INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2022-2023

Magnetic bound states in two-dimensional superconductors

The presence of a nanoscale magnetic scatterer (a single atom, a molecule, a quantum dot or an atomic nanowire) on the surface of a superconductor can lead to the emergence of bound states, at energies below the superconducting gap, with peculiar spatial and spectral properties. In particular, these states can be topologically trivial (the case of so-called Shiba states) or not (predicted Majorana zero modes).

In this project we will investigate the properties of superconducting bound states in extremely thin superconductors, down to a single atomic layer. Here, the bound states can have a much longer spatial range, which will allow coupling different such nano-objects among them. Thereby we can engineer novel low energy states with exotic properties.

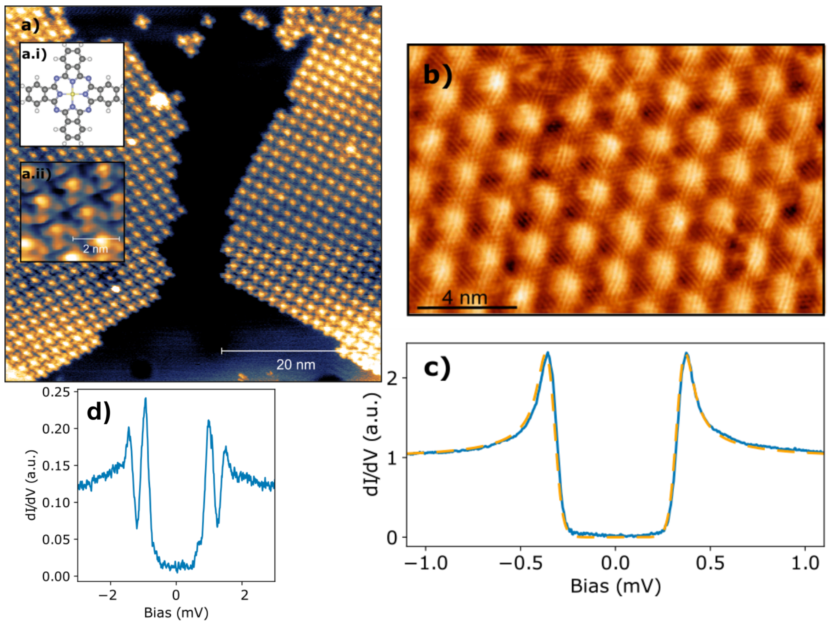

Figure 1 : (a) STM topograph of self-assembled monolayers of MnPc molecules on the Pb(111) surface. (b) STM topograph of the Moiré pattern of graphene on rhenium. (c) Tunneling spectroscopy of superconducting graphene on rhenium. The dashed line is the theoretical prediction. (d) Tunneling spectroscopy of a magnetic bound state on an individual MnPc molecule in (a). Data taken at 50 mK.

Scanning tunneling microscopy/spectroscopy (STM/STS) is an extremely sensitive and versatile tool to investigate atomic scale topographic features and variations in the local density of states. Using a low-temperature STM, we will study the signatures of magnetic interactions and possible topological superconductivity, using novel combinations of superconductors and magnetic nanostructures. The superconducting substrate will be provided either by (i) intrinsic superconductors in the single or few atomic layer limit, or (ii) non-intrinsically superconducting single-layer graphene into which superconductivity is induced from a nearby superconductor. We will study the quantum transport properties of electrons between the tip and the nanostructure, including its response to a microwave excitation and the ability to carry Josephson supercurrent.

The experimental work is at the interface between surface science and quantum transport studies. The experiments will be performed using a milliKelvin STM available in the host group. The work encompasses collaboration between STM groups in Grenoble (both at Néel/CNRS and IRIG/CEA), together with FU Berlin. The work is further supported by strong interactions with theory groups. The student's work will include:

- Preparing and growing combinations of superconducting substrates and magnetic nanostructures, by self-assembly or single-atom manipulation.
- Performing low temperature scanning probe measurements, with a particular focus on quantum transport effects (Josephson effect, photon-assisted tunneling, …)
- Theoretical analysis and interpretation.

Collaboration and networking: The work bases on a strong experimental collaboration between Inst. Néel (C. Winkelmann), IRIG/CEA (V. Renard), Spintec/CEA (M. Jamet), and FU Berlin (K. Franke), as well as several theory groups.

Required skills: MSc level in Physics or Applied Physics. Prior experience in low temperature physics, surface science or nanoelectronics is a plus.

Starting date: 2023

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