Yu-Shiba-Rusinov States of Magnetic Fe Adatoms on Superconducting Ni Kagome Lattice

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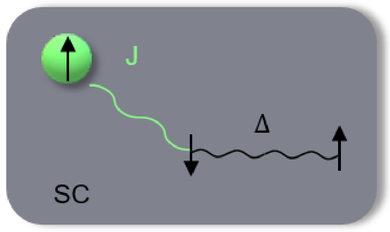
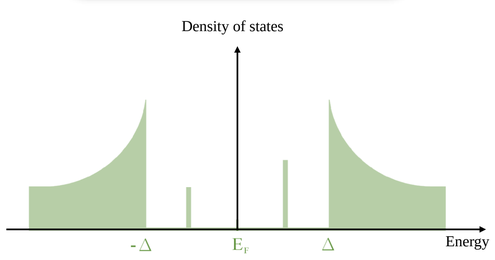
Introduction

✸ Yu-Shiba-Rusinov States

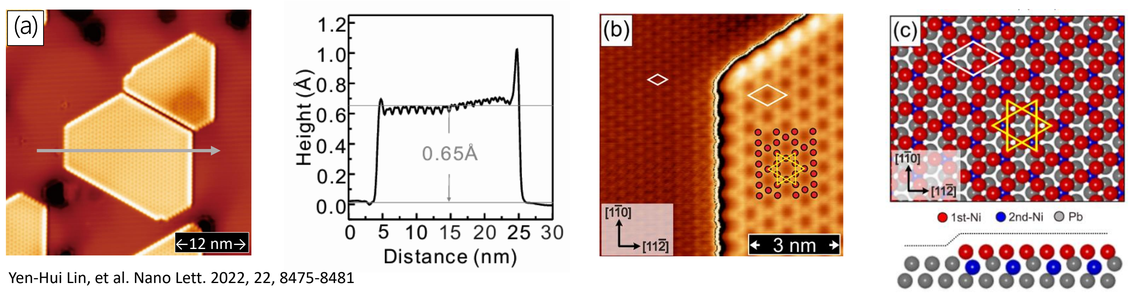


- The spins of magnetic impurities on a superconducting substrate are exchange-coupled with Cooper pairs.



- This interaction forms pairs of bound states within the superconducting gap that are symmetric with respect to the Fermi level.

✸ Literature review: Ni Kagome/Pb(111)

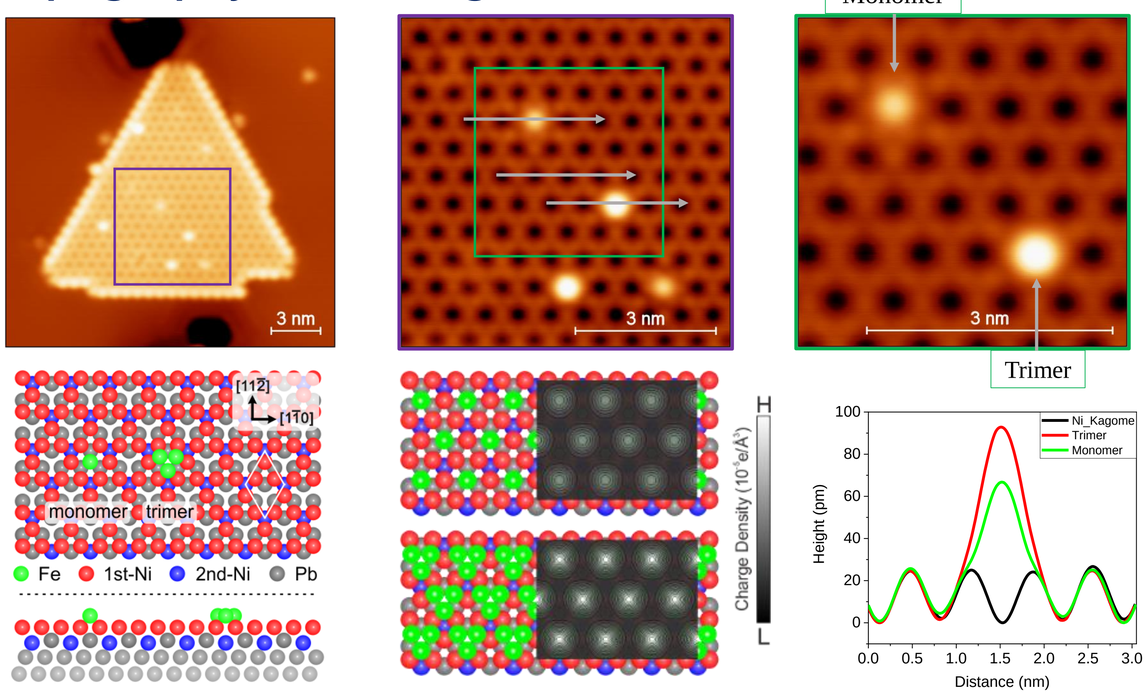


Yen-Hui Lin, et al. Nano Lett. 2022, 22, 8475-8481

- Deposit Ni on Pb(111) substrate at 80 K and post annealing 20mins at 200K.
- The Ni Kagome lattice constant is about 7.06 Å corresponding to a (2×2) supercell with respect to the Pb(111) (1×1) unit cell.

Experimental Results

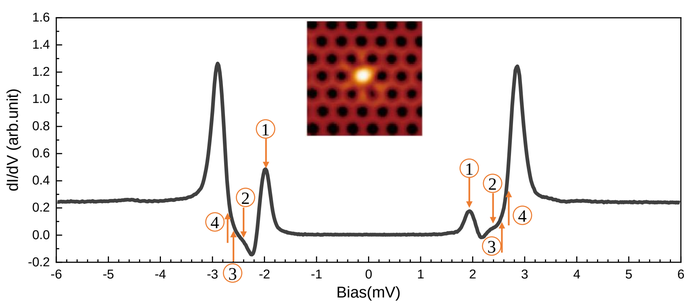
✸ Topography: Fe/Ni Kagome/Pb(111)

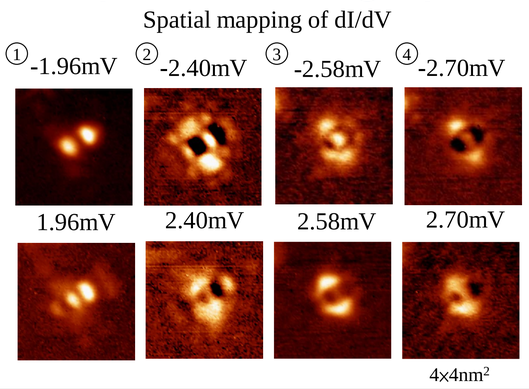


- Deposit Fe on superconducting Ni Kagome/ Pb(111) at 80K.
- There are two types of Fe adatoms on Ni Kagome/Pb(111): the higher one is trimer, and the lower one is monomer.

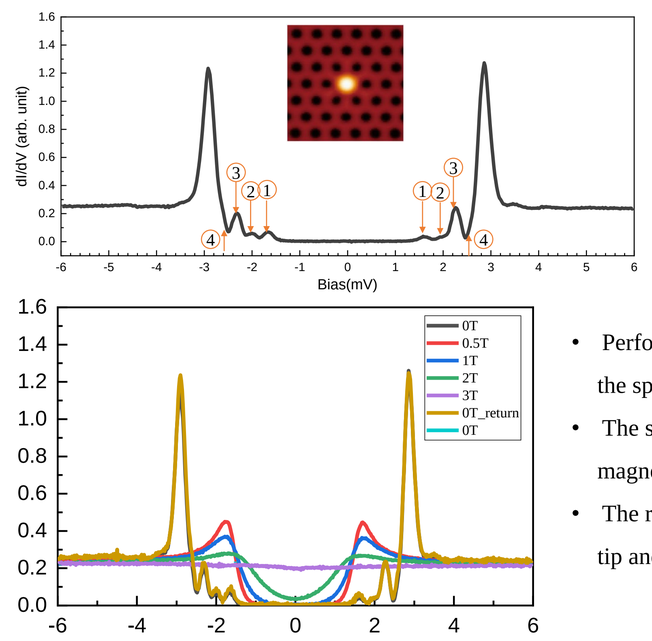
✸ High-Resolution Spectroscopy with Superconducting tip

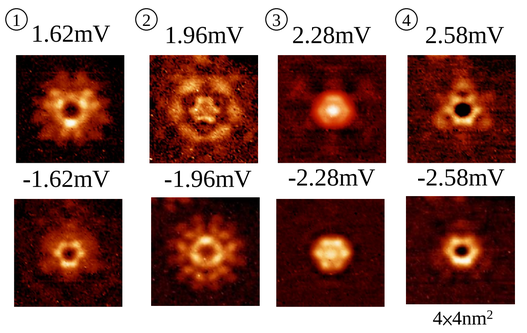
Fe Monomer





Fe Trimer

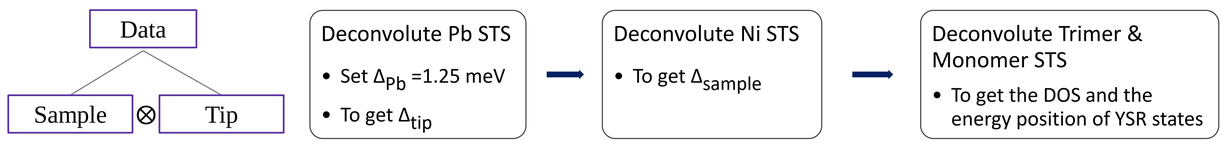


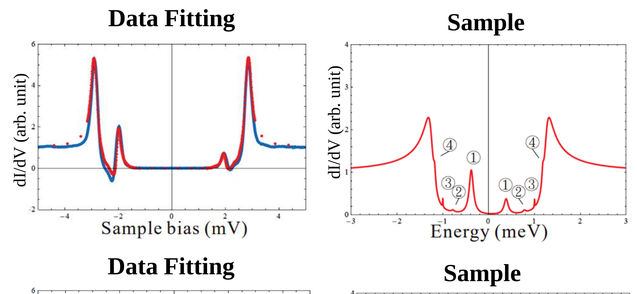


- Perform magnetic field-dependent measurements to verify the spectroscopic features with superconducting tip.
- The superconductivity of sample is quenched at 0.5T magnetic field.
- The remaining signal originates from the superconducting tip and is quenched after applying a magnetic field of 3T.

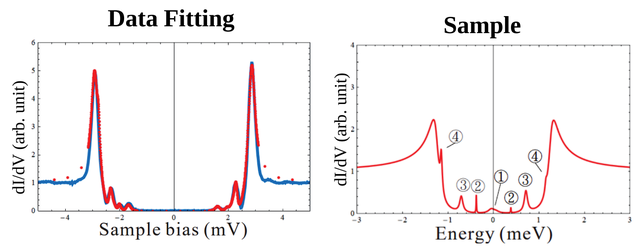
Theoretical Calculations

✸ Deconvolution method

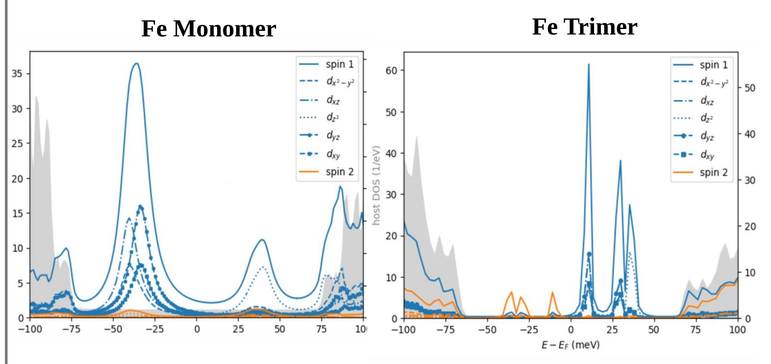




Fe Monomer	1	2	3	4
Energy position (meV)	±0.38	±0.78	±1.00	±1.18



Fe Trimer	1	2	3	4
Energy position (meV)	±0.05	±0.38	±0.71	±1.15

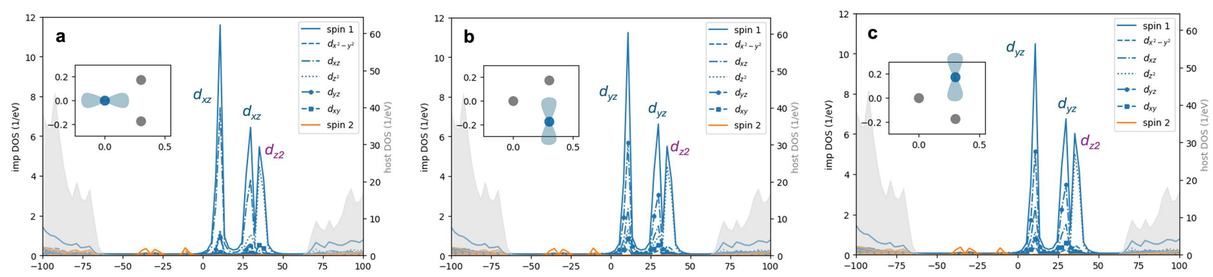


Fe Monomer:

- The contributions of d_{xz} and d_{yz} orbitals with the triangular symmetry of the Ni Kagome lattice explain the observed asymmetries in the spatial mapping of the YSR states.

Fe Trimer:

- Conbining the contributions of all three atoms results in the triangular charge density distribution observed in the experiment at ε =1.62 meV.
- At the largest energy position, all states display the d_{z^2} character, which is isotropic and corresponds to the spatial mapping at ε = 2.28 meV.



- As the distance between the tip and the Fe atoms increases, the strong asymmetry between the positive and negative YSR peaks disappears.

Summary

1. Fe atoms on Ni Kagome/ Pb(111) have scattering potential that breaks Cooper pairs and gives rise to the in-gap YSR states.
2. There are two types of Fe adatoms on Ni Kagome/Pb(111): one is a trimer, and the other one is a monomer.
3. The deconvolution method used to resolve the energy positions of YSR states is consistent with the experimental results.
4. The contributions from the different d-orbitals of Fe atoms can explain the asymmetry observed in the YSR states.

Reference

[1] Y.-H. Lin, C.-J. Chen, N. Kumar, T.-Y. Yeh, T.-H. Lin, S. Blügel, G. Bihlmayer, P.-J. Hsu, Nano Lett. 2022, 22, 8475.

[2] F. Küster, A. M. Montero, F. S. M. Guimarães, S. Brinker, S. Lounis, S. S. P. Parkin, P. Sessi, Nat Commun 2021, 12, DOI 10.1038/s41467-021-21347-5.