

MA 34: Surface and Interface Magnetism II (jointly with O)

Time: Thursday 10:30–13:00

Location: H33

MA 34.1 Thu 10:30 H33

Deviation from Coulombic behavior in short-range interactions of atoms on the GaAs(110) surface — ●DAVID GOHLKE^{1,2} and JAY GUPTA¹ — ¹Ohio State University, Columbus, OH USA — ²Universität Regensburg, Regensburg, Germany

Mn-doped GaAs is a prototypical dilute magnetic semiconductor where substitutional Mn act as electron acceptors while their magnetic moment allows for long-range magnetic interactions. By using low-temperature (5K) scanning tunneling microscopy (STM), we examine the electronic properties of individual Mn dopants in GaAs. We have previously shown that the binding energy of the Mn electron acceptor state can be tuned by controlled atomic-scale placement of a nearby charged defect, and that the shift of the binding energy due to repulsion between the bound hole and these charged defects follows a $1/r$ Coulombic behavior [Lee and Gupta, *Science* (2010), Gohlke et al., submitted]. Here we will discuss our observations of deviations from the $1/r$ behavior. First, our data show that the anisotropy of the GaAs(110) surface affects the interaction between Mn acceptors and charged adatoms. Second, for charged defects brought within 2nm of the acceptor, we observe defect-induced band bending that changes the occupancy of a hybridized Mn state located in the valence band, resulting in a turnaround behavior of the measured resonance energy. This research has implications in studying the interactions between atoms in Mn-doped GaAs, a material for which the mechanisms for magnetism are still debated.

MA 34.2 Thu 10:45 H33

Mapping of the spin-resolved band structure of fct cobalt films on Cu(100) — ●CHRISTIAN TUSCHE¹, MARTIN ELLGUTH¹, ALEXANDER KRASYUK¹, CARSTEN WIEMANN², VITALIY FEYER², MARTEN PATT², CLAUS M. SCHNEIDER², and JÜRGEN KIRSCHNER¹ — ¹Max-Planck-Institut für Mikrostrukturphysik, 06120 Halle, Germany — ²Forschungszentrum Jülich, 52428 Jülich, Germany

We report on the spin resolved band structure of ultra thin fct cobalt films grown on Cu(100), measured over large volumes in momentum space. Experiments were carried out at the NanoESCA beamline [1] of the Elettra synchrotron. The instrument, consisting of a photoelectron microscope and an imaging energy analyzer, directly maps the parallel momentum component of photoelectrons at a fixed energy. An imaging spin filter, based on the reflection of low energy electrons at a W(100) crystal, was installed temporarily at the exit of the energy filter [2]. This allowed to record the spin polarization at $4 \cdot 10^3$ discrete reciprocal space points, in each momentum image. This efficient approach gives direct access to majority and minority spin bands in the Fermi surface and their dispersion towards larger binding energies. Using 40 eV to 200 eV photons, several constant energy cuts in the 3D Brillouin zone are selected. The comprehensive data sets are expected to serve as valuable input for advanced concepts in theory for the refined treatment of spin-dependent electron correlation. — [1] Wiemann, Patt, Krug, Weber, Escher, Merkel, Schneider, e-J. Surf. Sci. Nanotech. **9**, 395 (2011) — [2] Tusche, Ellguth, Ünal, Chiang, Winkelmann, Krasnyuk, Hahn, Schönhense, Kirschner, Appl. Phys. Lett. **99**, 032505 (2011)

MA 34.3 Thu 11:00 H33

Investigation of the Si/Fe interface with standing-wave excited HAXPES — ●SVEN DÖRING¹, MICHAEL VOIGT², MARTINA MÜLLER², MIHAELA GORGOI³, DANIEL E. BÜRGLER², and CLAUS M. SCHNEIDER^{1,2} — ¹Experimentalphysik, Universität Duisburg-Essen, Lotharstr. 1, 47057 Duisburg — ²PGI-6, Forschungszentrum Jülich, 52425 Jülich — ³Helmholtz Zentrum Berlin für Materialien und Energie, Albert Einstein Str. 15, 12489 Berlin

The interface between the ferromagnet Fe and the semiconductor Si is supposed to be a crucial part of future spintronic devices. The possible formation of silicides and the degree of an intermixing between the layers at the interface has a large influence on the conductance and efficiency of spin-injecting currents from the metal layer into the semiconductor. Therefore, we studied the interface between thin MBE-grown layers of Si on Fe with standing-wave excited hard x-ray photoemission spectroscopy. This method gives us a chemically sensitive depth-profile of the sample with a depth-resolution of a few Å and we are able to compare the interface structure of samples that were grown

under different conditions.

The Si/Fe sample systems were grown on top of multilayer mirrors that give rise to a high reflectivity and thus to strong modulations of the HAXPES signals. The Fe layer was grown as a wedge which enables us to perform rocking-curve experiments as well as so-called Swedge scans.

MA 34.4 Thu 11:15 H33

Inverse proximity effects in superconductor/ferromagnet bilayer explored by polarized neutron reflectometry — ●YURY KHAYDUKOV¹, BELA NAGY², JUNG-HWA KIM¹, THOMAS KELLER¹, LASZLO BOTTYAN², and BERNHARD KEIMER¹ — ¹Max-Planck Institute for Solid State Research, Stuttgart, Germany — ²Wigner Research Centre for Physics, Budapest, Hungary

The inverse proximity effect, i.e. the appearance of magnetic correlations in the superconductor (S) close to the interface with a ferromagnet (F) was first considered theoretically in early 2000s. The origin of this effect is the exchange coupling of free (itinerant) electrons near the S/F interface. The spin up electron of a Cooper pair would prefer to be located in ferromagnetic region while spin down electrons would remain in the superconducting region. This leads to the development of a magnetic sublayer within the S layer close to the interface with its magnetization antiparallel to the magnetization of free electrons of F layer. Thickness of the sublayer is comparable with the superconducting coherence length, ξ . We studied the effect using different methods including transport measurements, SQUID magnetometry etc. However, the main method which allowed us to get the information about the thickness of proximity induced magnetic sublayer was Polarized Neutron Reflectometry. Dependence of this effect (sign and size) on the temperature, coherence length of the S layer ξ , exchange coupling strength of the F layer will be discussed in details.

MA 34.5 Thu 11:30 H33

Spin-density wave node on antiferromagnetic Cr(110) islands — ●TOBIAS MAUERER¹, PIN-JUI HSU¹, WEIDA WU², and MATTHIAS BODE¹ — ¹Institute of Experimental Physics II, University Würzburg, Am Hubland, 97074 Würzburg — ²Department of Physics and Astronomy and Rutgers Center for Emergent Materials, Rutgers University, Piscataway, New Jersey 08854, USA

We have performed a detailed analysis of the evolution of the charge-density wave (CDW) on the surface of nanoscale Cr islands grown on W(110). By combining conventional spin-averaged and spin-polarized scanning tunneling microscopy (SP-STM) we show that the CDW wavelength exhibits a striking thickness dependence. In particular, the CDW wavelength along the surface [110] direction increases by about 30% as the island thickness is decreased from about 50 nm to 5.2 nm. A gap with no CDW visible at the island surface appears for films within the thickness range of $3.7 \leq \Theta \leq 5.2$ nm. At even lower film thickness the CDW reappears until it vanishes at $\Theta \leq 2.5$ nm. By applying SP-STM we show that the Cr surface is non-magnetic within the CDW gap. The CDW gap and the thickness dependence is explained in terms of a reorientation of the SDW vector \mathbf{Q} , which rotates from bulk-like (001) directions into the [110] surface normal. We propose that the SDW pins with a node at the island surface, resulting in a vanishing surface magnetic moment.

MA 34.6 Thu 11:45 H33

Scanning tunneling microscopy and spectroscopy of MnPc on noble metal (111) surfaces — ●JENS KÜGEL, JEANNETTE KEMMER, PIN-JUI HSU, and MATTHIAS BODE — Institute of Experimental Physics II, University Würzburg, Germany

The growth, electronic structure, and magnetic excitations of transition metal phthalocyanine (TM-Pc) molecules adsorbed on noble metal fcc(111) substrates have recently attracted considerable interest. While phthalocyanines with a central ion consisting of Fe, Co, Ni, and Cu have already been studied extensively, only few studies deal with MnPc, even though this molecule carries the highest net magnetic moment in the gas phase ($S = 3/2$) [1]. This property makes it a promising candidate for the observation of collective interaction phenomena with the substrate, such as the Kondo effect. In this contribution we present low-temperature ($T = 5$ K) scanning tunneling microscopy and spectroscopy data of Mn-Pc adsorbed on Au(111) and

Cu(111). The tunneling spectra of Mn-Pc show a distinctly asymmetric conductance around the Fermi level. Our results indicate that this feature critically depends on the chemical state of the tip. By systematically modifying the coupling strength between the molecule and the substrate we will discuss under which conditions the Kondo effect can be observed.

[1] A. Stróżecka *et al.*, Phys. Rev. Lett. **109**, 147202 (2012)

MA 34.7 Thu 12:00 H33

Spin-resolved measurements of single molecular magnets on graphene — ●JENS BREDE, MACIEJ BAZARNIK, RÉGIS DECKER, JÖRG SCHWÖBEL, and ROLAND WIESENDANGER — Institute of Applied Physics, University of Hamburg, 20355 Hamburg, Germany

The use of magnetic molecules opens a gateway to a flexible design of novel spintronic devices to store, manipulate, and read spin information at the nanoscale. Crucial is the precise knowledge of molecular properties at the interface towards an electrode. Progress in this field relies on resolving and understanding the physics at the relevant interfaces. In particular the role of individual molecular constituents and the impact of the atomic environment on molecular properties, determine device relevant parameters, such as conductance and spin polarization. Recently, the incorporation of a graphene sheet to electronically decouple molecules from a ferromagnetic surface was addressed by surface averaging techniques.

Here, we applied spin-polarized scanning tunneling microscopy to resolve the physics of the molecule-graphene-ferromagnet interface. The analysis focuses on different phthalocyanine molecules adsorbed on cobalt intercalated graphene on Ir(111). The phthalocyanine constitutes of an organic macrocyclic ligand and can be functionalized with various metal ions in order to modify, e.g. the molecular spin state. We will discuss the spin-dependent transport from magnetic surfaces through such molecules. In particular, the spin polarizations of molecular frontier orbitals are resolved with sub-molecular spatial resolution and the variations in the lifetimes of different states are discussed.

MA 34.8 Thu 12:15 H33

Chemically programmable 2D electron spin arrays — CHRISTIAN WÄCKERLIN¹, ●JAN NOWAKOWSKI¹, SHI-XIA LIU², MICHAEL JAGGI², JAN GIROVSKY¹, DOROTA SIEWERT¹, ANELIA SHCHYRBA³, TATJANA HÄHLEN¹, ARMIN KLEIBERT¹, PETER M. OPPENEER⁴, FRITHJOF NOLTING¹, SILVIO DECURTINS², THOMAS A. JUNG¹, and NIRMALYA BALLAV⁵ — ¹Paul Scherrer Institute, Switzerland — ²University of Bern, Switzerland — ³University of Basel, Switzerland — ⁴Uppsala University, Sweden — ⁵Institute of Science Education and Research, Pune, India

Spin-bearing metal-organic complexes on ferromagnetic substrates are interesting model-systems which allow studying the magnetism of individual magnetic ions in the proximity of a ferromagnetic metal. In our most recent work we have employed synthetically directed self-assembly to fabricate a highly ordered, two-dimensional chessboard-like supramolecular structure of Fe and Mn building-blocks which is exchange-coupled to a suitable ferromagnetic substrate. On-surface coordination-chemistry is then used to selectively control the spin-states in the resultant Fe-Mn-Fe spin-array. We have combined Scanning Tunneling Microscopy (STM) and X-ray Magnetic Circular Dichroism (XMCD) experiments which provide local/spatially averaged and element-specific information, respectively. High resolution

STM also yields direct visualization of the axial ligands at the phthalocyanine cores.

MA 34.9 Thu 12:30 H33

Modifying the magnetic properties of adsorbed spin bearing porphyrins by chemical stimuli — ●JAN GIROVSKY¹, CHRISTIAN WÄCKERLIN¹, KARTICK TARAFDER², JAN NOWAKOWSKI¹, DOROTA SIEWERT¹, TATJANA HÄHLEN¹, ANELIA SHCHYRBA³, ARMIN KLEIBERT¹, FRITHJOF NOLTING¹, THOMAS A. JUNG¹, PETER M. OPPENEER², and NIRMALYA BALLAV⁴ — ¹Paul Scherrer Institut, Switzerland — ²Uppsala University, Sweden — ³University of Basel, Switzerland — ⁴Indian Institute of Science Education and Research (IISER-Pune), India

Metalloporphyrins adsorbed on and exchange coupled to ferromagnetic substrates [1], have been stimulated by different axial ligands like NO and NH₃. Beyond the modification of the electronic states in the ad-molecule by the chemical ligation [2], we now focus on the sign and strength of the exchange interaction with the substrate [3,4]. In our experimental (XMCD, STM, XPS) and theoretical (DFT+U) work we provide evidence for cooperativity between the axial ligand on top and the surface ligand below the porphyrin ("surface spin trans effect"). We present four magneto-chemical effects: reduction (HS → IS), quenching (S ≠ 0 → S=0), flipping ("S > 0" → "S < 0") and induction (S = 0 → S ≠ 0) of magnetic moments in specific ad-porphyrins upon coordination with different chemical ligands.

[1] A. Scheibal *et al.*, Chem Phys Lett 411, 214 (2005).

[2] W. Hieringer *et al.*, J Am Chem Soc 133, 6206 (2011).

[3] C. Wäckerlin *et al.*, Nat Comms 1, 61 (2010).

[4] C. Wäckerlin *et al.*, Chem. Science 3, 3154 (2012).

MA 34.10 Thu 12:45 H33

Structural and magnetic properties of pyridyl and benzonitrile based metal-organic networks — ●TOBIAS R. UMBACH¹, MATTHIAS BERNIEN¹, CLAUDIA HARTMANN¹, ALEXANDER KRÜGER¹, JANINA N. LADENTHIN¹, CONSTANTIN CZEKELIUS², JOSE I. PASCUAL^{1,3}, KATHARINA J. FRANKE¹, and WOLFGANG KUCH¹ — ¹Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — ²Institut für Chemie und Biochemie - Organische Chemie, Freie Universität Berlin Takustr. 3, 14195, Berlin, Germany — ³CIC nanoGUNE Consolider, Tolosa Hiribidea, 76, E-20018 Donostia, San Sebastian, Spain

Metal-organic networks offer the possibility to tune the electronic and magnetic functionality of surfaces on a nanometer scale. Here we use LT-STM to characterize the structure of metal-organic networks of transition metal atoms (Co, Fe) and triangular organic linkers, which exhibit either three pyridyl or three benzonitrile endgroups on Au(111). In the case of benzonitrile endgroups, the mixture with transition metal atoms leads to the formation of self-assembled ordered networks with a honeycomb structure. Every transition metal atom is surrounded by three benzonitrile groups forming three-fold coordination nodes. By changing the endgroups to pyridyl, the coordination motif changes significantly. The transition metal atoms exhibit the same in-plane coordination scheme with an additional molecule centered on top. The magnetic properties of the networks are investigated by XMCD measurements, which reveal that, despite their different structures, they all exhibit sizable magnetic moments and magnetic anisotropy.