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Optimization of Titanium Nitride as a Material for Superconducting Josephson Junctions in Quantum Computing Applications

The scalability of superconducting quantum computers remains fundamentally constrained by decoherence mechanisms in Josephson junction-based qubits, with two-level system (TLS) defects at material interfaces representing a primary source of energy dissipation. While aluminum has served as the conventional electrode material for superconducting qubits, its limitations in coherence times and susceptibility to surface oxidation have motivated the exploration of alternative superconductors. Titanium nitride (TiN) has emerged as a compelling candidate material, demonstrating superior resistance to oxidation, tunable kinetic inductance, and reduced TLS densities at critical interfaces. However, despite extensive application in superconducting resonators and capacitive elements, the systematic optimization of TiN-based Josephson junctions remains largely unexplored, representing a critical gap in quantum hardware development.
This research investigates the comprehensive optimization of titanium nitride as an electrode material for superconducting Josephson junctions, addressing fundamental material science challenges that have impeded its widespread adoption. The study focuses on three interconnected objectives; establishing reproducible fabrication protocols for TiN thin films with controlled stoichiometry, crystallinity, and superconducting properties through systematic variation of deposition parameters; engineering and characterizing barrier materials compatible with TiN electrodes to achieve tunnel junctions with high critical current uniformity and low loss tangents; and correlating material properties with quantum coherence metrics.

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