MA 14: Surface Magnetism

Time: Tuesday 9:30–11:45 Location: HSZ 04

Invited Talk MA 14.1 Tue 9:30 HSZ 04

Antiferromagnetism-driven two-dimensional topological nodal-point superconductivity — •Roberto Lo Conte[1], Maciej Bazarnik[1,2], Eric Mascot[1], Krisztián Palotás[3], Levente Rózsa[4], László Szunyogh[3], André Kubetzka[1], Dirk K. Morr[5], Kirsten von Bergmann[1], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, Germany — [2]Institute of Physics, Poznan University of Technology, Poland — [3]Department of Theoretical Physics, Budapest University of Technology and Economics, Hungary — [4]Department of Physics, University of Konstanz, Germany — [5]Department of Physics, University of Illinois at Chicago, USA

In the recent years, pioneering studies have been carried out on magnet/superconductor hybrid systems[1-4], motivated by their potential to host emergent quantum phases such as topological superconductivity. Here, we present the discovery of a topological nodal-point superconducting phase in antiferromagnetic manganese (Mn) monolayer islands on superconducting niobium (Nb) via low temperature spin-polarized STM[5]. Low-energy edge modes are found to separate the topological phase from the trivial one. The relative spectral weight of the edge modes depends on the edge's atomic configuration, which is a fingerprint of the discovered topological state. [1]S. Nadj Perge et al., Science 346, 602(2014). [2]A. Palacio-Morales et al., Sci. Adv. 5, eaav6600(2019). [3]L. Schneider et al., Nat. Phys. 17, 943(2021). [4]S. Kezilebieke et al., Nature 588, 424(2020). [5]R. Lo Conte et al., PRB 105, L100406(2022). M. Bazarnik et al., arXiv:2208.12018(2022).

MA 14.2 Tue 10:00 HSZ 04

Structure–Property Relationship of Reversible Magnetic Chirality Tuning — •Jing Qi[1], Paula M. Weber[1], Tilman Kisslinger[2], Lutz Hammer[2], M. Alexander Schneider[2], and Matthias Bode[1] — [1]Julius-Maximilians-Universitaet Wuerzburg, Germany — [2]Universitaet Erlangen-Nuernberg, Germany

The Ruderman-Kittel-Kasuya-Yosida (RKKY) interaction mediates collinear magnetic interactions via the conduction electrons of a nonmagnetic spacer, resulting in a ferro- or antiferromagnetic magnetization in magnetic multilayers [1]. Recently it has been discovered that heavy non-magnetic spacers are able to mediate an indirect magnetic coupling that is non-collinear and chiral. This Dzyaloshinskii-Moriya-enhanced RKKY (DME-RKKY) interaction causes the emergence of a variety of interesting magnetic structures, such as skyrmions and spin spirals [2]. Here, we show by spin-polarized STM that the interchain coupling between manganese oxide chains on Ir(001) can reproducibly be switched from chiral to collinear antiferromagnetic by increasing the oxidation state of MnO_2 while the reverse process can be induced by thermal reduction. The underlying structure–property relationship is revealed by low-energy electron diffraction intensity (LEED-IV) analysis. Density functional theory calculations suggest that the magnetic transition may be caused by a significant increase of the Heisenberg exchange which overrides the DMI interaction upon oxidation.

[1] P. Bruno et al., Phys. Rev. Lett. **67**, 1602-1605 (1991).
[2] M. Schmitt et al., Nat. Commun. **10**, 2610 (2019).

MA 14.3 Tue 10:15 HSZ 04

Lifting the frustration of higher-order exchange interactions in ultrathin films — •Felix Nickel[1], Soumyajyoti Haldar[1], Roland Wiesendanger[2], Stefan Heinze[1], and Kirsten von Bergmann[2] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel — [2]Department of Physics, University of Hamburg

The 3Q state – a three-dimensional spin structure on a two-dimensional lattice predicted about 20 years ago [1] – has been observed in a Mn monolayer on Re(0001) using spin-polarized scanning tunneling microscopy (SP-STM) [2]. The 3Q state is a superposition of three symmetry equivalent spin spirals with the same period and can be stabilized by higher-order exchange interactions (HOI) such as the biquadratic or four-spin interactions [1,2]. Recently, it has been suggested based on density functional theory (DFT) calculations that the 3Q state in Mn/Re(0001) is significantly distorted due to topological chiral magnetic interactions [3]. Here, we show using DFT that the competition of biquadratic, four-spin, and topological chiral interactions can be tuned in Mn/Re(0001) by single atomic adlayers of Pd or Rh. Thereby, the frustration of HOI present in Mn/Re(0001) is lifted which results in the occurrence of the ideal 3Q state. SP-STM experiments confirm the predicted 3Q ground state of Pd/Mn/Re(0001) and Rh/Mn/Re(0001) and reveal differences to Mn/Re(0001).

[1] Ph. Kurz *et al.*, Phys. Rev. Lett. **86**, 1106 (2001)
[2] J. Spethmann *et al.*, Phys. Rev. Lett. **124**, 227203 (2020)
[3] S. Haldar *et al.*, Phys. Rev. B **104**, L180404 (2021)

15 min. break

MA 14.4 Tue 10:45 HSZ 04

Conical spin-spirals at a ferromagnet's surface: experimetal observations — •Patrick Haertl[1], Gustav Bihlmayer[2], Markus Leisegang[1], Stefan Bluegel[2], and Matthias Bode[1] — [1]Universität Würzburg, Germany — [2]Forschungszentrum Jülich and JARA, Germany

The spin-orbit–driven Dzyaloshinskii-Moriya interaction (DMI) can lead to chiral spin structures in magnetic systems with broken inversion symmetry [1]. The purely interfacial origin of DMI generally results in a reciprocal scaling with the magnetic layer thickness [2]. Here we report on the observation of a conical spin-spiral state at the surface of epitaxial Gd(0001) films grown on W(110). In a recently performed spin-polarized scanning tunneling microscopy (SP-STM) investigation of the thickness-dependent domain structures of Gd/W(110) we confirmed the existence of a spin reorientation transition (SRT) [3] from in-plane to out-of-plane magnetized films at a critical thickness $\Theta_{\mathrm{crit}} \approx (100 \pm 20)$ AL [4]. In the vicinity of this SRT, we identify striped regions with a periodicity of about 2 nm. The application of an external magnetic field induces a rearrangement of the stripes, thereby unambiguously confirming its magnetic origin. The experimental observations are discussed on the basis of density functional theory (DFT).

[1] T. Moriya, Phys. Rev. **120**, 91-98 (1960).
[2] J. Cho et al., Nature Comm. **6**, 7635 (2015).
[3] A. Berger et al., Phys. Rev. B **52**, 1078 (1995).
[4] P. Härtl et al., Phys. Rev. B **105**, 174431 (2022).

MA 14.5 Tue 11:00 HSZ 04

Conical spin-spirals at a ferromagnet's surface: a theoretical analysis — •Gustav Bihlmayer[1], Patrick Härtl[2], Markus Leisegang[2], Matthias Bode[2], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Universität Würzburg, Germany

The properties of surface layers of a magnetic material can differ substantially from those of the bulk material. A prominent example is the Dzyaloshinskii-Moriya interaction (DMI), resulting from inversion-symmetry breaking at the surface, but also the magnetic anisotropy and the exchange interactions are locally modified. Gd(0001) is here a well-investigated model surface but despite its sensitivity of exchange interactions to the local environment, experimental data indicated that it behaves as homogeneous Heisenberg system [1]. Recent observations of spin-spirals at the surface of epitaxial Gd(0001) with spin-polarized scanning tunneling microscopy let us re-investigate this system. Density functional theory (DFT) calculations show that not only a sizable DMI can be found at the Gd(0001) surface but also the exchange interactions are modified to drive the system locally towards a conical spin-spiral state. Since the magnetic anisotropy and the exchange interactions with the ferromagnetic bulk material disfavor non-collinear magnetic states, only slight modifications of the exchange interactions make these spirals visible. We explore the phase diagram numerically and with the help of atomistic spin-dynamics simulations.

[1] C. S. Arnold and D. P. Pappas, Phys. Rev. Lett. **85**, 5202 (2000)

MA 14.6 Tue 11:15 HSZ 04

Non-collinear spin structure of trilayer Mn films on W(001) — •Tim Drevelow[1], Paula M. Weber[2], Jing Qi[2], Matthias Bode[2,3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, Leibnizstraße 15, 24098 Kiel, Germany — [2]Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Wilhelm Conrad Röntgen-Center for Complex Material Systems (RCCM), Universität Würzburg, Am Hubland, 97074 Würzburg, Ger-

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The spin structure of Mn films on the W(001) surface depends sensitively on the number of atomic layers. It has been shown that a Mn monolayer exhibits a spin spiral driven by the Dzyaloshinskii-Moriya interaction (DMI) [1] while the Mn double layer possesses an antiferromagnetic checkerboard state and vanishing Mn moments at the interface [2]. Here, we study the Mn trilayer on W(001) with a combination of spin-polarized scanning tunneling microscopy (SP-STM) and density functional theory (DFT) calculations. Experimentally, it is shown that the Mn films grow pseudomorphically and exhibit a c(4×2) magnetic superstructure consistent with a conical spin spiral ground state. Based on our DFT calculations we compare the total energies of different collinear and non-collinear spin structures including the effect of spin-orbit coupling. We find a complex interplay of magnetic interactions and structural relaxations of the Mn trilayer.

[1] Ferriani *et al.* Phys. Rev. Lett. **101**, 027201 (2008).
[2] Meyer *et al.* Phys. Rev. Research **2**, 012075(R) (2020)

MA 14.7 Tue 11:30 HSZ 04

Structural transitions of magnetic thin films induced by two-dimension materials — •Hangyu Zhou[1,2], Manuel dos Santos Dias[1,3,4], Weisheng Zhao[2], and Samir Lounis[1,3] — [1]Peter Grünberg Institut and Institute for Advanced Simulations, Forschungszentrum Jülich & JARA, 52425 Jülich, Germany — [2]School of Integrated Circuit Science and Engineering, MIIT Key Laboratory of Spintronics, Beihang University, Beijing 100191, China — [3]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany — [4]Scientific Computing Department, STFC Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

Interfaces of magnetic thin films play a key role in determining magnetic behaviors and implementations of spintronic devices. In the last decade, the increased availability of high-quality two-dimensional (2D) materials has helped to broaden the scope of interfaces, leading to the discovery of novel electronic and magnetic properties. Here, we explore with density functional theory calculations the impact of hexagonal boron nitride (h-BN) on the magnetism and structural properties of magnetic monolayers placed on heavy metal surfaces. We found that h-BN induces various structural transitions, and we investigate how magnetic interactions, such as the Heisenberg exchange interaction and the Dzyaloshinskii-Moriya interaction (DMI), are influenced by these reconstructions. These results contribute to new avenues for stabilizing complex spin-textures.

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