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Oxygen vacancies in niobium pentoxide as a source of two-level system losses in superconducting niobium

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Two-level systems (TLS) have long been a catch-all explanation for RF loss and quantum decoherence in superconducting devices. In our study, the first to directly link TLS losses to a specific physical mechanism, we demonstrate that oxygen vacancies in the naturally formed Nb_2O_5 on oxidized niobium are a major driver of such dissipation. We performed sequential in situ vacuum-baking treatments on niobium superconducting radio-frequency (SRF) cavities and used time-of-flight secondary ion mass spectrometry (TOF-SIMS) to reveal a nonmonotonic evolution in cavity quality factor (Q_0). This behavior correlates with the interplay of Nb_2O_5 vacancy generation and oxide-thickness dissolution. We localize this effect to the oxide itself and present the insignificant role of diffused interstitial oxygen in the underlying Nb by regrowing the oxide via wet oxidation, revealing a mitigation of aggravated TLS losses. We hypothesize that such vacancies in the pentoxide serve as magnetic impurities and are a source of TLS-driven rf loss. Although our measurements center on 3-D SRF cavities, the insights gained here have significant implications for mitigating decoherence in 2-D superconducting qubits.

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Yes

Footnotes

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Author: BAFIA, Daniel (Fermi National Accelerator Laboratory)

Co-authors: MURTHY, Akshay (Fermi National Accelerator Laboratory); ROMANENKO, Alexander (Fermi National Accelerator Laboratory); GRASSELLINO, Anna (Fermi National Accelerator Laboratory)

Presenter: BAFIA, Daniel (Fermi National Accelerator Laboratory)

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