NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

2D superconductivity in cuprate oxychlorides

General Scope: Cuprates oxychlorides are unique among the high temperature superconducting cuprates (HTSCs) since it: lacks high Z atoms; has a simple I4/mmm 1-layer structure, typical of 214 (LSCO) cuprates, but which is stable at all doping and temperatures; and has a strong 2D character due to the replacement of apical oxygen with chlorine. All these characteristics made them particularly well adapted to calculation including correlation effects, a subject that we are actively investigating (1). Recently we obtained puzzling results on their superconducting properties that are highly anisotropic. This could be the result of an intrinsic bi-dimensional electronic structure, that would made them the equivalent, for superconductors, of graphite for the 2D graphene layers. This would also be highly unusual and will allow to study 2D phenomenology in a bulk sample, instead of a single CuO_2 layer, a fascinating possibility. By the way, an anomalous *in-plane* superconducting penetration depth $\lambda_{ab}(0)$ was already reported (2), but so far not compared to the values in the perpendicular *c* direction, a question we need to explore for a complete understanding of the problem.

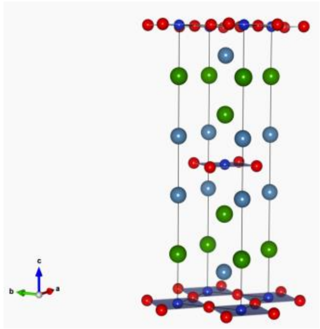

Figure 1: Unit cell of $Ca_2CuO_2Cl_2$ (Cu blue, O red, Cl green, Ca cyan), with the square unit of the CuO_2 plane visible, where the superconductivity take place.

(1) B. W. Lebert, *et al., Phys. Rev. B* **108**, 024506 (2023) ; L. Chaix, *et al., Phys. Rev. Research* **4**, 033004 (2022)

(2) R. Khasanov *et al., Phys. Rev. B* **76**, 094505 (2007).

Research topic and facilities available: The above-mentioned results are very recent, and many points needs to be clarified, namely: do this superconducting anisotropy arise only in a limited part of the phase diagram? How these superconducting anisotropies relate with the normal state resistivity one? During the internship we will start to address part of these questions, using magnetization and penetration depth measurements, using in house Tunnel Diode Oscillator (TDO) system, as a function of the crystallographic direction. Preparation of these experiments will require special care, as the materials are sensitive to air, with a special glove box at the Néel institute, as well as instrument for crystalline properties (x-ray diffraction) and superconducting measurements (magnetometry, TDO).

Possible collaboration and networking : Sample synthesis will be made in collaboration with the group of Prof. Hajime Yamamoto (Tohoku Univ., Sendai, Japan).

Possible extension as a PhD : Yes, this project is part of a PhD program, of which this Master Internship could be a first approach, and during the possible PhD we will extend our investigation to transport properties, measuring resistivity and point-contact-spectroscopy.

Required skills: A good background in electronic properties of material, with the will to have a global approach, from material synthesis and characterization to advanced spectroscopic properties. Team work will be an essential part of the project success.

Starting date : from winter 2024

Contact :

Name : Matteo d'Astuto, Pierre Rodière
Institut Néel - CNRS
Phone : (+33)(0)4 76 88 12 84
e-mail : matteo.dastuto@neel.cnrs.fr

More information : http://neel.cnrs.fr