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Niobium-nitride-based superconducting qubit

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Abstract

We present an investigation focused on advancing superconducting qubits by using niobium-nitride (NbN)-based qubit. In conventional superconducting qubits utilizing aluminum-based Josephson junctions (JJs), the decoherence from microscopic two-level systems in amorphous aluminum oxide is concerned. As alternative materials for the JJs of the qubits, we introduce fully epitaxial nitride JJs consisting of NbN/AlN/NbN tri-layer. The all-nitride qubits offer several advantages, such as the potential for epitaxial tunnel barriers, resulting in reduced two-level fluctuators, and a larger superconducting gap of approximately 5.2 meV for NbN, compared to ~0.3 meV for aluminum, which suppresses the excitation of quasiparticles.

To investigate qubit properties, we have fabricated a capacitively-shunted flux qubit coupled to a half-wavelength coplanar waveguide resonator. By employing a Si substrate with TiN buffer layer instead of the conventional MgO substrate for the epitaxial growth of the NbN film, our nitride qubit has demonstrated a significant improvement in coherence times, such as T1 = 16.3 μs and T2 = 21.5 μs [1], which are more than an order of magnitude longer than those reported in the literature using MgO substrates [2]. These results represent a significant step towards constructing a new platform for superconducting quantum hardware.

[1] S. Kim et al., Communications Materials 2, 98 (2021).

[2] Y. Nakamura et al., Appl. Phys. Lett. 99, 212502 (2011).