INSTITUT NÉEL Grenoble

Topic for Master 1 internship – Academic year 2024-2025

Tantalum: a new material platform for fluxonium qubits

General Scope:
Superconducting circuits have emerged as one of the leading platforms for quantum computing. While most academic labs and industry giants use a circuit called Transmon as a qubit, our lab specializes in an alternative qubit dubbed Fluxonium [1]. This alternative circuit holds promise to overcome the coherence limitations of current quantum processors, which is the main obstacle to practical quantum computation.

With the most advanced fabrication techniques, Fluxoniums have relaxation times that exceed a few hundred microseconds to milliseconds when operating at frequencies around 1 GHz. We currently use Aluminum circuits patterned on silicon substrates, which has resulted in high dielectric losses and relaxation times below the state-of-the-art. Researchers worldwide have explored the performance of quantum electrical circuits made of various new materials, including Ta, TiN, NbN, and Nb. Tantalum (Ta) is particularly promising as it forms a native oxide of much better quality than the typically used niobium or aluminum [2]. Sapphire is known to be one of the best substrates, with dielectric losses that are an order of magnitude better than silicon [3]. The goal of this project is to fabricate a fluxonium device based on Tantalum on a sapphire substrate.

Research topic and facilities available:
The intern will be responsible for creating fluxonium devices on sapphire substrates with Ta used for resonators and capacitor pads. He will then perform relaxation time measurements of the devices to assess the fabrication quality. He will learn all the cleanroom fabrication techniques required for the project as well as the microwave engineering skills needed to characterize the samples inside a dilution refrigerator at 20 mK. To deposit Ta, we can use either e-gun or sputtering. The process should be carried out at a high temperature of 823 K to obtain the α phase of Ta, which has a high Tc of around 4.5 K. After that, we will use an e-beam masker to perform lithography of the resonator and capacitor pads. Then, we will define the capacitor and resonators using either dry RIE (Reactive Ion Etching) or wet etching. In the final stages, we will utilize e-beam lithography to pattern the junctions and contact them on tantalum using Ar ion milling.

References:

[1] W. Ardati, S. Leger, S. Kumar, V. N. Suresh, D. Nicolas, C. Mori, F. D'Esposito, T. Vakhtel, O. Buisson, Q. Ficheux, and N. Roch, Using bi-fluxon tunneling to protect the Fluxonium qubit, Using bi-fluxon tunneling to protect the Fluxonium (2024).
[2] A. Place, A. P. M. et al. New material platform for superconducting transmon qubits with coherence times exceeding 0.3 milliseconds. Nat. Commun. 12, 1779 (2021).
[3] B, V., Ilchenko, V. Bagdassarov, K. S. Experimental observation of fundamental microwave absorption in high-quality dielectric crystals. Phys. Lett. A 120, 300–305 (1987).

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