Characterization of Tantalum Films for transmon molecule implementation

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Superconducting qubits performance is limited by decoherence mechanisms such as dielectric losses. We are investigating a transmon molecule design featuring an original coupling mechanism that produces a non-perturbative cross-Kerr interaction between the qubit and the readout microwave cavity [1]. This setup has already achieved high readout fidelity (99.2% [2]) and long coherence times ($T_1 \cong 120\mu s, T_2 \cong 23\mu s$ [2]). Our current objective is to implement such a transmon molecule, utilizing tantalum capacitive pads in conjunction with aluminum junctions. Indeed, recent advancements suggest that tantalum (Ta) on sapphire substrates can significantly enhance qubit performance, achieving relaxation times (T_1) in the millisecond range [3]. The tantalum film is grown on sapphire substrate using electron gun evaporation in an ultra-high vacuum chamber, with a static pressure of approximately 10^{-10} mbar and a substrate temperature of 400°C. We employ a combination of characterization techniques including x-ray diffraction, atomic force microscopy (AFM), and resistance versus temperature (R(T)) measurements, to assess the structural, surface, and superconducting properties of the Ta films. In order to evaluate microwave losses, we fabricated superconducting resonators. We measured quality factors ranging from 0.7×10^6 to 7×10^6, placing our results close to the current state-of-the-art. I will present systematic measurements of the internal quality factor and resonance frequency as a function of temperature and microwave power, providing insight into dielectric losses and superconducting properties.

[1] R. Dassonneville et al, Phys. Rev. X 10, 011045 (2020).

[2] C. Mori, V. Milchakov, et al. *High fidelity readout in the high-power regime using a transmon*, to be submitted.

[3] A. Place et al. *Nature communications* 12.1 (2021)