O 80: Focus Session: Atomic-Scale Studies of Spins on Surfaces with Scanning Tunneling Microscopy 3

Time: Friday 10:30–12:15 Location: S051

O 80.1 Fri 10:30 S051

Synthesis and Characterization of Triangulene: a novel concept of magnetic nanostructure made of carbon — •Francisco R. Lara[1], Silvia Castro[2], Jeremy Hieulle[1], Manuel Vilas-Varela[2], Alessio Vegliante[1], Niklas Friedrich[1], Lorenz Meyer[1], Unai Uriarte-Amiano[1], Sofia Sanz[3], Dulce Rey[2], Natalia E. Koval[1], Martina Corso[4,3], Emilio Artacho[1,5], Thomas Frederiksen[3], Diego Peña[2], and Jose Ignacio Pascual[1] — [1]CIC nanoGUNE BRTA, Donostia, Spain — [2]Centro Singular de Investigación en Química Biolóxica e Materiais Moleculares, Santiago de Compostela, Spain — [3]Donostia International Physics Center, Donostia, Spain — [4]Centro de Física de Materiales, Donostia, Spain — [5]Cavendish Laboratory, Cambridge, United Kingdom

In this talk, we present the synthesis and characterization of a [3]-triangulene ring of 6 units, the [3]-triangulene nanostar (TNS), and an aza-[5]-triangulene (A5T), on a Au(111) surface.

By means of scanning tunneling microscopy (STM) and spectroscopy (STS) the precise spin states of such carbon-based nanostructures have been studied. Such experimental findings, are supported by calculations from density functional theory (DFT), mean-field Hubbard model (MFH), and Heisenberg model.

Both nanostuctures are achieved thanks to on-surface synthesis. TNS hosts antiferromagnetically coupled spin-1 showing a complex many-body inelastic excitation spectrum. A5T ground state has a spin larger than one. Here the presence of the N heteroatom substitution plays an important role in the spin state on surface.

O 80.2 Fri 10:45 S051

Local access to the Ln-Ln bonding orbital in dimetallofullerene molecular magnets — •Fabian Paschke[1], Tobias Birk[1], Fupin Liu[2], Stanislav M. Avdoshenko[2], Alexey A. Popov[2], and Mikhail Fonin[1] — [1]Department of Physics, Universität Konstanz, 78457 Konstanz — [2]Leibniz Institute for Solid State and Materials Research (IFW Dresden), 01069 Dresden

One of the key players in the single-molecule magnet community are members of the lanthanide (Ln) dimetallofullerene family that combine air-stable chemical robustness, easy functionalization, a large magnetic moment and slow magnetic relaxation up to 28 K [1]. Two Ln^{3+} ions are ferromagnetically coupled by a singly occupied Ln – Ln bonding orbital in the void of a C_{80} fullerene cage. In this talk I will first demonstrate the robust on-surface magnetism of $\{Ln_2\}$ complexes that show outstanding magnetic blocking temperatures [2,3], an important prerequisite to address its molecular magnetism on a local scale. Subsequently, scanning tunneling spectroscopy unambiguously identifies the unoccupied component of the single-electron Ln – Ln bonding orbital in the spectrum of $\{Dy_2\}$ on a graphene/Ir(111) surface [4]. This finding outlines a new route how to access the molecular spin dynamics of single $\{Ln_2\}$ complexes and provides a working point for spin manipulation using chemical doping.

[1] F. Liu *et al.*, Nat. Commun. 10, 571 (2019). [2] F. Paschke *et al.*, Adv. Mater. 2102844 (2021). [3] L. Spree *et al.*, Adv. Funct. Mater. 2105516 (2021). [4] F. Paschke *et al.*, Small 2105667 (2022).

O 80.3 Fri 11:00 S051

indirect spin-readout of rare-earth-based single-molecule magnet with STM — •hongyan chen[1], timo frauhammer[1], timofey balashov[2], gabriel derenbach[1,3], svetlana klyatskaya[4], eufemio moreno-pineda[5], mario ruben[3,4,6], and wulf wulfhekel[1,3] — [1]Physikalisches Institut, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany — [2]Physikalisches Institut, RWTH Aachen, 52074 Aachen, Germany — [3]Institute for Quantum Materials and Technologies, KIT, 76021 Karlsruhe, Germany — [4]Institute of Nanotechnology, KIT, 76021 Karlsruhe, Germany — [5]Departamento de Química-Física, Escuela de Química, Facultad de Ciencias Naturales, Exactas y Tecnología, Universidad de Panamá 0824, Panama — [6]Centre Européen de Sciences Quantiques (CESQ) in the Institut de Science et d'Ingénierie Supramoléculaires (ISIS), 8 allée Gaspard Monge BP 70028, 67083 Strasbourg Cedex, France

Rare-earth based SMMs are promising candidates for magnetic information storage as their large magnetic moments are carried by localized 4f electrons. However, this in turn hampers a direct readout of the moment. Here, we present the indirect readout of the Dy moment in $DyPc_2$ molecules on Au(111) using mK-STM. Because of an unpaired electron on the Pc ligand, the molecules show a Kondo resonance that is, however, split by the ferromagnetic exchange interaction between the unpaired electron and the Dy spin. Using spin-polarized STS, we read out the Dy spin as a function of the applied magnetic field, exploiting the spin polarization of the exchange-split Kondo state.

O 80.4 Fri 11:15 S051

Yu-Shiba-Rusinov states of Fe dimers on $NbSe_2$ — •Lisa M. Rütten[1], Eva Liebhaber[1], Harald Schmid[1], Gaël Reecht[1], Kai Rossnagel[2,3], Felix von Oppen[1], and Katharina J. Franke[1] — [1]Fachbereich Physik, Freie Universität Berlin, 14195 Berlin, Germany — [2]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel, 24118 Kiel, Germany — [3]Ruprecht Haensel Laboratory, Deutsches Elektronen-Synchrotron DESY, 22607 Hamburg, Germany

Unpaired adatom spins on superconductors interact with the Cooper pairs of the substrate and induce Yu-Shiba-Rusinov (YSR) states inside the superconducting gap. These can be probed by scanning tunneling spectroscopy at the single-atom scale. $2H$-$NbSe_2$ is a superconducting, layered van der Waals material, where the YSR wave functions of magnetic impurities extend over several nanometers. This provides a wide range of adatom spacings over which their interaction is sufficiently strong to be potentially observed as a splitting in the tunneling spectra. In addition to superconductivity, $2H$-$NbSe_2$ hosts an incommensurate charge-density wave (CDW). The imposed variation of the local density of states leads to shifts in the energy of the YSR states and alters the spatial symmetry of YSR wave functions. Here, we arrange Fe atoms on $2H$-$NbSe_2$ using the tip of a scanning tunneling microscope and realize dimers with different spacings and symmetries. We investigate the influence of spacing and position with respect to the CDW on the interaction between the YSR states.

O 80.5 Fri 11:30 S051

Atomic manipulation of spin structures on the β-Bi_2Pd Superconductor — Cristina Mier[1], Divya Jyoti[1,2], Jiyoon Hwang[3], Jinkyung Kim[3], Yujeong Bae[3], Andreas Heinrich[3], Nicolas Lorente[1,2], and •Deung-Jang Choi[1,2,4] — [1]Centro de Fisica de Materiales, CFM/MPC (CSIC-UPV/EHU), Paseo Manuel de Lardizabal 5, 20018 Donostia-San Sebastian, Spain — [2]Donostia International Physics Center (DIPC), Paseo Manuel de Lardizabal 4, 20018 Donostia-San Sebastian, Spain — [3]Center for Quantum Nanoscience (QNS), Institute for Basic Science (IBS), Seoul 03760, South Korea — [4]Ikerbasque, Basque Foundation for Science, 48013 Bilbao, Spain

Recently, the introduction of impurity states in the superconducting gap has received a lot of attention. Indeed, the search of a new superconducting state called topological superconductivity is strongly based in the combination of doping classical (s-wave) superconductors with magnetic impurities that arrange spins in a chiral fashion. We present the first results of controlled single-atom manipulation to assemble a chain of Cr atoms on a β-Bi_2Pd superconductor [1,2]. Such magnetic impurities on different substrates allow us to explore many-body effects and exotic phenomena in different experimental spin systems giving an understanding on the parameters on each system.

[1] C. Mier et al., Atomic Manipulation of In-gap States on the β-Bi_2Pd Superconductors, Phys. Rev. B 104 (4), 045406 (2021). [2] Cristina Mier, Deung-Jang Choi and Nicolás Lorente, Phys. Rev. B 104 (24), 245415 (2021).

O 80.6 Fri 11:45 S051

Theory of transport between superconducting states bound to magnetic impurities — •Ciprian Padurariu[1], Haonan Huang[2], Björn Kubala[1,3], Christian R. Ast[2], and Joachim Ankerhold[1] — [1]Institute for Complex Quantum Systems and IQST, Ulm University, Ulm, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [3]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany

The realization of the Majorana chain [1], a 1D-chain of superconducting states bound to magnetic impurities, suggests that Majorana edge states can be probed using the superconducting tunneling microscope

(STM). Recently, we have developed an ideal tool to probe and manipulate the edge states of a Majorana chain. It consists of a mK-STM with its own in-gap Yu-Shiba-Rusinov (YSR) state created by a magnetic impurity on the tip. With this device we have studied the sharp resonant transport between the YSR state on the tip and another YSR on the sample, and have developed the theory [2].
Here, we summarize and expand the theory of YSR-YSR tunneling to phenomena that occur when one YSR state is close to zero energy, near its quantum phase transition. If the zero-energy state sits at the edge of a Majorana impurity chain, theory predicts that the topological edge state will transfer from the chain to the tip.
[1] S. Nadj-Perge, *et al.*, "Observation of Majorana fermions in ferromagnetic atomic chains on a superconductor", Science **346**, 602 (2014).
[2] H. Huang, *et al.*, "Tunneling dynamics between superconducting bound states at the atomic limit", Nat. Phys. **16**, 1227 (2020).

O 80.7 Fri 12:00 S051

Many-body Excitations of a Quantum Spin on a Proximitized Superconductor — Stefano Trivini[1], •Jon Ortuzar[1], Katerina Vaxevani[1], Jingchen Li[2], Ane Garro[1], F. Sebastian Bergeret[3], Miguel.A Cazalilla[4,5], and José Ignacio Pascual[1,5] — [1]CICnanoGUNE, San Sebastian,Spain — [2]School of Physics, Sun Yat-sen University, Guangzhou 510275, China — [3]Centro de Fìsica de Materiales (CFM-MPC), 20018 San Sebastiàn, Spain — [4]Donostia International Physics Center (DIPC), 20018 San Sebastian, Spain — [5]Ikerbasque, Basque Foundation for Science, 48013 Bilbao, Spain

In magnetic molecules intrinsic magnetic anisotropy breaks spin degeneracy, allowing inelastic spin excitations that can be protected by a superconducting gap. The coupling of the spin to the superconductor induces Yu-Shiba-Rusinov (YSR) states, detected by scanning tunnelling microscopy (STM) as long-lived quasiparticles excitations inside the superconducting gap.

Here, we observe the signature of both described excitations in an Fe-porphyrin adsorbed on a Au/V(100) proximitized superconducting surface. We found that the STM tip affects in a similar way both in-gap and out-gap states, hint that they are correlated. Solving an effective Hamiltonian of the system, we describe the observed signals as multiple excitations of entangled states formed by the molecular spin and superconductor.