O 4: Surface Magnetism: Atoms and Molecules

Time: Monday 10:30–12:30 Location: S052

O 4.1 Mon 10:30 S052

Magnetic Hysteresis in Er trimers on Cu(111) — •Aparajita Singha[1], Fabio Donati[1], Christian Wäckerlin[1], Romana Baltic[1], Jan Dreiser[1,2], Marina Pivetta[1], Stefano Rusponi[1], and Harald Brune[1] — [1]École Polytechnique Fédérale de Lausanne, Switzerland — [2]Swiss Light Source, Paul Scherrer Institute, Switzerland

The aim to explore the ultimate density limit of magnetic information storage has triggered increasing interest in surface-supported magnetic nanostructures. Currently the smallest surface-adsorbed ferromagnet consists of only five Fe atoms with magnetic stability up to several hours at 0.3 K [1]. Here, we present evidence of magnetic hysteresis in rare earth Er clusters at 2.5 K starting from the size of three atoms. We combine x-ray magnetic circular dichroism, scanning tunneling microscopy and mean-field nucleation theory to determine the size-dependent magnetic properties of the Er clusters adsorbed on Cu(111). We observe that the magnetization of Er atoms [2] and dimers is oriented in-plane. In contrast, trimers and bigger clusters exhibit out-of-plane anisotropy and a butterfly-shaped magnetic hysteresis at 2.5 K. Their magnetization lifetime is larger than 120 s at 0.1 T.

[1] Khajetoorians et al., Science, 339, 55 (2013) [2] Donati et al., Phys. Rev. Lett., 113, 237201 (2014)

O 4.2 Mon 10:45 S052

Calibration of highly efficient FeO-based spin polarization detector — •Pika Gospodaric, Ewa Mlynczak, Markus Eschbach, Mathias Gehlmann, Sven Döring, Lukasz Plucinski, and Claus Michael Schneider — Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52425 Jülich, Germany

A recently developed FeO-based spin polarization detector (1) was adapted to a high-resolution hemispherical MBS A-1 electron analyzer to study the spin degree of freedom in the electronic band structure of spintronic materials with spin- and angle-resolved photoemission spectroscopy (spinARPES). The operation of the polarimeter is based on the exchange scattering of electrons from an oxidized Fe(100) film, which can be magnetized in four orthogonal in-plane directions. Our setup employs a 90° deflector, which allows probing one of the in-plane and the out-of-plane spin components. In this talk, performance calibration tests of the system using the Rashba spin-orbit split surface states of the single crystal Au(111) and various topological insulator thin films will be presented. At optimized scattering energy the asymmetry function reaches 30% and the reflectivity up to 10%, which results in a 20-40 times higher figure of merit compared to the conventional Mott spin detectors. Experiments were performed using an unpolarized noble-gas discharge lamp and a laser-based 6 eV photon source with light polarization control. The high energy and angular resolution of the spinARPES spectra clearly distinguishes the two spin polarized branches of the Au(111) surface state.

(1) M. Escher et al., e-J. Surf. Sci. Nanotech. Vol. 9 (2011)

O 4.3 Mon 11:00 S052

Electronic and magnetic properties of Au/Fe(001) bilayers epitaxially grown on MgO(001) — •Ewa Młyńczak[1,2], Pika Gospodarič[1], Markus Eschbach[1], Mathias Gehlmann[1], Sven Döring[1], Lukasz Plucinski[1], and Claus Michael Schneider[1] — [1]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, al. Mickiewicza 30, 30-059 Kraków, Poland

The electronic band structure of ferromagnetic films is a basis for magnetotransport phenomena, which are important for future spintronics, such as tunneling anisotropic magnetoresistance or spin-orbit torque (SOT). In the context of SOT, it is especially interesting to study the electronic structure of the interface between a ferromagnet (characterized by high exchange coupling) and a heavy metal (known for high spin-orbit coupling). In this study, ultrathin Au layers were deposited onto Fe(001)/MgO(001) thin film using different preparation conditions. The Au growth was monitored by recording changes of the film resistance with the deposition time. A laboratory based high-resolution angle resolved photoemission spectroscopy was used to study the near-surface electronic band structure. Spin detection was performed using a highly efficient spin polarimeter (FERRUM). It was possible to observe the development of the electronic bands characteristic for Au, while still having experimental access to the band structure of the underlying Fe(001). The magnetic properties of the bilayers were determined by in-situ anisotropic magnetoresistance measurements.

O 4.4 Mon 11:15 S052

The fascinating versatility of wustite surfaces — •Silvia Gallego and Ivan D. Bernal-Villamil — Instituto de Ciencia de Materiales de Madrid, Madrid, Spain

Wustite (FeO) belongs to the magnetic transition metal monoxides series, a set of antiferromagnetic Mott insulators with a simple rock-salt structure. Among them, wustite is singular in its high content of Fe vacancies at ambient conditions, that introduce local polaronic charge distributions and alter the magnetization.

Mono- and bi-layer FeO has been grown and largely studied, but it reverts to Fe3O4 as the thickness increases, accompanied by a yet not solved 2x2 surface structure with unexpected magnetic features. Based on ab initio calculations, in this talk we will provide our solution for this 2x2 structure, explaining the evolution of FeO to Fe3O4, and the origin of the magnetism. Furthermore, we will show how surface processes are involved in the growth of unusually thick stoichiometric FeO films, that hold a 1x1 symmetry and robust bulk-like antiferromagnetic order.

O 4.5 Mon 11:30 S052

Theory of Inelastic Electron Tunneling through an Adatom: Perturbation Expansion around the Atomic Limit — •Jindrich Kolorenc — Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic

We investigate tunneling of electrons from an STM tip to a substrate through a magnetic adatom. We assume weak coupling between the tip and the adatom as well as between the adatom and the substrate, and we include these couplings only in the lowest order of the perturbation theory. We employ the Kramers–Heisenberg formula to evaluate the probabilities of coherent two-step processes that contribute to the tunneling current (for instance, an electron tunnels from the tip to the adatom and then continues from the adatom to the substrate). Our method is closely related to the cotunneling theory of Ref. [1], but it appears somewhat more straightforward and allows us to derive a relatively compact formula for the differential conductance. The steps appearing in the differential-conductance spectra are identified with excitations in the magnetic adatom that can be parametrized on the basis of first-principles calculations without resorting to an effective spin model. The method is straightforwardly applicable to cases with strong spin-orbital coupling (f electrons) where the spin is not a good quantum number.

[1] F. Delgado and J. Fernández-Rossier, Phys. Rev. B **84**, 045439 (2011)

O 4.6 Mon 11:45 S052

Investigation of the superconducting gap of nano-sized Pb-islands in high magnetic fields — •Steffen Rolf-Pissarczyk[1,2], Jacob Burgess[1,2], Shichao Yan[1,2], and Sebastian Loth[1,2] — [1]Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany — [2]Max Planck Institute for Solid State Research, Stuttgart, Germany

Superconductors change drastically their properties when they are confined in geometries with dimensions of the order or less than the London penetration depth or coherence length of the bulk material. To get experimental access to the effects of strong confinement we prepared small hexagonal Pb-islands with diameter of less than 50 nm and a uniform height of 7 atomic layers on Si(111) 7x7. The islands were formed by depositing Pb at low temperature and annealing at 300 K. We investigated the Pb-islands with scanning tunneling spectroscopy in magnetic fields up to 9 T and at 0.6 K temperature.

We found the critical magnetic field in such small islands to be several Tesla, which represents an enhancement greater than 50 compared to the bulk value. The critical field was directly measured and verified by the vanishing superconducting gap. By independently measuring the size of the superconducting gap and the critical magnetic field that quenches superconductivity we were able to correlate these two fundamental parameters. This correlations allows us to estimate the highest critical field expected for 7 atomic layer thin Pb-islands.

O 4.7 Mon 12:00 S052

Sensing Nanomagnets with an Atomically Assembled Quantum Spin Sensor — •Luigi Malavolti[1,2], Shichao Yan[1,2], Jacob Burgess[1,2], Steffen Rolf-Pissarczyk[1,2], and Sebastian Loth[1,2] — [1]Max-Planck Institut für Struktur und Dynamik der Materie, Hamburg, Deutschland — [2]Max-Planck Institut für Festkörperforschung, Hamburg, Deutschland

Quantum spin systems can be used for sensing the magnetic environment with unprecedented accuracy and sensitivity [1]. Atom manipulation in the scanning tunnelling microscope allows construction of the quantum sensor in close proximity to the objects or region of interest.

Here, we show that a quantum spin sensor consisting of three Fe atoms on a monolayer copper nitride surface [2] can be used to probe the magnetic state of nearby nanomagnet. We built a nanomagnet that show no net spin and switches spontaneously between two Néel states. By characterizing the dynamic magnetic behaviour of the sensor using a dynamic pump-probe technique [2,3] we were able to detect the state of the nanomagnet at distance up to 3nm. We also demonstrate that, by an appropriate tuning of the properties of our sensor, the non-local sensing is possible even without a direct access to the relaxation time of the sensor. This opens the way to non-locally detect the magnetic state of other magnetic objects such as single molecule magnets and local atomic conditions on surfaces.

[1] Damadian, R. Science 171(3976), 1151-1153 (1971).
[2] Yan, S., et al., Nat Nano 10(1), 40-45 January (2015).
[3] Loth, S., et al., Science 329(5999), 1628-1630 (2010).

O 4.8 Mon 12:15 S052

X-ray magnetic dichroism of small, size-selected FeV clusters on Cu(100) — •Fridtjof Kielgast[1], Torben Beeck[1], Ivan Baev[1], Deniza Chekrygina[1], Michael Martins[1], and Wilfried Wurth[1,2] — [1]Physics Department, University of Hamburg — [2]DESY Photon Science, Hamburg

The electronic and magnetic properties of clusters tend to change strongly depending on size and composition of the clusters. This change is of great interest both in fundamental and applied research. Here we investigate clusters of 3d metal alloys produced by high energy sputtering. A magnetic field is used to separate the clusters depending on their mass-to-charge ratio. Pure Fe and V adatoms, $Fe_{2,3}$ and V_2 as well as V_1Fe_1 clusters, deposited onto a Cu(100) surface were studied using XMCD. The magnetic XMCD signal was obtained by switching an external magnetic field ($\pm$7 T) and scanning the $L_{2,3}$ edges with circular polarized light at the P04 beamline at PETRA III, DESY. To avoid fragmentation or implantation of the clusters into the substrate, the deposition was carried out by using a soft landing scheme. This work is supported by the DFG in the framework of the SFB 668.