TT 32: Superconductivity: Yu-Shiba-Rusinov and Andreev Physics

Time: Wednesday 15:00–16:30 Location: H32

TT 32.1 Wed 15:00 H32

Ab-initio Investigation of YSR States of Fe Adatoms Interacting with Rashba-Split Surface States on $BiAg_2$ — •Ilias Klepetsanis[1,2], Philipp Rüssmann[1,3], and Samir Lounis[1,2] — [1]Forschungszentrum Jülich & JARA, Germany — [2]University of Duisburg-Essen and CENIDE, Germany — [3]University of Würzburg, Germany

One of the most sought after topics in modern condensed matter physics research, has been the creation of topological superconductivity systems that are able to host Majorana states. A plethora of material configurations have been proposed to that end, with emphasis on the interplay between magnetism, SOC and superconductivity. Here, we investigate the behaviour of Fe adatoms deposited on a $BiAg_2$ surface with a superconducting Nb substrate, using the Bogoliubov-de-Gennes full-potential relativistic Korringa-Kohn-Rostoker Green function method [1]. We explore the emergence of Yu-Shiba-Rusinov (YSR) states and their dependence on the adatom deposition site and magnetic moment rotation, as well as the effect of the strong spin-orbit coupling from the substrate. We construct chains of Fe adatoms and study the YSR state behaviour with an increasing chain length and its correlation with the magnetic ground state. Finally we explore the possibility of non-trivial end-states emerging on the Fe chain.

[1] P. Rüßmann, and S. Blügel, Phys. Rev. B 105, 125143 (2022).

TT 32.2 Wed 15:15 H32

Shiba States in Magnet/Superconductor Heterostructures from First Principles — •Arnold Kole, Andrés Botello-Méndez, and Zeila Zanolli — Utrecht University, Utrecht, The Netherlands

The search for topological superconductors (TSC) with potential applications in quantum computing motivates the study of hybrid systems combining superconductivity, magnetism, and spin-orbit coupling. Previous work has shown the presence of in-gap states in these systems [1]. Of particular interest are Yu-Shiba-Rusinov (YSR) states, that arise due to interactions of magnetic impurities with a superconductor [1]. It has been proposed that these can be used to engineer topological superconductivity [1].

We demonstrate the emergence of topologically trivial in-gap YSR states in $CrCl_3$ islands on superconducting $NbSe_2$ [2]. Using Density Functional Theory (DFT), we show an increase of the Cr 3d density-of-states at the edge and an enhanced exchange interaction between the $CrCl_3$ edge and the $NbSe_2$ substrate [2]. This means that the $CrCl_3$ edge acts as a one-dimensional chain of magnetic impurities interacting with the superconducting $NbSe_2$. This can explain the emergence of the YSR states. Finally, we systematically show that these findings are robust to changes in computational details such as stacking, magnetic configuration and Hubbard U parameters [3].

[1] L. Schneider et al., Nat. Nanotechnol. 17, 384 (2022);
[2] J.P. Cuperus, A.H. Kole et al., submitted (2024);
[3] A.H. Kole et al., manuscript in preparation (2025).

TT 32.3 Wed 15:30 H32

Spin Dynamics in a Josephson Junction Between Two Superconducting Magnetic Impurity States — Fabian Ziesel[1], Björn Kubala[1,2], Joachim Ankerhold[1], and •Ciprian Padurariu[1] — [1]ICQ and IQST, Ulm University, Germany — [2]Institute of Quantum Technologies, German Aerospace Center (DLR), Ulm, Germany

We study the Josephson effect in a junction formed between two superconducting magnetic impurities. Such a junction was recently realized using a scanning tunneling microscope tip functionalized with a magnetic impurity that probes a second impurity on the sample [1]. Our work extends a recent theoretical investigation [2] by considering the mutually coupled dynamics between the impurity spins and the Josephson phase. We suggest that the Josephson effect can be exploited to manipulate the relative magnetic orientation of the impurities due to a Josephson-induced exchange interaction that arises.

Our theoretical approach treats the Josephson and spin dynamics equally. We identify a key experimental signature of spin dynamics: a small d.c. bias results in excess d.c. current due to the coupling between spins and the Josephson phase. We also discuss spin control, exemplified by inducing a spin-flip of an impurity using an adiabatic voltage pulse.

[1] H. Huang *et al.*, Phys. Rev. Res. **3**, L032008 (2021);
[2] S. Chakraborty *et al.*, Phys. Rev. B **108**, 094518 (2023).

TT 32.4 Wed 15:45 H32

Yu-Shiba-Rusinov Spectroscopy of Triple Quantum Dot Molecules — •Vladislav Pokorný[1] and Martin Žonda[2] — [1]FZU - Institute of Physics, Czech Academy of Sciences, Na Slovance 2, 182 00 Prague, Czech Republic — [2]Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, 121 16 Prague, Czech Republic

We study a system of three quantum dots in triangular geometry with equal distances connected to a common superconducting lead and coupled via interdot Coulomb interaction. We provide complete ground state phase diagrams for the half-filled system in various regimes and study the behavior of the in-gap Yu-Shiba-Rusinov states. We use the superconducting impurity Anderson model to describe the system and solve it using a combination of effective methods based on the superconducting atomic limit and the continuous-time hybridization expansion quantum Monte Carlo. The results can provide deep insight into experiments involving trimers made of magnetic molecules on superconducting substrates.

TT 32.5 Wed 16:00 H32

Experimental Signal of Multiple Andreev Reflexion in Spin Splitted Tunneling Junctions — •David Caldevilla-Asenjo[1], Sara Catalano[2,3], Pietro Cattaneo[4], Fernando Sebastian Bergeret[1], Maxim Ilyn[1], and Celia Rogero[1] — [1]Centro de Fisica de Materiales (CSIC-UPV/EHU),20018 Donostia San Sebastian — [2]Materials Physics Center (MPC), Paseo Manuel de Lardizabal 5,20018 Donostia, Spain. — [3]IKERBASQUE, Basque Foundation for Science, 48009 Bilbao, Basque Country, Spain. — [4]Politecnico di Milano, 20133, Milano, Italy

A ferromagnetic insulator in contact with a superconductor induces an effective exchange field, resulting in a spin splitting of the BCS density of states [1,2]. In this work, we study planar Josephson Junctions where one electrode is in contact with a thin layer of the ferromagnetic insulator europium sulfide. Samples are grown in situ by using the hard-mask technique in UHV. We characterized the junctions through DC transport measurements at a base temperature of 10mK, observing Josephson coupling and Multiple Andreev Reflection according to the transparency of the barrier. We propose a theory model to interpret the junction spectra taking into account the exchange field. Our results provide an experimental and theoretical description of in-gap transport processes in superconducting junctions proximitized by a ferromagnetic insulator [3].

[1] R. Meservey and P.M. Tedrow, Phys. Rep. 238, 173 (1994);
[2] A. Hijano et al., Phys. Rev. Res. 3, 021031 (2021);
[3] B. Lu et al., Phys. Rev. B 101, 020502 (2020).

TT 32.6 Wed 16:15 H32

Nonequilibrium Josephson and Andreev Transport in Quantum Dot Junctions — •Jordi Picó-Cortés[1], Gloria Platero[2], Andrea Donarini[1], and Milena Grifoni[1] — [1]Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Instituto de Ciencia de Materiales de Madrid (CSIC) 28049 Madrid, Spain

We investigate nonequilibrium transport through superconducting nanojunctions using a Liouville space approach [1]. The formalism allows us to study finite-gap effects, and to account for both quasiparticle and Cooper-pair tunneling. With focus on the weak-tunneling limit, we study the stationary dc and ac current up to second order (cotunneling) in the hybridization energy. For the particular case of a strongly interacting quantum dot sandwiched between two superconductors, we identify the characteristic virtual processes that yield the Andreev and Josephson current and obtain the dependence on the gate and bias voltage for the dc current, the critical current, and the phase-dependent dissipative current. In particular, the critical current is characterized by regions in the stability diagram in which its sign changes from positive to negative, resulting in a multitude of $0-\pi$ transitions. The latter signal the interplay between strong interactions and tunneling at finite bias.

[1] J. Picó-Cortés, G. Platero, A. Donarini, M. Grifoni, Phys. Rev. B 110, 125418 (2024).