TT 7: Surface Magnetism and Topological Insulators (joint session MA/TT)

Time: Monday 9:30–12:00 Location: POT/0351

TT 7.1 Mon 9:30 POT/0351

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

The static magnetic proximity effect (MPE) describes the occurrence of spin polarization at the interface of nominally paramagnetic materials caused by its adjacency to a ferromagnetic material. KeV-He light ion bombardment (IB) of thin-film interfaces offers the opportunity to modify the interface properties of thin-film systems without destroying the thin films, e.g., as shown for exchange-bias systems [1].

Samples of Pt 4 nm/Fe 10 nm//MgO(001) were fabricated by sputter deposition and the subsequent IB was performed with 10 keV He^+ ions with a varying ion dose from 10^{15} to 10^{17} ions/cm^2 in a few steps. To analyze the strength of the MPE in Pt, x-ray resonant magnetic reflectivity measurements were performed at the Pt L_3 absorption edge (11.567 keV) at DESY beamline P09 [2].

The fits of the x-ray reflectivity measurements provide a significant difference for the roughness σ of the Pt-Fe interface due to IB while substrate and surface roughnesses as well as layer thicknesses remained nearly unchanged. The resulting maximum Pt moment at the interface for the sample with IB is higher than without IB, due to the increasing intermixing of Pt and Fe atoms at the Pt-Fe interface.

[1] Ehresmann et al., J. Phys. D: Appl. Phys. 38, 801 (2005)
[2] Kuschel et al., Phys. Rev. Lett. 115, 097401 (2015)

TT 7.2 Mon 9:45 POT/0351

Exchange splitting at surfaces: a new paradigm for spin-polarization in antiferromagnets — •William Schaarman and Sophie Weber — Chalmers University of Technology, Göteborg, Sweden

There has been recent interest in combining the robustness and ultrafast dynamics of antiferromagnets with the transport properties of spin-polarized band structures. While antiferromagnetic bands are typically spin-degenerate, exceptions to this rule such as the altermagnets have demonstrated the possibility to obtain spin polarization in bulk antiferromagnets via selective symmetry lowering. Here, we use symmetry analysis and density functional theory to examine a ferromagnetic-like exchange splitting at certain surfaces. Such spin polarization of the surface-projected band structure can occur for surface orientations with a net two-dimensional magnetization which can emerge via symmetry-lowering at the antiferromagnet's surface. By analyzing the band structure of a slab geometry projected onto a single surface, we confirm surface spin polarization in two representative materials, magnetoelectric Cr2O3 and altermagnetic FeF2. We rationalize the magnitudes of exchange splitting on distance surface orientations in these two materials as a complex interplay between the exchange and crystal field splittings of individual magnetic atoms making up the surface. Notably, our analysis shows the effect of surface exchange splitting can in some cases be of the order of eV which has important implications for spintronic devices.

TT 7.3 Mon 10:00 POT/0351

Image-potential states on a 2D Gr-ferromagnet hybrid: enhancing spin and stacking sensing — Maciej Bazarnik[1,2] and •Anika Schlenhoff[1,2] — [1]Institute of Physics, University of Münster, Germany — [2]Department of Physics, University of Hamburg, Germany

With the increasing research interest in 2D materials, image-potential states (IPSs) have regained attention as sensitive probes, e.g. for a charge transfer at buried graphene(Gr)-metal interfaces. For a Gr-ferromagnet hybrid, the question arises how IPSs sense a respective spin transfer laterally varying within the moiré heterostructure.

Here, we present spin-resolved scanning tunneling microscopy and spectroscopy studies on Fe intercalated Gr/Ir(111), that show the IPSs' sensitivity to the spatial variation of the Gr-Fe distance, and of the interfacial charge and spin transfer within the moiré unit cell [1]. A stacking contrast between fcc and hcp sites, indistinguishable in the direct tunneling mode, is provided by the IPSs. We observe a moiré-site- and energy-dependent spin-polarization of the IPSs that can be mapped across the entire moiré unit cell. Unlike the electronic states around the Fermi energy, the lowest IPSs are found to exhibit a high spin-polarization on the on-top sites attributed to their interfacial character at the respective Gr-Fe distance. Since the physisorbed Gr is only weakly spin-polarized on these sites, our work demonstrates that the lowest order IPSs can be used to locally sense the spin density at magnetic interfaces buried by a nonmagnetic passivation layer.

[1] M. Bazarnik and A. Schlenhoff, ACS Nano 19, 25812 (2025).

TT 7.4 Mon 10:15 POT/0351

Theoretical Investigation of Intrinsically Patterned 2D Transition Metal Halides: Defects, Structure, and Magnetic Phenomena — •Neeta Bisht[1], Andreas Görling[1], Feifei Xiang[2], Binbin Da[2], Mohammad Sajjan[2], Sabine Maier[2], and Christian Neiss[1] — [1]Lehrstuhl für Theoretische Chemie, Friedrich-Alexander-Universität Erlangen-Nürnberg,
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— [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, 91058 Erlangen

In the quest for complex structured functional materials, defect engineering and patterning in two-dimensional (2D) systems are critical for tuning material properties and enabling new functionalities. Herein, we report on intrinsically patterned 2D transition metal dihalides (TMDs) on a gold surface, featuring periodic halogen vacancies in the upper and bottom halide layers that result in alternating coordination of the transition metal atoms throughout the film.

We explore the formation pathways leading to periodic halogen vacancies and their role in modifying the electronic and magnetic structure of TMDs. Our calculations also explores the possibility of non-collinear magnetic textures through the magnetic anisotropy calculations. The excellent match between the experimental findings and the DFT calculations, confirms the intrinsic vacancy lattice. By coupling our theoretical results with experimental observations, we provide a comprehensive framework for understanding the structure formation and magnetic properties of 2D materials.

TT 7.5 Mon 10:30 POT/0351

Magnetic domain structure of holmium films at low temperatures — •Patrick Härtl[1], Vijayalaxmi Sankeshwar[2], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany — [2]Indian Institute of Science Education and Research(IISER), Pune, Maharashtra 411008, India

Rare-earth metals play a central role in modern magnetism, with their behavior largely governed by the element-specific sign and oscillation period of the RKKY interaction. However, real-space investigations of their complex magnetic domain structures remain scarce. Here, we present a systematic study of the structural and magnetic properties of epitaxial holmium (Ho) films grown on W(110), using low-temperature spin-polarized scanning tunneling microscopy (SP-STM).

Bulk Ho crystallizes in a hexagonal close-packed structure and exhibits an exceptionally large magnetic moment of approximately $10\,\mu_B$, forming a helical spin spiral below $T_C = 20\,\mathrm{K}$. In our films, we find predominantly ferromagnetic in-plane domains for thicknesses up to about 50 atomic layers (AL), with domain walls strongly pinned to crystalline defects. For coverages above 50 AL, additional out-of-plane stripe domains emerge, which we attribute to the uncompensated c-axis magnetization of the helical cone state. Domain wall analysis reveals Néel-capped Bloch-type walls with characteristic widths of roughly $\approx 1.2\,\mathrm{nm}$ (60°), $\approx 3\,\mathrm{nm}$ (120°), and $\approx 4\,\mathrm{nm}$ (180°). The stripe domains are suppressed by out-of-plane magnetic fields of $\mu_0 H = \pm 300\,\mathrm{mT}$.

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TT 7.6 Mon 10:45 POT/0351

Electronic bounds in magnetic crystals — •Daniel Passos[1] and Ivo Souza[1,2] — [1]Centro de Física de Materiales, Universidad del País Vasco, 20018 San Sebastián, Spain — [2]Ikerbasque Foundation, 48013 Bilbao, Spain

A quantum system in its ground-state must display non-negative optical absorption. This simple statement forms the basis for a string of inequalities between moments of the absorptive conductivity. Through the use of sum rules, these inequalities provide bounds on quantities of physical interest. Recent discoveries include new constraints on the

electronic localization length in insulators, and an upper bound on the bandgap of topological insulators. Current research focuses on finding inequalities relating ground-state properties such as the quantum metric to more directly measurable quantities.

We present a systematic study of bound relations between different electronic properties of magnetic crystals: electron density, effective mass, orbital magnetization, localization length, Chern invariant, and electric susceptibility. New results include a lower bound on the electric susceptibility of Chern insulators, and an upper bound on the sum-rule part of the orbital magnetization. In addition, bounds involving the Chern invariant are generalized from two dimensions (Chern number) to three (Chern vector). Bound relations are established for metals as well as insulators, and are illustrated for model systems. The manner in which they approach saturation in a model Chern insulator with tunable flat bands is analyzed in terms of the optical absorption spectrum.

15 min break

TT 7.7 Mon 11:15 POT/0351

Hidden Dirac-Like Crossings in a Prototypical Topological Insulator — •Wei-Sheng Chiu[1,2], Ina Marie Verzola[3], Ying-Jiun Chen[1], Rovi Angelo Beloya Villaos[3], Claus Michael Schneider[1,2], Feng-Chuan Chuang[3], and Christian Tusche[1,2] — [1]Forschungszentrum Jülich, Germany — [2]Universität Duisburg-Essen, Germany — [3]National Sun Yat-sen University, Taiwan

The prototypical topological insulator Bi_2Se_3 has been extensively studied for its topological surface state characterized by a $\mathbb{Z}_2$ topological invariant. By using spin-resolving momentum microscopy with an Au passivated Ir(100) imaging spin filter, we simultaneously recorded the spin-resolved momentum maps (k_x, k_y) over entire surface Brillouin zone of Bi_2Se_3. In addition to the well-known Dirac cone near Fermi energy, we observe a sequence of several Dirac-like spin textures and crossings spanning binding energies down to 4 eV at the $\overline{\Gamma}$ point. Moreover, a Dirac-like crossing is also found at a binding energy 2.3 eV at the $\overline{\mathrm{M}}$ point. Our first-principles calculations indicate that those overlooked bands are attributed to surface states. The Dirac-like crossing at the $\overline{\mathrm{M}}$ point arises from crystalline-symmetry-enforced degeneracy at the high symmetry point, showing that Bi_2Se_3 has a more complex surface electronic structure than previously expected.

TT 7.8 Mon 11:30 POT/0351

Single domain spectroscopic signatures of a magnetic Kagome metal — •Lukasz Plucinski[1], Gustav Bihlmayer[1], Yuriy Mokrousov[1], Yishui Zhou[2], Yixi Su[2], Jonathan Denlinger[3], Aaron Bostwick[3], Christopher Jozwiak[3], Eli Rotenberg[3], Dmitriy Usachov[4], and Claus M. Schneider[1] — [1]FZ Jülich — [2]JCNS/MLZ Garching — [3]ALS/LBNL Berkeley — [4]DIPC San Sebastian

We investigate the magnetic Kagome metal $DyMn_6Sn_6$ using high-resolution micro-focused circular-dichroic angle-resolved photoemission (μ-CD-ARPES) to probe its magnetic and electronic properties. By tuning the kinetic energy to various features of the Dy $4f$ multiplet, we resolve magnetic domains in samples cryo-cooled down to 20 K. Smaller, but clear signatures are detected in the Mn $3p$ levels. The behavior of both Dy $4f$ and Mn $3p$ features are in remarkable agreement with our modeling based on the Hartree-Fock method, revealing ferrimagnetic alignment of Dy and Mn local moments, and further strengthening our interpretation. Adjusting the energy to the Mn $3d$-dominated valence bands reveals signatures which we relate to the orbital magnetization through a comparison to *ab initio* electronic structure calculations. Our study establishes the spectroscopic access to a single magnetic domain in a Kagome metal, paving the way for further research into imaging magnetic phases of novel magnetic materials using μ-CD-ARPES. Preprint is available at https://arxiv.org/abs/2507.12085.

TT 7.9 Mon 11:45 POT/0351

Topologically non-trivial Kondo insulating state in graphene nanoribbons — •Amogh Kinikar[1,2], Guangze Chen[3], Yanwei Gu[4], David Jacob[5,6], Joaquín Fernández-Rossier[7], Gonçalo Catarina[2], António T. Costa[7], Oliver Gröning[2], Carlo Antonio Pignedoli[2], Klaus Müllen[4], Pascal Ruffieux[2], Jose L. Lado[8], Akimitsu Narita[4], and Roman Fasel[2,9] — [1]KIT, Karlsruhe, Germany — [2]Empa, Dübendorf, Switzerland — [3]Chalmers University of Technology, Gothenburg, Sweden — [4]MPIP, Mainz, Germany — [5]UPV/EHU, San Sebastián, Spain — [6]Basque Foundation for Science,Bilbao, Spain — [7]INL, Braga, Portugal — [8]Aalto University, Espoo, Finland — [9]University of Bern, Bern, Switzerland

Metallic rare-earth alloys display characteristic correlated electron phenomena due to interactions between electrons which give rise to a narrow heavy-fermion band near the Fermi level that hybridizes with the metallic band and opens a hybridization gap. When the Fermi level falls within this gap the system forms a Kondo insulator, which can also acquire a topologically non-trivial character. Here we provide evidence for a topological Kondo insulating state in a specific atomically precise graphene nanoribbon synthesized on Au(111) by on surface methods and characterized by scanning probe microscopy. We observe a sharp resonance near the Fermi level and a pronounced zero-bias peak at the ribbon termini. We show that these spectroscopic signatures are a fingerprint of a topological Kondo insulating state in this graphene nanoribbon.