MA 43: Magnetic textures I

Time: Thursday 9:30–12:15 Location: EB 407

MA 43.1 Thu 9:30 EB 407

Topological defects and emergent electromagnetism in cylindrical nanowires — •Michalis Charilaou[1], Hans-Benjamin Braun[2], and Jörg F. Löffler[1] — [1]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich — [2]School of Physics, University College Dublin

Magnetic switching in nanoparticles, particularly with cylindrical symmetry, is associated with curling-type processes but conventional wisdom neglects topological constraints that preclude a continuous complete reversal. In this work [1] we present evidence that in cylindrical nanowires the process of athermal magnetization switching is initiated by the formation of smooth topological defects in the form of skyrmion lines. As long as the magnetization evolves continuously the switching is prevented by the skyrmion lines, effectively acting like radial exchange springs. Switching becomes irreversible only after a skyrmion line breaks into a pair of hedgehogs, which move along the wire. Importantly, the movement of the hedgehogs produces an emergent electric field of circular polarization and substantial magnitude. Hence, by considering a generic case of cylindrical magnetic particles we show that irreversibility is directly linked to the formation and dynamics of topological point-defects.

[1] M. Charilaou, H.-B. Braun, J. F. Löffler, arXiv:1711.03511

MA 43.2 Thu 9:45 EB 407

Spin-polarized STM study of the Fe monolayer on Rh(111) — •Markus Böhme[1], Jens Kügel[1], Martin Schmitt[1], Nicolai Seubert[1], Julia Küspert[1], Andreas Krönlein[1], Bandar Alonazi[2], Hamad Albrithen[2], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik II, *Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia

Skyrmions in thin magnetic films stabilized by the Dzyaloshinskii-Morija interaction (DMI) have recently attracted considerable interest. Whereas Skyrmions are usually only stable in applied magnetic fields, the Fe monolayer on Ir(111) turned out to be unique as it exhibits a square lattice ground state of nano-skyrmions even without a field [1]. Here we report spin-polarized STM experiments performed on a monolayer Fe on Rh(111), a substrate that is isoelectronic and isostructural to Ir(111), but with Rh having a much smaller spin-orbit interaction than Ir and thus negligible DMI. In agreement with earlier calculations [2], which predicted a double–row-wise antiferromagnetic (↑↑↓↓) spin structure, we observe stripes oriented along ⟨110⟩-equivalent directions of the substrate. The periodicity of (1.0 ± 0.1) nm corresponds well with the expected value of 0.931 nm. These stripes exists in three orientational domains. Magnetic field-dependent data indicate that domain walls are associated with uncompensated magnetic moments that give rise to hysteresis effect due to domain wall movement.

[1] S. Heinze *et. al.*, Nature Physics **7**, 713 (2011).
[2] A. Al-Zubi *et. al.*, phys. stat. sol. (b) **248**, 2242 (2011).

MA 43.3 Thu 10:00 EB 407

Influence of hydrogen on noncollinear magnetic order in ultrathin Fe films on Ir(111) — •Levente Rózsa[1], Pin-Jui Hsu[1,2], Aurore Finco[1], Lorenz Schmidt[1], Krisztián Palotás[3,4], Elena Vedmedenko[1], László Udvardi[5], László Szunyogh[5], André Kubetzka[1], Kirsten von Bergmann[1], and Roland Wiesendanger[1] — [1]University of Hamburg, Hamburg, Germany — [2]National Tsing Hua University, Hsinchu, Taiwan, R.O.C. — [3]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia — [4]University of Szeged, Szeged, Hungary — [5]Budapest University of Technology and Economics, Budapest, Hungary

Magnetic skyrmions have lately attracted significant research attention due to their possible applications in data storage and logic devices[1]. In ultrathin films and multilayers, most of the efforts so far have concentrated on tuning the balance between interactions preferring collinear and noncollinear ordering by the appropriate choice of magnetic materials and heavy metals with high spin-orbit coupling[2]. Based on *ab initio* calculations, here we discuss how the addition of hydrogen to an Fe double-layer on Ir(111) influences the magnetic interactions through modifying the hybridization between the ultrathin magnetic film and the heavy metal substrate[3]. This effect leads to the stabilization of the magnetic skyrmion lattice in the presence of external magnetic fields, also demonstrated in spin-polarized scanning tunneling microscopy measurements performed on the system. [1] A. Fert *et al.*, Nat. Nanotechnol. **8**, 152 (2013). [2] B. Dupé *et al.*, Nat. Commun. **7**, 11779 (2016). [3] P.-J. Hsu *et al.*, arXiv:1711.06784 (2017).

MA 43.4 Thu 10:15 EB 407

Structure and magnetism of an hydrogenated Fe monolayer on Ir(111) — •Aurore Finco[1], Pin-Jui Hsu[1,2], André Kubetzka[1], Kirsten von Bergmann[1], and Roland Wiesendanger[1] — [1]University of Hamburg, Germany — [2]National Tsing Hua University, Hsinchu, Taiwan

The incorporation of H atoms in a Fe bilayer on Ir(111) affects significantly its magnetic state. In particular, it was found that a skyrmionic phase appears when a magnetic field is applied [1].

H atoms can also be used to modify the monolayer Fe on Ir(111). Depending on the amount of hydrogen dosed, two different phases can form. One exhibits a hexagonal superstructure whereas the other one is roughly square. Spin-polarized scanning tunneling microscopy measurements reveal that these hydrogenated structures show complex nanometer-scale magnetic states which are different from the nanoskyrmion lattices found in the pristine Fe monolayer on Ir(111)[2,3]. This work thus provides a further example how to tune a non-collinear magnetic system by hydrogenation.

[1] Hsu et al, arxiv 1711.06784.
[2] Heinze et al, Nature Physics, 7, 713 (2011).
[3] von Bergmann et al, Nano Letters, 15, 3280 (2015).

MA 43.5 Thu 10:30 EB 407

Direct observation of chiral magnetic bobbers — F. Zheng[1,2], F. N. Rybakov[3], A. B. Borisov[4], D. Song[5], S. Wang[6,7], Z-A. Li[8], H. Du[6,7], •N. S. Kiselev[2], J. Caron[1,2], A. Kovács[1,2], M. Tian[6,7], Y. Zhang[6,7], S. Blügel[2], and R. E. Dunin-Borkowski[1,2] — [1]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, Germany — [2]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [3]Department of Physics, KTH-Royal Institute of Technology, Stockholm, Sweden — [4]M.N. Miheev Institute of Metal Physics, Ekaterinburg, Russia — [5]National Center for Electron Microscopy in Beijing, Tsinghua University, China — [6]High Magnetic Field Laboratory, Hefei, China — [7]Collaborative Innovation Center of Advanced Microstructures, Nanjing University, China — [8]Institute of Physics, Beijing, China

We report the direct observation of a new theoretically predicted hybrid particle-like magnetic state - a chiral bobber (ChB)[1] - which can be thought of as skyrmion tube, which is coupled to the surface and whose end takes the form of a Bloch point. We use quantitative off-axis electron holography to identify ChBs in a thin plate of B20-type FeGe and to find the range of their stability in a temperature-field phase diagram. We reveal two distinct mechanisms of ChB nucleation and confirm the coexistence of ChBs with ordinary magnetic skyrmions over a wide range of field, temperature and film thickness[2]. Our work provides a perspective for the practical application of ChBs in data storage technology. [1] F. N. Rybakov et al. Phys. Rev. Let. **115**, 117201 (2015). [2] F. Zheng et al. arXiv:1706.04654.

15 minutes break

MA 43.6 Thu 11:00 EB 407

Experimental Investigation into the thermomagnetic Phase Diagram of Pd/Fe/Ir(111) — •Philipp Lindner, Lennart Bargsten, Johannes Friedlein, Jonas Harm, Stefan Krause, and Roland Wiesendanger — Department Physik, Universität Hamburg, Jungiusstraße 11A, 20355 Hamburg

First individual atomic scale skyrmions have been observed in the system of an atomic layer of Fe sandwiched between an Ir(111) surface and a Pd monolayer [1].
At low temperature ($T < 8$ K), the application of an external magnetic field results in phase transitions from the spin spiral (SS) ground state to the skyrmion (SK) state (B $>$ 1 T) and finally into the ferromagnetic (FM) state (B $>$ 2 T). For potential spintronics applications, the thermal stability of the SK state is of high relevance.
In our study we epitaxially grew Pd nanoislands on the Fe-monolayer

on top of Ir(111) and investigated the sample system via scanning tunneling microscopy within our home-built ultra-high vacuum system, which allows the application of magnetic fields up to 3 T perpendicular to the (111) sample plane at the full temperature range of 1 K to 100 K.

We explored the thermomagnetic phase diagram and report the observation of the SK-FM transition even at $T \approx 80\,\mathrm{K}$. Additionally, indications of a disordered magnetic state at elevated temperatures are compared to a possible fluctuation-disordered state as predicted by Monte-Carlo and spin dynamics simulations [2].

[1] N. Romming *et al.*, Science **341**, 713 (2013).
[2] L. Rózsa *et al.*, Phys. Rev. B **93**, 024417 (2016).

MA 43.7 Thu 11:15 EB 407

SEMPA investigation of the Dzyaloshinskii-Moriya interaction in the single, ideally grown Co/Pt(111) interface — •Susanne Kuhrau, Edna C. Corredor, Fabian Kloodt-Twesten, Robert Frömter, and Hans Peter Oepen — Center for Hybrid Nanostructures, Universität Hamburg, Germany

The experimental investigation of the Dzyaloshinskii-Moriya interaction (DMI) of a single, ideally grown interface is compelling, as it allows the direct comparison with ab-initio calculations. We present a study of domains and domain walls in epitaxial, single-layer cobalt films on Pt(111) with a pseudomorphic, atomically flat interface by means of scanning electron microscopy with polarization analysis (SEMPA) [1], which is a surface-sensitive, vectorial imaging technique with a magnetic probing depth of < 5 atomic layers. Uncapped, thermally evaporated cobalt on a clean platinum single-crystal surface is imaged in situ in ultrahigh vacuum. For a cobalt thickness of 1.4 nm we observe Néel-like domain walls that show a fixed, counterclockwise sense of rotation indicating a strong DMI that originates from the single Co/Pt interface. From the observation of a pure Néel-like rotation, we derive a lower bound for the DMI strength of 0.5×10^{-3} J/m^2, which gives a DMI energy per interface atom larger than 0.8 meV. An upper bound for the DMI energy of 4.3 meV per interface atom is derived from the observation of stable domains at the onset of ferromagnetism at 0.3-nm Co thickness, corresponding to an average Co coverage of 1.5 monolayers.

[1] E.C. Corredor et al., Phys. Rev. B 96, 060410(R), 2017

MA 43.8 Thu 11:30 EB 407

Magnetism of Co monolayer on Pt(111) capped by 5d overlayers — •Eszter Simon[1], Levente Rózsa[2], Krisztián Palotás[3,4], and László Szunyogh[1] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]University of Hamburg, Hamburg, Germany — [3]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia — [4]University of Szeged, Szeged, Hungary

We study the magnetic properties of a Co monolayer on Pt(111) surface as capped by a monolayer of 5d elements (Re, Os, Ir, Pt and Au) by determining the tensorial exchange interactions and magnetic anisotropies from first principles. We find a close relationship between the magnetic moment of the Co atoms and the nearest-neighbor isotropic exchange interaction due to the electronic hybridization between the Co and the capping layers. All overlayers decrease the magnitude of the Dzyaloshinskii-Moriya (DMI) interaction compared to the Co/Pt(111) system, while even the sign of the DMI changes in case of Ir overlayer [1-3]. We conclude that the variation of the DMI is well correlated with the change of the magnetic anisotropy energy. The unique influence of the Ir overlayer to the DMI is traced by scaling the strength of the spin-orbit coupling of Ir atoms and in terms of the $Au_{1-x}Ir_x$/Co/Pt(111) system. Our spin-dynamics simulations indicate that the magnetic ground state for Re/Co/Pt(111) is an elliptic conical spin spiral, while for the other systems it is ferromagnetic.

[1] G. Chen et al., Nat. Comm. 4, 2671 (2013)
[2] A. Hrabec et al., Phys. Rev. B 90, 020402 (2014)
[3] Gy. J. Vida et al., Phys. Rev. B 94, 214422 (2016)

MA 43.9 Thu 11:45 EB 407

Current-driven skyrmion dynamics in ultra-thin magnetic films — •U. Ritzmann[1,2], S. von Malottki[3], J.V. Kim[4], J. Sinova[2], S. Heinze[3], and B. Dupé[2] — [1]Uppsala University, Uppsala, Sweden — [2]Johannes Gutenberg University Mainz, Mainz, Germany — [3]Christian-Albrechts-Universität zu Kiel, Kiel, Germany — [4]C2N, CNRS, Université Paris-Sud, Université Paris-Saclay, Orsay, France

Skyrmions are topologically stabilized spin structures. They can be manipulated with electric current densities that are orders of magnitude lower than those required for moving domain walls. Especially, isolated magnetic skyrmions can occur in ultra-thin transition metal films at surfaces [1,2] and interfaces [3]. We have shown that skyrmions, antiskyrmions and higher order antiskyrmions exist in Pd(fcc)/Fe/Ir(111) due to a competition between magnetic interactions beyond the nearest neighbour approximation [4].

Here, we present a study on the motion of skyrmions and antiskyrmions via spin transfer torques excited by the spin Hall effect in the substrate. We will show that in general the current-driven motion of these metastable states cannot be described by a rigid body approximation and internal degrees of freedom have to be included. Furthermore, we will describe the different impact of the nature of the DMI on the motion of skyrmions and antiskyrmions [5].

[1] Romming et al., Science 341, 636 (2013); [2] Dupé et al., Nat. Commun. 5, 4030 (2014); [3] Dupé et al., Nat. Commun. 7, 11779 (2016); [4] Dupé et al., New J.Phys. 18, 055015 (2016); [5] Ritzmann et al., in preparation

MA 43.10 Thu 12:00 EB 407

Surface spin flop in synthetic layered perpendicular antiferromagnets — •Benny Böhm[1], Lorenzo Fallarino[2], and Olav Hellwig[1,2] — [1]Institute of Physics, Chemnitz University of Technology — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf

In 1968 the surface spin flop transition was theoretically predicted by Mills [1] for antiferromagnetic superlattices. At a later time, Wang et al. [2] showed experimentally the surface spin flop for Fe/Cr epitaxial superlattices on MgO for in-plane uniaxial anisotropy by comparing theoretical hysteresis loops with magnetometry data.

Here we show for the first time that the surface spin flop state can occur in synthetic layered antiferromagnets with perpendicular magnetic anisotropy (PMA). PMA synthetic antiferromagnets made of Ir-coupled Co/Pt multilayer blocks exhibit different magnetization reversal behavior, depending on their exact magnetic energy balance. If the interlayer exchange energy term, which is mediated by the Ir interlayers, is tuned to be the dominating term in our system, then the synthetic antiferromagnets with even number of Co/Pt blocks reveal a surface spin flop. The magnetic reversal of systems with odd and even number of repeats are compared and discussed in relation to micromagnetic simulations. The latter indicates the possibility to extend the surface spin flop state with its vertical domain wall through the system down to remanence.

[1] D. L. Mills, *Phys. Rev. Lett.* 20, **1968**, p. 18-21
[2] R. W. Wang et al., *Phys .Rev. Lett.* 72, **1994**, p. 920-923