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Abstract

Subgap Quasiparticle Transport and Low Frequency Critical Current Fluctuations in $Nb/AlO_x/Nb$ Josephson Junctions

By

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An ideal qubit for quantum computation is one that follows the DiVincenzo criteria. Superconducting rf-SQUIDs meet part of the ideal qubit criteria in their ability for control and measurement, and scalability. But, it is the mechanisms that cause decoherence in the rf-SQUID qubit that are of greater importance for their utilization as a qubit in quantum computation applications. The decoherence time of coherent quantum states in a superconducting rf-SQUID qubit has inherent limitations related to the quality of the Josephson junction(s) in the qubit. Critical current fluctuations and the low-voltage subgap resistance of the junction(s) impose these limits through the Josephson energy and damping of the qubit. These limits suggest that with a decay time from the excited qubit state of $\tau_{1/e} \sim 2$ μs at the operating temperature of the qubit having a Josephson junction with area of 4.5 μm^2, critical current of 2.25 μA and a level spacing $\delta \sim 10^9\ s^{-1}$ between the coherent states, the normalized critical current fluctuations should be $S_{IcN}(1\ Hz) \sim 10^{-22}\ (A^2/Hz)(\mu m/\mu A)^2$ or less and the subgap resistance should be $10^9\ \Omega$ or greater. The quasiparticle tunneling current (subgap leakage) and the low frequency critical current fluctuations in Josephson junctions fabricated at Stony Brook have been studied. The devices are fabricated from a $Nb/AlO_x/Nb$ trilayer using a lift-off process and employ optical and electron beam lithography. Subgap leakage measurements were performed down to 360 mK, and a subgap resistance greater than $10^9\ \Omega$ is demonstrated. Low frequency current noise measurements of externally shunted junctions and unshunted junctions were acquired via a bridge circuit with a SQUID null current detector. Excess 1/f noise at low frequency was observed to decrease linearly from 4.2 K down to 410 mK, and the normalized critical current fluctuations measured at 1 Hz was 2.2 10^{-24} $(A^2/Hz)(\mu m/\mu A)^2$ at 4.2 K.

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