

O 30: Poster Session - Surface Magnetism

Time: Monday 18:15–20:00

Location: P1A

O 30.1 Mon 18:15 P1A

Study of Magnetic Molecules on Superconductors by STM/AFM — ●SOROUSH ARABI¹, YUQI WANG¹, KLAUS KERN², and MARKUS TERNES^{3,4} — ¹Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — ²École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland — ³RWTH Aachen University, Institute of Physics, D-52074 Aachen, Germany — ⁴Peter-Grünberg-Institute (PGI-3), Forschungszentrum Jülich, D-52425 Jülich, Germany

We use a combined scanning tunneling microscope (STM) and atomic force microscope (AFM) to investigate the interplay of magnetism and superconductivity in single magnetic molecules adsorbed on s-wave superconductors. For this study, we use cobalt phthalocyanine (CoPc) adsorbed on NbSe₂ and Fe-porphin (FeP) adsorbed on Pb(111). Such proximity offers a rich spectrum of phenomena, due to the formation of Yu-Shiba-Rosinov (YSR) states inside the superconducting gap which at strong enough interaction can screen the magnetic moment by breaking off a Cooper pair [1]. Taking advantage of the unique capabilities of the AFM, we can dynamically drive the ground state of FeP/Pb(111) towards or away from such a quantum phase transition by manipulating the exchange interaction between the molecule and substrate while tracking the interacting force. Moreover, we show that symmetry-reduced adsorption sites for CoPc molecules leads to a singlet ground state and a sharp molecular singlet-triplet transition at an energy outside the superconducting gap of the NbSe₂.

[1] Laetitia Farinacci, et al., Phys. Rev. Lett. **121**, 196803 (2018).

O 30.2 Mon 18:15 P1A

Yu-Shiba-Rusinov states of Manganese atoms on Vanadium — ●JENNIFER HARTFIEL, GAËL REECHT, MARTINA TRAHMS, RIKA SIMON, and KATHARINA J. FRANKE — Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

The adsorption of a magnetic adatom on a superconducting substrate perturbs the Cooper pair condensate in close proximity to the surface. The unpaired magnetic moment induces localized bound states, so-called Yu-Shiba-Rusinov (YSR) states, inside the superconducting energy gap, which can be probed by scanning tunneling spectroscopy (STS). The coupling strength between the magnetic moment of the impurity and the Cooper pairs determines the energy needed for tunneling into the YSR state.

In this work, we perform STS measurements on Mn adatoms on a V(110) surface and find a variety of YSR state energies. Vanadium is very reactive and therefore oxygen atoms assemble on the surface, causing reconstructions in the upmost layer [1]. This makes it difficult to investigate a possible adsorption-site dependence of the YSR energies. To obtain a more homogeneous surface structure we grow Ag islands of a few monolayers on top of the Vanadium, before depositing the Mn atoms. We find that the islands exhibit a preferential growth direction with a specific angle to the V lattice. The Ag is proximitized by the superconducting substrate, and we also observe YSR states for Mn on Ag/V. In both cases we are able to manipulate the Mn atoms with the STM tip, causing a change in the YSR state energies.

[1] R. Koller et al., Surface Science 512 (2002).

O 30.3 Mon 18:15 P1A

Single-Co and two-site Kondo effect in atomic Cu wires on Cu(111) — ●NICOLAS NÉEL¹, MARKUS BOHN¹, JÖRG KRÖGER¹, MALTE SCHÜLER², BIN SHAO², TIM O. WEHLING², ALEXANDER KOWALSKI³, and GIORGIO SANGIOVANNI³ — ¹Institut für Physik, Technische Universität Ilmenau, D-98693 Ilmenau, Germany — ²Institute for Theoretical Physics, University Bremen, D-28359 Bremen, Germany — ³Institut für Theoretische Physik und Astrophysik and Würzburg-Dresden Cluster of Excellence ct.qmat, Universität Würzburg, D-97074 Würzburg, Germany

Linear atomic chains containing a single (two) Co and several non-magnetic Cu atoms were assembled on Cu(111) with the tip of a STM. For single Kondo atom chains the resulting Cu_mCoCu_n clusters (0 ≤ m, n ≤ 5) exhibit a rich evolution of the Kondo effect with the variation of m and n, as inferred from changes in the line shape of the Abrikosov-Suhl-Kondo (ASK) resonance. The most striking result is the quenching of the resonance in CuCoCu₂ and Cu₂CoCu₂ clusters. State-of-the-art first-principles calculations were performed to unravel

possible microscopic origins of the experimental observations.

For linear atomic chains containing two Kondo atoms, CoCu_nCoCu_m, the addition of a Cu atom to one edge Co atom of the chain (m = 0 → m = 1) strongly reduces the amplitude and line width of the ASK resonance of that Co atom for all investigated chain lengths (n = 2 – 4). On the opposite edge Co atom the Kondo effect remains unaffected. Hybridization together with the linear geometry of the cluster are likely to drive the effect.

O 30.4 Mon 18:15 P1A

Demonstration of single atom ESR and pump-probe with a 30 mK STM setup — ●WERNER M.J. VAN WEERDENBURG¹, MANUEL STEINBRECHER¹, NIELS P.E. VAN MULLEKOM¹, JAN W. GERRITSEN¹, FABIAN D. NATTERER², and ALEXANDER A. KHAJETOORIANS¹ — ¹IMM, Radboud University Nijmegen, the Netherlands — ²Physik Institut, University of Zurich, Switzerland

The recent advances in electron spin resonance (ESR) with STM have allowed the detection of low-energy spin excitations with neV energy resolution on a single atom [1]. Combined with all-electrical pump-probe schemes, these methods have been used to probe spin relaxation times [2,3] and decoherence times [4] in the nanosecond regime.

Here, we demonstrate the implementation of ESR and all-electrical pump-probe on a 30 mK STM. By measuring the transmission of rf voltages and doing pulse shape analysis, we characterize the time-domain performance of our setup. We extract the magnetic moments of Fe on MgO/Ag(100) from the linear progression of the ESR resonance in field-sweep and frequency-sweep mode. With pump-probe schemes [5], we also reproduce comparable lifetimes for Fe on MgO/Ag(100) [3] and show how these are affected by an externally applied in-plane and out-of-plane magnetic field.

[1] S. Baumann et al., Science 350, 417-420 (2015)

[2] S. Loth et al., Science 329, 1628-1630 (2010)

[3] W. Paul et al., Nature Physics 13, 403-407 (2017)

[4] K. Yang et al., Science 366, 509-512 (2019)

[5] F. Natterer, ArXiv. 1902.05609 (2019)

O 30.5 Mon 18:15 P1A

Magnetic coupling between ferromagnetic semiconductors and organometallic phthalocyanines — ●CARMEN GONZÁLEZ-ORELLANA¹, MAXIM ILYN¹, MARCO GOBBI^{1,2,3}, PAUL DREHER⁴, and CELIA ROGERO¹ — ¹Centro de Física de Materiales, San Sebastián, Spain — ²IKERBASQUE, Basque Foundation for Science, Bilbao, Spain — ³CIC nanoGUNE, San Sebastián, Spain — ⁴DIPC, San Sebastián, Spain

The study of the interaction between organometallic phthalocyanines and magnetic metals has attracted interest due to its application in the field of spintronics. Most of the studies were focused on the magnetic properties of these metal-organic complexes coupled to ferromagnetic and antiferromagnetic metallic surfaces [1]. In the present work we study the interaction between the organic layer and ferromagnetic semiconducting/insulating substrates, in particular EuS and CrSiTe₃. EuS is a 3D material where all the neighbours interact magnetically, whereas CrSiTe₃ is a laminar material where magnetic interactions are confined in the plane and has been proposed as candidate single-layer ferromagnetic semiconductor.

Using a multi-technique surface science approach, combining XPS, LEED, XAS and XMCD, we analyze the coupling of the organic layer and its effect on the magnetic response of the system.

[1] A. Lodi et al., Surf. Sci., vol. 630, pp. 361-374, 2014.

O 30.6 Mon 18:15 P1A

The alloy Mn₈₈Ni₁₂: An Intrinsically Spin-Polarised Tip Material? — ●J. RIKA SIMON, MARTINA TRAHMS, JENNIFER HARTFIEL, GAËL REECHT, and KATHARINA J. FRANKE — Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Spin-polarised tips are necessary for the realisation of electron-spin resonance (ESR) in a scanning tunnelling microscope (STM). These tips are typically obtained by transferring a few magnetic atoms to the tip apex and controlling their magnetisation by an external magnetic field [1]. Recently, Forrester et. al. have suggested Mn₈₈Ni₁₂ as an alternative tip material because of its intrinsic magnetic properties [2]. Moreover, it has been shown very recently by Willke et. al.

that the magnetic field created by a spin-polarised tip is sufficient to perform single-atom ESR [3]. Combining both would allow for ESR-setups without the need for an external magnetic field.

We fabricate a $Mn_{88}Ni_{12}$ tip and investigate its properties using different model systems to study their spin-polarisation: Co nano-islands on Cu(111), and Fe(III)-octaethylporphyrin (FeOEP) on Au(111) and on Pb(111). Our experimental results do not yield unambiguous observation of spin-polarisation. The discrepancy of the results of our measurement techniques to those utilised by Forrester et. al. could be due to differences in preparation and treatment of the tip prior to the measurements, requiring a detailed analysis of the tip fabrication.

[1] M. Bode, Reports on Progress in Physics 66, 523–582 (2003)

[2] P. R. Forrester et al, Rev. Sci. Instrum. 89, 123706 (2018)

[3] P. Willke et al., arXiv: 1908.11061 [cond-mat.mes-hall] (2019)

O 30.7 Mon 18:15 P1A

Quantum Stochastic Resonance in a Single Atom — ●GREGORY McMURTRIE¹, MAX HÄNZE^{1,2}, LUIGI MALAVOLTI^{1,2}, and SEBASTIAN LOTH^{1,2} — ¹University of Stuttgart, Institute for Functional Matter and Quantum Technologies, Stuttgart, Germany. — ²Max Planck Institute for Solid State Research, Stuttgart, Germany.

The behavior of fluctuating spins is particularly relevant in nanoscale materials, where it determines the observable magnetic phases as well as giving rise to exciting phenomena such as quantum critical behavior.

Accessing these dynamic phenomena on their intrinsic atomic length and time scales is an important step towards an understanding of their underlying quantum behavior.

Scanning tunneling microscopy experiments with high frequency signals [1, 2] both give access to the spin dynamics of nanostructures as well as allowing them to be resolved in real space on the atomic scale.

In particular, by applying a small harmonic voltage signal, stochastic resonance [3] can be induced, leading to a synchronization of the spin state evolution.

This phenomenon has never been observed previously in atomic systems, and gives unprecedented access to the time domain behavior of spins, even allowing transduction of picosecond-speed dynamics.

References 1. S. Loth, Science 329 1628 (2010) 2. S. Baumann, Science 350 6259 (2015) 3. R. Benzi, J. Phys. A: Math. Gen 14, L453 (1981)

O 30.8 Mon 18:15 P1A

Spin dependent transmission of nickelocene-copper contacts probed with shot noise — MICHAEL MOHR¹, MANUEL GRUBER¹, ALEXANDER WEISMANN¹, DAVID JACOB², PAULA ABUFAGER³, NICOLÁS LORENTE⁴, and ●RICHARD BERNDT¹ — ¹Christian-Albrechts-Universität zu Kiel, Kiel, Germany — ²UPV/EHU, Donostia-San Sebastián, and IKERBASQUE, Bilbao, Spain — ³CONICET and Universidad Nacional de Rosario, Rosario, Argentina — ⁴CFM/MPC and DIPC, Donostia-Sebastián, Spain

The current I through nickelocene molecules and its noise are measured with a low temperature STM on a Cu(100) substrate. Density functional theory calculations and many-body modeling are used to analyze the data. During contact formation, two types of current evolution are observed, an abrupt jump to contact and a smooth transition. These data along with conductance spectra (dI/dV) recorded deep in the contact range are interpreted in terms of a transition from a spin-1 to a spin-1/2 state that is Kondo screened. Many-body calculations show that the smooth transition is also consistent with a renormalization of spin excitations of a spin-1 molecule by Kondo exchange coupling. The shot noise is significantly reduced compared to the Schottky value of $2eI$ but no influence of the Kondo effect or spin excitations are resolved. The noise can be described in the Landauer picture in terms of spin-polarized transmission of $\approx 35\%$ through two degenerate d_{π} -orbitals of the nickelocene molecule. Support via the European Union's Horizon 2020 research and innovation programme (766726) is acknowledged.

O 30.9 Mon 18:15 P1A

Measuring the exchange force field of a non-collinear mag-

netic structure on the atomic scale — NADINE HAUPTMANN¹, SOUMYAIYOTI HALDAR², TZU-CHAO HUNG¹, WOUTER JOLIE¹, ●LORENA NIGGLI^{1,3}, MARA GUTZEIT², DANIEL WEGNER¹, STEFAN HEINZE², and ALEXANDER A. KHAJETOORIANS¹ — ¹Scanning Probe Microscopy Department, IMM, Radboud University, Nijmegen, Netherlands — ²Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität zu Kiel, Germany — ³Department of Physics, University of Zurich, CH-8057 Zurich, Switzerland

One route toward creating magnetic memory down to the level of individual atoms, relies on utilizing chiral magnetic structures, which are stabilized by a combination of various atomic-scale exchange interactions. Understanding these interactions is vital toward creating magnetic memory, necessitating methodology to quantify and manipulate exchange interactions on the atomic scale. Here, we present high-resolution imaging of a chiral magnetic structure along with quantifying atomic-scale magnetic exchange interactions [1]. Using the combination of spin-polarized tunneling current and exchange force detection (SPEX), we quantify the exchange interaction between a ferromagnetic probe and the cycloidal spin spiral in 1ML Mn/W(110). We not only resolve the nearly antiferromagnetic atomic unit cell, but also the exchange force field along the spin spiral.

[1] N. Hauptmann et al., arXiv:1908.00959

O 30.10 Mon 18:15 P1A

Kondo Resonance of NO on Au(110)-(1×2) — ●HIROYUKI KOSHIDA, HIROSHI OKUYAMA, SHINICHIRO HATTA, and TETSUYA ARUGA — Department of Chemistry, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan

Nitric oxide (NO) is a diatomic molecule that has a localized spin due to its unpaired electron in a $2\pi^*$ state. We studied the interaction of NO with Au(110)-(1×2) using STM/STS, and observed Kondo resonance states originated from the survived spin of NO.

We found three types of NO adsorbed states on the surface: two kinds of NO monomer (denoted as A and B), and a NO trimer. Monomer (B) could be produced from monomer (A) by applying a voltage pulse ($\sim \pm 300$ mV) onto the monomer (A). By conducting STS (dI/dV) measurements using a lock-in amplifier at 4.5 K, we observed dip and peak structures at 0 mV for monomer (B) and the trimer, respectively, whereas no structure was observed for monomer (A). From the temperature-dependent measurements, the dip and peak structures were attributed to Kondo resonance states. Besides, we observed sidebands at ± 5 meV and ± 36 meV for the trimer, which stemmed from the coupling of Kondo resonance with molecular vibrations. This study demonstrates the strong dependence of the Kondo resonance states of NO, i.e., the magnetic properties of the molecule, on the adsorbed states.

O 30.11 Mon 18:15 P1A

Setup for time-resolved photoemission electron microscopy of ferromagnetic surfaces and magnetization dynamics triggered by back-side illumination — ●MAXIMILIAN PALESCHKE, CHENG-TIEN CHIANG, and WOLF WIDDRA — Martin-Luther-Universität Halle-Wittenberg, Institute of Physics, Halle (Saale), Germany

Over the last 20 years, the growing interest in the field of ultrafast magnetism and spintronics sparked a demand for experimental techniques capable of detecting dynamical phenomena on the nanometer-femtosecond scale[1]. Our approach combines state-of-the-art time-resolved photoemission electron microscopy (tr-PEEM) with a back-side pumping geometry. A tunable laser system with MHz repetition rate and a wide selection of different wavelengths enhances the PEEM's capabilities by eliminating inadvertent effects like space charge broadening. The setup is optimized to image magnetic nanostructures using magnetic valence band dichroism in photoemission[2,3]. In this poster, we will present the experimental setup and the achieved temporal and spatial resolutions. First results for ultrathin films of Fe grown on MgO(001) will be discussed.

[1] A. Kirilyuk *et al.*, Rev. Mod. Phys. **82**, 2731 (2010)

[2] C. M. Schneider, G. Schönhense, Rep. Prog. Phys. **65**, 1785 (2002)

[3] W. Kuch, C. M. Schneider, Rep. Prog. Phys. **64**, 147 (2001)