NÉEL INSTITUTE Grenoble

Topic for Master 2 internship – Academic year 2023-2024

Pressure induced high T_c superconductivity in $Ln_3Ni_2O_7$ nickelate

General Scope :

The search of high T_c superconductivity in other analogous materials than cuprates has started more than 35 years. For Ni, the discovery of unconventional superconductivity in thin film of hole-doped infinite-layer nickelate $Nd_{1-x}Sr_xNiO_2$ (with square planar coordinated Ni^+ in d^9 configuration for x = 0) below T_c = 15 K (for x~0.2) by the group of H.Y. Hwang (Stanford) mid-2019 has suddenly intensified the research in this field. So far, no superconducting bulk nickelates were discovered until very recent report of superconductivity near 80 K in $La_3Ni_2O_7$ (La-327) under high pressure (HP) by M.Wang et al. (Beijing) [Fig.1]. On the contrary of previous nickelates this bilayer compound shows a mixed valency state $Ni^{2.5+}$ (i.e. d^7/d^8) and several theoretical scenarios have been proposed to understand the related high T_c superconductivity mechanism but the question is not yet resolved. Like cuprates, La-327 shows a $3d_{x^2-y^2}$-based Fermi surface but also an additional pocket involving $3d_{z^2}$ orbitals which is potentially crucial to reach superconductivity. In fact, superconductivity occurs just above a structural phase transition at 10-14 GPa, where the Ni-O_{apical}-Ni angle, closely related to oxygen 2p/nickel $3d_{z^2}$ orbitals hybridization, changes from 168° to 180°.

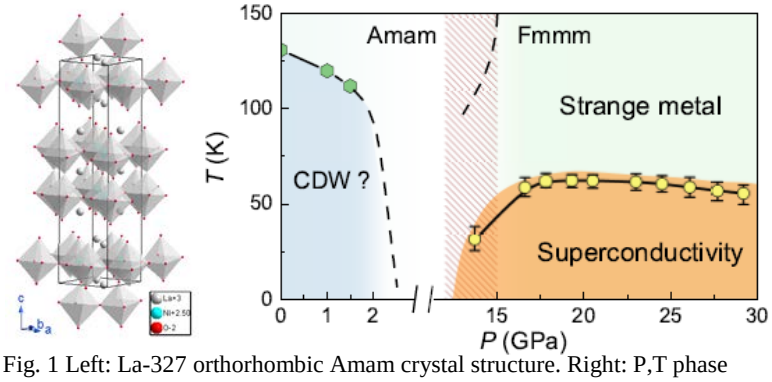

Fig. 1 Left: La-327 orthorhombic Amam crystal structure. Right: P,T phase diagram [Y. Zhang *et al.* Arxiv : 2307.14819]

Research topic and facilities available:

Presently the Chinese discovery has been confirmed by two other groups (in Japan and China). At Néel Institute, in the last three years, we worked on related infinite-layer Ni oxides. In MRS group, we have also synthesized several $Ln_{n+1}Ni_nO_{3n+1}$ compounds, in particular the n = 2 member $La_3Ni_2O_7$. The related internship will include the (high pressure – high temperature) synthesis of $(La_{1-x}Ln_x)_3Ni_2O_7$ samples (with one Ln = Pr, Nd or Sm). The study of the structural, magnetic and electronic properties of the synthesized nickelates, will be carried out as a function of temperature, thanks to the various experimental setups available in our laboratory. Measurements under high pressure (HP) are planned: x-ray diffraction (XRD) and possibly resistivity or Raman spectroscopy measurements in collaboration with MagSup team. For XRD/HP experiments several proposals have been submitted to different synchrotrons x-ray sources (ESRF, SOLEIL and Elettra in Italy) and were accepted; the trainee will participate to these large scale facilities experiments.

Possible collaboration and networking: We have currently a joint research ANR project on nickelates with CRISMAT in Caen and several laboratories in Parisian region.

Possible extension as a PhD: this internship will be extended into a PhD where potential superconductivity in palladates will also be explored. Funding may be obtained via the Physics Graduate School of Grenoble.

Required skills: A good background in material science and condensed matter physics is required.

Starting date: Spring 2024

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