NÉEL INSTITUTE Grenoble

Topic for master 2 internship – Academic year 2023-2024

Quantum circuit based on aluminum/germanium hybrid Josephson junctions

General Scope:

A Josephson junction consists of two superconductors coupled by a weak link (a thin insulating layer or a non-superconducting material) and is the main building block of many quantum circuits including superconducting qubits. The main advances in terms of quantum circuit complexity have been achieved using tunnel Josephson junctions made out of aluminum contacts separated by an AlOx oxide layer in a transmon geometry. Indeed up to now, they are mostly made up of polycrystalline Al films and amorphous AlO_x tunnel barriers which produces two level fluctuators and quasi-particles generation. Our project intends to develop a new type of superconducting devices in which the tunnel Josephson junction is replaced by a gate tunable Josephson junction field effect transistor (JoFET) made from aluminum/germanium/aluminum heterostructures. To demonstrate the feasibility, we propose to study single JoFETs with only three terminals (source, drain and gate) and more complex quantum circuits.

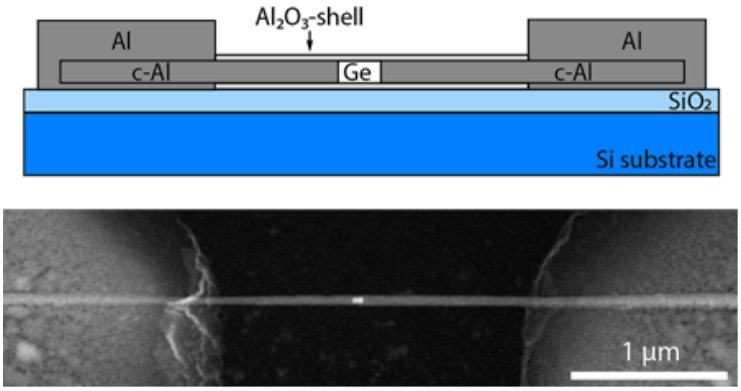

Figure: Al/Ge/Al nanowire heterojunction

Research topic and facilities available:

In our previous studies, we have demonstrated the formation of perfectly crystalline Al/Ge hybrid junctions by a thermal induced Al/Ge substitution; A Ge nanowire is connected with two Al pads in a first step. Then a thermal annealing insure the propagation of the two Al/Ge interfaces through the nanowire leading to a monolithic and mono-crystalline quasi 1D Al/Ge/Al junction [1,2,3]. The research topic is to perform quantum transport measurements at very low temperature in order to understand the interplay between the superconductor and the semiconductor and to build quantum circuits starting these hybrid junctions.

[1] M. Sistani et al. , "Highly Transparent Contacts to the 1D Hole Gas in Ultra-Scaled Ge/Si Core/Shell Nanowires", ACS Nano 13, 12, 14145 (2019).
[2] M. Sistani et al., " Coulomb Blockade in Monolithic and Monocrystalline Al-Ge-Al Nanowire Heterostructures", Appl. Phys. Lett. 116, 013105 (2020); https://doi.org/10.1063/1.5126088.
[3] J. Delaforce et al. , "Al–Ge–Al Nanowire Heterostructure: From Single-Hole Quantum Dot to Josephson Effect", Adv. Mater. 2101989 (2021). DOI: 10.1002/adma.202101989

Possible collaboration and networking :

This project is the result of a collaboration with the Institute for Solid State Electronics at the Technical University of Vienna (Dr. Alois Lugstein).

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