MA 57: Focus Session: Spins on Surfaces III (joint session O/MA)

Time: Friday 10:30–13:00 Location: H24

Invited Talk MA 57.1 Fri 10:30 H24

Quantum simulation through atomic assembly — •Sander Otte — Delft University of Technology, Delft, The Netherlands

The magnetic and electronic properties of materials often find their origin in basic atomic- scale interactions. Yet, due to the large number of atoms involved, many phenomena can be very difficult to predict: we call these 'emergent'. The ability to build structures atom-by-atom by means of scanning tunneling microscopy (STM) provides an excellent platform to explore emergence as a function of system size. By properly tuning the anisotropy and coupling of magnetic atoms on a thin insulator, we have been able to engineer finite spin chains hosting spin waves [1] as well as the beginnings of a quantum phase transition at a critical magnetic field [2]. In a more recent experiment, we have engineered spin structures that are frustrated by design, exhibiting a spin spiral that can snap between different configurations. Unfortunately, the maximum size of assembled structures is often limited due to e.g. crystal impurity and crystal strain. In this talk, I will present a way to mitigate these limitations and show recent advances in sample preparation that will allow us to build much larger spin structures [3].

[1] A. Spinelli et al., Nature Matererials 13 (2014) 782
[2] R. Toskovic et al., Nature Physics 12 (2016) 656
[3] J. Gobeil et al., Surface Science 679 (2019) 202

MA 57.2 Fri 11:00 H24

Exploring magnetic frustration in atomically engineered closed chains — •Jeremie Gobeil, David Coffey, Shang-Jen Wang, and Alexander F. Otte — Department of Quantum Nanoscience, Kavli Institute of Nanoscience, Delft University of Technology, Delft, The Netherlands

Modelling quantum systems with a large number of degrees of freedom can be a daunting task from a computational standpoint. Scanning Tunneling Microscopy (STM) offers an alternative path by enabling atom-by-atom engineering and probing of such systems. Spin-Polarized STM (SP-STM) can provide direct insight into a system's spin configuration, while at the same time providing a tunable interaction parameter. This enables the study of frustrated spin systems, which pose a particular modelling challenge as they are governed by a delicate balance of competing interactions.

Here we present the study of such a frustrated spin system, consisting in closed chains of single iron atoms assembled on a single nitride layer grown on $Cu_3Au(100)$. As in the similar Cu_2N system, the nitride layer provides a uniaxial framework with different ferromagnetic and antiferromagnetic interatomic couplings depending on the relative position on the lattice. This allows us to assemble closed loop chains with an odd number of antiferromagnetic couplings, leading to frustration. We explore the role of an external magnetic field, interatomic exchange, as well as the exchange interaction with the spin-polarized tip in the stabilization of the resulting spin configuration.

MA 57.3 Fri 11:15 H24

Revealing spin states in Co-salophene chains grown on $GdAu_2$ — •Maciej Bazarnik[1,2], Micha Elsebach[1], Emil Sierda[1,2], Maxim Ilyn[3], Jan Dreiser[4], Jens Brede[3], and Roland Wiesendanger[1] — [1]Department of Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg, Germany — [2]Institute of Physics, Poznan University of Technology, Piotrowo 3, 60-965 Poznan, Poland — [3]Centro de Física de Materiales, P° Manuel de Lardizabal 5, Donostia - San Sebastián, E-20018 Spain — [4]Swiss Light Source, Paul Scherrer Institut (PSI), CH-5232 Villigen, Switzerland

Lately, a polymerization of well-aligned organic nanowires was presented on a magnetic $GdAu_2$ surface alloy [1]. Apart from growing graphene on, i.e., a Ni surface, this was the first successful approach to a surface catalyzed reaction on a magnetic substrate. Such a ferromagnetic substrate in combination with magnetic molecules offers a very interesting interface for spintronic applications.

Here, we will present the growth behaviour of Co-salophene oligomers on the $GdAu_2$ surface alloy prepared on a Au(111) substrate. By combining spin-polarized scanning tunneling microscopy and X-ray magnetic circular dichroism we have revealed the evolution of the spin-* state residing on the Co-centers of the salophene molecules upon adsorption and thermally activated Ullmann coupling.

[1] M. Abadia et al. ACS Nano, 2017, 11 (12), pp 12392-12401

MA 57.4 Fri 11:30 H24

Noncollinear spin density of an adatom on a magnetic surface — •Soumyajyoti Haldar and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, University of Kiel, 24098, Kiel, Germany

Today, noncollinear spin structures at surfaces and interfaces receive great attention due to potential applications in spintronic devices. In such magnetic structures, the spin direction changes from atom to atom. Besides this inter-atomic noncollinear magnetism, there is also intra-atomic noncollinear magnetism in which the spin direction varies for different orbitals of an atom [1]. It can occur due to spin-orbit coupling or due to a noncollinear spin structure.

Here, we demonstrate that intra-atomic noncollinear magnetism can occur for adatoms on a magnetic surface with a noncollinear spin structure [2]. As an example, we study Co and Ir adatoms on Mn/W(110) using density functional theory. We find that the canted spin structure of the Mn surface layer is encoded into different orbitals of the adatoms. Our conclusions apply in general to adatoms on surfaces with a noncollinear magnetic structure e.g. spin spirals, skyrmions or domain walls and explain recent experimental results of spin-polarized scanning tunneling microscopy experiments [3].

[1] L. Nordström *et al.*, Phys. Rev. Lett. **76**, 4420 (1996)
[2] S. Haldar and S. Heinze, arXiv:1811.00865 (2018)
[3] D. Serrate *et al.*, Phys. Rev. B **93**, 125424 (2016)

MA 57.5 Fri 11:45 H24

Interplay of spin-orbit and exchange interaction in ultrathin Ni films on W(110) — •Pascal Jona Grenz[1], Philipp Eickholt[1], Koji Miyamoto[2], Eike Schwier[2], Taichi Okuda[2], and Markus Donath[1] — [1]Institute of Physics, Westfälische-Wilhelms-Universität Münster, Germany — [2]Hiroshima Synchrotron Radiation Center, Japan

Ferromagnetic adsorbates on W(110) are prototypical systems for studying the influence of spin-orbit and exchange interaction on electronic states. We investigated ultrathin Ni films on W(110) with spin- and angle-resolved photoemission with particular emphasis on (i) the influence of the Ni adsorbates on the Dirac-cone-like surface state of W(110), (ii) the spin dependence of electronic states at the interface between Ni and W, and (iii) the appearance of ferromagnetic order in the Ni overlayer. We will discuss our results in relation to similar systems reported in literature, Fe/W(110) and Co/W(110) [1,2].

[1] K. Honma *et al.*, Phys. Rev. Lett. **115**, 266401 (2015).
[2] P. Moras *et al.*, Phys. Rev. B **91**, 195410 (2015).

MA 57.6 Fri 12:00 H24

Spin-dependent electron reflection at W(110) — •Christoph Angrick[1], Jürgen Braun[2], Hubert Ebert[2], and Markus Donath[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität Münster, Germany — [2]Department Chemie, Ludwig-Maximilians-Universität München, Germany

The knowledge of the occupied, spin-dependent electronic structure of surfaces offers insights into spin phenomena and their possible use in spintronic devices. This knowledge can be obtained by photoemission techniques with subsequent spin-polarization analysis of the photoelectrons. The spin-polarization analysis relies on spin-dependent electron scattering and can be used in single- and multichannel modes [1,2,3,4].

Due to its strong spin-orbit coupling the W(110) surface is a promising candidate for the use as a scattering target in a spin-polarization analyzer. Therefore, the spin-dependent electron reflectivity of the W(110) surface was experimentally investigated for a wide range of incident electron energies and polar angles and compared with calculations. Two possible working points for spin-polarization analysis with a reversed sign in the Sherman function were found. The characteristics of the working points are discussed in view of an implementation in a single- and multichannel spin-polarization analyzer.

[1] Winkelmann *et al.*, Rev. Sci. Instrum. **79**, 083303 (2008).
[2] Okuda *et al.*, Rev. Sci. Instrum. **79**, 123117 (2008).
[3] Kolbe *et al.*, Phys. Rev. Lett. **107**, 207601 (2011).
[4] Tusche *et al.*, Appl. Phys. Lett. **99**, 032505 (2011).

MA 57.7 Fri 12:15 H24

Investigation of superconductivity in spin chains on Re(0001) — •Lucas Schneider, Manuel Steinbrecher, Levente Rósza, Thore Posske, Jens Wiebe, and Roland Wiesendanger — Department of Physics, Hamburg University, 20355 Hamburg, Germany

Chains of magnetic atoms on high-Z s-wave superconductors can exhibit topological superconductivity and therefore host Majorana bound states at their ends [1, 2]. Most previous experimental work focused on self-assembled systems [3-4] where a change of the composition along the chain is difficult to achieve. In this study, we use the superconducting Re substrate which enables scanning tunneling microscope-tip induced assembly of chains that show indications for topological superconductivity [5]. This technique allows us to perfectly control the geometric properties and chemical composition of the chains. We evaporate different $3d$ transition metal adatoms as building blocks, assemble various linear chains and investigate their in-gap states. In particular, we studied the transition between magnetic and nonmagnetic regions in composite chains.

We acknowledge funding by the ERC via the Advanced Grant ADMIRE (No. 786020).

[1] Klinovaja *et al.*, PRL **111**, 186805 (2013). [2] J. Li *et al.* PRB **90**, 235433 (2014). [3] S. Nadj-Perge *et al.*, Science **346**, 6209 (2014). [4] M. Ruby *et al.*, Nano Letters **17**, 4473, (2017). [5] H. Kim *et al.*, Science Advances **4**, eaar5251 (2018).

MA 57.8 Fri 12:30 H24

Thin film formation and processes in organic diradicals — •Tobias Junghöfer[1], Nolan Gallagher[2], Andrzej Rajca[2], and Maria Benedetta Casu[1] — [1]Eberhard Karls Universität Tübingen, Institut für Physikalische und Theoretische Chemie, 72076 Tübingen, Germany — [2]Department of Chemistry, University of Nebraska, Lincoln, Nebraska 68588-0304, USA

Organic radical thin films are of great interest for organic electronics such as spin filtering devices, data storage devices, and as quantum bits for quantum computing devices. The investigated diradicals possess two coupled spins with a combined magnetic moment (S = 1) which is of interest for novel applications in spintronics. In our work, we investigate chemically stable diradicals, deposited via organic molecular beam deposition (OMDB) in ultra-high vacuum. For our experiments, we use soft X-ray techniques, such as X-ray photoelectron spectroscopy (XPS) and near-edge X-ray absorption fine structure (NEXAFS) spectroscopy, as well as atomic force microscopy (AFM). We demonstrate that we are able to deposit thin films of intact diradicals. We investigate their film formation properties and stability towards different environments.

MA 57.9 Fri 12:45 H24

Optical and spin-orbit induced spin orientation of photoelectrons in the soft X-ray range — •Dmitry Vasilyev, Katerina Medjanik, Sergey Babenkov, Martin Ellguth, Gerd Schönhense, and Hans-Joachim Elmers — Institut für Physik, Johannes Gutenberg-Universität, Mainz, Germany

Angular- or k-resolved photoelectron spectroscopy in the soft X-ray range gives access to the bulk electronic structure of materials. Time-of-flight momentum microscopy with parallel spin detection extends this information to the spin degree of freedom. We choose tungsten as a paramagnetic model system in order to exclude any initial-state spin polarization from exchange-split bands. By measurement of four independent photoemission intensities for two opposite spin directions and opposite light helicity, we distinguish between spin polarization contributions of optical spin-orientation by circularly polarized X-rays (Fano component) and a second contribution with polarization direction perpendicular to the scattering plane. The latter phenomenon has been observed for surface states and is usually attributed to the surface-related inversion symmetry breaking. In the case of soft X-ray radiation, only inversion symmetric bulk states of tungsten are probed. Their finite perpendicular spin polarization thus represents a novel phenomenon originating from the spin-dependent interference of final state partial waves.