Fabrication and Characterization of Overlap Josephson Junctions and CPW Resonators for the Development of Superconducting Quantum Network

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Abstract: We develop a fully complementary metal-oxide semiconductor (CMOS) fabrication technique for realization of a superconducting qubit network (SQN).

Up to now, the Al double-angle evaporation and lift-off technique is widely used for the fabrication of a superconducting qubit with long coherence time, suitable for the realization of quantum simulations and quantum processors with an intermediate scale number of qubits [1]. Several drawbacks of double-angle technology, such as qubit excitation-energy inhomogeneity and low reproducibility on large-diameter wafers, make it unsuitable for realizing a large-scale practical computer, necessitating the development of an alternative technology [2]. We develop a fully complementary metal-oxide-semiconductor (CMOS)-based fabrication technique [3] to realize a superconducting qubit network (SQN). In our current research, we develop a planar single-angle overlap fabrication process [4] for Al/AlOx/Al Josephson junctions on a Si (100) substrate. To increase the fabrication yield, we proposed a combined approach that included both gentle wet etching to define the base electrode (BE) and radio frequency (RF) Ar cleaning of the BE before oxidation at low pressure for a long time. We comparatively investigated the lift-off process and the wet etching technique for BE patterning. The wet etching process forms the BE edges without residual photoresist, thereby improving fabrication yield. Long-term RF Ar plasma cleaning of the BE improves its smoothness, enabling the formation of a thinner AlOx tunnel barrier and increasing the Josephson critical current density.

Superconducting microwave Coplanar waveguide (CPW) resonators are essential components of modern qubits (Transmon) in the framework of circuit quantum electrodynamics (cQED) [5]. A high-quality-factor, low-microwave-loss CPW resonator is demanded for the readout and manipulation of superconducting qubits during dispersive measurements [6]. As for the material research on CPW resonators to maximize their internal Q_i quality factor, CPW resonators with different geometries are designed for resonant frequencies ranging from 4 GHz to 12 GHz in 0.5 GHz steps. Sapphire and Si as substrates and tantalum, niobium, and aluminum as superconducting materials have been investigated for CPW resonators. Preliminary results for Tantalum CPW resonators on C-plane sapphire with niobium buffer layer were fabricated and tested in terms of measurements of scattering parameters $|S_{21}|$ as a function of frequency. From the experimental data, we extract an internal quality factor Q_i of 10^6 using the fitting procedure.

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