TT 26: Focus Session: Engineered Magnetic Impurities: Interaction and Superconductivity

Future spintronic and quantum computing devices require magnetic nanostructures with specifically designed functionality. This focus session features theoretical aspects and experimental results on tunable properties of magnetic atoms and molecules on surfaces and artificial nanostructures in contact to normal metals and superconductors.

Organizers: Wolfgang Belzig (U Konstanz) and Katharina Franke (FU Berlin)

Time: Tuesday 9:30–12:15 Location: H20

Invited Talk TT 26.1 Tue 9:30 H20

Classical and quantum correlation induced bias asymmetries in coupled spin systems — •Markus Ternes — Max-Planck Institute for Solid State Research

In recent years inelastic spin-flip spectroscopy using a low-temperature scanning tunneling microscope has been a very successful tool for studying not only individual spins but also complex coupled systems. When these systems interact with the electrons of the supporting electrodes correlated many-particle states can emerge, making them ideal prototypical quantum systems. In this presentation I will show how the controlled coupling of individual spin systems can lead not only to an energy shift of the eigenstates reminiscent of an externally applied field, but also to a bias asymmetry in the differential conductance. Using $S = 1$ and $S = 1/2$ model systems of CoH_x on a h-BN/Rh(111) substrate [1] in conjunction with model Hamiltonians [2] which takes the coupling and correlation to the environment explicitly into account enables to precisely determine and control the emergence of correlations between the two subsystems on tip and sample.

[1] P. Jacobson et al. , Nature Communications **6**, 8536 (2015)
[2] M. Ternes, NJP **17**, 063016 (2015)

Invited Talk TT 26.2 Tue 10:00 H20

Magnetic anisotropy goes spintronic — •Maarten R. Wegewijs[1,2], Maciej Misiorny[3], and Michael Hell[4,5] — [1]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [2]Institute for Theory of Statistical Physics and JARA, RWTH Aachen, Germany — [3]Department of Microtechnology and Nanoscience MC2, Chalmers University of Technology, Göteborg, Sweden — [4]Division of Solid State Physics and NanoLund, Lund University, Sweden — [5]Center for Quantum Devices and Station Q Copenhagen, Niels Bohr Institute, University of Copenhagen, Denmark

Magnetic anisotropy of quantum spins as found in magnetic atoms and single-molecule magnets has traditionally been considered an intrinsic effect, generated locally by the combination of spin-orbit coupling and ligand field effects. In this talk I will show that magnetic anisotropy can appear in an entirely new way in very simple spintronic setups where a spin-isotropic quantum dot is exposed to the influence of magnetic electrodes. Magnetic anisotropy can thus appear as a dissipative transport quantity which is able to "pile up" in a system, quite similar to how spin accumulates in a spin-valve. Moreover, magnetic anisotropy can also be *generated from scratch* by coherent transport processes, resulting in a quadrupolar proximity effect [1], similar to the well-known controllable dipolar exchange field [2]. This turns an isotropic quantum spin $> 1/2$ into a full-blown single-molecule magnet with electrically controllable magnetic bistability.

[1] M. Misiorny, M. Hell , M. R. Wegewijs, Nature Phys. **9**, 801, (2013)
[2] M. Hell et al., PRB **91**, 195404 (2015)

Invited Talk TT 26.3 Tue 10:30 H20

Engineering the Kondo Effect in clean Carbon Nanotubes — •Christoph Strunk — Inst. f. Experimental and Applied Physics, University of Regensburg

Ultraclean carbon nanotubes (CNTs) form quantum dots of well-defined atomic structure at low temperatures. Transport spectroscopy of ground and excited states as a function of electron numbers in a parallel magnetic field results in detailed information about the band structures, in particular on spin-orbit and KK'-mixing effects.

This information is exploited in the analysis of the SU(4) Kondo effect [1] occurring at larger electron numbers, where the devices become more transmissive. The slightly broken fourfold degeneracy in our device gives rise to satellites of the Kondo peak that shift in a characteristic way in perpendicular and parallel magnetic field. Our observations reflect discrete symmetries of the CNT Hamiltionian, and are well reproduced by state of the art theoretical modeling [2].

On the other hand, multichannel electron interference is observed on the hole side of the CNT spectrum, where Coulomb effects are suppressed. A secondary interference effect is observed that provides information about the chiral angle of the CNTs by virtue of the trigonal warping of the underlying graphene band structure.

[1] P. Jarillo-Herrero et al., Nature **434**, 484 (2005)
[2] S. Smirnov and M. Grifoni, Phys. Rev. B **87**, 121302 (2013)

15 min. break

Invited Talk TT 26.4 Tue 11:15 H20

Majorana Fermions in Atomic Chains — •Ali Yazdani — Princeton University

In this talk, I will review the experimental progress in the realization of Majorana fermions in chains of magnetic atoms on the surface of a superconductor. Experimental results on the system of Fe on Pb(110) will be reviewed to show that this system has all the theoretically required criteria for hosting these exotic quasiparticles. We further show spectroscopic evidence for the presence of Majorana end modes in this system. The high resolution experimental signatures of their spatial structure agrees well with our detailed theoretical modeling of such edge modes. Finally, there has been proposal for detecting the spin signatures of these edge modes with spin polarized STM techniques. I will also describe our progress toward high resolution spin resolves measurements of the Majorana edge modes.

Invited Talk TT 26.5 Tue 11:45 H20

Magnetic adatoms on superconductors - a new venue for Majorana bound states? — •Felix von Oppen — Dahlem Center for Complex Quantum Systems & Fachbereich Physik, Freie Universität Berlin

In a recent experiment, Nadj-Perge et al.[1] (see also [2]) provide possible evidence for Majorana bound states in chains of magnetic adatoms on conventional superconductors. The formation of topological superconductivity in this system relies on ferromagnetic order of the magnetic moments and spin-orbit coupling provided by the substrate superconductor. In this talk, I will discuss the physical picture underlying this experiment, including an explanation of the unexpectedly strong localization of the observed end states [3,4], and will suggest additional experiments to probe the Majorana end states [5].

[1] S. Nadj-Perge et al., Science **346**, 602 (2014)
[2] M. Ruby, F. Pientka, Y. Peng, F. von Oppen, B. W. Heinrich, K. J. Franke, arXiv:1507.03104 (2015); to appear in PRL
[3] F. Pientka, L. I. Glazman, F. von Oppen, PRB **88**, 155420 (2013)
[4] Y. Peng, F. Pientka, L. I. Glazman, F. von Oppen, PRL **114**, 106801 (2015)
[5] Y. Peng, F. Pientka, Y. Vinkler-Aviv, L. I. Glazman, F. von Oppen, arXiv:1506.06763 (2015)