Quantum Science and Technology Mini-Symposium
Room 208 W - Session QS2-MoA

Surface Engineering for Quantum Applications

Moderators: Dave Pappas, Rigetti Computing, **Drew Rebar**, Pacific Northwest National Laboratory

4:00pm **QS2-MoA-11 Towards Reducing Dielectric Loss from Josephson Junctions in Superconducting Qubits***, **Arany Goswami**, Hung-Yu Tsao, Chia-Chin Tsai, Kyle Serniak, Jeffrey A. Grover, William D. Oliver,* Massachusetts Institute of Technology

Superconducting qubits are a promising platform to build large-scale quantum computers. However, material imperfections and defects induced by various nanofabrication processes result in the formation of two-level systems (TLSs). TLS's reduce coherence times and increase temporal fluctuations, making qubits harder to operate in a system. One of the major sources of such TLS's has been observed to arise from the dielectric inside the Josephson junctions as well as residues/surface dielectric oxide on the metal surrounding the junction. Here we study this in two parts.

First, we look at the impact of oxidation parameters on the behavior of the Al/AlOx/Al Josephson junctions. We specifically study the effects of oxidation pressure and flow during the AlOx formation on the coherence times of the qubits. Using this process, we attempt to identify oxidation conditions that improve coherence and reproducibility for wafer-scale qubit processing.

In the second part of this talk, we present a wafer-scale inorganic stencil-mask based technique to fabricate the Josephson junctions for superconducting qubits. Using this platform, we compare the effects of a resist-free vs resist-based processes on the coherence times of transmon qubits.

4:15pm **QS2-MoA-12 HF Induced Degradation in High-Purity, Epitaxial Thin Film Niobium***, **Haozhi Wang**,* University of Maryland, College Park*; Tathagata Banerjee,* Cornell University*; Thomas Farinha,* University of Maryland, College Park*; Aubrey Hanbicki,* Laboratory for Physical Sciences*; Valla Fatemi,* Cornell University*; Benjamin Palmer, Christopher Richardson,* Laboratory for Physical Sciences

As a high-gap superconductor, Niobium (Nb) is a natural choice for making supercomputing qubits that can be operated at elevated temperatures. Nowadays, HF based acid cleans have become a regular processing step to remove native oxide and boost device performance. However, one impurity that severely degrades the superconducting properties of Nb is hydrogen (H). Without a protective NbOx layer, Nb can absorb H, and at a large enough H concentration, niobium hydrides (NbH) precipitate. In this talk, we present the impact of HF-based acid cleans on an ultrahigh purity single crystal Nb film grown on sapphire with Tc = 9.23 K, RRR = 40, and resonators with single-photon quality factors more than 10E6. Depending on the exposure to HF-based solutions, a degradation of the both dc and rf performances are observed. Unique crystallite defects with heights of 50 nm and 3-fold symmetry, which we identify as hydrides, are also observed. The contaminated Nb material is further characterized using x-ray diffraction, x-ray photoelectron spectroscopy, and Raman spectroscopy.

4:30pm **QS2-MoA-13 Reducing Losses in Transmon Qubits Using Fluorine-Based Etches** *, **Michael Gingras**, Bethany Niedzielski, Felipe Contipelli, Ali Sabbah, Kate Azar, Greg Calusine, Cyrus Hirjibehedin, David Kim, Jeff Knecht, Christopher O'Connell, Alexander Melville, Hannah Stickler, Mollie Schwartz, Jonilyn Yoder,* MIT Lincoln Laboratory*; William Oliver,* MIT*; Kyle Serniak,* MIT Lincoln Laboratory

Superconducting qubits have developed from proof-of principle single-bit demonstrations to mature deployments of many-qubit quantum processors. Reducing materials- and processing-induced decoherence in superconducting qubit circuits is critical to further the development of large-scale quantum architectures. In this talk we discuss the results of applying selective fluorine-based etches, targeting lossy silicon oxides, in close proximity to sensitive aluminum circuit elements such as Josephson Junctions, resonators and crossover tethers. These fabrication improvements can be implemented with little to no damage to existing structures. The impact that these have on transmon qubit coherence will be discussed.

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4:45pm **QS2-MoA-14 Understanding and Mitigating Coherence and Frequency Fluctuations in Superconducting Transmon Qubits***, **Tanay Roy**, Xinyuan You, Bektur Abdisatarov, Daniel Bafia, Mustafa Bal, David van Zanten, Alexander Romanenko, Anna Grassellino,* Fermi Lab

Transmon qubits are a cornerstone of superconducting quantum computing platforms. However, their frequency and coherence properties exhibit temporal fluctuations, leading to performance degradation in quantum processors over time. A common mitigation approach involves frequent recalibration, which, while effective, results in increased system downtime. Enhancing the long-term stability of transmon qubits is therefore critical for scalable and reliable quantum computing. In this study, we develop novel techniques for understanding the underlying mechanisms driving frequency and coherence fluctuations in fixed-frequency transmon qubits. We further explore strategies to mitigate these instabilities, aiming to improve overall system robustness. Our findings provide insights into optimizing superconducting quantum hardware for practical applications.

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5:00pm **QS2-MoA-15 Superconductor-Semiconductor Epitaxy in Hyperdoped Germanium***, **Javad Shabani**,* NYU **INVITED**

Introducing superconductivity into group IV elements by doping has long promised a pathway to introduce quantum functionalities into well-established semiconductor technologies. The non-equilibrium hyperdoping of group III atoms into Si or Ge has successfully shown superconductivity can be achieved, however, the origin of superconductivity has been obscured by structural disorder and dopant clustering. Here, we report the epitaxial growth of hyperdoped Ga:Ge films by molecular beam epitaxy with extreme hole concentrations 10^21cm^-3, that yield superconductivity with a critical temperature of Tc = 3.5K. Our findings, corroborated by first-principles calculations, suggest that the structural order of Ga dopants creates a narrow band for the emergence of superconductivity in Ge, establishing hyperdoped Ga:Ge as a low-disorder, epitaxial superconductor-semiconductor platform. This platform opens up a new path for integration of superconductivity for cryogenic and quantum applications in group IV.

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