Atomic-scale design of magnetic adsorbate structures on superconductors

Katharina J. Franke

Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

franke@physik.fu-berlin,de

Yu-Shiba-Rusinov (YSR) states arise from the exchange interaction between magnetic impurities and superconducting substrates. These bound states emerge within the superconducting energy gap, remaining isolated from the bulk states, which makes them an ideal platform for engineering hybridized states, band formation, and topological superconductivity. Their tunability offers exciting possibilities for exploring fundamental physics and designing novel quantum materials.

In this work, we use scanning tunnelling microscopy (STM) to investigate the interplay of magnetic atoms and molecules with superconducting surfaces. By leveraging molecular self-assembly and atomic manipulation, we demonstrate precise control over YSR states and their hybridization [1-3].

Establishing Josephson junctions by approaching magnetic adatoms with a superconducting STM tip reveals diode-like behaviour in the retrapping current [4]. This non-reciprocal phenomenon allows a non-dissipative supercurrent to flow in one direction while underlying dissipation in the opposite direction.

References

[1] E. Liebhaber, L. M. Rütten, G. Reecht, J. F. Steiner, S. Rohlf, K. Rossnagel, F. von Oppen, and K. J. Franke, Nat. Commun. 13, (2022) 2160.

[2] L. M. Rütten, H. Schmid, E. Liebhaber, G. Franceschi, A. Yazdani, G. Reecht, K. Rossnagel, F. von Oppen, K. J. Franke, ACS Nano 18, (2024) 30798.

[3] L. Farinacci, G. Reecht, F. von Oppen, K. J. Franke, Nat. Commun. 15, (2024) 6474

[4] M. Trahms, L. Melischek, J. F. Steiner, B. Mahendru, I. Tamir, N. Bogdanoff, O. Peters, G. Reecht, C. B. Winkelmann, F. von Oppen, K. J. Franke, Nature 615 (2023) 628