O 51: Surface Magnetism

Time: Wednesday 11:30–13:00 Location: REC C 213

O 51.1 Wed 11:30 REC C 213

Turning by hydrogen adsorption an exchange frustrated spin-spiral into elliptical magnetic skyrmions — Timo Knispel[1], Vasily Tseplyaev[2], Markus Hoffmann[2], Gustav Bihlmayer[2], Stefan Blügel[2], Thomas Michely[1], and •Jeison Fischer[1] — [1]II Physikalisches Institut, Universität zu Köln, Zülpicher Str. 77, 50937 Cologne, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany

Spin-spiral states may emerge either from the frustration of Heisenberg-type exchange interactions or from the competition of exchange and the relativistic Dzyaloshinskii-Moriya interaction resulting in atomic scale and mesoscale textures, respectively. However, to turn frustration-stabilized spin-spirals into skyrmions, high magnetic fields are required, hardly achievable in the lab. We report on a new principle using hydrogen adsorption to unwind an exchange-stabilized spin-spiral into skyrmions at accessible fields. With spin-polarized scanning tunneling microscopy we identify an atomic scale right-handed Néel-type spin spiral on the double layer Fe on Ir(110). Density functional theory calculations confirm the spin spiral is mainly frustration-stabilized with a formation energy of -12 meV/Fe with respect to ferromagnetic state. A field of the order of 80 T would be required to unwind the spin spiral. After adsorption of hydrogen, we observe that the nature of the spin spiral becomes of Dzyaloshinskii-type with a seven times longer period. Elliptical skyrmions can be formed at moderate magnetic fields.

O 51.2 Wed 11:45 REC C 213

Aging in the self-induced spin glass Nd(0001) — •Lorena Niggli, Julian H. Strik, Anand Kamlapure, Mikhail I. Katsnelson, Daniel Wegner, and Alexander A. Khajetoorians — Institute for Molecules and Materials, Radboud University, Nijmegen, the Netherlands

Elemental neodymium has been shown to be a self-induced spin glass, where glassy behaviour stems solely from the frustrated nature of the magnetic interactions [1]. This is in contrast to traditional spin glasses, where the presence of disorder is essential toward realizing glassy behaviour. The magnetic state of Nd(0001) is characterized by a lack of long range order, but exhibits local non-collinear order (Q-states). Upon increasing the temperature, neodymium displays an unusual magnetic phase transition from a self-induced spin glass to a long-range ordered multi-Q phase [2]. Here, we explore the aging behaviour of Nd(0001) in its self-induced spin glass state using spin-polarized scanning tunneling microscopy in varying magnetic fields and variable temperature. We explore how the favourability of the Q-states evolves as we age the system and relate these changes to the preferred structure of the ordered phase. These observations indicate that neodymium may be a multi-well system, which deviates from the traditional energy landscape expected of prototypical spin glass systems, thus providing a new platform to study aging dynamics as well as dynamic heterogeneity.

[1] U. Kamber et al., *Science* **368** (2020).
[2] B. Verlhac et al., *Nat. Phys.* **18** (2022).

O 51.3 Wed 12:00 REC C 213

Magnetic Phase Transition in MoS_2 detected with AFM — Alexina Ollier[1,2], •Akash Gupta[1], Marcin Kisiel[1], Mehdi Ramezani[1,2], Andreas Baumgartner[1,2], Christian Schönenberger[1,2], and Ernst Meyer[2] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel — [2]Swiss Nanoscience Institute, Klingelbergstrasse 82, CH-4056 Basel

Low doping electron-electron interactions in monolayer MoS_2 lead to a ferromagnetic spin order, whereas larger occupation of spin-polarized energy bands results in paramagnetism. The electron density of MoS_2 might be tuned with gate voltage, thus providing the switch ability of the ferromagnetic to paramagnetic first-order phase transition. Spontaneous phase transition in two-dimensional semiconductor gated MoS_2 monolayer is detected by magnetic force spectroscopy.
An abrupt and reproducible changes of the magnetic force were observed at doping concentration equal to $n_c = 3.0\times10^{12}$ cm^{-2} and are attributed to ferromagnetic to paramagnetic phase change. Linear dependence of force versus external magnetic field was noted in the paramagnetic state, whereas no such dependence was found in already polarised ferromagnetic state. The extracted spin susceptibility confirms the correlated electron system and the observed hysteresis of the measured magnetic force is a strong hint for first-order type of transition.

O 51.4 Wed 12:15 REC C 213

Electron Spin-Polarizing Mechanisms in Chiral CuO and CoO_x Catalyst Surfaces — •Paul Valerian Möllers[1], Jimeng Wei[2], Supriya Ghosh[2], Soma Salamon[3], Manfred Bartsch[1], Heiko Wende[3], David Waldeck[2], and Helmut Zacharias[1] — [1]Center for Soft Nanoscience, WWU Münster, Germany — [2]Department of Chemistry, University of Pittsburgh, Pittsburgh, USA — [3]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), Universität Duisburg-Essen, Germany

Spin-polarized catalytic surfaces can greatly enhance the selectivity of chemical reactions, e.g., in a photoinduced water splitting process. Here, we present new insights into the mechanisms that give rise to the spin polarization in chiral cupric oxide[1] (CuO) and cobalt oxide[2] (CoO_x) layers deposited using a method pioneered by Switzer et al.[3] Photoelectrons were excited with deep-UV laser pulses and their average spin polarization (SP) was measured. For CuO layers, the energy dependence of the spin polarization reveals that the measured SP values can be rationalized assuming an intrinsic SP in the chiral oxide layer and a chirality-induced spin selectivity (CISS)-related spin filtering of the electrons.[4] On chiral CoO_x layers, the SP was found to depend on the Co oxidation state, which allows for reversible switching of the preferred spin orientation. The results support efforts towards a rational design of further spin-selective catalytic oxide materials. [1]K.B. Ghosh et al., *J. Phys. Chem. C* **123**, 3024 (2019) [2]S. Ghosh et al., *J. Phys. Chem. C* **124**, 22610 (2020) [3]Kothari et al., *Chem. Mater.* **16**, 4232 (2004) [4]Möllers et al., *ACS Nano* **16**, 12145 (2022)

O 51.5 Wed 12:30 REC C 213

Magnetic circular dichroism of oxygen-passivated and bare Fe(100) in threshold PEEM — •David Huber[1], Friederike Wühl[1], Maximilian Paleschke[1,2], Frank Schumann[3], Stefan Förster[1], and Wolf Widdra[1] — [1]Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany — [2]Institute of Atomic and Molecular Sciences (IAMS), Academia Sinica, Taipei, Taiwan — [3]Max Planck Institute of Microstructure Physics, Halle (Saale), Germany

Magnetic circular dichroism (MCD) in threshold PEEM enables imaging of in-plane and out-of-plane oriented ferromagnetic domains in real and momentum space [1, 2]. Here, we compare PEEM and ARPES data for Fe(100) and the oxygen-passivated Fe(100)-(1×1)-O. Imaging the in-plane domains we observe four different asymmetry levels, which we assign to the four magnetization vectors pointing in the high symmetry directions. The observed asymmetry values vary from 3% up to 5,5% comparing Fe(100)-(1×1)-O and Fe(100). The domain-specific momentum space measurements on Fe(100) are thereby in good agreement with relativistic photoemission calculations [2]. Through off-normal photoemission we increase the sensitivity of the method by one order of magnitude in comparison to previous reports [1].

[1] Marx *et al.*, PRL **84**, 5888 (2000).
[2] Henk and Johansson, J. Electr. Spectr. Relat. Phenom. **94**, 259 (1998).

O 51.6 Wed 12:45 REC C 213

Utilizing symmetry for magnetic domain imaging via PEEM — •Frank O. Schumann[1], Jürgen Henk[2], Maximilian Paleschke[2], Cheng-Tien Chiang[3], and Wolf Widdra[2] — [1]Max-Planck Institut für Mikrostrukturphysik, Halle, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Germany — [3]Institute of Atomic and Molecular Sciences, Academia Sinica, Taiwan

It is a well-established fact that the photoemission intensity depends on the polarization state of the light and magnetization direction. For a microscopic description it is vital to include both the spin-orbit and exchange interaction on an equal footing. A photoelectron emission microscope (PEEM) allows the detection of all emitted electrons in the hemisphere. The magnetic contrast is achieved by collecting intensity images with circular polarized light of different helicities. Comput-

ing the difference images reveals magnetic domains in the real space imaging mode. In the momentum imaging the angle-resolved photoemission intensity becomes accessible. Symmetry considerations dictate a relation in momentum space of the asymmetry signal from opposite domains. We illustrate these insights by photoemission calculations on an Fe(100) surface for photon energies in the threshold region. These we compare with recent experiments on an Fe(100) surface employing a PEEM in this photon energy range. We discuss the benefit of selecting a window of the momentum of electrons which reach the detector. A careful choice of the allowed momentum range of the detected electrons leads to a selectivity of the magnetization direction of domains.