MA 53: Spin Structures at Surfaces and in thin films II

Time: Friday 9:30–12:00 Location: BEY 118

MA 53.1 Fri 9:30 BEY 118

Co nanodot arrays grown on a ferromagnetic $GdAu_2$ template: substrate/nanodot antiferromagnetic exchange coupling — •Laura Fernandez[1], Maria Blanco Rey[1,2], Maxim Ilyn[3], Lucia Vitali[4], Alex Correa[1], Philippe Ohresser[5], Enrique Ortega[1,2,3,4], Andrés Ayuela[1,3], and Frederik Schiller[1,3] — [1]Donostia International Physics Center, San Sebastian, Spain — [2]Universidad del Pais Vasco (UPV/EHU), San Sebastian, Spain — [3]Centro de Física de Materiales, San Sebastian, Spain — [4]Ikerbasque, Bilbao, Spain — [5]Soleil, Saint-Aubin, France

Controlling and manipulating exchange coupling and anisotropy in patterned magnetic nanostructures is the key for developing advanced magnetic storage and spintronic devices. Here we search the magnetic interaction between a Co nanodot array and its supporting ferromagnetic $GdAu_2$ nanotemplate. X-ray magnetic circular dichroism measurements reveal strong antiferromagnetic coupling across the Co/$GdAu_2$ interface, which is corroborated by full-potential linearized augmented plane wave calculations. These studies find that the anisotropy of the Co nanodots is profoundly modified by the influence of the $GdAu_2$ nanotemplate that induces large anisotropy values. In clear contrast with non-magnetic Au substrates, $GdAu_2$ triggers the early switch in the anisotropy direction from out-of-plane in monolayer-thick Co, to in-plane, in bilayer Co films.

MA 53.2 Fri 9:45 BEY 118

Tuning of the magnetic properties of Co adatoms on Graphene through interaction with a metal substrate — •Alberto Cavallin[1,2], Fabio Donati[1], Luca Gragnaniello[1], Fabian D. Natterer[1], François Patthey[1], Quentin Dubout[1], Jan Dreiser[1,3], Cinthia Piamonteze[3], Frithjof Nolting[3], Stefano Rusponi[1], and Harald Brune[1] — [1]Institute of Condensed Matter Physics (ICMP), École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland — [2]present address: Max-Planck-Institut für Mikrostrukturphysik, Halle (Saale), Germany — [3]Swiss Light Source (SLS), Paul Scherrer Institut (PSI), Villigen, Switzerland.

The magnetic properties of adatoms on graphene (G) are extremely relevant in view of potential applications in spintronics. Nowadays large efforts are devoted to predict the physics of long range interactions between magnetic moments localized on Co and Fe adatoms and mediated by the graphene conduction electrons.[1]

The magnetic ground state and anisotropy of Co adatoms on G are however much debated at present.[2] Here, we show a strong dependence of these properties on the metal substrate on which G is grown. A state of the art investigation based on XAS, XMCD, STM, STS and multiplet calculations reveals large spin and orbital moments, and an out-of-plane easy axis for Co/G/Ru(0001), while it shows comparatively weak magnetic moments and anisotropy for Co/G/Ir(111).

[1] S. R. Power and M. S. Ferreira, Crystals, **3**, 49 (2013).
[2] F. Donati, Q. Dubout *et al.*, Phys. Rev. Lett. **111**, (2013), and references therein.

MA 53.3 Fri 10:00 BEY 118

Unexpected behaviour of the magnetocrystalline anisotropy of adatoms as a function of the spin orbit coupling — •Ondřej Šipr[1], Sven Bornemann[2], Sergey Mankovsky[2], Hubert Ebert[2], and Ján Minár[2] — [1]Institute of Physics of the ASCR, Praha, Czech Republic — [2]Universität München, München, Germany

The origin of magneto-crystalline anisotropy in various 3D solids, in 2D ultra-thin films, as well as in 0D magnetic clusters, was discussed in the literature by many authors who demonstrated that for uniaxial systems its dependence on the strength of the spin orbit coupling (SOC) is quadratic. This property is the result of small magnitude of SOC energy when compared to the electron band width of such systems, which allows to account for its contribution within the second order perturbation theory.

However, the situation can be different in the case of single atoms deposited on a surface. We demonstrate by the ab-initio electronic structure calculations that for 3d transition metal adatoms on Au(111) the dependence of the magneto-crystalline anisotropy energy on the SOC becomes quite complicated and it is rather linear than quadratic for realistic SOC values. This feature can be attributed to the very narrow electronic bands associated with the adatoms being comparable to the SOC-induced changes upon the rotation of the magnetization direction.

MA 53.4 Fri 10:15 BEY 118

Magnetic hardening induced by nonmagnetic organic molecules — •Martin Callsen, Vasile Caciuc, Nikolai Kiselev, Nicolae Atodiresei, and Stefan Blügel — Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

One target of molecular spintronics is to design new, molecule based magnetic materials with predefined magnetic and electronic properties for spintronic applications. By means of *ab initio* calculations in the framework of density functional theory we revealed that the adsorption of a nonmagnetic π-conjugated organic molecule on a ferromagnetic surface locally increases the strength of the magnetic exchange interaction between the magnetic atoms binding directly to the molecule [1]. In particular, we investigated the prototypical, biplanar [2,2]paracyclophane molecule adsorbed on the Fe/W(110) surface. The observed magnetic hardening effect leads to the creation of a local molecule mediated magnetic unit with a stable magnetization direction and an enhanced barrier for the magnetization switching as compared to the clean surface. In addition, this hybrid organic-ferromagnetic system exhibits a spin-filter functionality with sharp spin-split molecular-like electronic features at the molecular site.

[1] M. Callsen *et al.*, Phys. Rev. Lett. **111**, 106805 (2013)

MA 53.5 Fri 10:30 BEY 118

Electric-field induced magnetic anisotropy on the atomic scale — •Andreas Sonntag, Jan Hermenau, Anika Schlenhoff, Johannes Friedlein, Stefan Krause, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Germany

One of the challenges in data storage applications is the control of magnetic anisotropy: To stabilize a magnetic bit against thermal magnetization reversal a large anisotropy is needed, while a low anisotropy is desired when writing information. A device employing electric fields to actively reduce the magnetic anisotropy during writing could benefit from smaller power consumption compared to conventional devices.

In our experiments we investigate the impact of an electric field onto the anisotropy of individual atomic-scale magnets. The superparamagnetic switching of uniaxial Fe magnets on W(110) [1] is studied using spin-polarized scanning tunneling microscopy (SP-STM). Electric fields up to 6 GV/m are applied at very low tunnel current, thereby excluding current induced effects. The experiments show that the electric field E can be used to increase or decrease the switching rate, depending on the sign of E. This is attributed to an electric-field induced anisotropy that favors in-plane magnetization for $E < 0$ and out-of-plane magnetization for $E > 0$. The interpretation of this concept is verified by changing from an in-plane to an out-of-plane system.

Our experiments demonstrate magnetic manipulation without exploiting spin or charge currents, thereby opening the pathway towards electric-field based spintronic applications on the atomic scale.

[1] S. Krause *et al.*, Phys. Rev. Lett. **103**, 127202 (2009).

MA 53.6 Fri 10:45 BEY 118

Spin states of single holmium adatoms with exceptionally long lifetimes — Toshio Miyamachi, Tobias Schuh, •Tobias Märkl, Timofey Balashov, Christopher Bresch, Alexander Stöhr, and Wulf Wulfhekel — Physikalisches Institut, Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany

In order to use single atomic spins in data storage and processing, stable spin states are crucial. Generally, transition metal atoms on metallic surfaces or thin insulating films show short spin lifetimes of less than a microsecond due to a strong hybridization between substrate electrons and the 3d-orbitals of the atom.

Here, we report on a series of experiments to investigate spin states of Ho atoms on a Pt(111) surface with STM. In this approach we combined the characteristics of a rare earth atom with the symmetries of the adsorption site to significantly decouple the 4f orbitals from the substrate, resulting in lifetimes up to several minutes. [1]

[1] T. Miyamachi et al., Nature 503, 242-246 (2013)

MA 53.7 Fri 11:00 BEY 118

Reduced dimensionality induced magnetic stripe phase in Fe nanoislands — •Soo-hyon Phark[1], Jeison Fischer[1,2], Marco Corbetta[1], Dirk Sander[1], and Jürgen Kirschner[1] — [1]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [2]Universidade Federal de Santa Catarina , Florianópolis, Brazil

Low-dimensionality in itinerant magnetic materials often leads to magnetic ground states of non-collinear magnetic order [1], such as spin helices and skyrmions. Recent theoretical works predicted that competing exchange interactions induce a spin helix in bcc Fe(110) monolayers [2]. Here we report an observation of a magnetic stripe phase with a period of 1.28 nm in bilayer Fe nanoislands on Cu(111) [3]. In-field spin-polarized scanning tunneling microscopy and spectroscopy reveal that the stripe phase originates from a helical spin ordering. Together with theoretical insights [2], our finding provides compelling experimental evidence that a non-collinear magnetic ordering can be stabilized in a system where a long-range antiferromagnetic exchange interaction is enhanced due to a reduced dimensionality.

[1] S. Mühlbauer, B. Binz, F. Jonietz, C. Pfleiderer, A. Rosch, A. Neubauer, R. Georgii, P. Böni, Science 323, 915 (2009). [2] K. Nakamura, N. Mizuno, T. Akiyama, T. Ito, A. Freeman, J. Appl. Phys. 99, 08N501 (2006). [3] A. Biedermann, W. Rupp, M. Schmid, P. Varga, Phys. Rev. B 73, 165418 (2006).

MA 53.8 Fri 11:15 BEY 118

Superconducting scanning tunneling microscope tips as probes for absolute spin-polarization — •Matthias Eltschka[1], Berthold Jäck[1], Maximilian Assig[1], Markus Etzkorn[1], Christian R. Ast[1], and Klaus Kern[1,2] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]Ecole Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

Spin-polarized tunneling pioneered by Robert Meservey and Paul Tedrow has become an essential field of study and opened up the way for many applications [1]. We transfer the concept of superconducting detector electrodes commonly used in standard thin film sandwich junctions to scanning tunneling microscopy (STM) to locally probe absolute spin-polarization. We have studied superconducting vanadium STM tips on normal conducting samples in high magnetic fields at 10 mK. The superconducting properties of those tips are determined by the confinement due to the specific tip geometry. Superconducting STM tips have been employed as local probe for the absolute spin-polarization of Co nanoislands on Cu(111). Our results qualitatively agree with experiments carried out by SP-STM [2] but the absolute values of the measured spin-polarization allows for further analysis of the orbital wave functions involved in the tunneling process.

[1] P. M. Tedrow *et al.*, Phys. Rev. Lett. **25**, 1270 (1970); P. M. Tedrow and R. Meservey, Phys. Rev. Lett. **26**, 192 (1971). [2] H. Oka *et al.*, Science **327**, 843 (2010).

MA 53.9 Fri 11:30 BEY 118

Interplay of orbital-dependent tunneling and spin-polarization in STM/STS — Gábor Mándi, Mátyás Seress, and •Krisztián Palotás — Budapest University of Technology and Economics, Department of Theoretical Physics, Budafoki út 8., H-1111 Budapest, Hungary

Scanning tunneling microscopy (STM) images of magnetic surfaces can show contrast changes depending on the bias voltage or tip magnetization orientation [1]. We investigate the interplay of orbital-dependent tunneling [2] and spin-polarization effects on constant-current STM images of the Fe(110) surface. We find that the atomic contrast inversion is sensitive to the spin-polarization and the orbital character of the STM tip [3]. Taking a moiré-patterned Co/Ag(111) surface [4], we calculate differential conductance tunneling spectra (STS), and the results demonstrate the sensitivity of the spectra on the spin-polarization and the orbital composition of the tip.

The simulations are performed using a three-dimensional Wentzel-Kramers-Brillouin tunneling model based on ab initio electronic structure data [5].

References:
[1] K. Palotás, Phys. Rev. B 87, 024417 (2013).
[2] K. Palotás et al., Phys. Rev. B 86, 235415 (2012).
[3] G. Mándi and K. Palotás, arXiv:1309.4696 (2013).
[4] T. G. Gopakumar et al., Chem. Phys. Lett. 484, 59 (2009).
[5] K. Palotás et al., Front. Phys., DOI: 10.1007/s11467-013-0354-4 (2013).

MA 53.10 Fri 11:45 BEY 118

Enhanced atomic-scale spin contrast due to spin friction — •Safia Ouazi, André Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

We report that atomic-scale magnetic contrast can be enhanced by one order of magnitude when a magnetic adatom is controllably trapped between a scanning tunneling microscope tip and a magnetic substrate during scanning. As model system, we study the $(\sqrt{3}\times\sqrt{3})R30^\circ$ magnetic superstructure of a monolayer Fe on Re(0001), with low-temperature spin-polarized scanning tunneling microscope measurements (SP-STM). The observed in-plane Néel ordered state has a magnetic unit cell of three atoms. We obtain magnetic atom manipulation images from the tunneling regime to almost contact regime by systematically varying the gap resistance. This parameter determines the tip-sample distance and tunes the magnetic interactions between the tip, sample and the magnetic adatom. At intermediate gap resistance, we observe that the motion of the manipulated atom depends on the spin alignment of the magnetic layer and consider this a manifestation of spin friction, as in [1]. We discuss the role of tip-sample distance for the observation of the magnetic structure of the sample and the mechanism for the boost of magnetic corrugation.

[1] Wolter, B. et al, Phys. Rev. Lett. 109, 116102 (2012)