Superconducting RF Resonators for Electron Spin Resonance

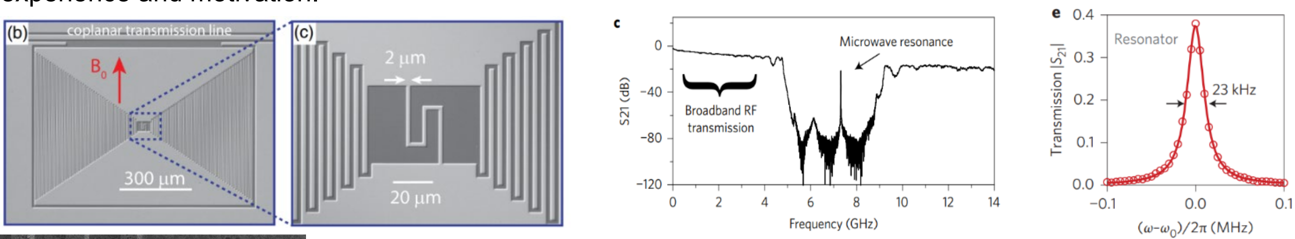
Master / Semester project

(Section: Microengineering – Physics – Electric Engineering – Materials Science)

Electron Spin Resonance (ESR) is a well-established characterization technique. In order to excite the spin ensembles a microwave signal needs to be provided. The sensitivity of this method is depending on many parameters. Among those parameters, one of the most important is the resonator quality factor, which, if increased, could boost the sensor's sensitivity. Resonators realized with superconducting materials allow to achieve higher quality factors with respect to those made of ordinary metals. Many examples of those resonators already exist in literature, realized with materials such as Nb [1-2] and Al [3].

At LMIS1, provided the application related constrains, we are currently investigating different designs and different superconducting materials to realize superconducting resonators, mainly low temperature superconductors (LTS) such as NbTi and NbTiN.

This student project will focus on developing and optimizing a fabrication process for YBCO, a high temperature superconductor (HTS). The process flow will be used to fabricate high quality factor superconducting resonators by optimizing the fabrication parameters, with the main goal of realizing a material independent and high patterning accuracy microfabrication process. The resulting resonators will be characterized in cryogenic environments (T~77 K) using liquid N_2. The topic is highly multidisciplinary, involving aspects of condensed matter physics, RF electronics design and test, cleanroom microfabrication and materials science: the focus can be adjusted depending on the student's interests, best knowledge, previous experience and motivation.



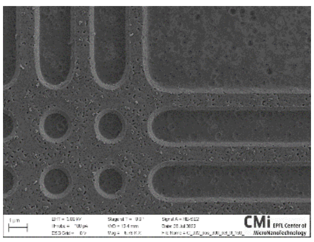


Figure 1 : *Thin film, superconducting coplanar waveguide resonators. Top Left: pattern example of a thin Nb film resonator [1]. Top Center: transmission frequency behavior of a Nb resonator [2]. Top Right: resonance frequency detail of an Al resonator [3]. Bottom Left: SEM image of first fabrication attempt on YBCO film.*

Possible tasks:

- Optimize superconducting RF resonators design to increase resonator quality factor.
- Design, optimize and execute process flows at EPFL's state-of-the-art CMi cleanroom:
    - Process flow conception
    - Drawing individual devices and aggregated chip/wafer lithography layouts,
    - Characterization of the resulting components using SEM, AFM, and other metrology tools.
    - Process flow optimization for pushing resolution and resonators' quality factor.
- Cryo-RF characterization of finalized devices in a cutting-edge experimental setup.

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[1] Eichler et al. (2017) PRL 118, 037701; (https://doi.org/10.1103/PhysRevLett.118.037701).
[2] Sigillito et al. (2017) Nature Nanotechnology 12, 958-962; (https://doi.org/10.1038/nnano.2017.154).
[3] Bienfait et al. (2015)) Nature Nanotechnology 11, 253-257 ; (https://doi.org/10.1038/nnano.2015.282).

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