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Crystallinity in niobium oxides: a pathway for mitigation of two-level system defects in niobium 3D resonator for quantum applications

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Materials imperfections in Nb-based superconducting quantum circuits—in particular, two-level-system (TLS) defects—are a major source of decoherence, ultimately limiting the performance of quantum computation and sensing. Thus, identifying and understanding the microscopic origin of possible TLS defects in these devices will help developing strategies to eliminate them and is key to superconducting qubit performance improvement. We will report in this presentation, an order of magnitude reduction in two-level system losses in three-dimensional superconducting radio frequency (SRF) niobium resonators by a 10 hour high vacuum (HV) heat treatment at 650 ℃, even after exposure to air and high pressure rinsing (HPR). X-ray photoelectron spectroscopy (XPS) and high-resolution scanning transmission electron microscopy (STEM) reveal an alteration of the native oxide composition re-grown after air exposure and HPR and the creation of nano-scale crystalline oxide regions, which correlates with the measured tenfold quality factor enhancement at low fields of the 1.3 GHz niobium resonator. Tunneling spectroscopy measurements show a pronounced proximity effect that further confirms the presence of metallic layers on the niobium surface.

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Footnotes

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