

Progress Towards Superconductor Electronics Fabrication Process with Planarized NbN Layers

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Abstract — In order to increase density of superconductor digital and neuromorphic circuits and reach integration scale of 10^8 Josephson junctions (JJs) per chip, we developed a new fabrication process on 200-mm wafers, using self-shunted Nb/Al-AIO_x/Nb JJs and kinetic inductors for cell miniaturization. The process has one layer of JJs, one layer of resistors, and ten fully planarized superconducting layers: 8 niobium layers and two layers of high kinetic inductance materials, Mo₂N and NbN, with sheet inductance of 8 pH/sq and 3 pH/sq, respectively. The minimum linewidth of NbN kinetic inductors is 250 nm. NbN films were deposited by two methods: with $T_c \approx 16$ K by reactive sputtering of a Nb target in Ar+N₂ mixture; with T_c in the range from 10 K to 13 K by plasma-enhanced chemical vapor deposition (PECVD) using Tris(diethylamido)(tert-butylimido)niobium(V) metalorganic precursor. PECVD of NbN was investigated to obtain conformal deposition and filling narrow trenches and vias with high depth-to-width ratios, $h/w > 1$, which was not possible to achieve using sputtering and other physical vapor deposition (PVD) methods at temperatures below 200 °C required to prevent degradation of Nb/Al-AIO_x/Nb junctions. Nb layers with 200 nm thickness are used in the process layer stack as ground planes to maintain a high level of interlayer shielding and low intralayer mutual coupling, for passive transmission lines with wave impedances matching impedances of JJs, typically $\leq 50 \Omega$, and for low-value inductors. NbN and NbN/Nb bilayer are used for cell inductors. Using NbN/Nb bilayers and individual patterning of both layers to form inductors allowed us to minimize parasitic kinetic inductance associated with interlayer vias and connections to JJs as well as to increase critical currents of the vias. Fabrication details and results of electrical characterization of NbN films and vias, and comparison with Nb properties are given.

Keywords (Index Terms) — AQFP, Josephson junctions, kinetic inductors, NbN films, niobium nitride, SFQ circuits, superconducting integrated circuit, superconducting integrated circuit fabrication, superconducting thin films, RSFQ