MA 47: Poster III

Time: Thursday 15:00–18:00 Location: Poster D

MA 47.1 Thu 15:00 Poster D

Twisted magnetocaloric effect by exchange bias in double perovskite SmCaCoMnO6 — •Manisha Bansal, Wasim Akram, and Tuhin Maity — School of Physics, Indian Institute of Science Education and Research Thiruvananthapuram, Thiruvananthapuram, Kerala 695551, India

Exchange bias (EB) is unarguably popular magnetic phenomenon due to its industry oriented applicability like memory devices and sensors. EB is widely reported in various types of materials such as core-shell nanoparticles, multiferroics, double-perovskites (DP), etc. Here, we report a twisted magneto caloric effect (MCE) from twisted crossover between isothermal magnetic hysteresis (MH) curves, due to a giant EB of ~8500 Oe in DP system of ferrimagnetic (FIM) SmCaCoMnO6-ferromagnetic (FM) Sm0.1Ca0.9MnO3 at T*10 K. The twisted MCE leads to an enhanced inverse MCE (entropy change ~ -3 J/Kg-K for the change of field ~70 kOe at 2 K); three times greater than the direct MCE observed. Both MCE and EB are found to be highly field dependent. Variation of EB with bias field emphasizes the importance of de-pinning threshold field which corroborates with the behavior of isothermal MH curves with respect to the field at low temperatures. The strong coupling between EB and MCE effects is due to the spin glass between the primary FIM SmCaCoMnO6 and secondary FM Sm0.1Ca0.9MnO3 phases, confirmed by magnetic remanence, ac susceptibility, and time dependent magnetic relaxation measurements. Thus, both EB and MCE have a common origin. The interesting results will lead to energy-efficient spintronic devices.

MA 47.2 Thu 15:00 Poster D

Out-of-plane magnetoresistance in vortex magnetic tunnel junctions — •Johannes Demir, Tobias Peters, Karsten Rott, and Günter Reiss — Bielefeld University, Germany

We investigated the magnetoresistance (MR) in magnetic tunnel junctions (MTJs) where the free layer magnetization exhibits a magnetic vortex state. The MTJ is a standard tunnel magnetoresistance (TMR) stack with a thin Ta layer and a thickness varied FeB layer as the vortex layer on top, nanostructed into pillars with different diameters. MR measurements are performed by bonding the MTJ pillars to the contact pads of a chip carrier and applying a bias voltage in the mV range. Sweeping the out-of-plane (OOP) magnetic field between 2 T and -2 T we observe a nearly parabolic behaviour for the current flowing through the pillar saturating in dependence of the diameter of the pillar and the thickness of the vortex layer. Here, MR ratios of up to 60 % were achieved. Micromagnetic simulations reveal a tilting of the magnetization towards the magnetic field direction for both the vortex and reference layer. The evaluation of the simulations with a cosine-model [1] leads to a good agreement with the measurements.

[1] A. Tavassolizadeh et al., Appl. Phys. Lett. **102**, 153104 (2013)

MA 47.3 Thu 15:00 Poster D

Magneto-Plasmonic Quasicrystal structure for Broadband Faraday Rotation Enhancement — •Shraddha Choudhary[1,2], Gajendra Mulay[1], and Venu Gopal Achanta[1] — [1]Department of Condensed Matter Physics and Materials Science, Tata Institute of Fundamental Research, Mumbai 400005, India. — [2]Institute of Physics, University of Münster, Wilhelm-Klemm-Straße 10, 48149 Münster, Germany

Magneto-plasmonic nanostructures integrating plasmonics and magneto-optics offer a novel way of controlling light using magnetic fields. The Faraday effect in magneto-optical materials causes a rotation of the polarization plane of light, which is primarily utilized in non-reciprocal photonic devices such as optical isolators and circulators. However, existing magneto-optical materials exhibit a weak Faraday effect in the visible to the near-infrared frequency range, resulting in bulky Faraday isolators. In this study, we report a broadband enhancement in the Faraday rotation in a plasmonic quasicrystal (PIQC) structure comprising of patterned gold pillars on top of ferromagnetic thin films. The enhancement primarily results from the excitation of surface plasmon polaritons that propagate at the interface between gold and garnet in the PIQC structure.

MA 47.4 Thu 15:00 Poster D

Spin Noise Experiments in Yttrium Iron Garnet Films — •Franz S. Herbst, Daniel Anic, Marvin A. Weiss, and Sebastian T. B. Goennenwein — Department of Physics, University of Konstanz, Germany

Thermal spin fluctuations can be used as a powerful yet non-perturbative experimental probe for the magnetic behavior of correlated materials. The analysis of magnetization fluctuation data using different statistical metrics, such as autocorrelation or noise power spectral density, grants direct access to equilibrium material properties and incoherent magnetization dynamics - even down to ultrafast time scales [1].

Yttrium Iron garnet ($Y_3Fe_5O_{12}$, YIG) is considered as a prototypical material for future spintronic devices, due to its extremely low magnon damping. However, spin fluctuations in YIG have not been systematically studied to date. Here we investigate the magnetization noise in YIG over a broad range of frequencies and for different external magnetic fields using the magneto-optical Faraday effect. We analyze our experimental data in particular regarding non-stationary relaxation processes and assess the effect of non-ergodicity using toy model simulations.

[1] Weiss et. al., Nat. Commun. **14**, 7651 (2023).

MA 47.5 Thu 15:00 Poster D

Crystallization behavior of Yttrium Iron Garnet thin films — •Sebastian Sailler[1], Gregor Skobjin[1], Benny Boehm[4,5], Heike Schlörb[2], Olav Hellwig[4,5], Andy Thomas[2,3], Sebastian T.B. Goennenwein[1], and Michaela Lammel[1] — [1]Department of Physics, University of Konstanz, Konstanz — [2]Leibniz Institute of Solid State and Materials Science, Dresden — [3]TUD Dresden University of Technology, Dresden — [4]Institute of Physics, Technische Universität Chemnitz, Chemnitz — [5]Center for Materials Architectures and Integration of Nanomembranes (MAIN), TU Chemnitz, Chemnitz

Yttrium iron garnet (YIG) is a ferrimagnetic insulator commonly used in spin transport and spin dynamics. High quality, single crystalline YIG thin films are typically fabricated, e.g., using sputter deposition at room temperature with a subsequent annealing step to induce crystallization. Interestingly, however, the exact crystallization dynamics from the amorphous to the crystalline state have not been systematically studied. We therefore analyze the crystallization behavior of YIG films on different substrates utilizing extensive annealing temperature and time series. Structural characterization using X-ray techniques as well as electron backscatter diffraction allow to differentiate between amorphous, partially crystalline, polycrystalline and epitaxial films, and to determine the optimal annealing parameters for each substrate. Our results provide an in-depth understanding about the formation of crystalline YIG and allow for a rigorous control over the crystallization induced by the subsequent annealing step.

MA 47.6 Thu 15:00 Poster D

Lateral Solid Phase Epitaxy of Yttrium Iron Garnet — Sebastian Sailler[1], Darius Pohl[2], Heike Schlörb[3], Bernd Rellinghaus[2], Andy Thomas[3,4], Sebastian T.B. Goennenwein[1], and •Michaela Lammel[1] — [1]Department of Physics, University of Konstanz, Konstanz — [2]DCN, cfaed, TUD Dresden University of Technology, Dresden — [3]Leibniz Institute of Solid State and Materials Science, Dresden — [4]TUD Dresden University of Technology, Dresden

Lateral solid phase epitaxy of yttrium iron garnet (YIG) enables the fabrication of single crystalline YIG on top of non-lattice matched carrier materials and therefore the realization of single crystalline, non-planar YIG structures. We demonstrate the lateral solid phase epitaxy of YIG over an artificial edge, such that the crystallization direction is perpendicular to the initial seed. We use micropatterned SiO_x mesas on top of single crystalline garnet seed substrates to study the lateral crystallization across and on top of the SiO_x. We find that YIG retains the crystal orientation of the substrate not only when in direct contact with the seed garnet, but also across the edge on top of the SiO_x mesa. By controlling the crystallization parameters it is possible to almost completely suppress the formation of polycrystals and to enable epitaxial growth of single crystalline YIG on top of SiO_x. From a series of annealing experiments, we extract an activation energy of 2.8 eV and a velocity prefactor of 5.1×10^{13} nm/s for the lateral crystallization of YIG along the <100> direction. Our results pave the way to engineer single crystalline non-planar yttrium iron garnet structures with controlled crystal orientation.

MA 47.7 Thu 15:00 Poster D

Giant current driven magnetic response in Ca_2RuO_4 — •Aditya Putatunda, Ravi Kaushik, and Sergey Artyukhin — Istituto Italiano di Tecnologia, Genova, Italy 16163

Current driven manipulation of spin states in magnetic systems, mediated via spin-orbit torque has attracted significant attention in recent times due to its performance potential for high speed, low power switching in the form of novel devices1. The ability to realize this functionality in antiferromagnetic systems offer the extra advantage of insensitivity to magnetic field perturbations, while being readily compatible with metal, semiconductor, or materials with an insulating electronic structure2.

Here we report our theoretical investigation on Ca2RuO4, an antiferromagnetic insulator, driven by strong $4d$ spin-orbit interactions, exploring the recently observed Raman spectra measurements. Driven by a miniscule current, prior to the onset of its conductivity transition, this material shows significant alteration to its low energy spectra, apparently due to a spin-flop transition. We will be discussing our analytical model, supported by first-principles calculations offering an explanation to this novel observation3.

1 Soumyanarayanan et al., Nature 539, 509517 (2016) 2 Železný et al., Phys. Rev. Lett. 113, 157201 (2014) 3 Kunkemöller et al., Phys. Rev. B 95, 214408 (2017)

MA 47.8 Thu 15:00 Poster D

Catalogue of *C*-paired spin-valley locking in antiferromagnetic system — •Mengli Hu[1], Xingkai Cheng[2], Zhenqiao Huang[2], and Junwei Liu[2] — [1]Institute for Theoretical Solid State Physics, IFW Dresden, Helmholtzstrasse 20, 01069 Dresden, Germany — [2]Department of Physics, Hong Kong University of Science and Technology, Clear Water Bay, Hong Kong, China

We propose an algorithm to determine *C*-paired spin-valley locking (SVL) in any magnetic space group (MSG) based on the little co-group and coset representatives, which allows us to naturally classify *C*-paired SVL into collinear, coplanar, and spatial categories and identify four elementary types that compose all possible *C*-paired SVL in 1651 MSGs. By combining the proposed algorithm and high-throughput first-principles calculations, we identify 140 out of 1794 antiferromagnetic (AFM) materials from MAGNDATA that can realize *C*-paired SVL with experimentally verified magnetic structure. Besides identifying new material candidates, the classification can also reveal the underlying mechanism of responses of *C*-paired SVL to external fields. As an example of $PbNiO_3$, two qualitatively different types of piezomagnetism via occupation imbalance or spin tilting can be realized by breaking the little co-group or coset representatives, respectively. Moreover, our algorithm is also applicable to locking between valley/momentum and any kind of pseudo-vector degree of freedom, e.g. Berry curvature distribution, as demonstrated in the example of $PbNiO_3$.

MA 47.9 Thu 15:00 Poster D

Strain Tuning of the Altermagnetic Candidate MnF_2 — •Rahel Ohlendorf[1,2], Hilary M. L. Noad[1], Elena Hassinger[2], Andrew P. Mackenzie[1,3], and Elena Gati[1] — [1]Max-Planck-Institute for Chemical Physics of Solids, Dresden, Germany — [2]Technical University, Dresden, Germany — [3]University of St Andrews, UK

Altermagnetism is a newly defined collinear magnetic phase unambiguously differentiated from the already known ferro- and antiferromagnetic phases within the framework of spin group symmetry [1]. This magnetic phase combines the highly sought after properties of compensated spin order in real space and spin-split bands in reciprocal space even without spin-orbit coupling, relevant for spintronic applications. Similar to the magnetic field for ferromagnets, the combination of strain and magnetic field is predicted to act as a conjugate field to the altermagnetic order parameter. Consequently, strain and magnetic field might be used to (i) probe the altermagnetic susceptibility, related to octupolar degrees of freedom in centrosymmetric systems and (ii) create a single-domain altermagnetic state exploiting the piezomagnetic effect [2,3]. We discuss the results of elastocaloric and stress-strain measurements of the altermagnetic centrosymmetric candidate MnF_2 under finite strain and magnetic field.

[1]L. Smejkal et al., Phys. Rev. X 12, 031042 (2022)
[2]S. Bhowal et al., ArXiv: 2212.03756v1 (2022)
[3]L. Ye et al., ArXiv: 2309.04633v1 (2023)

*Work is supported by the DFG through TRR288 (Elasto-Q-Mat).

MA 47.10 Thu 15:00 Poster D

Growth and surface characterization of epitaxial $CuFeS_2$ thin films on Si(001) — •Richard Justin Schenk, Anders Christian Mathisen, Stefanie Suzanne Brinkman, Xin Liang Tan, Matthias Hartl, Christoph Brüne, and Hendrik Bentmann — Center for Quantum Spintronics, Department of Physics, NTNU, Trondheim, Norway

Chalopyrite, $CuFeS_2$, has recently gained attention as a semiconducting, collinear antiferromagnet with a high Néel temperature (T_N = 823 K). As a representative of the magnetic space group ($I\bar{4}2d$) it has been predicted to host non-relativistic spin-polarized electronic bands, which have generated great interest in recent years in the context of altermagnetism. These properties make chalcopyrite a suitable candidate for future spintronics applications. We present $CuFeS_2$ thin films on a lattice-matched Si(001) substrate using molecular beam epitaxy. We will report on surface preparation and characterization of the films based on low-energy electron diffraction (LEED) and X-ray photoelectron spectroscopy (XPS). Furthermore, the electronic structure of these films was investigated by laboratory-based photoelectron momentum microscopy and soft X-ray angle-resolved photoemission spectroscopy (ARPES).

MA 47.11 Thu 15:00 Poster D

Ab-inito prediction of chiral spin structures in antiferromagnetic MnN based thin films — •Victor Deinhart[1,2,3], Stefan Blügel[2], and Felix Büttner[1,3] — [1]Helmholtz-Zentrum Berlin, 14109 Berlin, Germany — [2]Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [3]Universität Augsburg, 86159 Augsburg, Germany

Chiral magnetic structures are non-trivial spin structures with a topological charge and can exist in host materials with perpendicular magnetic anisotropy (PMA) where stray fields and Dzyaloshinskii-Moriya interaction (DMI) stabilize them. While chiral structures are readily observed in ferromagnetic materials, their existence in natural antiferromagnets (AFM) has still to be shown. To identify material systems able to host chiral spin structures, we study AFM/heavy metal heterostructures with the aim to stabilize these via spin-orbit interaction induced DMI. Herein, we focus on systems based on θ-MnN, the nitrogen richest phase of all MnN based compounds, featuring an antiferromagnetic ordering and PMA [1]. We present ab-initio calculations of the magnetic exchange interactions based on the FLEUR density functional theory code. Via subsequent atomistic spin simulations, the stability and properties of possible chiral spin structures in the considered thin film systems are analyzed and the most promising material systems for future experimental realization are discussed.

[1] Zilske et al., Appl. Phys. Lett. 110, 192402 (2017)

MA 47.12 Thu 15:00 Poster D

Detection of Nanoscale Magnetic Fields with Scanning NV Magnetometry — •Ricarda Reuter, Sibylle Sievers, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

The key component of Scanning nitrogen-vacancy (NV) measurements is the NV center, a point defect in a diamond host lattice. Due to its unique electronic structure, the NV center can be utilized to detect magnetic fields with sensitivities up to several nT/sqrt(Hz), which are read out optically. Scanning NV setups combine an optical excitation/detection path with an Atomic Force Microscope (AFM), ideally providing nanoscale magnetic and spatial resolution at the same time.

However, the actual magnetic resolution of Scanning NV depends on several factors, including the distance between NV center and sample surface, the shape of the nanodiamond tip, and the measurement time. Quantities like the coherence time and optically detected magnetic resonance (ODMR) contrast of the NV center have to be considered as well.

We discuss the impact of these factors on measurements of typical nanoscale magnetic structures with different characteristic dimensions and compare our results to vacuum Magnetic Force Microscope (MFM) measurements. Due to the versatility of our approach, the sensitivity of other magnetic field sensors such as Hall or SQUID sensors can be calculated in a similar way by considering the respective sensor's parameters. This way, assessing the magnetic resolution and comparing different measurement techniques will be simplified significantly.

MA 47.13 Thu 15:00 Poster D

MAXPEEM: Unique magnetic imaging at MAX IV laboratory — •Evangelos Golias, Yuran Niu, and Alexei Zakharov — MAX IV Laboratory, Lund University, Box 118, 22100 Lund, Sweden

The MAXPEEM beamline at the MAXIV synchrotron facility in Lund, Sweden, houses a state-of-the-art aberration-corrected spectroscopic photoemission and low-energy electron microscope (AC-SPELEEM). MAXPEEM is ideal for studies in material and surface science, 2D and low-dimensional systems, industrial applications, and magnetism. MAXPEEM can perform electron or photoelectron microscopy, diffraction and spectroscopy with spatial resolution down to a single digit in nm. MAXPEEM is the only beamline in the world where x-rays impinge perpendicular to the sample, a geometry that is beneficial for studying particular ferromagnetic and antiferromagnetic systems using x-ray magnetic circular (linear) dichroism (XMCD-PEEM, XMLD-PEEM). Here we present the technical capabilities of the MAXPEEM end-station along with sample studies that highlight how MAXPEEM can accelerate users' magnetic material research.

MA 47.14 Thu 15:00 Poster D

Quantitative magneto optical stray field characterization for magnetic scales — •Nils Magin and Sibylle Sievers — Physikalisch-Technische Bundesanstalt, Braunschweig, Germany

We present the application of magneto optical indicator film based magnetic field measurements to the characterization of magnetic scales. Magnetic scales with incremental pole pattern are combined with Hall or magneto-resistive sensors to build robust magnetic encoders. However, quality control of these scales requires a spatially resolved quantitative analysis of their stray field distribution, which is not possible with the typically several 100 μm wide encoder sensors.

MOIF is a fast (sub second resolution) imaging technique that allows a one-shot characterization and thus high throughput of samples with areas of several square centimeters. It combines the capability to detect fields from the millitesla (mT) to the tesla (T) range with sub-micron spatial resolution. Additionally, it can be used for rough samples without the need for surface treatments.

We here apply magneto-optical indicator film measurements to the characterization of the stray field distribution of magnetic scales and propose procedures to derive parameters of magnetic scales like pole width and field amplitude. The calibration and uncertainty of MOIF based characterizations is discussed.

This project (EMPIR 20SIP04 qMOIF) has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.

MA 47.15 Thu 15:00 Poster D

Quantitative evaluation of disordered remagnetization processes by Kerr microscopy — •Xian Yue Ai[1], Ivan Soldatov[2], Leon Oleschko[1], Rudolf Schäfer[2], and Sebastian T.B. Goennenwein[1] — [1]Department of Physics, University of Konstanz, Germany — [2]Institute for Emerging Electronic Technologies, IFW Dresden, Germany

A quantitative understanding of magnetic domain wall (DW) nucleation and propagation is important not only from a scientific perspective, but also for applications, e.g., in magnetic data storage devices. To date, DW velocity experiments often focus on one single propagation direction, and rely on magnetic field pulses to induce a step-wise DW motion. Strongly disordered, statistic magnetization dynamics remains a topic addressed mostly via simulations and theory.In our study, we use series of Kerr microscopy images taken as a function of time at constant magnetic field to explore re-magnetization in $Pt/Co/AlO_x$ thin films with perpendicular magnetic anisotropy. Inevitable mechanical vibrations and camera noise impede a direct spatially resolved analysis of re-magnetization in the creeping regime. To mitigate these issues, we have developed an approach based on analytical image processing techniques in combination with a correlation-based computational scheme. Our analysis scheme thus enables a quantitative categorization of highly disordered magnetization dynamics with unprecedented resolution. Our technique can be straightforwardly implemented in modern Kerr microscopes, opening interesting perspectives for magnetic material analysis.

MA 47.16 Thu 15:00 Poster D

Advanced transmission electron microscopy of the three-dimensional magnetization distribution of a pinned domain wall in a Sm-Co-based permanent magnet — Aurys Šilinga[1], Trevor P Almeida[1], •András Kovács[2], Ziyuan Rao[3], Tatiana Smoliarova[4], Konstantin P Skokov[5], Baptiste Gault[3], Oliver Gutfleisch[5], Michael Farle[4], and Rafal E Dunin-Borkowski[2] — [1]School of Physics and Astronomy, University of Glasgow, United Kingdom — [2]Ernst Ruska-Centre, Forschungszentrum Jülich, Germany — [3]Max-Planck-Institut für Eisenforschung, Düsseldorf, Germany — [4]Faculty of Physics and Center for Nanointegration, Universität Duisburg-Essen, Duisburg, Germany — [5]Institute of Materials Science, Technische Universität Darmstadt, Darmstadt, Germany

Sm(CoFeCuZr)7 permanent magnets have a high energy product and are commonly used in applications at elevated temperature. Their high coercivity results in part from the pinning of magnetic domain walls at Sm2Co17 and SmCo5 phase boundaries. Here, we use the advanced transmission electron microscopy technique of electron holographic tomography, in combination with model-based reconstruction, to measure the three-dimensional magnetization distribution at a pinned domain wall in a needle-shaped sample of the permanent magnet Sm(CoFeCuZr)7 . The results are discussed by considering both the shape and the magnetocrystalline anisotropy of the sample, as well local variations of its microstructure and chemical composition.

Financially supported by CRC/TRR 270 (HoMMage), Project-No. 405553726-TRR 270.

MA 47.17 Thu 15:00 Poster D

Visualizing Ferrimagnetic Domain Structure with Vector Maps in Dysprosium Iron Garnet — •Khang-Vi Becker[1], Julian Skolaut[2], Miela Josephine Gross[3], Caroline Ross[4], and Angela Wittmann[5] — [1]JGU, Mainz, Deutschland — [2]JGU, Mainz, Deutschland — [3]MIT, Cambridge, US — [4]MIT, Cambridge, US — [5]JGU, Mainz, Deutschland

Ferrimagnets play a key role in revolutionizing spintronic devices due to their favorable properties including low saturation magnetization and ultrafast spin dynamics. An in-depth understanding of the underlying mechanisms is paramount for the integration of ferrimagnets in next-generation memory technologies. For this, imaging the magnetic domain structure is a powerful tool. One method of visualizing magnetic textures are vector maps providing the opportunity to analyze the evolution of the orientation of the Néel vector. This poster will give detailed insight into constructing vector maps from x-ray magnetic linear dichroism images revealing the magnetic domain structure in Dysprosium Iron Garnet (DyIG) thin films. As this approach is based on an angle-dependent examination of the alignment of the Néel vector, this technique offers the possibility of expanding it to antiferromagnets.

MA 47.18 Thu 15:00 Poster D

Simultaneous Magneto-Optical Imaging of Temperature and Magnetic Fields Utilizing YIG Hysteresis Loops — •Michael Path and Jeffrey McCord — Institute for Materials Science, Kiel University, Germany

We present a novel approach for the simultaneous measurement of temperature and magnetic fields. By exploiting the Faraday effect in bismuth-doped yttrium iron garnet, changes in the magnetization state are detected through the rotation of the polarization axis. A Stokes polarization camera in a magneto-topical microscope is used for direct quantification of this rotation. The garnet is modulated with an external field to continuously measure four distinct points on the hysteresis loop. This enables a measurement of the saturation magnetization for temperature, as well as susceptibility and offset, allowing for a self-calibrated measurement of the out-of-plane component of the magnetic field. This method achieves a temporal resolution in the order of milliseconds and a spatial resolution in the micrometer range for temperature and magnetic field. To validate our method, we provide an example with a current-carrying wire.

MA 47.19 Thu 15:00 Poster D

Switching of Magnetic Force Microscopy probes in homogeneous and non-homogeneous magnetic fields — •Rachappa Ravishankar[1,2], Aniruddha Sathyadharma Prasad[1], Michael Heigl[3], Rudolf Schäfer[1], Yana Vaynzof[1,2], Manfred Albrecht[3], Thomas Mühl[1], and Volker Neu[1] — [1]Leibniz Institute for Solid State and Materials Research, 01069 Dresden — [2]Dresden University of Technology, 01187 Dresden — [3]University of Augsburg, 86159 Augsburg

In magnetic force microscopy's lift mode, long-range magnetic and electrostatic interactions dominate, and electrostatic contributions must be separated. This issue is resolved by switching magnetization MFM

(SM-MFM), involving tip magnetization reversals between images allowing us to differentiate non-magnetic and pure magnetic forces by combining scanned data with original and reversed tip magnetization.

We investigate the switching of commercial MFM tips in both homogeneous and non-homogeneous fields. The homogeneous field in z-direction is provided by an electromagnet on which a high-coercive, ferrimagnetic TbFe is placed as a test sample. The non-homogeneous field is created by applying a current pulse into a micro coil patterned on a flat substrate. The magnetization states of the tip are probed on the TbFe sample and we observed a reverse, and low moment (partially magnetized) state. Finally, we characterize the tip magnetization by quantitative magnetic force microscopy (q-MFM) on a well-characterized Co/Pt sample in both reversed and partially magnetized states, determining the corresponding tip transfer function (TTF).

MA 47.20 Thu 15:00 Poster D

The importance of the angle of incidence in magneto-optical Kerr microscopy investigated at micron-sized pyramidical magnetic thin films — •Bhavadip Rakholiya, Christian Janzen, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany

This study investigates the impact of shape anisotropy on the magnetic properties of micron-sized pyramidal magnetic thin films. Utilizing Magneto-Optical Kerr Microscopy (MOKE), we analyze shape-induced modifications in magnetic characteristics. MOKE, based on detecting changes in polarized light reflected from the sample, enables high-resolution examination of magnetic domains and their responses to external stimuli. Specifically, we focus on applying MOKE to study micron-sized pyramidal magnetic thin films, considering challenges related to optical interaction in non-uniform geometries. The spatially dependent angle of incidence introduced by pyramidal structures influences the magneto-optical response. Our findings underscore the significant influence of material shape on magnetic properties and stress the importance of considering light angle changes in MOKE studies of complex shapes, contributing to a deeper understanding of the interplay between shape, optics, and magnetism for enhanced control and application of magnetic materials in various technologies.

MA 47.21 Thu 15:00 Poster D

Understanding the role of phonons in the ion induced phase transition of FeV — •Simon Rauls[1], Benedikt Eggert[1], Shadab Anwar[2], Tom Helbig[1], Kay Potzger[2], Jürgen Lindner[2], Jürgen Fassbender[2], Rantej Bali[2], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

Depending on the Fe concentration, the binary alloy $\mathrm{Fe_{1-x}V_x}$ is usually *bcc*-ordered and exhibits a low energy product as well as low intrinsic Gilbert damping, which makes it a candidate platform for low-loss spintronic devices. While an optimum V concentration of $x = 0.2$ was found for the intrinsic Gilbert damping, at higher concentrations of $x = 0.4$ the formation of a paramagnetic (PM), amorphous phase can be exploited. Using post-growth ion irradiation on the 40 nm thin-films, a phase transition from PM to FM can be achieved, enabling one-step writing of FM structures in a PM template, yielding a Gilbert damping parameter of 0.0027. In order to gain a deeper understanding of the aforementioned phase transition, Nuclear Inelastic Scattering experiments were performed, giving direct insights into the Fe-partial vibrational density of states of the as-grown and ion irradiated films. Along with Mössbauer spectroscopy, the interplay of chemical and structural disorder is deduced.
We acknowledge funding by the DFG through project no. 322462997 and the ESRF for granting the beamtime at beamline ID18.

MA 47.22 Thu 15:00 Poster D

Magneto-transport studies on altermagnetic CrSb — •S. Naduvile Thadathil[1,2], M. Uhlarz[1], M. C. Rahn[2], T. Speliotis[3], J. Wosnitza[1,2], and T. Helm[1] — [1]Dresden High Magnetic Field Laboratory, HZDR — [2]Institute of Solid State and Materials Physics, TU Dresden — [3]Institute of Nanoscience and Nanotechnology, Demokritos, Greece

The recent discovery of a distinct magnetic phase called "altermagnetism" (AM) has been based on spin-symmetry groups. An anomalous Hall effect (AHE), as found in ferromagnets, has been predicted and observed in ruthenium dioxide (RuO_2) despite the antiparallel magnetic order, which is linked to the AM. Here, we present results from magnetotransport studies on micron-sized structures cut from single crystals of CrSb. The magnetoresistance and the Hall effect were investigated between 1.8 and 300 K in fields up to 16 T for structures with current applied along the *a* and *c* axis. Below 3 K and at low magnetic fields, the longitudinal resistance for structures where the current is applied along the *c* axis exhibits a significant deviation from the field-dependent high-temperature quadratic behavior. We observed a significant AHE in CrSb. Interestingly, a planar Hall contribution is observed when the current is applied along the *c* axis of the crystal, which is absent for the current applied along the *a* axis. These findings may provide further evidence for the altermagnetic phase.

MA 47.23 Thu 15:00 Poster D

Vortex-based magnetic field sensors characterised by in-plane and out-of-plane magnetic fields — •Sophie Knewitz[1], Giovanni Masciocchi[1,2], Johannes Paul[2], Mathias Kläui[1], and Angela Wittmann[1] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]Sensitec GmbH, Mainz, Germany

Magnetic sensors are indispensable for several everyday applications, due to their ability to measure speed, position, and orientation by means of magnetic fields [1]. Vortex-based magnetic field sensors can exhibit higher performance compared to conventional magnetic sensors due to hysteresis-free behaviour and low noise levels [2]. For developing them, it is essential to know about the spin structures' behaviour.

This project investigates the in-plane (IP) and out-of-plane (OOP) field sensitivity of circular vortex-based sensors. Using tunnel magnetoresistance, hysteresis curves of the samples are measured with a 2D vector magnet for varying OOP magnetic fields. We find that the magnetic vortex devices are remarkably robust against OOP fields up to at least 175 mT. Additionally, the hysteresis curves are sensitive to small misalignment of the sample with respect to the field axis. This implies careful characterisation is paramount for ensuring comparability.

These features, robustness in OOP fields and sensitivity to angular displacement, are very advantageous for IP sensors by facilitating accurate measurements of IP fields and detecting angular deviations.

References

[1] Jogschies, et al. Sensors 15.11, 28665-28689 (2015).
[2] Suess, et al. Nature Electronics 1.6, 362-370 (2018).

MA 47.24 Thu 15:00 Poster D

Optimizing MPMS Measurement Precision through 3D Printed Sample Holders: A Systematic Study on $\mathbf{Ba_3CrN_3H}_x$ — •Rebecca Müller-Zurlinden[1], Anton Jesche[1], Peter Höhn[2], Natalia Gloriozova[2], and Philipp Gegenwart[1] — [1]Experimental Physics VI, Center for Electronic Correlations and Magnetism, University of Augsburg, 86159 Augsburg, Germany — [2]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

The accuracy of MPMS measurements depends on several critical factors, including sample geometry, mounting position and magnitude of the magnetic moment. In order to obtain the best possible results, these factors, as well as the background contribution of the sample holder have to be considered. This study investigates the advantages of using 3D printed sample holders in the context of determining the magnetic properties of $\mathrm{Ba_3CrN_3H}_x$. Key benefits of 3D printed samples include uniform material in the holder throughout the MPMS scan range. A precisely designed sample space, printed to the exact dimensions of the sample minimises the measured background as well as axial or radial displacement errors during measurement. The sample space allows for mounting and measurement in any orientation, and measurement of reactive materials without contamination of varnish or adhesives. The airtight sample space ensures precise sealing allowing controlled mounting and measurement of air-sensitive samples. These benefits are demonstrated by precisely studying the field- and temperature-dependent magnetization of $\mathrm{Ba_3CrN_3H}_x$ (x = 0 - 0.5).

MA 47.25 Thu 15:00 Poster D

Quantitative Magnetic Force Microscopy from nm to mm — •Christopher Habenschaden[1], Sibylle Sievers[1], Andrea Cerreta[2], and Hans Werner Schumacher[1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Park Systems Europe GmbH, Mannheim, Germany

Magnetic Force Microscopy (MFM) is a well-established technique in Scanning Probe Microscopy (SPM) allowing imaging of magnetic samples with spatial resolution of tens of nm and stray fields down to the mT range.

Spatial resolution and field sensitivity can be pushed to several nm and the hundred μT range by measuring in vacuum conditions due to a higher Q-factor of the cantilever oscillation. This increasing field sensitivity, in turn, also allows increasing the working distance from the surface. We show that for μm-patterned magnetic samples, signals well above the noise floor are detectable even up to 100 μm above the surface. This enables scanning of mm-sized structures, which can be realized either by stitching 100 μm MFM scans or by much less time-consuming stage-scanning.

We present an implementation of both techniques into a Park Systems NX-Hivac vacuum SPM. A phase-locked loop-based signal detection is used to ensure high sensitivity and elimination of non-linearities. This setup enables MFM measurements to cover the full length range from the nm-regime up to several millimeters and thus to bridge the gap in spatially resolved magnetic field measurements from nano scale SPM to macroscopic measurements using optical indicator films.

MA 47.26 Thu 15:00 Poster D

SquidLab - a user-friendly program for background subtraction and fitting of magnetization data — •Matthew Coak[1,2,3,4,5], Cheng Liu[3,6], David Jarvis[3], Seunghyun Park[4,5], Matthew Cliffe[7], and Paul Goddard[2] — [1]University of Birmingham, Birmingham, UK — [2]University of Warwick, Coventry, UK — [3]University of Cambridge, Cambridge, UK — [4]CCES Institute for Basic Science, Seoul, South Korea — [5]Seoul National University, Seoul, South Korea — [6]CamCool Research Ltd, Cambridge, UK — [7]University of Nottingham, Nottingham, UK

We present an open-source program with full user-friendly graphical interface for performing flexible and robust background subtraction and dipole fitting on magnetization data. For magnetic samples with small moment sizes or sample environments with large or asymmetric magnetic backgrounds, it can become necessary to separate background and sample contributions to each measured raw voltage measurement before fitting the dipole signal to extract magnetic moments.

Originally designed for use with pressure cells on an MPMS3 magnetometer, SquidLab is a modular object-oriented platform implemented in Matlab with a range of importers for different widely-available magnetometer systems and has been tested with a broad variety of background and signal types. The software allows background subtraction of baseline signals, signal preprocessing, and performing fits to dipole data. A plugin system allows users to easily extend the built-in functionality. Squidlab now has over 1000 downloads, to labs worldwide. (Coak et al Rev. Sci. Instr. 91, 023901 (2020)

MA 47.27 Thu 15:00 Poster D

Magnetic properties of FeNi thin film systems — •Inga Ennen, Roland Schubert, Nancy Töws, Laila Bondzio, and Andreas Hütten — Bielefeld University, Bielefeld, Germany

FeNi alloys are the basis for a large number of different technical materials. Despite their widespread use, e.g. in stainless steel or Hall sensors, the influence of magnetism on the martensitic phase transition in FeNi alloys is not fully understood.

In this contribution, we focus on the magnetic properties of FeNi thin film systems that exhibit high strain coupling due to the preparation of alternating layers crystallized mainly in the martensite and austenite phase. Magnetometry measurements as well as magnetic imaging techniques using a transmission electron microscope are applied to the thin film systems and correlated with micromagnetic simulations.

MA 47.28 Thu 15:00 Poster D

Real-time in-situ giant magnetoresistance measurements in Co/Cu multilayers during sputter deposition — •Michael Mattern, Jan Michael Schmalhorst, and Günter Reiss — Bielefeld University, Faculty of Physics, Germany

Magnetoresistive sensors generate important input information that is further processed in complex microelectronic systems in a wide range of applications. For optimization purposes or the investigation of new material combinations, a permanent analysis of the influence of deposition conditions on the magnetoresistive performance is necessary. Today, research and development in the field of magnetic sensor technology ist slowed down due to slow feedback from results of ex-situ characterization of samples into modelling and production. This study presents an experimental technique for real-time in-situ measurements of magnetoresistive effects, such as giant magnetoresistance (GMR), during the sputtering process. As an example, an oscillating in-plane magnetic field with an amplitude of 420 Oe and a frequency of 10 Hz was applied to samples of cobalt/copper multilayers during film growth. By employing advanced instrumentation with a sampling rate of 20 kS/s and the implementation of real-time GMR amplitude calculation, we were able to obtain and analyze complete R versus H curves within 100 milliseconds. Correlations between the magnetic response of these samples and structural changes at different stages of film deposition are shown.

MA 47.29 Thu 15:00 Poster D

Ferromagnetic quantum critical point in $Sr_{1-x}Ca_xRuO_3$ approximated by artificial $[SRO_n/CRO_m]_l$ superlattices — •Robin Heumann, Robert Gruhl, and Philipp Gegenwart — Experimentalphysik VI, Universität Augsburg, 86159 Augsburg, Germany

Partial substitution of smaller Ca to the Sr site in the itinerant ferromagnetic $SrRuO_3$ (SRO) leads to the suppression of magnetic order and interesting non-Fermi liquid properties beyond about 70% Ca concentration [1]. However, the quantum critical point can smear out strongly by structural disorder [2]. Therefore, we explore the possibility whether a quantum critical point could also be realized in structurally ordered epitaxial heterostructures of SRO and $CaRuO_3$ (CRO).

Heterostructures $[SRO_n/CRO_m]_l$/STO(001) with $m = 2n$ and $m = 3n$ were prepared by metal organic aerosol deposition. Structural studies were performed via X-ray diffraction, reciprocal space mapping and TEM imaging. The electronic and magnetic properties were investigated via Hall-, magnetoresistance and magnetization measurements and compared to $Sr_{1-x}Ca_xRuO_3$ thin films with $x = 2/3$ and $x = 3/4$.

[1] M. Schneider *et al.*, phys. stat. sol. (b), **247** (2010) 200983004.
[2] L. Demkó *et al.*, Phys. Rev. Lett **108** (2012) 185701.

MA 47.30 Thu 15:00 Poster D

Isotropic Exchange-Bias in Twinned Epitaxial Co/Co3O4 Bilayer — •Martin Wortmann[1], Tapas Samanta[1], Maik Gaerner[1], Michael Westphal[1], Johannes Fiedler[2], Inga Ennen[1], Andreas Hütten[1], Tomasz Blachowicz[3], Luana Caron[1,4], and Andrea Ehrmann[2] — [1]Bielefeld University, Bielefeld, Germany — [2]Bielefeld University of Applied Sciences, Bielefeld, Germany — [3]Silesian University of Technology, Gliwice, Poland — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany

Exchange bias (EB) is a unidirectional anisotropy caused by interface coupling between a ferro- and an antiferromagnet. It causes a preferential direction of magnetization in the ferromagnet, which manifests as a shift of the hysteresis loop along the magnetic field axis. Here, we demonstrate a large EB of over 1000 Oe at 20 K in a twinned Co(111)/Co3O4(111) thin film epitaxially grown on sapphire(0001) with 6-fold rotational lattice symmetry, which is among the highest values reported for Co/Co1-yO systems. In such systems, the effect intensity is largest along the magnetic easy axes, which usually results in an anisotropy of the EB in epitaxial interfaces. However, we observed identical EB values for 0°, 15°, and 30° angles between the magnetic field and the nearest Co[002] magnetic easy axes. The measurements imply a relaxation of the magnetization to the nearest easy axis, suggesting increasingly isotropic EB fields with higher orders of rotational lattice symmetry.

MA 47.31 Thu 15:00 Poster D

Magneto-optical investigation of epitaxially grown Mn_2Au on Au capped Nb(100) — •Jendrik Gördes[1], Tauqir Shinwari[1], Tingwei Li[1], Arne Vereijken[2], Christian Janzen[2], Arno Ehresmann[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Berlin, Germany — [2]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Kassel, Germany

Antiferromagnetic materials are promising candidates for future data storage devices due to the absence of magnetic stray fields and spin dynamics in the THz range. Mn_2Au stands out as a particularly promising material, capable of electrical switching [1] through Néel spin-orbit torque without the need for an additional heavy metal layer. Here, we report on the co-evaporation of Mn_2Au and Fe on a Nb(100) substrate capped by a pseudomorphic monolayer of Au via flash annealing. This preserves the long-range crystallographic order and periodicity of Nb [2] while preventing surface oxidation. Layer-by-layer growth of Mn_2Au is monitored in-situ via medium-energy electron diffraction (MEED). Structural analysis is carried out by Auger electron spectroscopy (AES) and low-energy electron diffraction (LEED). After field-cooling, dynamics of the exchange-bias-shifted magnetization loop are studied by Kerr magnetometry and microscopy. Our results highlight the feasibility to expand the range of available substrates to metal single crystals for the growth of Mn_2Au layers.

[1] J. Zelezny, H. Gao, K. Vyborny et al., Phys. Rev. Lett. 113 (2014)
[2] E. Hüger, H. Wormeester, K. Osuch, Surf. Sci. 580 (2005)

MA 47.32 Thu 15:00 Poster D

Impact of ion bombardment on the magnetic proximity effect in Pt/Fe bilayers — •Mika Ossenschmidt[1], Maik Gaerner[1], Varun Vanakalapu[2], Arne Vereijken[2], Arno Ehresmann[2], and Timo Kuschel[1] — [1]Bielefeld University, Germany — [2]University of Kassel, Germany

KeV-He ion bombardment of thin-film interfaces offers the opportunity to modify the interface properties of thin-film systems, including the roughness σ. In case of magnetic interfaces, the magnetic properties can be altered by low-sputter yield keV light ion bombardment without destroying the thin films, e.g. as shown for exchange-bias systems [1].

We have prepared samples of Pt 4.5nm/Fe 10nm//MgO(001) by sputter deposition and investigated the impact of ion bombardment on the magnetic proximity effect in Pt. The subsequent ion bombardment dose varied from 10^{15} to 10^{17} 1/cm^2. We measured x-ray resonant magnetic reflectivity [2,3] at the Pt L_3 absorption edge (11.568keV) at room temperature and in air at DESY beamline P09. The fits of the x-ray reflectivity measurements provide a significant difference for the roughness σ of the Pt/Fe interface due to ion bombardment while layer thicknesses, substrate roughness, and surface remained nearly unchanged. The resulting maximum Pt moment at the interface for the sample with ion bombardment is higher than without ion bombardment.

[1] Ehresmann et al., J. Phys. D: Appl. Phys. 38, 801 (2005)
[2] Macke et al., J. Phys.: Condens. Matter 26, 363201 (2014)
[3] Kuschel et al., Phys. Rev. Lett. 115, 097401 (2015)

MA 47.33 Thu 15:00 Poster D

Magnon-phonon interactions from first principles — •László Udvardi — Budapest University of Technology and Economics, Budapst, Hungary

Spintronics is an emerging field of recent solid state researches. In spintronics magnons hold great promise for quantum and classical information processing due to excellent scalability, tunability and energy-efficiency of magnonic devices. Among several important aspects of spin waves their interactions with phonons is one of the interesting area. Magnetic systems are often described by classical spin models. The exchange couplings, Dzyaloshinsky-Moriya interactions and magnetic anisotropy parameters appearing in the spin models can be determined from first principles. A recent review [1] discusses the most frequently used ab-initio methods. In point of view of magnon-phonon interactions the change of the exchange interactions against small displacement of the magnetic atoms have crucial importance.

In spirit of torque method we derived formulas for the change of the exchange couplings and magnetic anisotropy parameters with respect of small displacement of the atomic positions by means of multiple scattering theory. We have found a contribution which is not present in a recent paper by Mankovsky et al.[2]. The results are demonstrated on a Fe monolayer on surface of Au(001).

[1] A. Szilva et al., Rev. Mod. Phys. 95,035004 (2023)
[2] S. Mankovsky et al., Phys. Rev. Letter 129,067202 (2022)