NÉEL INSTITUTE Grenoble

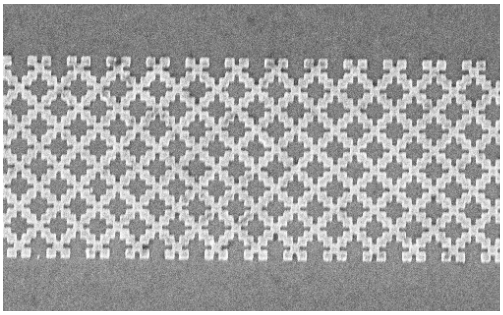
Topic for Master 2 internship – Academic year 2024-2025

Attempt to nano-engineer flat bands to increase critical superconducting temperatures

General Scope :
Superconductivity is a fascinating state of matter corresponding to zero electrical resistance and magnetic field expulsion occurring in some materials cooled down below a critical temperature. Microscopically it corresponds to a condensate of electron pairs. Such a condensate of fermions can occurred only because electron paired up to form Cooper pairs. In conventional superconductors, the glue binding the electron pairs is the exchange of lattice vibrations: the phonons. In conventional superconductors the critical temperature is expected to scale with the pairing interaction g as $T_c \sim \exp(-1/g)$.

In flat-band systems, i.e. when the Fermi velocity is zero, theories predict that the superconducting critical temperature Tc depends linearly on the pairing interaction g, $T_c \sim g$. As a result, critical temperatures much higher than those of conventional superconductors can be envisaged (without changing the nature of the pairing interaction).

Research topic and facilities available :
This project aims to explore experimentally structures in which superconductivity could be enhanced by the emergence of flat bands. The idea is to control the emergence of flat bands via the geometry of the nano-patterning. To this end, we plan to produce flat band superconducting structures using nano-lithography techniques and measure the evolution of the critical temperature and the Fermi velocity via magneto-transport measurements. The final objective is to study wether the critical temperature correlates with the Fermi velocity for different nano-patterning of the very same material as suggested by recent theoretical predictions. For this projet the student will be trained in nano lithography and low-temperature resistance measurement techniques.



MEB image of nano-pattern wire.
Grey: silicon substrate. White: superconducting material. This is a second-order fractal pattern. The wire is connected to four pads (not shown) for resistivity measurements.

Possible collaboration and networking :
The project is part of the Institut Néel's collaboration with the theoretician George Bouzerar.

Required skills:
Solid state physic knowledge, taste for experimental manipulation and strong motivation.

Starting date : January-April 2025

Contact : Institut Néel - CNRS :
Florence Lévy-Bertrand, 04 76 88 12 14, florence.levy-bertrand@neel.cnrs.fr
Cécile Naud, 04 56 38 71 76, cecile.naud@neel.cnrs.fr