1], Roman Adam[1], Denis Rudolf[1], Robert Frömter[2], Patrik Grychtol[3], Gerrit Winkler[2], André Kobs[2], Hans Peter Oepen[2], Margaret M. Murnane[3], Henry C. Kapteyn[3], and Claus M. Schneider[1] — [1]Forschungszentrum Jülich GmbH, Peter Grünberg Institut (PGI-6), JARA-FIT, 52425 Jülich, Germany — [2]Universität Hamburg, Institut für Angewandte Physik, Jungiusstr.11, 20355 Hamburg, Germany — [3]University of Colorado, Department of Physics and JILA, Colorado 80309 Boulder, USA

Extreme ultraviolet light sources based on high-order harmonic generation (HHG) have recently been used to investigate magnetization dynamics on the femtosecond timescale with element selectivity. In these studies the photon energy has been tuned to the M-absorption edges of Fe, Co and Ni located at 52 eV, 61 eV and 67 eV. In addition, HHG sources are well suited for resonant magnetic scattering (RMS) experiments, where magnetic domains can be resolved with nanometer precision. We present RMS investigations of Co/Pt multilayer films before and after an intense laser illumination and discuss the influence of laser-induced modifications on the scattering image.

MA 49.13 Thu 15:00 Poster A

Formation of remanence states in permalloy rectangles investigated via magnetotransport and SEMPA — •Björn Beyersdorff[1,2], Philipp Staeck[2], André Kobs[2], Mahmoud Reza Rahbar Azad[2], Stefan Rössler[2], Robert Frömter[2], and Hans Peter Oepen[2] — [1]DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]INF, Universität Hamburg, Jungiusstr. 11a, 20355 Hamburg, Germany

Permalloy rectangles of $1000 \times 500 \times 20\,\mathrm{nm}^3$, structured by Focused Ion Beam milling, are investigated with Scanning Electron Microscopy with Polarization Analysis (SEMPA) and magnetotransport at room temperature. For these rectangles the well-known Landau, diamond and single domain C- and S-states are local minima of the energy landscape. By means of SEMPA we found that the remanence state can be tuned by varying the angle of a previously applied external saturation field within the film plane. The Landau state is only found for fields within an angle of $\alpha < 10°$ to the hard axis, while for angles $\alpha > 15°$ the C/S-state is found. This result can be understood with the help of micromagnetic simulations. An in situ magnetoresistance setup is used to further investigate the magnetization reversal [1]. The characteristics of the MR curves can be used to identify the remanence state and even allows to differentiate between the iso-energetic C-/S-states from symmetry arguments. Finally, it is shown that the observed variance of remanence states within nominally identical rectangles is due to structural variation, while stochastic influences of thermal activation are of minor importance. [1] A. Kobs et al., PRB 80, 134415 (2009).

MA 49.14 Thu 15:00 Poster A

High Resolution Imaging of Spin Current-driven Magnetization Manipulation in Nanoscale Structures using SEMPA — •Pascal Krautscheid, Robert M. Reeve, and Mathias Kläui — Institut für Physik, Johannes Gutenberg-Universität, 55128 Mainz

For proposed spintronic devices such as memory, logic and sensors a control over the static spin configuration and an ability to understand and manipulate the dynamics is required. The initial configuration, such as the domain wall spin structure can be tailored through the geometry. Manipulating the magnetic state of a system including the domain wall spin configuration can subsequently be achieved by utilizing the electron spin degree of freedom. The interaction between a spin current and the magnetic moments of a system is governed by an adiabatic and a non-adiabatic spin torque and can be described by the implicit Landau-Lifshitz-Gilbert equation [1]. In order to understand the origin of the non-adiabatic torque and the dependence on damping we study a magnetic vortex state within permalloy-disks with different rare earth doping levels [2] and image the vortex core displacement on current injection [3]. An alternative spin current source is the spin-hall effect which can also be employed for magnetization manipulation which we study in wires of materials with different spin-hall angles. We use a scanning electron microscope with polarization analysis, which offers the necessary high-resolution magnetic imaging. [1] A. Thiaville et al., Europhys. Lett. 69, 990 (2005).[3] B. Krüger et al., Phys. Rev. Lett. 104, 077201 (2010).[2] T. A. Moore et al., Phys. Rev. B 80, 132403 (2009).

MA 49.15 Thu 15:00 Poster A

Sherman mapping of Fe(001)-p(1x1)-O: exchange vs. spin-orbit interaction — •Christian Thiede[1], Christian Langenkämper[1], Anke B. Schmidt[1], Stephan Borek[2], Jürgen Braun[2], Jan Minár[2], Hubert Ebert[2], and Markus Donath[1] — [1]Physikalisches Institut, Universität Münster, Germany — [2]Ludwig-Maximilians-Universität München, Germany

A recent development in spin-polarimeter design is the introduction of a spin-polarizing electron mirror which permits multichannel spin-polarization analysis. An electron beam specularly reflected from high Z-targets such as W(001) carries spin information due to spin-orbit interaction.[1] The use of a ferromagnetic target such as Fe(001)-p(1x1)-O provides a high figure of merit [2], easy access to spin information and opens the way for multichannel analysis for two transverse spin-polarization directions in one set-up. For the spin component parallel to the scattering plane, the asymmetry is entirely caused by exchange interaction. Large reflectivity and figure of merit were found [3]. For the spin component perpendicular to the scattering plane, the asymmetry is additionally influenced by spin-orbit interaction.

We present reflectivity and Sherman maps for the latter scattering geometry in comparison with data for the other. We discuss the data in the context of theoretical predictions based on ab initio calculations.

[1] Kolbe *et al.*, Phys. Rev. Lett. **107**, 207601 (2011)
[2] Okuda *et al.*, Rev. Sci. Instrum. **79**, 123117 (2008)
[3] Thiede *et al.*, Phys. Rev. Appl. **1**, 054003 (2014)

MA 49.16 Thu 15:00 Poster A

A new setup for temperature and frequency dependent ferromagnetic resonance measurements at high magnetic fields — •Moritz Riebisch, Mehmet Acet, Ralf Meckenstock, Horst Zähres, and Michael Farle — Universität Duisburg-Essen, Fakultät für Physik, AG Farle

A new setup for temperature and frequency dependent magnetic resonance measurements at high magnetic fields up to 12 T was built. It consists of a superconducting magnet and a gas-flow cryostat in a ^{4}He bath. The FMR-probe is placed inside the gas-flow cryostat and contains a field modulation coil, a temperature sensor and the short-circuited end of a semi-rigid coaxial cable. The sample is placed in the near-field region of the short circuit and can be excited with microwave frequencies between 1 and 20 GHz. The sample temperature can be varied between 4.2 and 300 K. First data on the the field-induced transition between the antiferromagnetic and the ferromagnetic state of Mn_3GaC are presented [1], [2].

Financial support by DFG is acknowledged.

[1]: Journal of Applied Physics **115**, 043913 (2014); doi: 10.1063/1.4862903
[2]: Applied Physics Letters **100**, 202404 (2012); doi: 10.1063/1.4717181

MA 49.17 Thu 15:00 Poster A

TMOKE study for characterizing magnetic properties of ferromagnetic thin films — •maryam youhannayee, aniela scheffzyk, adrian jaspers, and mathias getzlaff — Institut für Angewandte Physik, heinrich heine universität , düsseldorf, germany

Nowadays magneto optic Kerr effect (MOKE) is one of the standard tool for investigating magnetic properties of magnetic systems such as ferromagnetic thin films and nanoparticles. In this research, we have built up a set up to measure the transverse magneto optic Kerr effect (TMOKE) which results in a change of intensity of p-polarized laser beam after reflection from ferromagnetic ultrathin films. Lock-in technique have also been used in order to increase the signal-to-noise ratio . The measurements were carried out on Fe thin films with a thickness of 0.5 mm and Co with a thickness of 5 and 15 nm with a capping layer of Cr/Au and without coating. The thin films are prepared by electron beam evaporation on a GaAs crystal under ultra-high vacuum condition. Hysteresis loops show properties of Fe and Co like coercivity, remanence and saturation behavior.

MA 49.18 Thu 15:00 Poster A

Fabrication and characterization of micro-Hall-Magnetometers for high-resolution local magnetic induction measurements — •Maryam Akbari, Merlin Pohlit, and Jens Müller — Physikalisches Institut, Goethe-Universität, Frankfurt (M), Germany

Micro-Hall magnetometry is an ultra-sensitive tool for studying the magnetic properties of individual micro- and nanostructures by detecting their magnetic stray field. To that end the samples are positioned onto the surface of a homebuilt sensor, where a series of adjacent lithographically-defined Hall crosses allows for spatially-resolved measurements with micron-size resolution. The technique is based on a sensor element made from a high-mobility two-dimensional electron gas (2DEG) in a GaAs/AlGaAs heterostructure. The main aspect of the presented work is to investigate the suitablility of a more advanced 2DEG wafer material, e.g., in terms of a shallower 2DEG to further increase the sensitivity by minimizing the sample to sensor distance. It is important to characterize the wafer material's transport properties (e.g. charge-carrier density, electron mobility) and, in particular, it is noise behavior by performing fluctuation spectroscopy. Additionally the versatility of the magnetometers is demonstrated by various measuring techniques including eight-terminal Hall gradiometry and, as a new application, FORC-measurements (first order reversal curves) for investigating interaction effect in ensembles of nano magnets.

MA 49.19 Thu 15:00 Poster A

Investigation of a Spin forbidden transition on the molecular nanomagnet Fe3CrPh using Torque detected broad band electron spin resonance (TDESR) in combination with Photon induced methods — •Eric Heintze[1], Michael Slota[1], Marian Blankenhorn[1], Andrea Cornia[2], Joris van Slageren[3], Brad Moores[4], Christian L. Degen[4], Martin Dressel[1], and Lapo Bogani[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Dipartimento di Scienze Chimiche e Geologiche and UdR INSTM, Università di Modena e Reggio Emilia, via G. Campi 183, 41125 Modena, Italy — [3]Institut für Physikalische Chemie, Universität Stuttgart, Pfaffenwaldring 55, 70569 Stuttgart, Germany — [4]Department of Physics, HPF F6, ETH Zürich, Otto Stern Weg 1, 8093 Zürich, Switzerland

We show TDESR to measure the high frequency electron spin resonance spectra of the molecular nanomagnet Fe3CrPh. We demonstrate the use of a mechanically-detected EPR setup with optical excitations and tunable frequency sources to induce magnetic resonance transitions which are detected using cantilever torque magnetometry. Furthermore we show how we combined TDESR with Photon excited Torque Magnetometry (PheToM) to excite and detect a spin forbidden transition in Fe3CrPh. The results are compared to simulations, W-Band-ESR and AC-SQUID data. We present an interferometric setup to increase the sensitivity of TDESR and we provide the key points for the improvement of the sensitivity down to sub-monolayer coverages, as required for molecular spintronic devices and investigations.

MA 49.20 Thu 15:00 Poster A

Investigation of light-induced magnetic changes in nanomagnets using static and dynamic SQUID magnetometry — •Michael Slota[1], Eric Heintze[1], Andrea Cornia[2], Martin Dressel[1], and Lapo Bogani[1] — [1]1. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany — [2]Dipartimento di Scienze Chimiche e Geologiche and UdR INSTM, Università di Modena e Reggio Emilia, via G. Campi 183, 41125 Modena, Italy

The behavior of nanomagnets in molecular spintronic materials can be changed by using external stimuli such as photons. Although the use of photons offers a clean way to control spin states, undesired effects as heating processes makes the investigation of light-induced properties challenging. We demonstrate the use of static and dynamic susceptibility measurements under continuous light irradiation via a SQUID magnetometer to quantify heating effects and extract magnetic changes, where the used light-coupling setup enables a distinct control of the irradiation strength on a sample. The molecular nanomagnet Fe3CrPh serves as an example, of which a short lived light-induced spin forbidden transition from S=6 to S=7 has already been detected in Torque-detected ESR combined with Photon-excited Torque Magnetometry (PheToM) as a change of the magnetic response. In near future this technique is used to detect spin changes novel classes of molecular spintronic systems, where light-induced currents manipulates spintronic properties rather than light directly.

MA 49.21 Thu 15:00 Poster A

Circularly polarized microwave radiation for ferromagnetic resonance experiments — Hannes Maier-Flaig[1,2], •Sho D. Watanabe[1,2,3], Rudolf Gross[1,2,4], Hans Huebl[1,4], and Sebastian T. B. Goennenwein[1,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, D-85748 Garching — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Department of Physics, Keio University, 223-8522 Yokohama, Japan — [4]Nanosystems Initiative Munich, 80799 München, Germany

Ferromagnetic resonance (FMR) is a widely applied spectroscopy method allowing to probe magnetization dynamics and the spin-wave spectrum of a ferromagnet. In conventional FMR setups, linearly polarized microwave radiation is used. In contrast, circularly polarized microwave magnetic fields allow to selectively excite a magnetic dipole transition with $\Delta m_s = \pm 1$. We follow the approach by Henderson *et al.* [1] for the generation of cicularly polarized microwave radiation, but apply this principle to coplanar waveguide stuctures. Circularly polarized microwave radiation is created in a structure composed of half-wavelength resonators, with a sample space of about 1.15 mm^2. We discuss the properties of our resonators and present first FMR spectra.

[1] J.J. Henderson *et al.*, Rev. Sci. Instrum. **79**, 074704 (2008).

MA 49.22 Thu 15:00 Poster A

VekMag - a vector magnet for BESSY II — •Hanjo Ryll[1], Florin Radu[1], Radu-Marius Abrudan[2], Hartmut Zabel[2], Wolfgang Kuch[3], Georg Woltersdorf[4], and Christian Back[5] — [1]Helmholtz-Zentrum Berlin, Germany — [2]Ruhr-Universität Bochum, Germany — [3]Freie Universität Berlin, Germany — [4]Martin-Luther-Universität Halle-Wittenberg, Germany — [5]Universität Regensburg, Germany

VekMag is a vector superconducting magnet station, which is being jointly developed by Universität Regensburg, Freie Universität Berlin, Ruhr-Universität Bochum, and Helmholtz-Zentrum Berlin. The instrument will be installed at the PM2 dipole beamline of the synchrotron facility BESSY II in Berlin. The instrument is designed for the time-resolved research of future spintronic materials, such as multi and single-layer magnetic thin films, nanostructures, and molecules.

Experimental probes include XAS, XMCD/XMLD measurements, resonant soft X-ray scattering methods, as well as time-resolved ferromagnetic resonance (FMR) and electron paramagnetic resonance (EPR) using XMCD. The available temperature range extends from 2 K up to 500 K. It will provide a 9 T field in the beam direction, a 2 T vector field in the horizontal plane, and a 1 T full vector field.

MA 49.23 Thu 15:00 Poster A

Nitrogen Vacancy center based nanoscale magnetometry enchanced by repetitive quantum error correction. — •Priyadharshini Balasubramanian[1], Thomas Unden[1], Daniel Louzon[3], Martin Plenio[2], Alex Retzker[3], Boris Naydenov[1], and Fedor Jelezko[1] — [1]Institute of Quantum Optics,University of Ulm — [2]Institute for Theoretical Physics, University of Ulm — [3]Racah Institute of Physics, The Hebrew University of Jerusalem,Israel

Nitrogen Vacancy (NV) center in diamond is proving to be an indispensible tool in numerous areas, specially NV based magnetometer has shown unprecedented sensitivity and spatial resolution owing to its long coherence time and atomic size. Such sensitive magnetic field probe has a sensitivity which is intrinsically limited by its phase memory time($\delta B \propto 1/\sqrt{T*T2}$). Here we experimentally demonstrate the approach presented in[Arrad,G et al.PRL 112,(2014)] of combining sensing with quantum error correction, which promises to tackle noise of high frequency where dynamical decoupling fails. The experiment uses a robust nuclear spin (13C) as an auxiliary qubit to store the coherence of the sensing qubit, while the sensor(e-spin of NV)is reset. Combined with echo based sensing protocol, the proposed method is shown to correct bit flip errors on the electron spin, while sensing in the code-space in orthogonal direction.Even with a limited gate fidelity(80%), we show significant improvement in the sensitivity even after 2 rounds of error correction.The presented method has the potential to handle complex noise, thus reaching the realm of magnetometry for detecting weak magnetic field associated with biological molecules.

MA 49.24 Thu 15:00 Poster A

Magnetic and Charge Ordering in $La_{1/3}Sr_{2/3}FeO_3$ powder samples, single crystals, and thin films — •Markus Waschk, Alexander Weber, Jörg Persson, and Thomas Brückel — Jülich Center for Neutron Science JCNS and Peter Grünberg Institut PGI: Streumethoden, Forschungszentrum Jülich GmbH, 52428 Jülich

In recent years the multifunctional oxides are considered promising candidates for future, highly efficient storage devices in information technology. Transition metal oxides with mixed valances, exhibit fascinating magnetic and electronic properties, governed closely to the system of correlated electrons. A very interesting material is the distorted perovskite $La_{1/3}Sr_{2/3}FeO_3$ (LSFO). This complex compound, as well as showing charge disproportionation through mixed valency, also exhibits magnetic and charge ordering. The complex interplay between these effects is extremely interesting, where the magnetic ordering in terms of antiferromagnetic order and the charge order occur at circa 200 K. A Verwey "like" transition is also seen as a significant jump in resistivity measurements. In order to understand LSFO in detail, the consideration of different self-made sample types (powder, single crystal and thin films) is necessary. This will lead to a further understanding of the underlying mechanism of the complex ordering. Characterization of these highly stoichiometric single phase samples with X-rays, magnetization and polarized neutron measurements provides a greater insight into the intrinsic magnetism and crystal structure and their influence on each other.

MA 49.25 Thu 15:00 Poster A

Exchange bias in antiferromagnetic Heusler alloy Ru2MnGe thin films — •Jan Balluff, Markus Meinert, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

The Heusler compounds Ru2MnZ are experimentally known to be antiferromagnetic with Neel temperatures above room temperature [1,2]. Hence, they might be suitable as exchange biasing materials for spintronic devices. Here we report on results for the Ru2MnGe compound. Magnetic characterization of epitaxially grown samples on MgO and polycrystalline samples on thermally oxidized Si was done. A notable exchange bias at low temperatures was measured. We evaluate the exchange bias and discuss possible improvements of the effect, e.g. domain wall pinning. [1] Fukatani et al. (2013). Journal of the Korean Physical Society, 63(3), 711-715. [2] Ishida et al. (1995). Physica B: Condensed Matter, 210(2), 140-148.

MA 49.26 Thu 15:00 Poster A

Preparation and characterization of perpendicularly magnetized $Mn_{3\pm x}Ge$ thin films — •Manuel Glas[1], Daniel Ebke[2], and Günter Reiss[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany. — [2]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany

The continuous miniaturization process for spintronic devices requires consistently new materials with a low current density for spin transfer torque (STT) switching. The tetragonally distorted $Mn_{3-x}Ga$ seemed to be a promising candidate for STT-switching MRAM devices. However, to achieve a high TMR effect the interface between the ferromagnetic electrodes and MgO barrier plays an important role. Recent results showed that a Ga/MgO interface lowers the TMR effect drastically.[1] Therefore we replaced the Ga by Ge, due to the predicted non-vanishing TMR effect.[1] Different $Mn_{3\pm x}Ge$ (x = -0.4, 0.2, 0.6) stoichiometries were prepared on $SrTiO_3$ substrates to achieve epitaxial (001)-oriented thin films. The crystallographic and magnetic properties were investigated by X-ray diffraction, X-ray reflection and anomalous Hall effect. All samples showed a single $D0_{22}$ phase. However, the surface roughness and magnetic properties exhibit a strong dependence on the stoichiometry. The lowest surface roughness of 1.3 nm and highest perpendicular anisotropy ($\mu_0 H_c = 3.7$T) was found for $Mn_{3.2}Ge$. By increasing the Mn content to $Mn_{3.6}Ge$ an increasing in-plane anisotropy was observed.

[1] Y. Miura and M. Shirai, Magnetics, IEEE Transactions on 50, 1 (2014).

MA 49.27 Thu 15:00 Poster A

Magnetic dichroism study on $Mn_{3+x}Co_{1-x}Ga$ thin film using a ombination of X-ray absorption and photoemission spectroscopy — •Siham Ouardi[1], Takahide Kubota[2], Gerhard H. Fecher[1], Stanislav Chadov[1], Shigemi Mizukami[2], Tetsuya Nakamura[3], Eiji Ikenaga[3], Shigenori Ueda[3,4], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany. — [2]WPI-Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Sendai 980-8577, Japan — [3]Japan Synchrotron Radiation Research Institute, SPring-8, Hyogo, Japan — [4]National Institute for Materials Science, SPring-8, Hyogo, Japan

Using circularly and linearly polarised radiation and a combination of bulk-sensitive hard X-ray photoelectron spectroscopy and X-ray-absorption spectroscopy (XAS) we studied the electronic and magnetic structure of epitaxial $Mn_{3-x}Co_{1+x}Ga$ thin films. Element-specific magnetic moments and spin-resolved partial densities of states were determined by using XAS and XMCD. The valence states were investigated by using linear dichroism in the angular distribution and comparing the results to spin-resolved densities of states based on a first-principles analysis with fully relativistic Korringa-Kohn-Rostoker calculations.

MA 49.28 Thu 15:00 Poster A

Travelling solvent floating zone growth of Ni-Mn-Sn Heusler alloys — •Seunghyun Khim[1], Christian C. F. Blum[1], Maria Belesi[1], Ahmad Omar[1], Bernd Büchner[1,2], and Sabine Wurmehl[1,2] — [1]Leibniz Institute for Solid State and Materials Research, Helmholtzstrasse 20, 01069 Dresden, Germany — [2]Institute for Solid State Physics, TU Dresden, 01069 Dresden, Germany

We present a travelling solvent floating zone growth of Heusler alloys $Ni_2Mn_{1+x}Sn_{1-x}$. In certain Mn-rich compositions, this alloy undergoes a martensitic transition from a high temperature cubic $L2_1$ to a low temperature orthorhombic/tetragonal phase. Owing to a strong entanglement between the structure and magnetism, multifunctional properties such as shape memory effects, exchange bias, inverse magnetocaloric, and giant magnetoresistance are realized in this alloy. As the structure and magnetic properties are highly sensitive to disorder, microstructure and an inclusion of a secondary phase, a high quality single crystal is an ideal platform to investigate the intrinsic nature of those properties along with the anisotropies of the material. In this motivation, we have grown $Ni_2Mn_{1+x}Sn_{1-x}$ compounds by using the travelling solvent floating zone technique. We will discuss the evolution of structural and magnetic properties with varying the Mn/Sn ratio combining different techniques as nuclear magnetic resonance.

MA 49.29 Thu 15:00 Poster A

Spin polarization in Co2MnGe thin films observed by magnetooptics — •rajkumar patra[1], d. bürger[1], a. bildhaiya[1], n. du.[1], c. fischer[2], m. kreller[3], h. stöcker[4], b. abendroth[4], s.

pofahl[5], o. g. schmidt[5], and h. schmidt[1] — [1]TU Chemnitz — [2]Metrolux GmbH — [3]DREEBIT GmbH — [4]TUBA Freiberg — [5]IFW Dresden

Band theory [1] predicts that Co2MnGe Heusler alloys in L21 phase are fully spin-polarized. Here we investigate Co2MnGe thin films in L21, B2, and L21 / B2 mixed phase by magnetooptics [2]. As confirmed by XRD, three thin film samples have been prepared by dc magnetron sputtering on SQ1 glass substrates, namely one 150 nm thick sample with perfect L21 phase, one 150 nm thick sample with B2 phase, and one 200 nm thick sample in L21 / B2 mixed phase. In agreement with the electronic band structure [1] and spin polarization of Co2MnGe in L21 phase, magnetooptics reveals a strongly magnetic field dependent response in the spectral range around 3.5 eV. In addition, the spin easy-axis of a laser-treated Co2MnGe sample is rotated by ca. 30° with respect to the spin easy-axis of the pristine sample which lies along the z-axis. Because Heusler alloys with spin polarization will reveal magnetic field dependent magnetooptical features, we expect that magnetooptical investigations will play an important role in the future when characterizing Heusler alloys in different heterostructures which are highly relevant for spintronic applications [3]. [1] S. Ouardi et al., Phys. Rev. B 84 (2011), [2] K. Mok, H.S. et al., Rev. Sci. Instr. 82 (2011), [3] M. Jourdan et al., Nat. Commun. 5 (2014)

MA 49.30 Thu 15:00 Poster A

Order-disorder transitions in $Co_2FeAl_{0.5}Si_{0.5}$ probed via in-situ neutron diffraction — •Ahmad Omar[1], Matthias Frontzek[2], Alexey Alfonsov[1,3], Bernd Büchner[1,4], and Sabine Wurmehl[1,4] — [1]IFW Dresden, 01069, Germany — [2]Paul Scherrer Institute, 5232 Villigen, Switzerland — [3]Molecular Photoscience Research Center, Kobe University, Kobe 657-8501, Japan — [4]Institut für Festkörperphysik, TU Dresden, 01062, Germany

The $Co_2FeAl_{0.5}Si_{0.5}$ Heusler compound is predicted to be a half-metallic ferromagnet in the ordered $L2_1$ structure [1], and a high TMR ratio has been reported [2]. Heusler compounds are prone to anti-site disorders which strongly affect the physical properties. It is thus pertinent to understand the existential regimes of different disorders and order-disorder transitions. Here we present neutron diffraction measurements performed in-situ during annealing of powder samples. We have also measured pre-annealed powder samples at room temperature to compare the effect of annealing. We do not observe any sharp transition between the $L2_1$-B2 and B2-A2 disorders, which is in contrast to literature [3]. The transitions seem to be predominantly entropy-driven, although the T_{Curie} and the transition temperature seem coupled. Also, zero-field NMR on powder with alternate annealing, as per neutron data, shows a higher $L2_1$ ordering. In summary, we gain an understanding of the order-disorder transitions and propose an alternate annealing for improved ordering. Ref.: [1] Fecher et al. J. Phys. D: Appl. Phys. 40 (2007) 1582-1586 [2] Tezuka et al. Appl. Phys. Lett. 94 (2009) 162504 [3] Balke et al. Appl. Phys. Lett. 90 (2007) 242503

MA 49.31 Thu 15:00 Poster A

Transport properties of MgAgAs-type half-Heusler compounds — •Enkhtaivan Lkhagvasuren, Guido Kreiner, Siham Ouardi, Walter Schnelle, Gerhard Fecher, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Half Heusler compounds are found to be promising candidates for many technological applications.

We present transport properties of several half Heusler compounds with wide range of band gap from 3 eV to 0.3 eV. The compounds show MgAgAs type cubic crystal structure (space group F$\bar{4}$-3m).

LiZnAs and LiZnP show electrical resistivity of 10^{-1} Ωcm and 10^{-2} Ωcm at room temperature respectively. LiZnAs shows more than five order magnitude of electrical resistivity change in the temperature range from 100K to 150K.

MA 49.32 Thu 15:00 Poster A

The effect of the microstructure on the structural dopant-host coordination of Co implanted TiO2 films — •Oguz Yildirim[1,2], Steffen Cornelius[1], Georgy Zukov[3], Andrey Novikov[3], Elena Ganshina[3], Alexander Granovsky[3], Alevtina Smekhova[3], Carsten Baehtz[4], and Kay Potzger[1] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf e.V. , D-01328 Dresden, Germany — [2]Technische Universität Dresden, D-01062 Dresden, Germany — [3]Lomonosov Moscow State University (MSU), Faculty of Physics, Moscow, Russia — [4]Rossendorf Beamline, European Synchrotron Radiation Facility, F-38043 Grenoble, France

TiO2 films, exhibiting amorphous, polycrystalline anatase or epitaxial anatase structures have been implanted with Co ions up to an atomic concentration of 5%. The influence of the structure of the host lattice on the local environment of the implanted Co atoms was investigated by a variety of techniques. For decreasing structural order, more oxide coordination was found for Co ions. I.e., for the epitaxial and polycrystalline films, Co atoms exhibit a mixed oxidation state of (+2) and (0) interpreted as substitutional and metallic environment at x-ray absorption measurements, respectively. The presence of metallic Co clusters inside the epitaxial film has also been confirmed by magnetometry and transmission electron microscopy. Substitutional CoTi for implanted epitaxial and polycrystalline anatase TiO2 films was confirmed by magneto-optic (MO) spectroscopy. On the other hand, for the amorphous film, the Co ions show oxidic environment.

MA 49.33 Thu 15:00 Poster A

Influence of oxygen vacancies on the magnetic properties of $ZnFe_2O_4$ — •Karen L. Salcedo Rodríguez[1], Martin Hoffmann[2,3], Jhon J. Melo Quintero[1], Gustavo Pasquevich[1], Pedro Mendoza Zelis[1], Leonardo A. Errico[1], Silvana J. Stewart[1], Wolfram Hergert[2], and Claudia E. Rodríguez Torres[1] — [1]National University of La Plata, Argentina — [2]Martin Luther University Halle-Wittenberg, Germany — [3]Max Planck Institute for Microstructure Physics, Halle, Germany

We continue our experimental and theoretical study on bulk $ZnFe_2O_4$ (ZFO) powders [1]. ZFO samples were annealed in vacuum up to 600°C to control and increase the number of oxygen vacancies. The x-ray diffraction patterns indicate that all samples consist of single-phase ferrite. However, the magnetic measurements show the coexistence of ferromagnetic-like and paramagnetic components. For the saturation magnetization, the paramagnetic susceptibility and the Mössbauer spectroscopy, we observed a qualitative difference for samples which were annealed at temperatures either below or above 400°C.

Furthermore, we studied with *ab initio* calculations ZFO in the normal/inverted spinel structure and in the oxygen-deficient regime. The comparison between the experimental and calculated hyperfine parameters indicated a reduction of inversion by increasing the annealing temperature up to 400°C. For higher temperatures, we attributed the oxygen vacancies formation for the observed increase in the saturation magnetization and paramagnetic susceptibility.

[1] PRB 89, 104411 (2014)

MA 49.34 Thu 15:00 Poster A

Cyclic magnetocaloric behavior of Ni-Mn-In Heusler alloys — •Tino Gottschall[1], Konstantin P. Skokov[1], Elias Palacios[2], Ramon Burriel[2], and Oliver Gutfleisch[1] — [1]TU Darmstadt, Institute of Material Science, Alarich-Weiss-Str. 16, 64287 Darmstadt, Germany — [2]Institute of Materials Science of Aragon, University of Zaragoza, Spain

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. In order to utilize a material as a refrigerant in a magnetocaloric cooling device both the adiabatic temperature change ΔT_{ad} and the entropy change ΔS should be as large as possible. For direct measurements of the adiabatic temperature change it is possible to vary the measurement speed in a broad range and also the cyclic behavior can be investigated. In order to determine the entropy change either calorimetry or magnetic measurements can be performed. Unlikely these methods are typically rather slow in comparison to the conditions in a real magnetocaloric cooling device and they do not provide any information about the reversible part. But especially for Heusler alloys with large thermal hysteresis this is a crucial issue which will be discussed in this work.

This work was supported by DFG (Grant No. SPP1599)

MA 49.35 Thu 15:00 Poster A

Influence of the composition on the martensitic transformation and structure of epitaxial Ni-(Co-)Mn-Sn thin films. — •Daniel Kucza, Niclas Teichert, and Andreas Hütten — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Due to its promising magentocaloric properties, structure, transformation temperatures, thermal hysteresis and surface morphology (AFM) of epitaxial Ni-Co-Mn-Sn thin films were examined. Measured with different compositions these Heusler alloys show a structural transition carried out from the low temperature martensitic to the high temperature austenitic phase. The compositions of the four alloys is set between $Ni_{50}Co_0Mn_{36}Sn_{13}$ and $Ni_{47}Co_3Mn_{37}Sn_{12}$. The films itself are prepared by magnetron co-sputtering from elemental targets on MgO(001) substrates.

The structure and surface morphology of the films is determined by X-ray diffraction and atomic force microscopy. To study the transformation temperatures and thermal hysteresis, several temperature dependent X-ray diffractions of a complete circle of cooling and heating of each sample are carried out.

The results show a widening of the thermal hysteresis with a change in the composition in case of increasing Co content.

MA 50: Mitgliederversammlung des Fachverbandes Magnetismus

Time: Thursday 18:00–19:00 Location: H 0110

Um rege Teilnahme der Mitglieder des Fachverbandes wird gebeten !

MA 51: Magnetic Shape Memory Alloys (Joint Session with MM)

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

MA 51.1 Fri 9:30 H 0112

A new device for thermography measurements of the adiabatic temperature change — •Lars Helmich, Niclas Teichert, and Andreas Hütten — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

Phase transitions in Magnetic Shape Memory Alloys involve an adiabatic temperature change which can be observed by means of infrared thermography. These infrared investigations can be challenging for metallic thin-film samples for several reasons: On the one hand these thin films are grown on certain substrates which provide a large heat sink. Therefore the samples need to be lifted-off from the substrates. On the other hand a metallic surface reflects parasitical infrared radiation from the environment. This reflection needs to be suppressed in order to measure the real sample temperature.

We report on a new, versatile setup for the measurement of the adiabatic surface temperature change in magnetocaloric samples. The measurement are performed in vacuum, thus heat losses due to convection can be neglected. Furthermore the sample temperature can be varied. Therefore magnetocaloric properties can be observed as a function of the initial temperature.

A special, custom-developed thin film absorption layer is applied to prevent reflections. Heat losses to this absorption layer can be corrected based a numerical heat-transfer model.

MA 51.2 Fri 9:45 H 0112

Spin polarized Fermi surface and conduction electron polarization in the Heusler Cu_2MnAl meausred with 2D ACAR — •Josef Andreas Weber[1], Andreas Bauer[1], Peter Böni[1], Hubert Ceeh[1], Stephen Dugdale[2], Michael Leitner[3], Christian Pfleiderer[1], and Christoph Hugenschmidt[1,3] — [1]Technische Universität München, Physik Department, Lehrstuhl E21/E51, James-Franck-Straße, D-85748 Garching, Germany — [2]H.H. Wills Physics Laboratory, University of Bristol, Tyndall Avenue, Bristol BS8 1TL, UK — [3]Technische Universität München, Forschungs-Neutronenquelle Heinz Maier-Leibnitz, Lichtenbergstraße 1, D-85748 Garching, Germany

Although a conceptual understanding for the so-called Heusler systems exists, the nature of the electronic interactions is known to be rather delicate. Especially if it is required to tailor special features, a deep insight into these interactions is necessary. We want to contribute to the knowledge about this class of materials by the investigation of the prototypical Heusler alloy Cu_2MnAl with the two Dimensional Angular Correlation of positron electron Annihilation Radiation (2D-ACAR) technique. In order to extract the spin polarized Fermi surface, a refined reconstruction method is introduced. Furthermore, a comparison of the measurements with ab-initio calculations additionally to a procedure to extract the sign of the conduction electron polarization is presented.

MA 51.3 Fri 10:00 H 0112

Angular-resolved photoemission spectra of Heusler alloys: Ni_2MnGa as a case study — •Václav Drchal[1], Vitalyi Feyer[2], Claus Michael Schneider[2], Yaroslav Polyak[1], Josef Kudrnovský[1], Oleg Heczko[1], Jan Honolka[1], Vladimír Cháb[1], Jaromír Kopeček[1], and Ján Lančok[1] — [1]Institute of Physics, Acad. Sci. Czech Republic, Praha, Czech Republic — [2]Peter-Grünberg-Institut, Forschungszentrum Jülich, 52425 Jülich, Germany

We have calculated the electronic structure and angular-resolved photoemission spectra of Heusler alloys from first principles using the TB-LMTO method. The disorder, caused either by non-stoichiometry, or by swapping of atoms between sublattices is treated within the CPA. Matrix elements are included within the dipole approximation. Theoretical results are compared with experimental data of a weakly off-stoichiometric $Ni_{49.7}Mn_{29.1}Ga_{21.2}$ alloy that were measured by a photoelectron microscope at the NanoESCA beamline of the Elettra synchrotron. We will discuss the dependence of spectra on the structure (austenitic/martensitic) and the role played by disorder.

MA 51.4 Fri 10:15 H 0112

Effects of annealing on the martensitic transformation of Ni-based ferromagnetic shape memory Heusler alloys and nanoparticles — •Tina Fichtner, Changhai Wang, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

We report on the effects of annealing on the martensitic phase transition in the Ni-based Heusler system: bulk Ni-Mn-Sn and Co-Ni-Ga nanoparticles. For the powdered Ni-Mn-Sn, structural and magnetic measurements reveal that re-annealing reduces the martensitic phase transformation. This might be associated with a release of internal stress in Ni-Mn-Sn compound during the annealing process. Whereas in the case of Co-Ni-Ga nanoparticles, a *vice versa* phenomenon is observed. The as-prepared Co-Ni-Ga nanoparticles do not show the martensitic phase transition, as revealed by temperature-dependent x-ray diffraction measurements. However, post-annealing followed by ice quenching is found to trigger the formation of the martensitic phase in Co-Ni-Ga nanoparticles. The occurrence of the martensitic transition is attributed to the modified phase structure and the introduced stress due to annealing.

MA 51.5 Fri 10:30 H 0112

Ordering kinetics in Ni-Mn based ferromagnetic shape memory alloys — •Pascal Neibecker[1], Michael Leitner[1], Georg Benka[2], and Winfried Petry[1] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstr. 1, 85748 Garching, Germany — [2]Physics Department, Technische Universität München, James-Franck-Str. 1, 85748 Garching, Germany

Ni-Mn based Heusler alloys of the type Ni_2MnX have gained significant interest in recent years due to their magnetic shape memory properties. These alloys usually crystallize in the high temperature B2 phase and undergo at lower temperatures first a transition to the higher ordered $L2_1$ phase and later to a variant-rich martensitic phase.

Yet, the existence and characteristics of the martensitic transition as well as the temperature of the magnetic transition are heavily dependent on the degree of $L2_1$-type order adjusted in the alloy. While in Ni_2MnGa, the degree of $L2_1$ order is inherently high, other promising alloys such as Ni_2MnAl are lacking thereof.

In this respect, we report on the kinetics of $L2_1$ order adjustment in Ni_2MnAl, both in the case of thermodynamic equilibrium vacancy concentrations and in the case of quenched-in vacancy excess. We demonstrate the acceleration of ordering kinetics under vacancy excess, which permits the adjustment of hitherto unreachable states of order in the Ni_2MnAl system. Our results were obtained employing

Differential Scanning Calorimetry (DSC), magnetic measurements using a Physical Property Measurement System (PPMS) as well as X-ray Powder Diffractometry (XRD).

MA 51.6 Fri 10:45 H 0112

Coupling of Structural and Micromagnetic Properties in Twinned Epitaxial Ni-Mn-Ga films — •Aleksej Laptev[1], Mikhail Fonin[1], Yuansu Luo[2], Konrad Samwer[2], Gesa Welker[3], and Kristof Lebecki[4] — [1]Fachbereich Physik, Universität Konstanz, 78457 Konstanz — [2]I. Physikalisches Institut, Georg-August-Universität Göttingen, 37077 Göttingen — [3]Leiden University, Leiden Instute of Physics, 2333 CA Leiden, Netherlands — [4]Nanotechnology Centre, VSB-TU Ostrava, 70833 Ostrava-Poruba, Czech Republic

Isothermal and temperature-dependent magnetization properties for (010)-oriented Ni-Mn-Ga epitaxial films deposited on MgO(001) substrates have been studied. In particular, the pronounced abrupt changes in slope of the magnetization loop near ±0.06 T found in these films have been addressed. The mechanism of this characteristic hysteretic behavior could be understood with the help of micromagnetic simulations, which have been compared to experimental data. The results suggest that the abrupt changes in slope, which could be observed down to 10 K, can be attributed to the movement of 180° magnetic domain walls within one of four existing twin variant orientations. The occurrence of such specific hysteresis loops is facilitated by the specific twinned microstructure, which leads to a periodic orientation change of the magnetic easy axis on micrometer scale.

MA 51.7 Fri 11:00 H 0112

Study of magneto-elastic properties in shape-memory Heusler alloys by resonant ultrasound spectroscopy — •Catalina Salazar Mejia[1], Ajaya K. Nayak[1], Claudia Felser[1], Michael Nicklas[1], Jason Schiemer[2], and Michael A. Carpenter[2] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany — [2]Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK

Resonant ultrasound spectroscopy (RUS) is a versatile technique in materials science for measuring elastic constants. We have applied RUS to study the magneto-elastic properties in Heusler alloys. Heusler alloys that undergo a martensitic transformation (MT) have been shown to exhibit diverse functional properties such as the shape memory effect, magnetic-driven superelasticity and giant magnetocaloric and barocaloric effects, which derive from magnetoelastic couplings. The study of the magneto-elastic properties in these materials is important both from fundamental and the application points of view. We have studied polycrystalline Heusler alloys from the Ni-Mn-Ga and Ni-Mn-In families, in a temperature range that include the ferromagnetic and the martensitic transitions. We have observed fundamental differences in the behavior of the crystal lattice at the martensitic transition, i.e., stiffening versus softening, determined by the presence or absence of a pre-martensitic transition and the relation between the Curie temperature and the MT temperature. We will discuss these results in connection with magnetization and calorimetric data.

MA 51.8 Fri 11:15 H 0112

The effect of stoichiometry on the magnetic interactions in NiMn-based martensitic Heusler alloys. — •Ivan S. Titov[1,2], Mehmet Acet[1], Ralf Meckenstock[1], Yixi Su[3], and Michael Farle[1] — [1]Universität Duisburg-Essen, Duisburg, Germany — [2]M.V. Lomonosov Moscow State University, Moscow, Russia — [3]Heinz Maier-Leibnitz Zentrum, Garching, Germany

NiMn-based Heusler alloys doped with Ga, In and Sn exhibit in the martensitic state a thermally broad, coupled antiferromagnetic-ferromagnetic (AF-FM) magnetic transition below the Curie temperature T_C^M giving rise to a splitting between ZFC and FC magnetization curves and exchange bias effects. We explain this by Mn atoms, coupling together both AF and FM depending on the Mn-Mn distance. These are evidenced from FMR and polarized neutron scattering experiments on NiMnZ Heusler alloys with Z as In, Sb and Sn. To study the conditions giving rise to mixed magnetism, we consider the magnetic interactions in over and under Mn-stoichiometry with respect to Ni_2MnZ with Z as Ga and Sn. In such stoichiometries, the system can be adjusted so that Mn-Mn neighbors can either only be next nearest or both nearest and next nearest. FMR and polarized neutron studies on Ni-Mn-Ga and Ni-Mn-Sn alloys with varying concentrations of Sn and Ga provide complementary information on the nature of the coupling in such alloys. The results show that for understoichiometry predominantly FM interactions are observed, whereas for overstoichiometry additional AF coupling is observed.

Work supported by the DFG (SPP 1239).

MA 51.9 Fri 11:30 H 0112

Structural and magnetic phase transition in epitaxial Ni-Mn-Ga-Co films on ferroelectric substrates — •Benjamin Schleicher[1,2], Robert Niemann[1,2], Anett Diestel[1], Ludwig Schultz[1,2], and Sebastian Fähler[1,2] — [1]IFW Dresden, Institute for Metallic Materials, P.O. Box 270116, D-01171 Dresden, Germany — [2]TU Dresden, Institute for Solid State Physics, D-01062 Dresden, Germany

To reduce today's demand of energy for cooling applications solid-state cooling cycles relying on magnetic field induced phase transitions have been proposed. Promising materials are Heusler alloys such as Ni-Co-Mn-Ga which show an inverse magnetocaloric effect with a structural and magnetic phase transition between a ferromagnetic austenite at high T and a weak magnetic martensite at low T. Additionally to high external magnetic fields, the transformation can also be induced by the application of mechanical stress. This can be achieved by the deposition of a magnetocaloric thin film on a ferroelectric substrate. We present first results on sputter deposited epitaxial Ni-Mn-Ga-Co thin films on ferroelectric $Pb(Mg_{1/3}Nb_{2/3})_{0.72}Ti_{0.28}O_3$ (PMN-PT) substrates. Temperature dependent texture and magnetic measurements show the magnetic and structural phase transition in the material. By applying an electric field at the ferroelectric PMN-PT substrate we can induce the martensitic transformation in Ni-Mn-Ga-Co electrically which changes the magnetization significantly. This work is supported by DFG through SPP 1599 www.FerroicCooling.de.

MA 51.10 Fri 11:45 H 0112

Structure and Giant Inverse Magnetocaloric Effect of Epitaxial Ni-Co-Mn-Al Films — •Niclas Teichert[1], Daniel Kucza[1], Oguz Yildirim[2,3], Ilker Dincer[4], Anna Behler[5], Lars Helmich[1], Alexander Boehnke[1], Anja Waske[5], Yalcin Elerman[4], and Andreas Hütten[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany — [3]Dresden University of Technology, Germany — [4]Ankara University, Department of Engineering Physics, Faculty of Engineering, Turkey — [5]IFW Dresden, Institute for Complex Materials, Germany

The structural, magnetic, and magnetocaloric properties of epitaxial Ni-Co-Mn-Al thin films with different compositions have been studied. The films were deposited on MgO(001) substrates by co-sputtering on heated substrates. All films show a martensitic transition where the transition temperatures are strongly dependent on the composition. The structure of the martensite phase is shown to be 14M. The metamagnetic martensitic transition occurs from a strong ferromagnetic austenite to a weak magnetic martensite. The structural properties of the films were investigated by atomic force microscopy and temperature dependent X-ray diffraction. Magnetic and magnetocaloric properties were analyzed using temperature dependent and isothermal magnetization measurements. We find that $Ni_{41}Co_{10.4}Mn_{34.8}Al_{13.8}$ films show giant inverse magnetocaloric effects with magnetic entropy change of $5.8\,\mathrm{J\,kg^{-1}K^{-1}}$ for $\mu_0 \Delta H = 1\,\mathrm{T}$.

MA 51.11 Fri 12:00 H 0112

Density functional and tight-binding analysis of energy balance between $L1_0$ and $L2_1$ structures in Ni-Mn-X (X=Ga, Sn, In) Heusler alloys — •Ingo Opahle, Georg K. H. Madsen, and Ralf Drautz — ICAMS, Ruhr-Universität Bochum, Germany

The energy balance between the cubic $L2_1$ austenite structure and the tetragonal $L1_0$ martensite structure of Ni-Mn-X (X=Ga, Sn, In) Heusler alloys is analyzed using density functional theory and tight-binding (TB) models. Without spin-polarization the $L1_0$ structure with $c/a > 1$ is favoured over the cubic $L2_1$ structure. In contrast, magnetic contributions are found to stabilize the cubic austenite structure. The presence or absence of a martensitic ground state is determined by a subtle energy balance between the magnetic contributions and the nonmagnetic energy gain by a tetragonal distortion. The role of the electron per atom (e/a)-ratio, the size of the p-element X and the Jahn-Teller distortion for the martensitic transition temperature in the Ni-Mn-X Heusler alloys is discussed. The absence of a martensitic ground state in stoichiometric Ni_2MnIn can be understood from the different contributions of the p-element to the bond energy in the TB model compared to Ni_2MnGa.

MA 51.12 Fri 12:15 H 0112

Direct measurement of the magnetocaloric effect in $Ni_{50}Mn_{35}In_{15}$ in pulsed magnetic fields — •M. Ghorbani Zavareh[1,2], C. Salazar Mejia[3], A. K. Nayak[3], Y. Skourski[1], J. Wosnitza[1,2], C. Felser[3], and M. Nicklas[3] — [1]Hochfeld-Magnetlabor Dresden (HLD), Helmholtz-Zentrum Dresden-Rossendorf, D-01314 Dresden — [2]Institut für Festkörperphysik, TU Dresden, 01069 Dresden, Germany — [3]Max Plank Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Ferromagnetic shape-memory Heusler alloys undergo a martensitic transformation, i.e, a first-order structural transition from a cubic high-temperature phase to a low-temperature monoclinic phase. Due to a pronounced magneto-structural interaction in these compounds, a strong magnetic field can induce a metamagnetic transition and drive the system from a martensite to an austenite phase. In this case, both lattice and magnetic entropy contribute to the net magnetocaloric effect (MCE). We have measured the MCE of the shape memory Heusler alloy $Ni_{50}Mn_{35}In_{15}$ using a set-up for direct magnetocaloric measurements in pulsed magnetic fields. The martensitic transition occurs at about 246 K in zero field and the material has a Curie temperature of 315 K. We find a saturation of the inverse MCE, related to the first-order martensitic transition, with a maximum value of -7 K. The MCE associated with the Curie temperature evolves as typical for a second-order magnetic transition. The effect is positive, nearly temperature independent and yields a value of 11 K.

MA 52: Magnetic Thin Films II

Time: Friday 9:30–12:45 Location: H 1012

MA 52.1 Fri 9:30 H 1012

Magnetic anistropy energy of thin Fe layers on GaAs surface - the influence of defects — •Karel Carva and Ilja Turek — Charles University in Prague, Ke Karlovu 5, Prague 12116, Czech Republic

For thin Fe layers on top of GaAs surface an in-plane magnetic anisotropy energy (MAE) has been predicted, with an unusually high value. The experimental values vary by more than an order of magnitude here, which may be linked to the presence of defects, since the interface structure is not characterized sufficiently. We examine primarily the influence of intermixing between Fe and GaAs at the interface on the MAE. Interestingly, the calculated MAE does not only reduce its value with disorder, but may also change the sign. We examine more deeply the origin of this in-plane anisotropy. Layer-resolved calculations show that for this interface the contribution from the layer at the interface can be exceeded by that from more distant layers, which puts emphasis on the calculation precision.

We employ fully relativistic first-principles theory of metallic ferromagnetic systems. The theory is based on the all- electron tight-binding linear muffin-tin orbital (LMTO) method and the coherent potential approximation (CPA) is used to treat chemically disordered systems. Particular attention is devoted here to the spin and orbital magnetic moments, total energies, and transport properties. Data storage technology may significantly benefit from an increase of MAE allowing a higher data density. Understanding the dependence of MAE on various parameters allows to control it with a high precision.

MA 52.2 Fri 9:45 H 1012

Spin spirals and skyrmions in ultrathin films and in-plane magnetic fields investigated by SP-STM — •Lorenz Schmidt, Pin-Jui Hsu, Christian Hanneken, Andre Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, Universität Hamburg

Ultrathin magnetic films can exhibit topologically non-trivial spin textures as a result of competing magnetic interactions. Former spin-polarized scanning tunneling microscopy experiments (SP-STM) showed that a bilayer of palladium and iron on Ir(111) shows spin spirals in zero field and the application of a perpendicular magnetic field leads to the formation of skyrmions. It was also demonstrated that individual skyrmions can be written and deleted by local injection of electrons [1].

Here we investigate the changes inflicted by in-plane magnetic fields on the propagation direction of spin spirals and the switching behavior of skyrmions with SP-STM in a vectorial magnetic field. The propagation direction of the spin spiral is determined by the shape of the island and not changed by in-plane magnetic fields up to 1 T. Furthermore we examine if the switching rate and asymmetry between the ferromagnetic and skyrmionic states depend on in-plane magnetic fields.

[1] N. Romming *et al*, Science **341**, 636 (2013)

MA 52.3 Fri 10:00 H 1012

Epitaxial growth and characterization of Mn_2Au thin films for antiferromagnetic spintronics — •Helge Bräuning, Mathias Kläui, and Martin Jourdan — Institut für Physik, Johannes Gutenberg Universität, Staudingerweg 7, 55128 Mainz, Germany

The antiferromagnetic compound Mn_2Au is characterized by large spin-orbit coupling, which makes it a promising material for novel antiferromagnetic spintronics (see e.g. [Bar13, Zel14]).

We prepared thin films of Mn_2Au by RF-sputtering from a stoichiometric target on MgO and Al_2O_3 substrates using different buffer layers. Epitaxial samples with different growth directions such as [100], [001], and [101], were obtained. The samples were characterized by x-ray diffraction, magnetometry, AFM and SEM. Additionally, magnetotransport investigations will be presented.

[Bar13] V.M.T.S. Barthem et al. Nat. Commun. 4, 2892 (2013).

[Zel14] J. Zelezny et al. Phys. Rev. Lett. 113, 157201 (2014).

MA 52.4 Fri 10:15 H 1012

Magneto-transport in Sr2IrO4 epitaxial thin films — •Chengliang Lu[1,2], Dietrich Hesse[1], and Marin Alexe[3] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, D-06120 Halle (Saale), Germany — [2]School of Physics, Huazhong University of Science and Technology, Wuhan 430074, China — [3]Department of Physics, Warwick University, Coventry CV4 7AL, United Kingdom

The 5d iridates have been the subject of much recent attention due to the predictions of a large array of novel electronic phases driven by twisting strong spin-orbit coupling and Hubbard correlation. As a prototype, the single layered perovskite Sr2IrO4 was first revealed to host a Jeff=1/2 Mott insulating state. In this material, the approximate energy scale of a variety of interactions, involving spin-orbit coupling, magnetic exchange interaction, and the Mott gap, allows close coupling among the corresponding physical excitations. Here, we systematically investigate the magneto-transport in Sr2IrO4 thin films grown on various substrates inducing different strain states. We found an abnormal magnetoresistance which exhibits no apparent correlation with the magnetization, and interesting crossover behavior in the anisotropic magnetoresistance which probably can be associated with an isospin reorientation. In addition, the strain was revealed to play an important role in mediating the magneto-transport in Sr2IrO4 thin films, which is probably due to the modulation of the Jeff=1/2 state as predicted by Zhang et al. (PRL 111, 246402).

MA 52.5 Fri 10:30 H 1012

Structural, electronic, and magnetic properties of perpendicularly magnetised Mn_2RhSn thin films. — •Olga Meshcheriakova[1,2], Albrecht Köhler[1], Siham Ouardi[1], Yukio Kondo[3], Tahakide Kubota[3], Chandra Shekhar[1], Stanislav Chadov[1], Gerhard H. Fecher[1], Shigemi Mizukami[3], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Max Planck Institute of Microsctructure Physics, 06120 Halle, Germany — [3]WPI-Advanced Institute for Materials Research (WPI-AIMR), Tohoku University, Sendai 980-8577, Japan

Epitaxial thin films of Mn_2RhSn were grown on MgO(001) substrate by magnetron co-sputtering of the constituents. An optimized range of temperature for heat treatment was used to stabilize the tetragonal structure and to prevent the capping Rh layer from diffusing into the Heusler layer. Electronic and magnetic properties were analyzed by hard X-ray photoelectron spectroscopy as well as field- and temperature-dependent Hall and resistivity measurements. The measured valence spectra are in good agreement with the calculated density of states. The measured saturation magnetization corresponds to a magnetic moment of $1\mu_B$ in the primitive cell. The magnetization measurements revealed an out–of–plane anisotropy energy of 89 kJ/m^3 and a maximum energy product of 45.3 kJ/m^3. The magnetoresistance ratio is 2% for fields of 9 T. The lattice parameter of the compound has a very small mismatch with MgO, which makes it promising for coherent electron tunnelling phenomena.

MA 52.6 Fri 10:45 H 1012

Annealing Effects on Sputtered La0.67Sr0.33MnO3 Thin Films on Silicon (111) — •Manuel Monecke, Peter Richter, Peter Robaschik, Sreetama Banerjee, Georgeta Salvan, and Dietrich R.T. Zahn — Semiconductor Physics, Technische Universität Chemnitz, D-09107 Chemnitz, Germany

La1-xSrxMnO3 (LSMO) is a promising electrode material for spintronic devices. The electrodes are typically deposited by pulsed laser deposition on single crystalline substrates with similar lattice constants, e.g. SrTiO3 [1], to obtain single crystalline layers. Here we investigate LSMO films deposited by pulsed radio frequency magnetron sputtering at room temperature on silicon (111) substrates with native oxide. Afterwards the films were annealed in ambient atmosphere at different temperatures in the range from 600 °C to 875 °C. In order to understand how the LSMO film properties change with annealing temperature we evaluated spectroscopic ellipsometry and magneto-optical Kerr effect spectroscopy data to obtain the diagonal and off-diagonal elements of the dielectric tensor. Furthermore we measured Raman spectroscopy to investigate the phonon fingerprint of the LSMO layer and of the interface layer formed between the silicon substrate and the LSMO layer. Finally we determined the Curie temperature and the hysteresis loop parameters of the films via SQUID-VSM measurements. The results show that the magnetic properties improve with higher annealing temperatures. However, interdiffusion is observed for annealing temperatures higher than 775 °C. [1] W. Xu et al. Applied Physics Letters 90 (2007) doi: 10.1063/1.2435907

15 min. break

MA 52.7 Fri 11:15 H 1012

Charge Carrier Doping in Electrolyte-Gated Mesostructured $La_{1-x}Ca_xMnO_3$ and $La_{1-x}Sr_xMnO_3$ Thin Films with Cubic Pore Symmetry — •Christian Reitz, Philipp Moritz Leufke, Horst Hahn, and Torsten Brezesinski — Institute of Nanotechnology, Karlsruhe Institute of Technology, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

Here, we report on the preparation of mesostructured perovskite-type thin films of $La_{1-x}Sr_xMnO_3$ (LSMO) and $La_{1-x}Ca_xMnO_3$ (LCMO) from common sol-gel precursors by taking advantage of the superior templating properties of polyisobutylene-*block*-poly(ethylene oxide) diblock copolymers. We show that the overall sample preparation process is straightforward and both oxides are well defined in terms of structure and morphology after calcination, with complex percolation pathways for electron transport. We also show that the charge carrier density in electrolyte-gated LSMO and LCMO thin films can be modulated electrostatically to a large extent. This kind of doping allows for reversible "tuning" of the magnetization. Charge induced modulations of up to 5% at 300 K and 9% at 230 K can be achieved for LSMO and LCMO, respectively. These values are the highest thus far reported for electrolyte-gated mixed-valence manganese oxides with perovskite-type structure, thus emphasizing the benefits of nanoscale porosity. Overall, we will focus on the unique magnetic and magnetotransport properties as well as on the surface charge induced magnetization changes in polymer-templated LSMO and LCMO thin films with nanocrystalline walls.

MA 52.8 Fri 11:30 H 1012

Magnetoelectric coupling at the $La_{1-x}Sr_xMnO_3$/ionic liquid interface — •alan molinari, philipp leufke, christian reitz, robert kruk, and horst hahn — Karlsruhe Institute of Technology (KIT), Institute of Nanotechnology (INT), Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany

In the last years electric-field control of magnetism has been in the focus of an intense research activity, not only for fundamental research studies but also for the potential realization of novel-low power consumption microelectronic devices. $La_{1-x}Sr_xMnO_3$ (LSMO) is a half-metallic complex oxide with a Curie temperature above room temperature and a para-ferromagnetic transition correlated with the metal-insulator transition. A LSMO thin film has been combined with an ionic liquid in a plate capacitor-like geometry in order to investigate magnetoelectric coupling phenomena upon electrostatic surface charging. High quality epitaxial LSMO thin films have been grown on $SrTiO_3$ substrates by large-distance sputtering and characterized with atomic force microscopy, high-resolution x-ray diffraction and superconducting quantum interference device magnetometry. In situ measurements of magnetization response upon modulation of surface charge carriers have been performed in the 230-325 K temperature range by using a LSMO thin film as working electrode, a carbon cloth as counter electrode and an ionic liquid as charging medium.

MA 52.9 Fri 11:45 H 1012

Magnetoelectric MEMS sensors based on the ΔE-effect — Sebastian Zabel[1], Christine Kirchhof[2], Eckhard Quandt[1], and •Franz Faupel[2] — [1]Chair for Multicomponent Materials, Faculty of Engineering, Christian-Albrechts-University at Kiel, Kaiserstraße 2, D-24143 Kiel — [2]Chair for Inorganic Functional Materials, Faculty of Engineering, Christian-Albrechts-University at Kiel, Kaiserstraße 2, D-24143 Kiel

We present new developments of integrated MEMS magnetic field sensors based on the ΔE-effect, which extends our previous approach [Gojdka et al., Appl. Phys. Lett. 99, 223502 (2011); Nature 480, 155 (2011)]. This effect describes a change of elastic modulus in magnetostrictive materials upon application of a magnetic field. The change of elastic modulus is measured by the change of resonance frequency of a one side clamped cantilever. The 1 x 3 mm Si cantilever is 50 μm thick and coated with a 2 μm thick piezoelectric AlN layer on the top and a 2 μm thick magnetostrictive FeCoSiB amorphous film on the bottom. The piezoelectric layer is used for excitation of the first (7.6 kHz) or second (47 kHz) resonant bending mode as well as the readout of amplitude and phase by current measurements. The sensor shows linear amplitude response from several μT down to the limit of detection at 200 pT/Hz^1/2. High resonance frequencies enable a bandwidth of 60 Hz and prevent coupling to acoustic noise. Vector field capability is achieved by anisotropy control. In order to maximize sensitivity a bias field of 0.7 mT has to be applied.Funding by the DFG is gratefully acknowledged.

MA 52.10 Fri 12:00 H 1012

Anisotropy control in magnetic multilayer devices — •Kai Schlage[1], Denise Erb[1], Lars Bocklage[1,2], Hans-Christian Wille[1], Jade Comfort[1], and Ralf Röhlsberger[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

Spintronic multilayer devices are employed ubiquitously in modern magnetic data storage and sensor technology. Tremendous efforts were made to further improve these devices; however, the conventional RKKY coupling approach imposes fundamental limitations on the tunability of the magneto-electronic response.

In this contribution we describe a novel class of layered materials with magneto-electronic properties that can be almost arbitrarily tailored. A recently developed thin-film deposition technique, based on oblique incidence deposition, uniquely allows us to prepare multilayers with custom-designed magnetic properties for the first time [1]. Sample systems are characterized via magneto-optical Kerr and magnetoresistive measurements as well as with nuclear resonant reflectometry of synchrotron radiation [2].

[1] K. Schlage, D. Erb, H.-C. Wille, L. Bocklage, D. Schumacher and R. Röhlsberger, European Patent P91642 (2014) [2] K. Schlage and R. Röhlsberger, J. Electron. Spectrosc. Relat. Phenom. 189, 187 (2013)

MA 52.11 Fri 12:15 H 1012

In-situ thin-film electrodeposition in a SQUID magnetometer - a novel tool for studying the evolution of the magnetism during growth of Co films — •Stefan Topolovec[1], Heinz Krenn[2], and Roland Würschum[1] — [1]Institute of Materials Physics, Graz University of Technology, Graz, Austria — [2]Institute of Physics, University of Graz, Graz, Austria

Recently magnetic films formed by electrodeposition have attracted considerable attention [1]. To monitor the evolution of the magnetic moment m during the electrodeposition of thin Co films, we have designed a 3-electrode electrochemical cell for operation in a commercial state-of-the-art SQUID magnetometer, which enables the simultaneous measurement of magnetization and cyclic voltammograms [2,3].

With this new in-situ technique, a precise cancellation of the background signal of the cell and substrate is possible. This gives direct experimental access to the magnetic moment which arises exclusively from the electrodeposited film.

In-situ measurement cycles during growth and subsequent dissolution of Co films of different thicknesses yield evidence of an enhanced magnetic moment in the regime of a few monolayers in agreement with results obtained from theory and measurements of circular dichroism (XMCD) [4].

[1] P. Allongue et al., Surf. Sci. 603 (2009) 1831.
[2] S. Topolovec et al., J. Magn. Magn. Mater. 329 (2013) 43.
[3] E.-M. Steyskal et al., Beilstein J. Nanotechnol. 4 (2013) 394.
[4] M. Tischer et al., Phys. Rev. Lett. 75 (1995) 1602.

MA 52.12 Fri 12:30 H 1012

An in-situ μGISAXS investigation of growth of magnetic nanowires on rippled Si substrates — •Sarathlal Koyiloth Vayalil[1], Ajay Gupta[2], Gonzalo Santoro[1], Peng Zhang[1], and Stephan V. Roth[1] — [1]Photon Science, Deutsches Elektronen-Synchrotron, Notkestrasse-85, 22607, Hamburg, Germany — [2]Amity Center for Spintronic Materials, Amity University, Sector 125, NOIDA, 201313, India

Nanostructured magnetic thin films have gained significant relevance due to their applications in magnetic storage and recording media. Self-organized arrays of nanoparticles and nanowires can be produced by depositing metal thin films on nano-rippled substrates. The substrate topography strongly affects the film growth giving rise to anisotropic properties (optical, magnetic, electronic transport). Ion-beam erosion (IBE) allows for large area patterning of substrates and to tailor the pattern length scale by the ion beam parameters.

We investigated in real time the growth mechanism of magnetic thin films of Co and Permalloy thin films on such tailored nano-rippled Si (100) substrates using in-situ micro grazing incidence small-angle X-ray scattering (μGISAXS). In the very low thickness regime, the film replicates the morphology, rather an increase in the thickness lead to growth of nanowires in an orientation nearly 55^0 from the surface. The annealing followed by the deposition generates large range ordered nanowires. We are able to correlate observed magnetic anisotropy with anisotropic nanostructure deduced from GISAXS.

MA 53: Spintronics (incl. Quantum Dynamics) (jointly with HL, TT)

Time: Friday 9:30–12:00 Location: EB 202

Invited Talk MA 53.1 Fri 9:30 EB 202

Antiferromagnetic spintronics — •Tomas Jungwirth — Institute of Physics v.v.i., ASCR, Prague, Czech Republic

Atiferromagnets (AFMs) have for decades played a passive role in conventional spin-valve structures where they provide pinning of the reference ferromagnetic layer. This implies that on one hand, incorporation of some AFM materials in common spintronic structures is well established. On the other hand, limiting their utility to a passive pinning role leaves a broad range of spintronic phenomena and functionalities based on AFMs virtually unexplored. Apart from the insensitivity to magnetic fields and the lack of stray fields, AFMs are common among metals, semiconductors, and insulators and can have orders of magnitude shorter spin-dynamics timescales, to name a few immediate merits of the foreseen concept of AFM spintronics. Several non-relativistic and relativistic spin-transport phenomena have been proposed for AFMs to complement or replace ferromagnets in active parts of spintronic devices. We will focus on the theory of relativistic phenomena and their utility in experimental AFM magneto-resistors, memories, and structures in which AFMs are employed to control ferromagnets electrically.

J. Zelezny et al., Phys. Rev. Lett. 113 (2014) 157201 I. Fina et al., Nature Commun. 5 (2014) 4671 X. Marti et al., Nature Mater. 13 (2014) 367 P. Wadley et al., Nature Commun. 4 (2013) 2322 B.G. Park et al., Nature Mater. 10 (2011) 347

MA 53.2 Fri 10:00 EB 202

Stability of a single spin against readout — •Christoph Hübner[1], Benjamin Baxevanis[1,2], Alexander A. Khajetoorians[3,4], and Daniela Pfannkuche[1] — [1]I. Institute for Theoretical Physics, Hamburg University, Hamburg, Germany — [2]Lorentz Institute, Leiden University, Leiden, The Netherlands — [3]Institute of Applied Physics, Hamburg University, Hamburg, Germany — [4]Institute of Applied Physics, Radboud University Nijmegen, Nijmegen, The Netherlands

A magnetic atom or cluster is extremely sensitive to interactions with a scanning tunneling microscope (STM), that is used to read and write the magnetic state [1]. On the other hand the symmetry of the substrate allows magnetic adatoms to retain their magnetization for minutes, which is extremely long on an atomic time scale [2]. We systematically study this protection against magnetization fluctuations in the presence of a magnetic field and scattering with electrons from the STM and substrate with a non-equilibrium master equation. A combination of spin and substrate symmetry is proposed that produces a stable magnetic orientation even in the presence of a magnetic field [3]. Additionally characteristic features are presented that allow to deduce the spin and substrate symmetry by measurement.

[1] A. A. Khajetoorians et al., Science 339, 55 (2013)
[2] T. Miyamachi et al., Nature 503, 242 (2013)
[3] C. Hübner et al., Phys. Rev. B 90, 155134 (2014)

MA 53.3 Fri 10:15 EB 202

Electric field as a tool for tuning quantum entanglement in supported clusters — •Oleg O. Brovko, Oleg V. Farberovich, and Valeri S. Stepanyuk — Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany

Electric field has been recently gaining in reputation as a versatile tool for tuning adsorption, electronic and magnetic properties of nanostructures. In the present contribution we show that using this tool it is also possible to tune quantum entanglement of spins in small clusters on metallic surfaces. Relying on a combination of ab initio and Heisenberg-Dirac-Van Vleck quantum spin Hamiltonian calculations we show by the example of a typical transitional metal dimer (Mn) on Ag(001) surface, that in an inherently unentangled system, electric field can "switch on" the entanglement and change its critical temperature parameter by orders of magnitude. The physical mechanism allowing such rigorous control of entanglement by electric field is shown to be the field- induced change in the internal coupling of the supported nanostructure.

MA 53.4 Fri 10:30 EB 202

Transmission through correlated Cu_nCoCu_n heterostructures — •Liviu Chioncel[1], Cristian Morari[2], Ivan Runger[3], Andrea Drogetti[3], Andreas Oestlin[4], Ulrich Eckern[5], and Andrei Postnikov[6] — [1]Theoretical Physics III, Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, D - 86135 Augsburg, Germany — [2]National Institute for Research and Development of Isotopic and Molecular Technologies, 65-103 Donath, RO-400293 Cluj Napoca, Romania — [3]School of Physics and CRANN, Trinity College, Dublin 2, Ireland — [4]Department of Materials Science and Engineering, Applied Materials Physics, KTH Royal Institute of Technology, Stockholm SE - 100 44, Sweden — [5]Theoretical Physics II, Institute of Physics, University of Augsburg, D - 86135 Augsburg, Germany — [6]LCP-A2MC, Institute Jean Barriol, University of Lorraine 1, Bd Arago, F - 57078 Metz, France

We study the effects of local electronic interactions and finite temperatures upon the transmission across the Cu_4CoCu_4 metallic heterostructure in a combined density functional and dynamical mean field theory. We show that the total transmission at the Fermi level is reduced as the electronic correlations are taken into account via a local but dynamic self-energy, whereby such a reduction is more pronounced in the minority spin channel. Consequently, the spin polarization of the transmission increases. Our results also demonstrate that the enhancement in spin contrast is in mainly driven by interaction rather than finite temperature fluctuations.

MA 53.5 Fri 10:45 EB 202

Tricky details of tunnel magnetoresistance — •Christian Franz, Michael Czerner, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University, Giessen, Germany

The basic mechanism responsible for the large TMR in coherent tunnel junctions has already been clarified in the first publications [1,2]. These predictions initiated a broad investigation continuing for more than a decade. Nevertheless, the quantitative understanding of TMR is still incomplete. In particular, the agreement between experiments and calculations remains deficient. The reason for these shortcomings is a complicated interplay of many effects, several of which are not yet fully understood.

We contribute by investigating several effects in great detail using advanced *ab initio* methods [3]. In particular, we discuss the effects of disorder, several interface resonance states and bulk states of different materials. These effects are illustrated by the example of $Fe_{1-x}Co_x$ alloys as ferromagnetic layers [4] which show substitutional disorder for finite concentrations, a complicated concentration dependence of the interface resonance states and variety of bulk states which become available via band filling.

[1] W.H. Butler, X.-G. Zhang, T.C. Schulthess, J.M. MacLaren, Phys. Rev. B 63, 054416 (2001)
[2] J. Mathon, A. Umerski, Phys. Rev. B 63, 220403 (2001).
[3] C. Franz, M. Czerner, C. Heiliger, J. Phys.: Condens. Matter 25, 425301 (2013).
[4] C. Franz, M. Czerner, C. Heiliger, Phys. Rev. B 88, 094421 (2013).

MA 53.6 Fri 11:00 EB 202

Electronic transport in carbon nanotube quantum dots functionalized with magnetic molecules — •Carola Meyer[1,2], Claire Besson[1,2], Michael Schnee[1,2], Henrik Flötotto[3], Robert Frielinghaus[1,2], Lothar Houben[2,4], Paul Kögerler[2,3], and Claus M. Schneider[1,2] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]JARA - Fundamentals of Future Information Technologies, Germany — [3]RWTH Aachen University, Institute for Inorganic Chemistry, 52074 Aachen, Germany — [4]Ernst Ruska-Center for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, 52425 Jülich, Germany

Transport devices built from individual functionalized carbon nanotubes (CNTs) show great potential for instance in spintronics applications. We graft magnetic complexes to CNTs [1]. The route for the CNT functionalization is very general, based on ligand exchange, and can be applied for different molecules, in particular SMMs. We present first quantum transport measurements on individual functionalized CNTs that prove only weak distortion of the electron wave function by the covalent functionalization. The g-factor of the chemically modified CNT quantum dot (QD) is much smaller compared to pristine CNT QDs indicating spin interaction between the QD and the attached molecules. A clear random telegraph signal is recorded depending on the states of the QD. Origin of timescale and energy of the signal are discussed. [1] Meyer, C. et al., Phys. Status Solidi B 249, 2412(2012)

MA 53.7 Fri 11:15 EB 202

Spin transport and its gate-induced modulation in nondegenerate Si at room temperature — •Masashi Shiraishi[1], Tomoyuki Sasaki[2], Yuichiro Ando[1], Makoto Kameno[1], Hayato Koike[2], Toshio Suzuki[3], and Tohru Oikawa[2] — [1]Kyoto Univ., Japan — [2]TDK Corporation, Japan — [3]AIT, Akita Prefectural Industrial Center, Japan

Si spintronics has been collecting tremendous attention, because of its long spin lifetime and achievement of spin transport at room temperature (RT) [1,2]. In the course of our study in Si spintronics, we have revealed that the so-called 3-terminal method [3] cannot completely preclude spurious signals [4], which is now widely recognized [5-7]. Here, we introduce some methods enabling to avoid detection of spurious signals, and report on reliable RT spin transport in nondegenerate n-type Si and gate-induced modulation of spin signals [8]. This is the first experimental demonstration of spin MOSFET at RT, which can pave a way to establish spin-based logic systems.

[1] T. Suzuki, T. Sasaki, M. Shiraishi et al., Appl. Phys. Express 4, 023004 (2011). [2] E. Shikoh, M. Shiraishi et al., Phys. Rev. Lett. 110, 127201 (2013). [3] S. Dash et al., Nature 462, 491 (2009). [4] Y. Aoki, M. Shiraishi et al., Phys. Rev. B86, 081201(R) (2012). [5] O. Txoperena et al., Appl. Phys. Lett. 102, 192406 (2013). [6] T. Uemura et al., Appl. Phys. Lett. 101, 132411 (2012). [7] O. Txoperena, H. Dery et al., Phys. Rev. Lett. 113, 146601 (2014). [8] T. Sasaki, M. Shiraishi et al., Phys. Rev. Applied 2, 034005 (2014).

MA 53.8 Fri 11:30 EB 202

Spin transfer by pure spin current at magnetic interfaces — •Wei Chen[1], Manfred Sigrist[2], Jairo Sinova[3], and Dirk Manske[1] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]ETH-Zurich, Zurich, Switzerland — [3]Johannes Gutenberg University-Mainz, Mainz

We present a microscopic theory for the spin transfer torque, spin pumping, spin mixing conductance, and Onsager relation caused by the pure spin current in the normal metal/ferromagnetic insulator bilayer (such as Pt/YIG) and normal metal/ferromagnetic metal/oxide trilayer (such as $Pt/Co/AlO_x$). The spin Hall effect in the normal metal generates a pure spin current which, upon quantum tunneling into the ferromagnet, causes the magnetization dynamics. The field-like and damping-like component of these spin-transfer quantities are expressed in terms of characteristic energy scales such as the insulating gap and $s-d$ hybridization, which are applicable to a wide range of materials, hence the result can guide the search for materials that have a particular function in spin transport.

MA 53.9 Fri 11:45 EB 202

Spin pumping experiments in Gadolinium Iron Garnet/Pt thin films — Johannes Lotze[1], •Kathrin Ganzhorn[1], Stephan Geprägs[1], Francesco Della Coletta[1], Rudolf Gross[1,2,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

Magnetically compensated rare earth garnets, such as Gadolinium Iron Garnet ($Gd_3Fe_5O_{12}$, GdIG), exhibit a pronounced temperature dependence of the sublattice magnetizations, leading to a magnetization compensation temperature $T_{\mathrm{comp,\ M}}$. The investigation of spin currents in GdIG/Pt heterostructures thus can give important insight into the processes involved in the spin current generation in ferrimagnetic insulator/Pt bilayers. Temperature dependent spin Seebeck effect experiments have recently been performed in GdIG/Pt thin film samples [1], revealing two sign changes of the spin Seebeck voltage, a first one at $T_{\mathrm{comp,\ M}}$ and a second one at a lower temperature. We have performed microwave heating induced spin Seebeck together with spin pumping measurements as a function of temperature in doped GdIG/Pt heterostructures. Our experiments confirm the temperature dependent evolution of the spin Seebeck voltage reported in Ref. [1]. We critically discuss this evolution and compare it to the temperature dependence of the spin pumping voltage observed.

Financial support by DFG via SPP 1538 is gratefully acknowledged.

[1] S. Geprägs *et al.*, arXiv 1405.4971 (2014)

MA 54: Magnetic Coupling Phenomena

Time: Friday 9:30–11:15 Location: EB 301

MA 54.1 Fri 9:30 EB 301

Role of antiferromagnetic spin configuration in dual exchange biased structure in $[Pt/Co]_6/CoO/[Co/Pd]_8$ system — •Sri Sai Phani Kanth Arekapudi[1], Dmitriy Mitin[2], and Manfred Albrecht[2] — [1]Institut für Physik, Technische Universität Chemnitz, D-09107 Chemnitz, Germany — [2]Institut für Physik, Universität Augsburg, D-86159 Augsburg, Germany

The exchange bias effect and magnetic reversal processes in the dual exchange bias structure, $[Pt/Co]_6/CoO/[Co/Pd]_8$ trilayer with an easy axis magnetization out-of-plane were studied. The individual reversal of the ferromagnetic multilayers was achieved by fine-tuning the switching field, and the exchange coupling was studied by observing the independent magnetic reversal processes, which was explicitly contemplated via minor loops. This allows us to set the trilayer system in two different magnetic cooling configurations. Where the net magnetic moment in the ferromagnetic layers were aligned either parallel or antiparallel to each other. After field cooling the samples from room temperature to below the blocking temperature of the antiferromagnet, we were able to probe the exchange interaction between two biased systems through a common antiferromagnetic interface. The dependence of exchange bias field on the thickness of the antiferromagnetic spacer (CoO) layer as well as the measurement temperature were systematically analyzed. Furthermore, the exchange bias field tends to decrease with increase in the thickness of the antiferromagnet and can be attributed to modification of the bulk spin structure and the domain walls of the AF layer ultimately influencing the exchange bias field.

MA 54.2 Fri 9:45 EB 301

Large exchange bias in epitaxial MnN/CoFe bilayers — Jan Balluff, Mareike Dunz, and •Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

MnN is an antiferromagnet with a high Neel temperature and thus seems promising for exchange bias applications [1]. We investigated epitaxial MnN/CoFe film stacks grown on MgO(001) for their magnetic properties. We observed large exchange bias reaching up to 1000 Oe at room temperature. MnN film thickness, working pressure and deposition temperature dependencies of the exchange bias and the coercive field were studied in detail. Our results suggest that the MnN/CoFe system may become a substitute for the common IrMn or PtMn based exchange bias systems.

[1] Suzuki, K., Yamaguchi, Y., Kaneko, T., Yoshida, H., Obi, Y., Fujimori, H., and Morita, H. (2001). Journal of the Physical Society of Japan, 70(4), 1084-1089.

MA 54.3 Fri 10:00 EB 301

Light-ion bombardment induced magnetic patterning (IBMP) of exchange bias layer systems by He-ion microscope — •Alexander Gaul[1], Daniel Emmrich[2], André Beyer[2], Johanna Hackl[3], Hatice Doganay[3], Timo Kuschel[4], Andreas Hütten[4], Günter Reiss[4], Slavo Nemsak[3], Armin Gölzhäuser[2], and Arno Ehresmann[1] — [1]Department of Physics & CINSaT, University of Kassel — [2]Physics of Supramolecular Systems and Surfaces, University of Bielefeld — [3]PGI-6, FZ-Jülich — [4]Thin Films & Physics of Nanostructures, University of Bielefeld

Light-ion bombardment induced magnetic patterning (IBMP) of exchange bias (EB) bilayer systems by Helium ion bombardment through a shadow mask is a well known technique to tailor the magnetic anisotropy locally on the micrometer scale. Here we show the use of a Helium ion microscope (HIM) to create complex magnetic patterns in EB systems without masks. In this way lateral dimensions of the magnetic patterns down to a few tenths of a nanometer become feasible and experimetns to investigate the ultimate resolution limit of IBMP are at hand. Therefore designed patterns were written by a He-ion beam of 10~nm diameter in the EB layer. The influence of size and shape on magnetic domain walls within one sample has been analyzed by magnetic force microscopy (MFM) to detect changes in the domain wall charge distribution and by x-ray magnetic circular dichroism photoemission electron microscopy (XMCD-PEEM) to get a detailed information about the magnetization orientation within the domains and domain walls.

MA 54.4 Fri 10:15 EB 301

Unusual ferromagnetic $YMnO_3$ phase in $YMnO_3/La_{2/3}Sr_{1/3}MnO_3$ heterostructures — •Carmine Autieri and Biplab Sanyal — Department of Physics and Astronomy, Uppsala University, Box-516, SE-75120 Uppsala, Sweden

By means of ab-initio density functional calculations in the Hubbard model framework, we have studied the structural, magnetic and electronic properties of $YMnO_3/La_{2/3}Sr_{1/3}MnO_3$ heterostructures. Although in the bulk the ground state of $YMnO_3$ is a ferroelectric antiferromagnet, the $YMnO_3/La_{2/3}Sr_{1/3}MnO_3$ heterostructure stabilizes the ferromagnetic phase in $YMnO_3$ in the interface region. The hypothetical ferromagnetic phase of bulk $YMnO_3$ is dielectric and due to substantial differences between the lattice constants in the ab plane, a strong magnetocrystalline anisotropy is present. This anisotropy produces a high coercivity of the unusual ferromagnetic $YMnO_3$ that can explain the large vertical shift in the hysteresis loops observed in recent experiments. The correlation between weak exchange bias and vertical shift in hysteresis loops is proposed, which calls for reinvestigation of various systems showing vertical shifts.

MA 54.5 Fri 10:30 EB 301

Room temperature antiferromagnetism and exchange bias in $BiFeO_3$ / CoFe — •Christian Sterwerf, Jan-Michael Schmalhorst, and Günter Reiss — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

In this work we report room temperature exchange bias in bilayers of antiferromagnetic $BiFeO_3$ and ferromagnetic CoFe.

Epitaxial $BiFeO_3$ thin films were grown by reactive DC and RF magnetron co-sputter deposition on $SrTiO_3$ (100) substrates. Additional ferromagnetic CoFe layers with varying thicknesses were deposited to investigate the magnetic coupling between the films.

The crystallographic properties of the films are determined by means of x-ray diffraction and x-ray reflectivity. The amplitude of the exchange bias is investigated by the magneto-optical Kerr effect (MOKE) and the temperature dependent anisotropic magnetoresistance.

We found an exchange bias of more than H_{ex} = 75 Oe at room temperature accompanied by an increase of the coercive field of the CoFe layers to H_c=60 Oe.

MA 54.6 Fri 10:45 EB 301

Room temperature ferromagnetism in CoO/Co3O4 nanocrystals — •Zi-An Li[1], Nerio Fontaíña-Troitiño[2], András Kovács[3], Sara Liébana-Viñas[1], Marina Spasova[1], Rafal E. Dunin-Borkowski3[3], Markus Müller[4], David Doennig[4], Rossitza Pentcheva[1,4], Michael Farle[1], and Veronica Salgueiriño[2] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg-Essen,Germany — [2]Departamento de FísicaAplicada, Universidade de Vigo, Spain — [3]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Research Centre Jülich, Germany — [4]Department of Earth and Environmental Sciences, Section Crystallography, LMU Munich, Munich, Germany

Hetero-interfaces formed between oxide perovskite structures can exhibit novel functionality that is not available in the bulk constituents. Here, we present a detailed high-resolution transmission electron microscopy and quantitative magnetometry study of a robust (above room temperature) environmentally-stable ferromagnetically-coupled interface layer, which forms between the antiferromagnetic rocksalt CoO cores and the surrounding 2-4 nm-thick antiferromagnetic spinel Co3O4 surface layers of octahedral nanocrystals [1, 2]. The origin of the experimentally observed ferromagnetic phase is discussed based on density functional theory calculations including a Hubbard U term.

References 1. N. Fontaina-Troitino et al. Nano Letters 14, 640 (2014) 2. Financial support by the European Research Council Grant *IMAGINE* and SFB/TR80 is gratefully acknowledged.

MA 54.7 Fri 11:00 EB 301

Comparison of magnetic properties in amorphous and crystalline Fe/Fe-O core/shell nanoparticles — •Anil Kumar P.[1,2], Gurvinder Singh[3], Wilhelm R Glomm[4], Davide Peddis[5], Erik Wahlstrom[6], and Roland Mathieu[1] — [1]Department of Engineering Sciences, Uppsala University, Box 534, 751 21 Uppsala,Sweden

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Fe and Fe-O nanoparticles form an important part of several biomedical and technological applications. We report on the magnetic properties of amorphous Fe/Fe-O core/shell nanoparticles compared to those of a reference system with crystalline Fe/Fe-O core/shell nanoparticles. These nanoparticles are prepared by thermal decomposition and the nature of particles, amorphous or crystalline, is controlled by the choice of the ligand/surfactant. The crystalline Fe/Fe-O nanoparticles remain blocked until room temperature and exhibit small exchange bias effect. However, the amorphous Fe/Fe-O nanoparticles show substantial exchange bias and collective magnetic behavior with features of magnetic frustration and disorder reminiscent of spin/superspin glass systems. We discuss the origin of these effects.*Conference attendance supported by the EU-project NU-MATHIMO.