KFM 7: Multiferroics

Time: Monday 15:00–18:30 Location: H47

KFM 7.1 Mon 15:00 H47

Insights into the coupled domains in conical spin-driven multiferroics — •Jonas K. H. Fischer, Kenta Kimura, Ryusuke Misawa, and Tsuyoshi Kimura — Department of Advanced Materials Science, University of Tokyo, Japan

Multiferroics offer opportunities for new and previously unattainable applications [1]. Especially sought-after is the mutual control of magnetization and electric polarization by electric and magnetic fields, the so-called magnetoelectric effect. The "conical spin structure" is a rather complicated spiral magnetic order that breaks both time-reversal and space-inversion symmetries and leads to a ferromagnetic-ferroelectric, i.e., multiferroic ground state. So far only a few conical spin-driven multiferroics have been reported, among them spinel-type $CoCr_2O_4$ [2] and olivine-type Mn_2GeO_4 [3]. Recently, an intriguing domain coupling, that is, magnetoelectric inversion of domain patterns, has been reported in Mn_2GeO_4 [4,5].
However, the coupling mechanism among the various domains of the conical spin-driven multiferroics has not yet been fully understood. In addition to electric and magnetic fields, uniaxial pressure is expected to affect their domain coupling. In this study, the effect of uniaxial stress on the magnetoelectric properties is examined.
[1] M. Fiebig *et al.*, Nat. Rev. Mater. **1**, 16046 (2016).
[2] Y. Yamasaki *et al.* Phys. Rev. Lett. **96**, 207204 (2006).
[3] J. S. White *et al.* Phys. Rev. Lett. **108**, 077204 (2012).
[4] T. Honda *et al.* Nat. Commun. **8**, 15457 (2017).
[5] N. Leo *et al.*, Nature **560**, 466 (2018).

KFM 7.2 Mon 15:20 H47

Domain dynamics in $LiCuVO_4$: Evidence for polarized nanoregions — •Christoph P. Grams[1], Severin Kopatz[1], Daniel Brüning[1], Sebastian Biesenkamp[1], Petra Becker[2], Ladislav Bohatý[2], Thomas Lorenz[1], and Joachim Hemberger[1] — [1]University of Cologne, Institute of Physics II, Zülpicher Str. 77, 50937 Cologne, Germany — [2]University of Cologne, Institute of Geology and Mineralogy, Section Crystallography, Zülpicher Str. 49b, 50674 Cologne, Germany

$LiCuVO_4$ is a model system of a 1D spin-1/2 chain that enters a multiferroic planar spin-spiral ground state below its Néel temperature of 2.4 K with electric polarization along the a axis. With external magnetic fields in c direction T_N can be suppressed down to 0 K at 7.4 T.

Here we report dynamical measurements of the polarization from $P(E)$-hysteresis loops, magnetic field dependent pyro-current and non-linear dielectric spectroscopy as well as thermal expansion and magnetostriction measurements at very low temperatures. Our measurements find a sizable magnetoelastic coupling in $LiCuVO_4$ that strongly influences all observed quantities. Most striking is the observation of a growth dimension $d \approx 0.25$, i.e. strong pinning of the domain walls, from the non-linear polarization dynamics. Further analysis finds the domain sizes to be in the nm range.

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KFM 7.3 Mon 15:40 H47

Low frequency phonons in rare-earth langasites — •Lorenz Bergen[1], Lukas Weymann[1], Andrei Pimenov[1], Artem Kuzmenko[2], Alexander A. Mukhin[2], and Evan Constable[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia

Rare-earth langasites are characterized by geometric magnetic frustration exhibiting magneto-electric effects, high piezoelectric properties, and may even support a spin-liquid ground state. To better understand the interplay between the structural and magnetic degrees of freedom it is important to study the phonon and crystal electric field spectra that can be observed in the far infrared (FIR) range. The langasite structure crystallizes in the P321 space group with a general formula $A_3BC_3D_2O_{14}$. Our study presents spectra of the rare-earth langasite $N_3Ga_5SiO_{14}$ using far-infrared reflection spectroscopy. Experiments have been performed with polarized radiation along different crystallographic axes and under different sample temperatures. Phonon excitations at unusually low frequencies are observed that brings the crystal structure of langasites close to a lattice instability. The results of neodymium and holmium-substituted langasites will be compared with the pure $La_3Ga_5SiO_{14}$ langasite compound that does not show effects like magnetic frustration.

KFM 7.4 Mon 16:00 H47

Magnetic Structure and Magnetoelectricity in Holmium-Doped Langasite — •Lukas Weymann[1], Lorenz Bergen[1], Thomas Kain[1], Anna Pimenov[1], Alexey Shuvaev[1], Evan Constable[1], David Szaller[1], Artem M. Kuzmenko[2], Alexander A. Mukhin[2], Vsevolod Yu. Ivanov[2], Nadezhda V. Kostyuchenko[1,3], Maxim Mostovoy[4], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]A. M. Prokhorov General Physics Institute of Russian Academy of Sciences, 119991 Moscow, Russia — [3]Moscow Institute of Physics and Technology, 141700 Dolgoprudny, Moscow region, Russia — [4]Theory of Condensed Matter, Zernike Institute for Advanced Materials, 9747 AG Groningen, The Netherlands

The family of the rare-earth langasites $R_3Ga_5SiO_{14}$ attracted significant attention due to their intriguing magnetic and magnetoelectric properties. However, in the langasites with only one magnetic sublattice of the rare-earth ions no magnetoelectric effect was observed till now.

In this work we present the results on a magnetoelectric effect, i.e. electric polarization induced by an external magnetic field, in the diluted rare-earth langasite $(Ho_{0.03}La_{0.97})_3Ga_5SiO_{14}$, with an unusual six-fold symmetry. Its rather complex magnetic structure can be resolved via magnetization, torque and dynamic experiments. Magnetic and magnetoelectric properties can be understood by taking into account the interplay between crystal symmetry and the local symmetry of the Holmium ions.

KFM 7.5 Mon 16:20 H47

Orbital-Order Driven Ferroelectricity and Dipolar Relaxation Dynamics in Multiferroic $GaMo_4S_8$ — •Korbinian Geirhos[1], Peter Lunkenheimer[1], Hiroyuki Nakamura[2], Takeshi Waki[2], Yoshikazu Tabata[2], and Istvan Kezsmarki[1] — [1]Experimental Physics V, EKM, University of Augsburg — [2]Department of Materials Science and Engineering, Kyoto University, Japan

$GaMo_4S_8$, a compound of the lacunar spinel family, was recently shown to exhibit non-canonical, orbitally-driven ferroelectricity [1]. Our dielectric spectroscopy measurements on this multiferroic material reveal complex relaxation dynamics, above as well as below its Jahn-Teller transition at $T_{JT} = 47$ K [2]. Above the Jahn-Teller transition, two types of coupled dipolar-orbital dynamics were found: On the one hand, relaxations within cluster-like regions with short-range polar order, as known from relaxor ferroelectrics. On the other hand, critical fluctuations of only weakly interacting dipoles, resembling the typical dynamics of order-disorder type ferroelectrics. Below T_{JT}, the system is driven into long range ferrolectric order by the onset of orbital order and dipolar dynamics within the ferroelectric domains is observed: The found marked differences to the skyrmion host GaV_4S_8, seem to be related to the different structural distortions in these systems.

[1] E. Neuber,*et al.*, J. Phys.: Condens. Matter **30**, 445402 (2018)
[2] K. Geirhos, *et al.*, arXiv:1810.07145

Break

KFM 7.6 Mon 17:10 H47

Interplay of structural distortions and magnetism in lacunar spinels — •Sergey Artyukhin[1], Giulia Biffi[1], and István Kézsmárki[2] — [1]Italian Institute of Technology, Genova, Italy — [2]University of Augsburg, Germany

Lacunar spinels contain tetrahedral clusters of transition metal compounds whose molecular orbitals host electrons, delocalized over the cluster. Partial occupations of degenerate molecular orbitals are thought to lead to Jahn-Teller distortions that influence magnetic exchange interactions between clusters, giving rise to a multitude of distortion patterns and magnetic ground states, including non-collinear states and skyrmion lattices. Here we use effective Hamiltonians with parameters derived from ab-initio calculations to address the complex

phase diagram of these compounds.

KFM 7.7 Mon 17:30 H47

Imaging of ferroelectric domains in $Ca_3Mn_{1.9}Ti_{0.1}O_7$ by second harmonic generation — •Yannik Zemp[1], Mads C. Weber[1], Thomas Lottermoser[1], Bin Gao[2], Sang-Wook Cheong[2], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich — [2]Rutgers University, New Jersey

One of the most important challenges towards the application of multiferroics – materials with coexisting magnetic and ferroelectric order, is to find a material with a robust coupling between ferroelectricity and magnetism and a sufficiently large polarisation at high temperatures. Magnetic hybrid-improper ferroelectrics, in particular $Ca_3Mn_2O_7$, where magnetism and ferroelectricity are induced through the same lattice instability, were theoretically proposed as a possible solution. Experimentally, however, ferroelectric switching at room temperature has still not been achieved. Already an important hallmark for ferroelectricity would be the observation of polar domains. Here, we investigate Ti-stabilised $Ca_3Mn_2O_7$ by optical second harmonic generation imaging – a method that is highly sensitive to a breaking of inversion symmetry and hence the ideal non-destructive tool to probe for ferroelectricity. We show the existence of polar domains, oriented 90° towards each other, at room temperature and additional 180° domains within them. This domain structure can be directly linked to the complex structural distortion mechanism and gives rise to a rich domain wall structure. These findings are an important milestone towards the detection of multiferroicity and magnetoelectric coupling in $Ca_3Mn_2O_7$.

KFM 7.8 Mon 17:50 H47

The ultrathin limit of improper ferroelectricity — •Johanna Nordlander[1], Marco Campanini[2], Marta D. Rossell[2], Rolf Erni[2], Quintin N. Meier[1], Andres Cano[1,3], Nicola A. Spaldin[2], Manfred Fiebig[1], and Morgan Trassin[1] — [1]Department of Materials – ETH, Zurich, Switzerland — [2]Electron Microscopy Center – EMPA, Dübendorf, Switzerland — [3]Institut Néel – CNRS, Grenoble, France

The secondary nature of spontaneous polarization in improper ferroelectrics is known to promote functional properties beyond those of conventional ferroelectrics. In technologically relevant ultrathin films, however, the improper ferroelectric behavior remains largely unexplored. Using state-of-the-art in-situ second harmonic generation and transmission electron microscopy, we probe the coupled improper polarization and primary order parameter in $YMnO_3$ thin films. The polarization displays a pronounced thickness dependence, which we show to originate from the strong modification of the primary order at epitaxial interfaces. Finite-size effects reduce the temperature of the phase transition, allowing us to reveal its order-disorder character with atomic resolution. Our results lay the foundation for understanding the emergence of improper ferroelectricity within the confinement of ultrathin films – essential for the successful implementation of these exotic materials in nanoscale devices.

KFM 7.9 Mon 18:10 H47

Magnetic monopoles in $LuFeO_3$: modelling inelastic neutron scattering and magnetoelectric effect — Francesco Foggetti[1,2], Sang-Wook Cheong[3], and •Sergey Artyukhin[1] — [1]Italian Institute of Technology — [2]University of Genova, Italy — [3]Rutgers University, USA

Multiferroic hexagonal manganites are an interesting realization of frustrated triangular lattice, where magnetic order is coupled to ferroelectricity and trimerization. They support 120 degrees antiferromagnetism with spin canting due to Dzyaloshinskii-Moriya interaction leading to magnetoelectricity. Here we study the possible spin orders and their neutron scattering signatures, as well as their connection to magnetoelectric effect. The calculations are performed using spin wave approximation, within the microscopic model that involves spin and structural degrees of freedom.