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Probing Molecular Spins on Superconducting Pb(111) Using Scanning Tunneling Microscopy

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Low-dimensional magnets proximitized to a superconductor are exciting platform for the realization of a topological superconductor. In order to built-up atomically-precise structures, we propose to use the toolbox of supramolecular chemistry developed on metallic surfaces for the synthesis of chains or two-dimensional arrays of spins on superconductors. In recent works [1,2], we studied the supramolecular assembly of radical molecules directly adsorbed on Pb(111), whose charge state can be tuned from anionic to neutral state by the electric field tip of a scanning tunneling microscope (STM) [1,2]. Anionic molecule obtained by an electron donated from the substrate carries a spin-1/2 state, as confirmed by the observation of Yu-Shiba-Rusinov (YSR) states in tunneling spectra at low temperature. At the border of supramolecular islands, low-energy sub-gap states appear localized at edges with an exponential decay towards the island interior. Tight-binding calculations suggest that their localization lengths and spectral signatures could be consistent with Majorana modes protected by mirror symmetry in an antiferromagnetic spin lattice [1].

The lateral manipulation of these radical molecules with the STM also enables the design of complex charge (spin) architectures such as chains or trimers [3,4]. Using dI/dV spectroscopy, we directly visualize discharging processes and characteristic Coulomb ring patterns associated with single-electron discharging events. The analysis also reveals that discharging rings are not necessarily associated with changes in the total charge of the cluster, but often originate from internal charge redistribution between molecular sites. Our results open up a vast playground for investigating electron-electron interactions within designed structures and for the synthesis of topological organic-superconductor hybrids.

References:

[1] Pawlak et al. Nano Lett., 25, 15206-115214 (2025)

[2] C. Dreschel et al. Nanoscale Horiz., 10, 2365-2373 (2025)

[3] C. Li et al. ACS Nano 2025, 19, 3403-3413 (2025)

[4] C. Li et al. Nat. Comm. accepted (2026)