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

Systems, Devices, and Manufacturing Technologies for Quantum Technology

Moderator: Aranya Goswami, Massachusetts Institute of Technology

10:30am **QS2-MoM-10 Superconducting Qubits at MIT Lincoln Laboratory**, ***Mollie Schwartz,*** MIT Lincoln Laboratory **INVITED**

Superconducting qubits are leading candidates in the race to build a quantum computer capable of realizing computations beyond the reach of modern supercomputers. Within this modality, the ability to robustly and reliably fabricate high-quality, quantum-compatible circuits is critical both for fundamental research efforts and for more complex and capable quantum processors.MIT Lincoln Laboratory has worked over the course of two decades to establish, and continually expand and improve, superconducting qubit fabrication capabilities.Recently, we have piloted a superconducting foundry model to enable the US quantum research and development community to leverage the most robust and reliable of these capabilities in order to accelerate research progress.This presentation will provide an overview of superconducting qubit fabrication at MIT Lincoln Laboratory, describe its transition from 50 mm prototyping tools to 200 mm fabrication to support an expanded user base, and provide perspectives on how to support and enable the broader quantum research community as the variety and complexity of questions at the research frontier continues to expand.

11:00am **QS2-MoM-12 Voltage Tunable MBE-grown Ge/SiGe Josephson Junctions for Gatemon Qubits**, ***Joshua Thompson****, Jason Dong, Junior Langa,* Laboratory for Physical Sciences*; Brycelynn Bailey,* University of Arkansas*; Chomani Gaspe, Riis Card,* Laboratory for Physical Sciences*; Shiva Davari, Mariam Afrose,* University of Arkansas*; Thomas Hazard, Kyle Serniak,* MIT Lincoln Laboratory*; Kasra Sardashti,* Laboratory for Physical Sciences*; Hugh Churchill,* University of Arkansas*; Christopher Richardson,* Laboratory for Physical Sciences

Voltage tunable Josephson junctions (JJs) based on planar semiconductor quantum wells have potential to realize voltage tunable qubits fabricated at scale. Josephson junctions are fabricated from undoped Germanium quantum wells (Ge-QWs), grown by Molecular Beam Epitaxy (MBE), with carrier mobility greater than 40,000 cm^2/Vs and hole density less than $1x10^{12}$ cm^{-2}. These junctions use epitaxial aluminum to make transparent contact to the Ge-QW and a mesa structure that is 2.5-μm tall with only the JJ on top, minimizes microwave loss from epitaxial layers, which is critical for superconducting qubits. This presentation will demonstrate gate tunable critical currents and discuss the characterization of MBE-grown Ge JJs along with the path toward integrating these JJs into gatemon qubits.

11:15am **QS2-MoM-13 Development of Ge/SiGe Semiconducting Quantum Dot Devices for Hole-Based Spin Qubits**, ***Giovanni Franco-Rivera****, Jason Dong,* University of Maryland College Park*; Alan Kramer,* Laboratory for Physical Sciences*; Kasra Sardashti,* University of Maryland College Park*; Robert Butera,* Laboratory for Physical Sciences

Confining few electrons in silicon-based heterostructures via lithographically-defined, gated on-chip quantum dots (QD) enables the manipulation of the spin degree of freedom for quantum information processing. In recent years, the hole-based QDs based on strained Ge/SiGe semiconducting quantum wells have rapidly advanced as a compelling platform for spin qubits [1]. Some of the appealing features of the Ge-based spin qubits are their coherent properties achievable by solid-state all-electrical control readout enabled by their intrinsic spin-orbit interaction [2], and their prospects of scalability resulting from long-range coupling via superconducting circuits [3]. From a fabrication standpoint, two key components for the formation of the Ge-QDs is the electrical contacts to the Ge-well and the gate dielectric interface quality over the active dot area. On the forementioned aspect, we explore the use of metallic germano-silicide contacts to the Ge quantum well due to their lower temperature requirements for the fabrication and ability to be proximitized to the quantum dot active area avoiding structural damages caused by a high fluence ion implantation. We estimate the contact resistance via low temperature transport measurements on gated transfer line method devices (TLMs) with contacts formed by platinum germano-silicides (Pt-Ge-Si). On the later aspect, the gate dielectric interface, we focus on optimizing the quality of the ALD-grown Al2O3/SiGe interfaces. We present the results from a series of X-ray photoemission spectroscopy (XPS) measurements on the Al_2O_3/SiGe and Al_2O_3/Pt-Ge-Si interfaces. Our XPS data points to the presence of unwanted Ge in the dielectric interface layer presenting a medium for charge traps that contribute a significant source of charge noise in the device. Lastly, we present methods to mitigate the Ge presence in the gate stack and near the Al_2O_3/Pt-Ge-Si interface.

References:

[1] Scappucci, G., Kloeffel, C., Zwanenburg, F.A. et al. The germanium quantum information route. Nat Rev Mater 6, 926–943 (2021).

[2] Hendrickx, N.W., Massai, L., Mergenthaler, M. *et al.* Sweet-spot operation of a germanium hole spin qubit with highly anisotropic noise sensitivity. *Nat. Mater.* **23**, 920–927 (2024).

[3] Sagi, O., Crippa, A., Valentini, M. et al. A gate tunable transmon qubit in planar Ge. Nat Commun 15, 6400 (2024).

11:30am **QS2-MoM-14 Post-processing of Josephson Junctions for Precision Tuning of Qubit Frequencies**, ***David P. Pappas****, X Wang, Joel Howard, Greg Stiehl, Cameron Kopas, Stefano Poletto, Xian Wu, Mark Field, Nicholas Sharac, Christopher Eckberg, Hilal Cansizoglu, Raja Katta, Josh Mutus, Andrew Bestwick, Kameshwar Yadavalli,* Rigetti Computing*; Jinsu Oh,* Ames Laboatory*; Lin Zhou, Matthew Kramer,* Ames Laboratory **INVITED**

Thin layers of thermal aluminum oxide are the dominant material for making Josephson tunnel-junctions (JJs). These JJs are the key component for qubits in most superconducting implementations of quantum computing. It has become clear that it is necessary to address the issue of JJ homogeneity in order to more precisely tune the qubit frequencies. Work towards this using the newly developed alternating-bias assisted annealing (ABAA) technique will be discussed. ABAA illuminates a promising path towards precision tuning of qubit frequency post-processing while attaining higher coherence due to an apparent reduction in junction loss. Here, we demonstrate precision tuning of the qubits by performing ABAA at room temperature using commercially available test equipment and characterizing the impact of junction relaxation and aging on the resistance spread after tuning. A study of the structural properties of the material using transmission electron microscopy will be given with some thoughts of what the driving mechanism for ABAA is at the atomic scale.

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