SCIENCES SORBONNE UNIVERSITÉ

2021-2022

Master thesis proposal

Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie

Campus Pierre et Marie Curie
Tower 23 - 4th floor -23-22
Director: A. Marco Saitta

Title: Topological Superconductivity for fault tolerant quantum computing

Keywords: superconductivity, topology, 2D materials

Scientific description:

Quantum computing relies on the manipulation of coherent quantum systems such as superconducting Josephson junctions. As external noises lead to decoherence, it is important to either heavily shield the quantum bits (or qubits) or, to design qubits that are inherently resilient. Topological insulators are materials whose bulk energy spectrum is gapped similarly to 'trivial' insulators, but their surface (or edge in 2D) presents conducting gapless states. The gapless surface states are intrinsically linked to the transition between the topologically trivial exterior, to the 'non-trivial' interior of the material, and as such are robust against defects and external stimuli, since they do not depend locally on the surface itself. Similar topologically protected edge states can be found in topological superconductors, where gapless edge states exist within the superconducting gap. Zero-bias excitations at the edge of such superconductors should be Majorana fermions which are protected by the whole superconductor. Hence topological superconductivity could play the leading role into building fault tolerant quantum computers from Majorana bound states.

In this project, we will investigate topological superconductivity in the tunnelling between 45° twisted heterostructures of *d*-wave high temperature superconductor BSCCO. The actual presence of topological superconductivity in these heterostructures can be probed by analysing the Frauenhofer patterns of these Josephson junctions.

The success of this project relies on our experience in fabricating and manipulating devices of 2D layers of HTSC BSCCO [F. Wang, J. Biscaras, A. Erb & A. Shukla. *Nature Commun.* **12**, 2926 (2021)] and making clean hetero-structures of 2D materials for which we have developed a glove-box 2D material transfer apparatus. These experiments will also require the fabrication of complex devices by clean room nanofabrication techniques and could be the focus of a thesis following the internship.

Techniques/methods in use: Device fabrication including clean room, exfoliation, low temperature transport.
Applicant skills: experimental skills, condensed matter physics, patience and perseverance.
Industrial partnership: N

Internship supervisor(s) (name, email, phone, webmail):
Abhay SHUKLA : abhay.shukla@sorbonne-universite.fr
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Internship location: Campus Pierre et Marie Curie

Possibility for a Doctoral thesis: Y, financing to be sought from ED397