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Designer Electronic States in Van der Waals - Metal-Organic Framework Heterostructures

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Heterostructures combining metal-organic frameworks (MOFs) with van der Waals (vdW) materials are a powerful platform for realizing and engineering electronic and magnetic states not found in naturally occurring materials. While bulk, three-dimensional MOFs have been synthesized in enormous structural variety, synthesis strategies for 2D MOFs remain much more limited [1]. 2D-MOFs are usually grown on metal surfaces (e.g. Au, Ag, Cu), where their intrinsic electronic properties are difficult to access. We target MOFs on epitaxial graphene and other vdW materials and characterize their atomic geometry and electronic structure by atomic force microscopy (AFM), scanning tunneling microscopy (STM) and spectroscopy (STS) [2-4].

While heterostructures with vdW materials allow expanding the range of electronic states that can be realized, combining magnetic MOFs with superconducting substrates also makes it possible to probe the MOF magnetism [5]. I will focus on our results on $NbSe_2$ substrates, where STM measurements reveal Yu-Shiba-Rusinov (YSR) bands arising from the interaction between the MOF magnetic moments and the superconducting substrate. These together with x-ray absorption spectroscopy (XAS) and x-ray magnetic circular dichroism (XMCD) measurements allow detailed probing of the MOF magnetism. I will the discuss the resulting unconventional 3×3 reconstruction of the magnetic ground state, directly visible as a real-space modulation of the YSR bands. Concluding, combining flexible molecular building blocks, frustrated magnetic textures, and superconductivity in a single heterostructure offers a route towards tuneable quantum materials, including unconventional superconductors and quantum spin liquids.

References:

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