MA 49: Surface Magnetism 2 (Joint Session with O)

Time: Thursday 9:30–12:30 Location: HSZ 401

MA 49.1 Thu 9:30 HSZ 401

First-principles ground state charge currents and orbital magnetic moments in magnetic nanostructures — •Sascha Brinker, Manuel dos Santos Dias, Filipe Souza Mendes Guimarães, and Samir Lounis — Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, 52425 Jülich

The classical definition of the orbital magnetic moment (OMM) using the ground state charge current is well-defined for finite systems, while for periodic systems the modern theory of orbital magnetization applies [1]. In this work we consider the intermediate case: magnetic nanostructures on surfaces from first-principles. We outline our density functional theory implementation in the Korringa-Kohn-Rostoker (KKR) Green function method, in a real-space approach. As an application we consider transition metal adatoms and clusters on a Pt(111) surface, and their ground state charge current distributions. We then find two contributions to the OMM – a local contribution corresponding to the swirling charge currents around each atom and a contribution related to the net currents flowing between atoms. Two mechanisms lifting the orbital degeneracy are investigated — spin-orbit coupling and non-collinear magnetic structures with finite scalar spin chirality.

Work funded by the HGF-YIG Programme VH-NG-717 (FunSiLab) and the ERC-consolidator grant DYNASORE.
[1] T. Thonhauser, Int. J. Mod. Phys. B **25**, 1429 (2011)

MA 49.2 Thu 9:45 HSZ 401

Quantum interference effects in molecular spin hybrids — •Taner Esat[1], Rico Friedrich[2], Frank Matthes[3], Vasile Caciuc[2], Nicolae Atodiresei[2], Stefan Blügel[2], Daniel E. Bürgler[3], F. Stefan Tautz[1], and Claus M. Schneider[3] — [1]Peter Grünberg Institute (PGI-3), FZ Jülich, Germany — [2]Peter Grünberg Institute (PGI-1) and Institute for Advanced Simulation (IAS-1), FZ Jülich — [3]Peter Grünberg Institute (PGI-6), FZ Jülich

Magnetism of molecules is in the focus of intense research, because it could lead to new spin-based electronic devices. An interesting approach is to tailor hybrid molecular magnets from a non-magnetic molecule by spin-dependent hybridization with a ferromagnetic building block, since such hybrid systems promise unique magnetic functionalities.

In this work we have studied by means of low-temperature scanning tunneling microscopy (STM) and spectroscopy (STS) single molecular spin hybrids formed upon chemisorbing a polycyclic aromatic hydrocarbon molecule on Co(111) nanoislands. The spin-dependent hybridization between the Co *d*-states and the π-orbitals of the molecule leads to a spin-imbalanced electronic structure of the chemisorbed organic molecule. Spin-sensitive measurements reveal that the spin polarization shows intramolecular variations among the different aromatic rings in spite of the highly symmetric adsorption geometry. We rather relate the varying degree of spin polarization to the superposition of the spin polarization of the molecule and the spatially modulated spin polarization of the Co(111) *sp* surface state.

MA 49.3 Thu 10:00 HSZ 401

Magnetic properties of the ultrathin Co films grown on the curved Ni(111) and Pd(111) single crystals — •Maxim Ilyn[1,2], Laura Fernandez[2], Ana Magaña[1,3], Philippe Ohresser[4], Enrique Ortega[1,2,3], and Frederik Schiller[1] — [1]Materials Physics Center CSIC-UPV/EHU, San Sebastian, Spain — [2]Donostia International Physics Center, San Sebastian, Spain — [3]Department of Applied Physics, University of Basque Country, Bilbao, Spain — [4]Synchrotron SOLEIL, LOrme des Merisiers, France

We investigated the effect of stress and coordination on the magnetic properties of Co nanostructures. The feature of the work is a use of the curved Pd and Ni single crystals as the substrates for the epitaxial growth of Co. The (111) face of these crystals was polished in a shallow cylindrical shape to expose gradually different vicinal surfaces with misorientation +/- 15 degrees towards [11-2] direction. Microscopically these surfaces consist of atomically flat terraces with (111) orientation separated by steps. Average terrace width changes along the curvature from few hundreds nm to 1-2 nm at the edge of the crystal.

In the curved crystals surface stress relaxes gradually with decreasing of the terrace allowing for the variable lattice mismatch between the substrate and the overlayer. Furthermore, atomic steps block diffusion of the adsorbed atoms between the terraces and being the preferential nucleation places change the morphology of the Co nanostructures from 2D islands in the big terraces to 1D atomic chains in the small ones. Our STM and XMCD data show variation of the growth mode and magnetic properties as a function of Co coverage and miscut angle.

MA 49.4 Thu 10:15 HSZ 401

towards non-perturbative reading of atomic spin states with STM — •luigi malavolti[1,2], steffen rolf-pissarczyk[1,2], shichao yan[1,2], jacob burgess[1,2], gregory mcmurtrie[1,2], and sebastian loth[1,2,3] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Deutschland — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Deutschland — [3]Institut für Funktionelle Materie und Quantentechnologien, Universität Stuttgart, Deutschland

Scanning tunneling microscopy (STM) has proven to be an essential tool for the investigation of magnetic phenomena at the atomic scale [1]. By using an STM it is possible to encode, and read information, in the spin state of nano-objects [2]. However, reading the spin state without erasing the information entails fundamental problems due to the quantum nature of the process [3]. This is related to the perturbations introduced by the STM reading: the proximity effect of the tip, the presence of electric field and the tunneling electrons-spin system interaction. Here, we use the high magnetic sensitivity of an atomic scale sensor to read the state of a nearby nano-antiferromagnet (nano-AF). The sensor detects small changes in the local magnetic environment induced by the presence of the nano-AF and transduces them into conductivity changes. This remote reading scheme removes the tip from the nano-AF and effectively mitigates the perturbation, allowing spin state read-out that is five times less invasive than direct inspection.

[1] R. Wiesendanger, Rev. Mod. Phys. 81, 1495 (2009). [2] S. Loth, et al., Science 335, 196 (2012). [3] J.-P. Gauyacq, et al., Phys. Rev. Lett. 110, 87201 (2013).

MA 49.5 Thu 10:30 HSZ 401

Interplay of magnetic coupling and anisotropy of $Ho_3N@C_{80}$ endohedral fullerenes on ferromagnetic substrates — •Matthias Bernien[1], Fabian Nickel[1], Jorge Miguel[1], Lucas M. Arruda[1], Lalminthang Kipgen[1], Norman Blümel[1], Dennis Krüger[1], Andrew J. Britton[1], Enrico Schierle[2], Eugen Weschke[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin

Magnetic endohedral fullerenes are promising candidates for a future molecular spintronics provided one can gain external control over their encapsulated magnetic moments. In $Ho_3N@C_{80}$ three Ho ions are coupled together with a non-collinear alignment of their magnetic moments. Each of the Ho^{3+} ions has a magnetic moment of $10\,\mu_B$ and strong magnetic anisotropy. We use field- and angle-dependent X-ray absorption and X-ray magnetic circular dichroism measurements at a temperature of $T = 4.5\,\mathrm{K}$ and an applied magnetic field up to $B = 6\,\mathrm{T}$ to investigate the magnetic properties of submonolayers of $Ho_3N@C_{80}$ adsorbed on ferromagnetic Ni and Co films. We find that the net moment of $Ho_3N@C_{80}$ couples ferromagnetically to Ni but antiferromagnetically to Co substrates. Both of these couplings to the substrate can be explained by an indirect exchange mechanism mediated by the carbon cage.

Financial support by the DFG (Sfb 658) is gratefully acknowledged.

15 min. break

MA 49.6 Thu 11:00 HSZ 401

Control of helical spin order in Fe nanoislands — •Jeison A. Fischer, Leonid Sandratskii, Dirk Sander, and Stuart Parkin — Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany.

An exchange driven helical spin order has been revealed for Fe bilayer islands on Cu(111 [1]. The driving force for the existence of the spin helix with a period of 1.28 nm has been attributed to the competition

between ferro- and antiferromagnetic interactions due to the reduced dimensionality of the Fe bilayer islands [1]. Mechanisms to control the non-collinear spin order via lateral confinement with ferromagnet and vacuum interfaces has been demonstrated [2]. Here we report an alternative form to control the magnetic spin order in Fe nanoislands by changing the Fe thickness. Spin-polarized scanning tunneling microscopy and spectroscopy reveals a magnetic stripe phase with a period of 2.3 nm in trilayer Fe nanoislands on Cu(111) [3]. The change in period represents an increase of 80% from bilayer to trilayer systems. Together with theoretical insights, we discuss our finding in view of the role of the layerwise dependence of the exchange interactions acting in the system.

[1] S.-H. Phark, J.A. Fischer, M. Corbetta, D. Sander, K. Nakamura, J. Kirschner, Nat. Commun. 5:5183 doi:10.1038/ncomms6183 (2014).
[2] J.A. Fischer, L.M. Sandratskii, S.-H. Phark, S. Ouazi, A. A. Pasa, D. Sander, S.S.P. Parkin, Nat. Commun. 7, 13000 doi: 10.1038/ncomms13000 (2016).
[3] A. Biedermann, W. Rupp, M. Schmid, P. Varga, Phys. Rev. B 73, 165418 (2006).

MA 49.7 Thu 11:15 HSZ 401

Surface orbitronics from the orbital Rashba physics — •Dongwook Go[1,2], Jan-Philipp Hanke[1], Patrick M. Buhl[1], Frank Freimuth[1], Gustav Bihlmayer[1], Hyun-Woo Lee[2], Yuriy Mokrousov[1], and Stefan Blügel[1] — [1]Institute for Advanced Simulation and Peter Grünberg Institut, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany — [2]Department of Physics, Pohang University of Science and Technology, 37673 Pohang, Korea

As the inversion symmetry is broken at a surface, spin-orbit interaction gives rise to spin-dependent energy shifts − a phenomenon which is known as the spin Rashba effect. Recently, it has been recognized that an orbital counterpart of the spin Rashba effect − the orbital Rashba effect − can be realized at surfaces even without spin-orbit coupling. Here, we propose a mechanism for the orbital Rashba effect based on *sp* orbital hybridization, which ultimately leads to the electric polarization of surface states. For an experimentally well-studied system of $BiAg_2$ monolayer, as a proof of principle, we show from first principles that this effect leads to chiral orbital textures in **k**-space. In predicting the magnitude of the orbital moment arising from the orbital Rashba effect, we demonstrate the crucial role played by the Berry phase theory for the magnitude and variation of the orbital textures. As a result, we predict a pronounced manifestation of various orbital effects at surfaces, and proclaim the orbital Rashba effect to be a key platform for surface orbitronics.

[1] arXiv:1611.04674.

MA 49.8 Thu 11:30 HSZ 401

Chiral spin coupling across the interface of Fe/W(110) monolayer - double layer coverages — •Anika Schlenhoff, Stefan Krause, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

Recently, various complex magnetic spin structures in metallic thin film systems arising from the interplay of exchange, anisotropy and Dzyaloshinskii-Moriya (DM) interaction have been discovered. For example, the Fe double layer (DL) on W(110) exhibits an inhomogeneous right-rotating cycloidal spin spiral with magnetic domains separated by chiral domain walls [1]. On the Fe monolayer (ML) on W(110) in-plane magnetized domains have been observed [2], but the domain wall chirality has not been investigated yet.

Here, we present spin-polarized scanning tunneling microscopy experiments on combined ML and DL of Fe/W(110). In the ML, adjacent domain walls show a unique rotational sense, indicating an inhomogeneous spin spiral. At the interface between the ML and the DL a deformation of the magnetic domain pattern of the DL is found. Our observations indicate a chiral magnetic coupling of the DL to the ML and a DM vector at the ML - DL interface being perpendicular to the surface.

[1] S. Meckler *et al.*, Phys. Rev. Lett. **103**, 157201 (2009).
[2] M. Pratzer *et al.*, Phys. Rev. Lett. **87**, 127201 (2001).

MA 49.9 Thu 11:45 HSZ 401

All-electrochemical-approach towards voltage-tunable nanomagnets — •Kenny Duschek[1], Andreas Petr[1], Margitta Uhlemann[1], Veronika Hähnel[1], Kornelius Nielsch[1,2], and Karin Leistner[1] — [1]Leibniz-Institute for Solid State and Materials Research, Dresden, Germany — [2]TU Dresden, Germany

Electric field control of magnetism in thin metal/metal oxide nanostructures offers new energy-saving opportunities for the development of microelectromechanical systems, microfluidics and spintronics. Recently, it was shown that large changes in magnetism can be realized by exploiting magneto-ionic effects [1, 2]. In previous studies we obtained large changes of the saturation magnetization in sputter deposited thin iron films by using them as an electrode in an aqueous electrolyte containing 1 M KOH [2]. Changes were achieved by reversibly switching the oxidation state of a 1.5 nm Fe reaction layer. Much larger effects can be obtained by increasing the surface-to-volume ratio of the magnetic nanostructures. Here we demonstrate an all-electrochemical-approach where the magnetism of an electrodeposited nanogranular iron film can be switched almost on and off reversibly. The effects were proved by in situ measurements of the anomalous Hall effect and the ferromagnetic resonance.

[1] U. Bauer, S. Emori and G. S. D. Beach, Nature Nanotechnology 8 (2013) 411-416; [2] K. Duschek, D. Pohl, S. Fähler, K. Nielsch and K. Leistner, APL Materials 4 (2016) 032301-1 - 032301-10

MA 49.10 Thu 12:00 HSZ 401

Purely Antiferromagnetic Magnetoelectric RAM — •Tobias Kosub[1], Martin Kopte[1], Patrick Appel[2], Brendan Shields[2], Patrick Maletinsky[2], René Hübner[1], Jürgen Fassbender[1], Oliver G. Schmidt[3], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Dresden, Germany — [2]University of Basel, Basel, Switzerland — [3]IFW Dresden e.V., Dresden, Germany

Magnetic RAM schemes employing magnetoelectric coupling to write binary information promise outstanding energy efficiency [1]. We propose and demonstrate [2] a purely antiferromagnetic magnetoelectric RAM (AF-MERAM) that offers a remarkable 50-fold reduction of the writing threshold compared to ferromagnet-based counterparts and is robust in magnetic fields.

Using the magnetoelectric antiferromagnet Cr_2O_3, we demonstrate reliable operation at room temperature. The antiferromagnetic state is written via gate voltage pulses and is read out all-electrically via Zero-Offset Hall [3]. Based on our prototypes of these novel AF-MERAM elements, we construct a comprehensive model of the magnetoelectric selection mechanism in thin films of magnetoelectric antiferromagnets. We identify that growth induced effects lead to emergent ferrimagnetism, which is detrimental to the robustness of the storage. After pinpointing lattice misfit as the likely origin, we provide routes to enhance or mitigate this emergent ferrimagnetism as desired.

[1] F. Matsukura et al., *Nature Nano.* **10** 209 (2015).
[2] T. Kosub et al., *Nature Commun.* accepted (2016).
[3] T. Kosub et al., *Phys. Rev. Lett.* **115** 097201 (2015).

MA 49.11 Thu 12:15 HSZ 401

Current-induced switching and magnetic relaxation in antiferromagnetic memory devices — •Sonka Reimers[1,2], Carl Andrews[1], Peter Wadley[1], Richard P Campion[1], Kevin W Edmonds[1], Andrew W Rushforth[1], Bryan L Gallagher[1], and Vasily Moshnyaga[2] — [1]School of Physics and Astronomy, University of Nottingham, Nottingham NG7 2RD, United Kingdom — [2]I. Physical Institute, Georg-August-Universität, 37077 Göttingen, Germany

To date antiferromagnets (AFs) play only a passive role in spintronic applications. Manipulating and measuring the magnetic state is more difficult than in ferromagnets (FM). On the other hand, purely AF-based devices offer several advantages compared to their FM counterparts including robustness against electric and magnetic perturbations, and ultrafast spin dynamics. It has recently been demonstrated that the local magnetic moment can be switched between stable configurations in biaxial AF CuMnAs thin film devices using electrical current pulses [1].

Future memory applications require a thorough understanding of the magnetic relaxation processes following a current pulse. Experimentally we analyse the dynamics by measuring the time-dependence of the anisotropic magnetoresistance (AMR). We examine the data regarding their information on the magnetic anisotropy of the sample, which may be modified by an externally applied strain, offering an important parameter for controlling the stability of the AF state.

References: [1] P. Wadley et al. "Electrical switching of an antiferromagnet". In: Science 351, 587 (2016)