MA 31: Functional Antiferromagnetism II

Time: Wednesday 15:00–17:15 Location: HSZ 04

MA 31.1 Wed 15:00 HSZ 04

Role of substrate clamping on anisotropy and domain structure in the canted antiferromagnet α-Fe2O3 — •Angela Wittmann[1,2], O Gomonay[1], K Litzius[2,3], A Kaczmarek[2], A Kossak[2], D Wolf[4], A Lubk[4], T N Johnson[5], E Tremsina[2], A Churikova[2], F Büttner[6], S Wintz[6], M A Mawass[6], M Weigand[6], F Kronast[6], L Scipioni[7], A Shepard[7], T Newhouse-Illige[7], J A Greer[7], G Schütz[3], N O Birge[2,5], and G S D Beach[2] — [1]Johannes Gutenberg Universität Mainz, Germany — [2]Massachusetts Institute of Technology, USA — [3]Max Planck Institute for Intelligent Systems, Germany — [4]Leibniz IFW Dresden, Germany — [5]Michigan State University, USA — [6]Helmholtz-Zentrum Berlin, Germany — [7]PVD Products, USA

Antiferromagnets are at the forefront of research in spintronics. However, many of the underlying phenomena remain to be explored. This work investigates the domain structure in a thin-film canted antiferromagnet α-Fe2O3 in an external magnetic field. Using x-ray magnetic linear dichroism (XMLD) and spin Hall magnetoresistance (SMR) measurements, we find that the internal long-range destressing fields driving the formation of domains do not follow the crystal symmetry of α-Fe2O3 but fluctuate due to substrate clamping [1]. This leads to locally varying effective anisotropy in thin films allowing for the stabilization of long-range complex domain structures. The insights gained from our work serve as a foundation for further studies of electrical and optical manipulation of the domain structure of antiferromagnetic thin films. [1] arXiv:2210.16141

MA 31.2 Wed 15:15 HSZ 04

Two-directional electrical switching of insulating antiferromagnetic thin films — •Christin Schmitt[1], Adithya Rajan[1], Grischa Beneke[1], Aditya Kumar[1], Tobias Sparmann[1], Hendrik Meer[1], Rafael Ramos[2], Miguel Angel Niño[3], Michael Förster[3], Eiji Saitoh[2,4], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [2]WPI-AIMR, Tohoku University, Japan — [3]ALBA Synchrotron Light Facility, Spain — [4]Department of Applied Physics, The University of Tokyo, Japan

Antiferromagnets (AFMs) have gained increasing interest as active elements in spintronic devices due to intrinsic dynamics in the THz range and the absence of stray fields. However, efficient electrical writing and reading is necessary for applications. For insulating antiferromagnets different switching mechanisms based on spin-orbit torques or thermo-magnetoelastic effects have been put forward [1,2]. Here, we focus on CoO/Pt thin films where we observe that electrical pulses along the same trajectory can lead to an increase or decrease of the electrical signal, depending on the current density of the pulse. By photoemission electron microscopy (PEEM) employing the x-ray magnetic linear dichroism (XMLD) effect we shed light on this observation and determine whether this is a sign for two competing switching mechanisms or rather some result of the sensitivity distribution of how the electrical measurement is conducted [3]. [1] T. Moriyama, et al., Sci. Rep. 8, 14167 (2018). [2] P. Zhang, et al., Phys. Rev. Lett. 123, 247206 (2019). [3] F. Schreiber, et al., Phys. Rev. Applied 16, 064023 (2021).

MA 31.3 Wed 15:30 HSZ 04

Control and manipulation of antiferromagnetic domains in NiO — •Hendrik Meer[1], Christin Schmitt[1], Olena Gomonay[1], Stephan Wust[2], Paul Herrgen[2], Baerbel Rethfeld[2], Benjamin Stadmüller[1,2], Martin Aeschlimann[2], Jairo Sinova[1], Rafael Ramos[3,4], Lorenzo Baldrati[1], Eiji Saitoh[4,5], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Mainz, Germany — [2]Department of Physics and Research Center OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [3]CIQUS, Departamento de Quimica-Fisica, Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [4]WPI-Advanced Institute for Materials Research, Tohoku University, Sendai, Japan — [5]Department of Applied Physics, The University of Tokyo, Tokyo, Japan

Control of the spin structure is key for the development of future antiferromagnetic spintronic devices. We show how the antiferromagnetic domains of NiO/Pt bilayers can be modified by applying electric currents [1], patterning geometric elements [2], and irradiating with laser light [3]. We image the induced changes in the antiferromagnetic order with synchrotron and lab-based magnetic microscopy. We are able to reveal writing mechanisms for the antiferromagnetic order, laying the foundation for an active role of antiferromagnets in future devices.

[1] H. Meer *et al.*, Nano Lett. **21**, 114 (2021).
[2] H. Meer *et al.*, Phys. Rev. B **106**, 094430 (2022).
[3] H. Meer *et al.*, arXiv:2210.11009 [cond-mat.mtrl-sci] (2022).

MA 31.4 Wed 15:45 HSZ 04

Gate-tunable anomalous Hall effect in an antiferromagnet — Seo-jin Kim[1], Jihang Zhu[2], Mario Piva[1], Marcus Schmidt[1], Dorsa Fartab[1], Andrew Mackenzie[1,3], Michael Baenitz[1], Michael Nicklas[1], Helge Rosner[1], Ashley Cook[1,2], and •Haijing Zhang[1] — [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 — [3]Scottish Universities Physics Alliance, School of Physics and Astronomy, University of St Andrews, St Andrews KY16 9SS, UK

Probing and engineering the magnetic states is a key goal in contemporary condensed matter physics because it can facilitate the understanding of underlying mechanisms of many fundamental physical phenomena, such as the anomalous Hall effect. Here, we report the observation of an anomalous Hall effect in $AgCrSe_2$, a layered triangular lattice metal that lacks inversion symmetry, and has a sizeable antiferromagnetic coupling between Cr spin 3/2 moments in adjacent layers. The anomalous Hall resistivity 3 $\mu\Omega$ cm is comparable to the largest magnitude observed in any antiferromagnetic system to date. We further demonstrate that the anomalous Hall response in thin layer devices can be switched on and off by an ionic gate. We also present the results of an illustrative model that suggests the anomalous Hall effect is driven by Berry curvature that correlates closely with the Rashba spin-orbit coupling. The capability of electrically switching the anomalous Hall effect opens up new avenues for potential voltage controlled spintronic devices.

15 min. break

MA 31.5 Wed 16:15 HSZ 04

In plane magnetic field dependence of anomalous Hall effect in a non-collinear antiferromagnet — •Adithya Rajan[1], Tom Saunderson[1,2], Fabian Lux[1], Dongwook Go[1], Hasan Abdullah[3], Tetsuya Hajiri[4], Hidefumi Asano[4], Udo Schwingenschloegl[3], Yuriy Mokrousov[1,2], and Mathias Klaeui[1] — [1]Institute of Physics, Johannes Gutenberg University, Staudingerweg 7, 55128 Mainz, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich, 52424 Jülich, Germany — [3]King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia — [4]Department of Materials Physics, Nagoya University, Nagoya 464-8603, Japan

Non-collinear antiferromagnets (NC-AFM) have attracted much attention recently due to the observation of the anomalous Hall effect (AHE) in these materials [1]. Here we study the AHE as a function of magnetic field direction in the Kagome plane of the antiperovskite nitride Mn3Ni0.35Cu0.65N. We explain the results in the context of irreducible representations of the three-spin unit cell, showing a strong interplay between field dependence of AHE and the octupole moment by fitting to density functional theory calculations. Further, we present non-trivial features in the field dependent AHE loops signifying additional stable spin configurations, and potentially novel transport phenomena. These results open the possibility of a lever through which the spin structure in NC-AFMs can be controlled.

[1] S.Nakatsuji et al., Nature 527, 212 (2015).

MA 31.6 Wed 16:30 HSZ 04

Anomalous Hall Effect in Antiperovskite Nitride Thin Films Driven by Structural Disorder — •Berthold H. Rimmler, Binoy K. Hazra, Holger L. Meyerheim, and Stuart S. P. Parkin — Max Planck Institute of Microstructure Physics, Halle

Antiperovskites display unusual properties such as complex magnetism, superconductivity, negative thermal expansion and distinct magneto-transport effects, which render them interesting for various applications. For instance, Mn-based antiperovskite nitrides, Mn3ZN (Z = Ni, Ga, Sn), have attracted attention in spintronics, as they can host non-collinear antiferromagnetism and other complex magnetic phases. These give rise to unusual intrinsic magneto-transport effects, such as the anomalous Hall effect in absence of magnetization or the spin Hall effect where spin currents display arbitrary spin polarization directions. Control of the antiferromagnetic domain structure in these materials is essential for using these effects in spintronic devices. Therefore, an imbalance of the otherwise fully compensated non-collinear antiferromagnetic textures is required. Previously, strain-driven tetragonal distortion was assumed to be the mechanism allowing for domain control. In this work we show, by comparison of different Mn-based antiperovskite nitrides and using advanced X-ray diffraction measurements, that domain structure control is, instead, enabled by displacements of Mn atoms out of high symmetry positions that locally break the global crystal and magnetic symmetry. We demonstrate that this effect is a general feature of a number of Mn3ZN compounds and might, therefore, also have implications for other antiperovskites.

MA 31.7 Wed 16:45 HSZ 04

Flexomagnetism and vertically graded Néel temperature of antiferromagnetic Cr_2O_3 thin films — •Pavlo Makushko[1], Tobias Kosub[1], Oleksandr Pylypovskyi[1], Natascha Hedrich[2], Jiang Li[1], Alexej Pashkin[1], Stanislav Avdoshenko[3], René Hübner[1], Fabian Ganss[1], Daniel Wolf[3], Axel Lubk[3,4], Maciej Oskar Liedke[1], Maik Butterling[1], Andreas Wagner[1], Kai Wagner[2], Brendan Shields[2], Paul Lehmann[2], Igor Veremchuk[1], Jürgen Fassbender[1], Patrick Maletinsky[2], and Denys Makarov[1] — [1]HZDR, Dresden, Germany — [2]University of Basel, Basel, Switzerland. — [3]IFW Dresden, Dresden, Germany — [4]TU Dresden, Dresden, Germany.

Thin films of antiferromagnetic insulators are a prospective material platform for magnonics, spin superfluidity, THz spintronics, and non-volatile data storage. Here, we explore the presence of flexomagnetic effects in epitaxial Cr_2O_3 [1]. We demonstrate that a gradient of mechanical strain affects the order-disorder magnetic phase transition, resulting in the distribution of the Néel temperature along the thickness of a Cr_2O_3 film. The inhomogeneous reduction of the antiferromagnetic order parameter induces a flexomagnetic coefficient of about $15\mu B\ nm^{-2}$. The antiferromagnetic ordering in the strained films can persist up to 100°C, rendering Cr_2O_3 as a prospective material for industrial electronics applications.

[1] P. Makushko et al., Nat Commun 13, 6745 (2022).

MA 31.8 Wed 17:00 HSZ 04

Ferromagnetism and Ferroelectricity in a Superlattice of Antiferromagnetic Perovskite Oxides Without Ferroelectric Polarization — •Avijeet Ray, Paresh C. Rout, and Udo Schwingenschlögl — Physical Sciences and Engineering Division (PSE), King Abdullah University of Science and Technology (KAUST), Thuwal 23955-6900, Saudi Arabia

Using density functional theory with onsite Coulomb interaction, we study the structural, electronic, and magnetic properties of the $SrCrO_3/YCrO_3$ superlattice and their dependence on epitaxial strain. We discover that the superlattice adopts an A-type antiferromagnetic (A-AFM) ordering in contrast to its constituents ($SrCrO_3$: C-AFM; $YCrO_3$: G-AFM) and retains it under compressive strain while becoming ferromagnetic (5 μ_B per formula unit) at +1% strain. The obtained ferroelectric polarization is significantly higher than that of the R_2NiMnO_6/La_2NiMnO_6 (R = Ce to Er) series of superlattices [Nat. Commun. 5, 4021 (2014)] due to a large difference between the antipolar displacements of the Sr and Y cations. The superlattice is a hybrid-improper multiferroic material with a spontaneous ferroelectric polarization (13.5 $\mu C/cm^2$) approaching that of bulk $BaTiO_3$ (19 $\mu C/cm^2$). In addition, the charge-order-driven p-type semiconducting state of the ferromagnetic phase (despite the metallic nature of $SrCrO_3$) is a rare property and interesting for spintronics. Monte Carlo simulations demonstrate a magnetic critical temperature of 90 K for the A-AFM phase without strain and of 115 K for the ferromagnetic phase at +5% strain, for example.