MA 1: Surface Magnetism (joint session MA/O)

Time: Monday 10:00–12:30 Location: H5

Invited Talk MA 1.1 Mon 10:00 H5

Utilizing Vacuum States above Surfaces for Imaging and Manipulation of Atomic-Scale Magnetism — •Anika Schlenhoff — Department of Physics, University of Hamburg, Germany

Non-collinear spin textures in ultra-thin films raise expectations for spintronic applications, demanding for atomic-scale, spin-sensitive, but yet robust probe techniques. Spin-polarized vacuum resonance states (sp-RS) are unoccupied electronic states in the vacuum gap between a probe tip and a magnetic sample. They exhibit the same local spin quantization axis as the surface, even when it rotates on the atomic scale [1]. In a spin-polarized scanning tunneling microscopy (SP-STM) setup, the sp-RS can be addressed by spin-polarized electrons tunneling resonantly from the magnetic tip via these states into the surface. As I will show, this technique allows for atomic-scale magnetic imaging at tip-sample distances of up to 8 nm, providing a loophole from the hitherto existing dilemma of losing spatial resolution when increasing the tip-sample distance in a scanning probe setup [2]. Experimental results will be discussed in terms of the sp-RS' spin-splitting and the magnetic contrast as a function of bias and tip-sample distance, and in terms of the atomic-scale nature of the resonant tunneling condition. In combination with thermally-assisted spin-transfer torque switching via sp-RS [3], our approach qualifies for a spin-sensitive read-write technique with ultimate lateral resolution in future spintronic applications. [1] A. Schlenhoff *et al.*, Phys. Rev. Lett. **123**, 087202 (2019). [2] A. Schlenhoff *et al.*, Appl. Phys. Lett. **116**, 122406 (2020). [3] A. Schlenhoff *et al.*, Phys. Rev. Lett. **109**, 097602 (2012).

MA 1.2 Mon 10:30 H5

The effect of trapped Helium atoms on spin polarized tunneling in an STM tunnel junction — •Christopher Trainer[1], Chi Ming Yim[1,2], Christoph Heil[3], Vladimir Tsurkan[4,5], Alois Loidl[4], Liam Farrar[1], and Peter Wahl[1] — [1]SUPA, School of Physics and Astronomy, University of St. Andrews, St. Andrews KY16 9SS, UK — [2]Tsung Dao Lee Institute & School of Physics and Astronomy,Shanghai Jiao Tong University, Shanghai, 200240, China — [3]Institute of Theoretical and Computational Physics, Graz University of Technology, NAWI Graz, 8010 Graz, Austria — [4]Center for Electronic Correlations and Magnetism, Experimental Physics V, University of Augsburg, D-86159 Augsburg, Germany — [5]Institute of Applied Physics, MD 2028 Chisinau, Republic of Moldova

I will present a study of the influence of a Helium probe particle on spin-polarized imaging with an STM. Helium was inserted into the junction between a magnetic Iron tip and an Iron Telluride sample. From tunneling spectra acquired at different tip-sample distances we have mapped out the binding energy of the Helium atom in the tunneling junction. We find that imaging with Helium trapped in the tunneling junction makes the STM sensitive to the magnetic exchange interaction between the tip and the sample. I will demonstrate that by changing the tip sample separation the intensity of the imaged magnetic order can be both enhanced and suppressed and that the overall spin polarization of the junction can be tuned by varying the bias voltage, effectively enabling voltage-control of the spin-polarization of the tunneling current across the junction.

MA 1.3 Mon 10:45 H5

Zero-point magnetic exchange interactions — •Juba Bouaziz[1,2], Julen Ibañez Azpiroz[3], Filipe S. M. Guimarães[1], and Samir Lounis[1,4] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Jülich 52425, Germany — [2]Department of Physics, University of Warwick, Coventry CV4 7AL, United Kingdom — [3]Centro de Física de Materiales, Universidad del País Vasco/Euskal Herriko Unibertsitatea, 20018 Donostia, San Sebastián, Spain — [4]Faculty of Physics, University of Duisburg-Essen, 47053 Duisburg, Germany

Quantum fluctuations are ubiquitous in physics. Their emergence, magnitude and impact on various physical properties is a fascinating research topic of strong implications in nanotechnologies. They impact non-trivially the behaviour of nanostructures. Hinging on the fluctuation-dissipation theorem and the random phase approximation [1], we show that quantum fluctuations play an important role in determining the fundamental magnetic exchange interactions and account for the large overestimation of the magnetic interactions as obtained from conventional static first-principles frameworks, filling in an important gap between theory and experiment. Our analysis further reveals that quantum fluctuations tend to promote the noncollinearity and stability of chiral magnetic textures such as skyrmions. [1] J. Bouaziz et al. PRR 2, 043357 (2020).

This work was supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (ERC-consolidator Grant No. 681405, DYNASORE)

MA 1.4 Mon 11:00 H5

Iron growth on Be(0001) studied by STM — •Hermann Osterhage, Karoline Oetker, Roland Wiesendanger, and Stefan Krause — Department of Physics, University of Hamburg, Germany

Under high pressure, bulk Fe undergoes a phase transition to the ϵ-phase in a hexagonal close-packed (hcp) structure [1]. To date, the need for anvil cells to create ϵ-Fe prohibits an experimental validation of the noncollinear or antiferromagentic ground states predicted theoretically [2]. In our approach, Be(0001) is used as a closely-spaced hcp substrate that may accommodate ϵ-Fe provided that pseudomorphic growth occurs.

The clean Be(0001) surface was characterized using scanning tunneling spectroscopy at low temperatures. It hosts a parabolically dispersing surface state that couples strongly to phonon modes as evidenced in inelastic tunneling spectroscopy [3].

Fe growth on this surface was studied in dependence of coverage and substrate temperature during deposition. The Fe grows in multilayer islands when deposited at room temperature. For elevated temperatures, a combination of high resolution scanning tunneling microscopy and Auger electron spectroscopy shows hints of the formation of a locally ordered alloy of Fe and Be. The morphology of the resulting films and scanning tunneling spectra acquired on this system will be presented and discussed.

[1] I. Leonov *et al.*, Phys. Rev. Lett. **106**, 106405 (2011).
[2] R. Lizárraga *et al.*, Phys. Rev. B **78**, 064410 (2008).
[3] H. Osterhage *et al.*, Phys. Rev. B **103**, 155428 (2021).

MA 1.5 Mon 11:15 H5

Spin-resolved Fermi Surface of Ultrathin Ferromagnetic FePd Alloy Monolayers — •Xin Liang Tan[1], Kenta Hagiwara[1], Ying-Jiun Chen[1,2], Vitaliy Feyer[1], Claus M. Schneider[1,2], and Christian Tusche[1,2] — [1]Forschungszentrum Jülich, Peter Grünberg Institut, Jülich — [2]Fakultät für Physik, Universität Duisburg-Essen, Duisburg

Magnetism in reduced dimensions is one of the preconditions for the realization of nanoscale spintronics. Despite the recent discovery of ferromagnetism in monolayers of two-dimensional materials, tunability and engineering on such systems are challenging. Here we have studied the electronic structure of ultrathin ferromagnetic iron-palladium alloy films using spin-resolved momentum microscopy. Momentum microscopy enables the two-dimensional detection of photoelectrons with an in-plane crystal momentum over the full Brillouin zone. By employing an imaging spin filter, spin-resolved momentum maps of the iron-palladium alloy were acquired. Breaking of time reversal symmetry by the remanent magnetization of the film manifests in a pronounced anisotropy of the electron states in the Fermi surface. In particular, the competition between exchange interaction and strong spin-orbit coupling in the FePd alloy leads to the formation of wave-vector dependent local gaps in the Fermi surface. Moreover, the spin-resolved maps recorded by the momentum microscope give evidence for a non-collinear spin texture of the electron states at the Fermi surface, where the local spin polarization vector points orthogonal to the remanent magnetization of the sample.

MA 1.6 Mon 11:30 H5

On-surface synthesis of magnetic organometallic chains on the superconducting Ag/Nb(110) substrate — •Jung-Ching Liu[1], Philipp D'Astolfo[1], Carl Drechsel[1], Xunshan Liu[2], Silvio Decurtins[2], Shi-Xia Liu[2], Rémy Pawlak[1], Wulf Wulfhekel[3], and Ernst Meyer[1] — [1]Department of Physics, University of Basel, Klingelbergstrasse 82, Basel, CH 4056 — [2]Department of Chemistry and Biochemistry, University of Bern, Freiestrasse 3, Bern, CH 3012 — [3]Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, D-76131 Karlsruhe, Germany

With proximity to s-wave superconductivity, spin texture arises on a magnetic chain and Majorana bound states (MBSs) can be found at two ends[1-3]. To study MBSs with diverse magnetic structures, we propose to conjugate magnetic atoms with organic molecules via on-surface reaction. Choosing Fe and PTO, we fabricate magnetic chains on the superconducting Ag/Nb substrate[4,5]. With the investigation with STM and AFM at 4.7K, we confirm the proximity-induced superconductivity on Ag from Nb, as well as the success in growing magnetic organometallic chains. We believe our work demonstrates the feasibility of growing tunable magnetic lattices by changing organic molecules. Above all, the direct synthesis on a superconductor offers a convenient way to study the interaction between magnetic lattices and superconductivity. [1]S. Nadj-Perge et al. Science 2014, 346, 602-607 [2]M. Ruby et al. Nano Lett. 2017, 17, 4473-4477 [3]R. Pawlak et al. Npj Quantum Inf. 2016, 2, 16035 [4]A. D. Pia et al. Chem. Eur. J. 2016, 22, 8105-8112 [5]T. Tomanic et al. Phys. Rev. B 2016, 94, 220503

MA 1.7 Mon 11:45 H5

Interplay of magnetic states and hyperfine fields of iron dimers on MgO(001) — •SUFYAN SHEHADA[1,2], MANUEL DOS SANTOS DIAS[1], MUAYAD ABUSAA[3], and SAMIR LOUNIS[1,4] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]Department of Physics, RWTH Aachen University, 52056 Aachen, Germany — [3]Department of Physics, Arab American University, Jenin, Palestine — [4]Faculty of Physics, University of Duisburg-Essen, 47053 Duisburg, Germany

Individual nuclear spin states can have very long lifetimes and could be useful as qubits. Progress in this direction was achieved on MgO/Ag(001) via detection of the hyperfine interaction (HFI) of Fe, Ti and Cu adatoms using scanning tunneling microscopy (STM) [1,2]. Previously, we systematically quantified from first-principles the HFI for the whole series of 3d transition adatoms (Sc*Cu) deposited on various ultra-thin insulators, establishing the trends of the computed HFI with respect to the filling of the magnetic s and d-orbitals of the adatoms and on the bonding with the substrate [3]. Here we take one step further by investigating the impact of the magnetic coupling between the dimer atoms on the HFI of Fe dimers on MgO(001) and its dependence on where the Fe atoms are located on the surface.

–Work funded by the Palestinian German Science Bridge (BMBF–01DH16027) and Horizon 2020–ERC (CoG 681405–DYNASORE).

[1] Willke *et al.*, Science **362**, 336 (2018); [2] Yang *et al.*, Nat. Nano. **13**, 1120 (2018); [3] Shehada *et al.*, Npj Comput. Mater. **7**, 87 (2021).

MA 1.8 Mon 12:00 H5

Pairwise magnetic exchange interaction tensor from tight-binding models of noncollinear magnetism — •KSENIIA VODENKOVA[1] and PAVEL BESSARAB[1,2] — [1]ITMO University, St. Petersburg, Russia — [2]University of Icelad, Reykjavik, Iceland

The microscopic origin of the exchange interactions for noncollinear ordering of atomic magnetic moments in itinerant-electron systems is a subject of ongoing scientific discussions. In this work, we derive by means of the multiple-scattering theory a general expression for pairwise magnetic exchange interaction parameters for an arbitrary noncollinear, nonstationary magnetic state. In contrast to previous approaches, our formalism takes into account the variation of the fast degrees of freedom such as charge density and magnetic moment length. Application of the formalism to a tight-binding model reveals a range of magnetic systems that can be described by a classical Heisenberg Hamiltonian reasonably well. For other systems, our approach makes it possible to systematically derive atomistic spin Hamiltonians beyond the Heisenberg model. Moreover, the expression for the pairwise interaction tensor describes a local curvature of the energy surface of the system as a function of the orientation of magnetic vectors. This can be used in various contexts including description of thermal stability of magnetic states within the harmonic transition state theory and efficient identification of stable magnetic configurations using the Newton-Raphson method.

MA 1.9 Mon 12:15 H5

The chiral Hall effect in canted ferromagnets and antiferromagnets — •JONATHAN KIPP[1], KARTIK SAMANTA[1], FABIAN LUX[1,2,3], MAXIMILIAN MERTE[1,2,3], DONGWOOK GO[1,3], JAN-PHILIP HANKE[1], MATTHIAS REDIES[1,2], FRANK FREIMUTH[1,3], STEFAN BLÜGEL[1], MARJANA LEZAIC[1], and YURIY MOKROUSOV[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum — [2]RWTH Aachen University, Aachen, Germany — [3]Institute of Physics, Johannes Gutenberg-University Mainz

There are numerous exciting classes of antiferromagnets, where the anomalous and recently discovered crystal Hall [1] effect as well as the topological Hall effect in non-coplanar antiferromagnets [2] have been studied in the past decades. In this work, we uncover a novel type of Hall effect emerging in generic canted spin systems. Identifying a clear fingerprint of this chiral Hall effect (CHE) in discrete tight-binding models as well as ab-initio calculations is central in establishing a solid understanding of this new phenomenon closely tied to real space topology of magnetic textures. We provide robust numerical evidence for the CHE in a honeycomb lattice of canted spins and present a material candidate, SrRuO3. We uncover contributions to the Hall conductivity sensitive to the canting angle between neighboring spins which can be directly related to the imprinted vector chirality. Exploring the symmetry properties of the CHE we demonstrate the complex interplay of symmetry, topology and chirality in canted spin systems. [1]L .Smejkal et al., Science Advances 6 (2020) [2]L. Smejkal et al., Nature Physics 14, 242-251 (2018) [3]J. Kipp et al., Comm. Phys. 4, 99 (2021)