O 26: Surface Magnetism

Time: Tuesday 10:30–12:45 Location: H4

O 26.1 Tue 10:30 H4

Investigation of bubble domains in Fe_3GeTe_2 by spin-polarized scanning tunneling microscopy — •Namrata Bansal[1], Hung-Hsiang Yang[1], Philipp Ruessmann[2], Markus Hoffmann[2], Lichuan Zhang[2], Dongwook Go[2], Amir-Abbas Haghighirad[3], Kaushik Sen[3], Matthieu Le Tacon[3], Yuriy Mokrousov[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany — [2]Peter Gruenberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1) Forschungszentrum Juelich GmbH, D-52425 Juelich — [3]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

We investigated the magnetic structure of the van der Waal material, Fe_3GeTe_2 (FGT), using a home-built low temperature (0.7 K) spin-polarized scanning tunneling microscope (SP-STM). Out-of-plane magnetic imaging with chromium-coated tungsten tip reveals bubble domains in FGT. When applying out-of-plane magnetic fields, the domain shape transitioned from elliptical to circular and collapsed at around 0.32 T. We observed an inverse relation between the size of the bubble domains and the magnetic fields. Benefiting from the spatial resolution of the SP-STM, the domain wall widths were determined, which contains information about the exchange stiffness and the anisotropy constant of FGT.

O 26.2 Tue 10:45 H4

Magnetization switching on self-assembled structure of alpha-helix-polyalanine molecules observed by ambient STM — •Nguyen T. N. Ha[1], L. Rasabathina[2], O. Helwig[2], A. Sharma[3], G. Salvan[3], S. Yochelis[4], Y. Paltiel[4], and C. Tegenkamp[1] — [1]Solid Surface Analysis, Technische Universität Chemnitz, Germany — [2]Functional Magnetic Materials, Technische Universität Chemnitz, Germany — [3]Semiconductor Physics, Technische Universität Chemnitz, Germany — [4]Department of Applied Physics, Hebrew University of Jerusalem, Israel

Polyalanine (PA) with an alpha-helix conformation has gathered recently a lot of interest as the propagation of electrons along the helical backbone structure comes along with spin polarization of the transmitted electron. The magnetization switching on self-assembly of PA molecules on Au(111)/Co/Au/Pt/Al2O3 substrate by an external magnetic field resulting the preferentially transmitted electrons depending on molecule's specific handedness and the direction of magnetization. The transmission of the electrons through this structure comes along with an quite high efficient spin polarization. The tip-sample distance variation due to magnetization switching on PA films has shown the jumping states between up and down magnetic direction, while on the bare substrate without PA film the stable tip-sample distance was observed. This observation is further confirmed the spin filter behavior of PA film on a magnetic substrate due to CISS effect at nanoscale.[1]N.T.N.Ha et al, J. Phys. Chem. C,124,10,5734-5739,2020.

O 26.3 Tue 11:00 H4

Inelastic Electron Tunneling through Nanomagnetic Structures — •Daria Medvedeva and Jindrich Kolorenč — Institute of Physics (FZU), Czech Academy of Sciences

Inelastic electron tunneling spectroscopy (IETS) is a well-established technique used for investigation of vibrational spectra and, more recently, also for characterization of spin excitations in nanosystems probed in scanning tunneling microscopes (STM). If a magnetic molecule is attached to the STM tip, the possibilities of the probe are expanded [1], for instance, one can observe how excitations in the molecule are modified by exchange interactions with the magnetic nanosystem adsorbed on a surface. We use an in-house implementation of cotunneling theory [2] to model IETS spectra of an STM tip decorated with nickelocene molecule (having spin 1) probing magnetic atoms with spins 3/2 and 2 subject to easy-axis anisotropy of varied direction. Experimentally, these situations were recently realized in an Fe adatom on Cu(100) [1] and in metal-organic chains, incorporating Co and Cr atoms, placed on Au(111) [3]. We discuss how accurate the theory is in reproducing the measured inelastic spectra, how the spectra depend on the direction of the magnetic anisotropy, and how important the appropriate alignment of the anisotropies of the probing molecule and the other spin is for efficient spin sensing.

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[1] B. Verlhac *et al.*, Science **366**, 623 (2019); [2] F. Delgado and J. Fernández-Rossier, Phys. Rev. B **84**, 045439 (2011); [3] Ch. Wäckerlin *et al.*, to be submitted (2022).

O 26.4 Tue 11:15 H4

Magnetocrystalline anisotropy in two-dimensional $EuAu_2$ and $GdAu_2$: the role of band structure — •Maria Blanco-Rey[1,2], Rodrigo Castrillo-Bodero[3], Khadiza Ali[2,3], Polina Sheverdyaeva[4], Enrique Ortega[1,3,2], Laura Fernandez[3], and Frederik Schiller[3,2] — [1]Universidad del País Vasco UPV/EHU, Spain — [2]Donostia International Physics Center, Spain — [3]Centro de Física de Materiales CSIC-UPV/EHU-MPC, Donostia-San Sebastián, Spain — [4]Instituto di Struttura della Materia ISM-CNR, Trieste, Italy

In rare earth (RE) intermetallic crystals, the magnetocrystalline anisotropy has a single-ion contribution from the f shell, often associated with a large orbital quantum number L, and an itinerant one, due to spin-orbit coupling effects in the band structure. As Eu and Gd are $4f^7$ RE atoms, L in 2D atom-thick $EuAu_2$ and $GdAu_2$ is essentially quenched. Therefore, these systems allow us to isolate the itinerant electron contribution in this 2D compound family. X-ray magnetic circular dichroism shows out-of-plane anisotropy in $EuAu_2$, in contrast to in-plane in $GdAu_2$. By means of angle-resolved photoemission and density-functional theory, we explain these behaviours in terms of the occupation of the spin-orbit-split dispersive RE(d)-Au(s) hybrid bands, which is ultimately dictated by the RE valence state (Eu^{2+} and Gd^{3+}). In terms of energy, the itinerant electron contribution is ≈ 1 meV per unit cell, which may eventually compete with the single-ion contribution.

O 26.5 Tue 11:30 H4

Magnetic Domain Structures of Gd(0001)/W(110) Films — •Patrick Haertl, Markus Leisegang, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Rare earth metal films are known to exhibit an extremely rich magnetic behavior. Depending on the sign of the RKKY coupling and details of the film preparation various domain structures have been observed, for example on Dy(0001)/W(110) films [1]. Here we report on experiments on Gadolinium (Gd) films epitaxially grown on W(110). Gd is a ferromagnetic metal with a Curie temperature of 293 K. Its half-filled 4f shell results in an almost spherical charge distribution which –in comparison to other rare earth metals– results in a very low magnetic anisotropy [2]. Our investigation on Gd(0001) films grown on W(110) indeed show a rather rich magnetic structure in spin-polarized STM studies. In agreement with earlier Kerr measurements [2], we find a thickness-dependent spin reorientation transition from in-plane at thin films to out-of-plane for films thicker than around 40 nm. The latter form up and down magnetized stripe domains which are tilted by $\pm 30^\circ$ with respect to the W[001] direction. With increasing coverage their periodicity increases from (50 ± 10) nm up to (120 ± 40) nm and domain branching is observed. We will discuss the energetics of transition of the magnetic structure.

[1] L. Berbil-Bautista et. al., Phys. Rev. B **76**, 064411 (2007).
[2] A. Berger et. al., Phys. Rev. B **52**, 1078 (1995).
[3] P. Härtl et. al., Phys. Rev. B **105**, 174431 (2022).

O 26.6 Tue 11:45 H4

Tuning the electron spin-polarization via tunneling through image states — Maciej Bazarnik[1,2] and •Anika Schlenhoff[2] — [1]Institute of Physics, Poznan University of Technology, Poland — [2]Department of Physics, University of Hamburg, Germany

Image-potential states (IS) are unoccupied electronic states in front of polarizable surfaces. Towards step edges, IS energy bands bend [1], leading to laterally localized IS at the rim of nanoislands [2]. Our spin-resolved scanning tunneling microscopy (SP-STM) and spectroscopy experiments on nanomagnets reveal a spin-polarization of the IS rim state, causing a spatial modulation of the electron spin-polarization above uniformly magnetized nanoislands. An inversion of the electron spin-polarization is found at specific energies. When the electrons relax from the IS into the surface, a spin-transfer torque (STT) is excerted on the sample [3]. We show that according to the IS-induced inversion of the electron spin-polarization, the STT also changes its sign. Our findings indicate that the IS in front of the surface serves as a spin-filter that can tailor the spin-polarization of the resonant tunneling current. The existence of the rim state and its impact on the electron spin-polarization is expected at the step edge of any magnetic adlayer-substrate system. Hence, nanostructuring a magnetic surface enables tuning the local spin-polarization and thus tailoring the STT for current-induced magnetization switching.

[1] J.-F. Ge *et al.*, Phys. Rev. B **101**, 035152 (2020)
[2] S. Stepanow *et al.*, Phys. Rev. B **83**, 115101 (2011).
[3] A. Schlenhoff *et al.*, Phys. Rev. Lett. **109**, 097602 (2012).

O 26.7 Tue 12:00 H4

Circular dichroic UV-PEEM measurements of magnetic surfaces: From Magnetic Domain Imaging to Magnetoplasmonics — •Maximilian Paleschke and Wolf Widdra — Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany

Over the last decades, the rapid progress in the ultrafast optical manipulation of magnetic materials has opened the development of several new methods for the investigation and control of spin and magnetization dynamics. Here, we investigate magnetic thin films and nanostructures on nanometer-femtosecond scales with a newly-designed experimental setup. We combine state-of-the-art time-resolved photoemission electron microscopy (PEEM) with circular dichroism imaging and normal incidence excitation via a tunable femtosecond fiber laser system.

In this talk, we report on two dichroism imaging techniques, namely magnetic circular dichroism (MCD) and the recently discovered plasmonic dichroism. The first is used to image magnetic in-plane and out-of-plane domains of ferromagnetic surfaces. The second was successfully used to image propagating surface plasmon polaritons (SPPs) on a ferromagnetic material in threshold photoemission for the first time [1]. With this, we show clear edge-induced SPPs with sub-micrometer wavelength and propagation length of about 3.5 μm on polycrystalline $Ni_{80}Fe_{20}$ microstructures. This finding extends experimental investigation of SPPs to materials with high plasma frequency and large damping.

[1] M. Paleschke *et al.*, New J. Phys. **23**, 093006 (2021)

O 26.8 Tue 12:15 H4

Chirality-induced electron spin polarization 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, 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 confirm that spin-polarized (photo)currents can be obtained from chiral cupric oxide[1] (CuO) and cobalt oxide[2] (CoO_x), and explore the underlying mechanism. Chiral oxide thin films were 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 thin films, correlating the SP values with electron energy spectra 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. 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] J. Phys. Chem. C **123**, 3024 (2019) [2] J. Phys. Chem. C **124**, 22610 (2020) [3] Chem. Mater. **16**, 4232 (2004)

O 26.9 Tue 12:30 H4

A spin-polarized STM investigation of 3 AL Mn films on W(001) — •Paula M. Weber, Jing Qi, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Julius-Maximilians-Universität Würzburg, Germany

Spin spirals and dead magnetic layers in the antiferromagnetic transition metal Mn on the heavy bcc(001) surface of W have recently attracted considerable interest [1,2]. In this talk, we present a spin-polarized STM investigation of 2-4 atomic layer (AL) thick Mn films on W(001). For 3 AL Mn on W(001) it has been theoretically proposed that this system grows pseudomorphically while exhibiting an antiferromagnetic state [3]. Our topographic STM data confirm that pseudomorphic growth even prevails up to a Mn film thickness of 4 AL. Spin-resolved data were acquired with W tips which had been magnetized on Mn layers by *in-situ* treatment on Mn/W(001). This allowed us to collect topographic and spin-resolved data on the same scanning area. Applying this method, we identify a magnetic zig-zag $2\sqrt{2} \times \sqrt{2}$ structure on 3 AL Mn and a strongly bias-dependent labyrinth overlay structure on 4 AL. Potential spin structures will be discussed.

[1] Ferriani *et al.*, Phys. Rev. Letters **101**, 027201 (2008).
[2] Meyer *et al.*, Phys. Rev. Research **2**, 012075 (2020).
[3] Dennler *et al.*, Phys. Rev. B **72**, 214413 (2005).