

Ultra-Small NbN Junction Technology For Superconducting Qubit Application

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Experiment and results

Despite the early progress in epitaxial NbN junctions on Si substrate, the main challenges remain on developing a reliable fabrication process in high-quality ultra-small size epitaxial junctions for various superconducting quantum circuits, particularly, large scale superconducting qubit arrays. So far, NbN junction fabrication in our lab is using traditional photolithography with a guaranteed 1 μm^2 junction size. However, the yield of junction fabrication drops significantly for junction size below 1 μm^2 . To solve this task, we introduced electron beam lithography and a thin Al layer acting as an etching mask for junction RIE and planarization by chemical mechanical polishing (CMP) to form a reliable electrical contact between the junction counter electrodes and the wiring layer. By using the new fabrication process, all junctions showed excellent tunneling properties with a junction size as small as 0.27 $\mu\text{m}\phi$. The gap voltage 2Δ well exceeds 5.5 mV, and quality factors R_{sg}/R_n are above 50, where R_{sg} and R_n are junction’s sub-gap resistance and normal state resistance, respectively. It also showed that there is no change to the junction properties after removing the SiO_2 dielectric layer

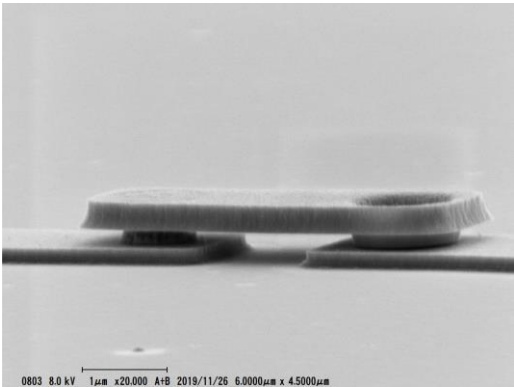


Fig. 1. SEM image of an epitaxial NbN/AlN/NbN tunnel junction with the SiO_2 dielectric layer being removed by BHF after the junction fabrication.

between NbN electrodes after the junction fabrication. The newly developed junction fabrication process allows us to meet the target of reliable, high-quality, full epitaxial, ultra-small NbN junction fabrication for large scale superconducting qubit circuit applications. More details will be discussed in this presentation.

Acknowledgments The authors would like to thank ERATO (JPMJER1601) and CREST (JPMJCR1775) under the Japan Science and Technology Agency for supporting this work.

TABLE I NbN junction properties at 4.2K

Diameter (μm)	$R_n A$ ($\times 10^{-6} \Omega \text{cm}^2$)	I_c (μA)	J_c (A/cm^2)	R_{sg} ($\text{M}\Omega$)	R_{sg}/R_n
1	88.56	0.369	48.8	0.69	59
0.8	78.62	0.194	54.9	1.88	84
0.7	75.27	0.146	57.4	1.67	57
0.6	78.59	0.095	55.0	6.00	132