

## Northwestern Quantum Week Opening Science Workshop: Superconducting Qubits for Quantum Computing

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### Mitigating Decoherence in Superconducting Quantum Devices via Surface and Interfacial Engineering

**Abstract:** Superconducting qubits are of high interest for quantum information technologies due to their high gate fidelity and scalability. Although the performance of superconducting qubits has increased dramatically over the past two decades, coherence times must increase further to achieve scalable quantum computing. Among the possible sources of decoherence, fabrication processes are leading culprits since they can introduce impurities or defects within the qubits that host microwave loss mechanisms, such as two-level systems and excess unpaired quasiparticles [1]. In this talk, surface and interfacial engineering strategies will be discussed that hold promise for mitigating decoherence in superconducting quantum devices. For example, sputtered Nb films on atomically flat and terraced monohydride Si(111) surfaces produced using ammonium fluoride passivation possess a spatially more uniform superconducting gap and lower quasiparticle

broadening than conventional Si(100) surfaces [2]. Controlled ultrahigh vacuum annealing further provides a pathway to controlling the phase and thickness of Nb silicides formed at the Nb/Si interface [3]. Following Nb patterning, the exposed regions of the Si substrate also benefit from ammonium fluoride etchants that yield more homogeneous Al deposition for Josephson junction devices [4]. Ammonium fluoride etchants additionally have the advantage of minimizing the formation of Nb hydrides that have been implicated in reducing the quality factor in superconducting radio frequency Nb cavities [5]. In addition to extensive surface and interface characterization (e.g., scanning probe microscopy, electron microscopy, X-ray photoelectron spectroscopy, and secondary ion mass spectrometry), superconducting quantum device measurements will be presented in an effort to quantify the technological benefits of surface and interface engineering for quantum computing applications.

- [1] M. Bal, *et al.*, *npj Quantum Information*, **10**, 43 (2024).
- [2] G. Berti, *et al.*, *Applied Physics Letters*, **122**, 192605 (2023).
- [3] X. Lu, *et al.*, *Physical Review Materials*, **6**, 064402 (2022).
- [4] C. J. Kopas, *et al.*, *Materials for Quantum Technology*, **4**, 045101 (2024).
- [5] C. G. Torres-Castanedo, *et al.*, *Advanced Functional Materials*, **34**, 2401365 (2024).

