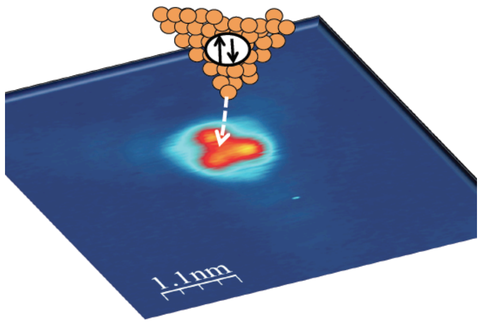
INSTITUT NEEL Grenoble

Proposition de stage Master 2 - Année universitaire 2021-2022

Superconductivity in atomic-scale magnetic nanostructures



Spatial map of a low-energy bound state around a Fe nanoisland on super-conducting Pb(111) and sketch of STM experiment.

Nanometer scale scatterers (a single atom, a molecule, a quantum dot or an atomic nanowire) can interact with a superconducting condensate via potential scattering and/or magnetic exchange coupling. This leads to bound states, at energies below the superconducting gap, with peculiar spatial and spectral properties [1]. 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, in the single atomic thickness limit. Here, the bound states can have a much longer spatial range, which will allow coupling different such nanoobjects among them. Thereby we can engineer novel low energy states with exotic properties.

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 in a range of novel combinations of superconductors and magnetic nano-objects. 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, and also in collaboration with FU Berlin [2]. The student's work will encompass:

- Preparing 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.

[1] Magnetic-Field-Induced Transition in a Quantum Dot Coupled to a Superconductor, A. García Corral, D.M.T. van Zanten, K.J. Franke, H. Courtois, S. Florens, and C.B. Winkelmann, Phys. Rev. Research 2, 012065(R) (2020).
[2] Resonant Andreev reflections probed by photon-assisted tunnelling at the atomic scale, O. Peters, N. Bogdanoff, S. Acero Gonzalez, L. Melischek, J.R. Simon, G. Reecht, C.B. Winkelmann, F. von Oppen, and K.J. Franke, Nature Phys. 16, 1222 (2020).

Collaboration and networking: The work bases on a strong experimental collaboration with FU Berlin, as well as theoreticians in Grenoble.

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

Starting date: 2022

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