Atomic Layer Deposition Niobium Nitride Films for High-Q Resonators

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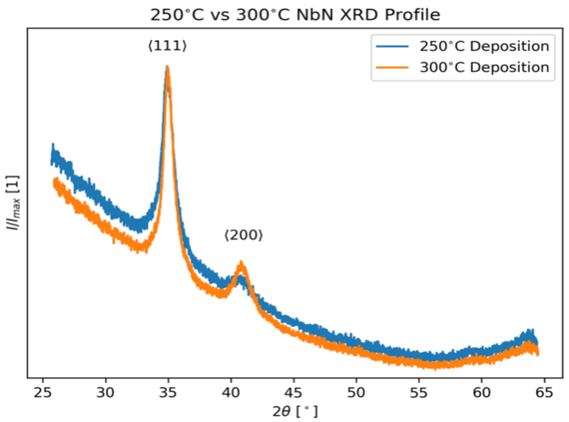
Atomic Layer Deposition

One Plasma-Enhanced Atomic Layer Deposition cycle consists of treating the substrate with the precursor, TBTDEN, removing the precursor from the chamber, lighting the plasma with P = 300W, waiting, turning off the Argon plasma, and removing the excess Ar from the chamber. Furthermore, since Nb has a low vapor pressure, we use three Ar boost cycles to improve chamber precursor concentration. One ALD cycle creates approximately one atomic monolayer of metal, and we repeat this process for a given cycle count to achieve the desired thickness.

Crystallographic Structure

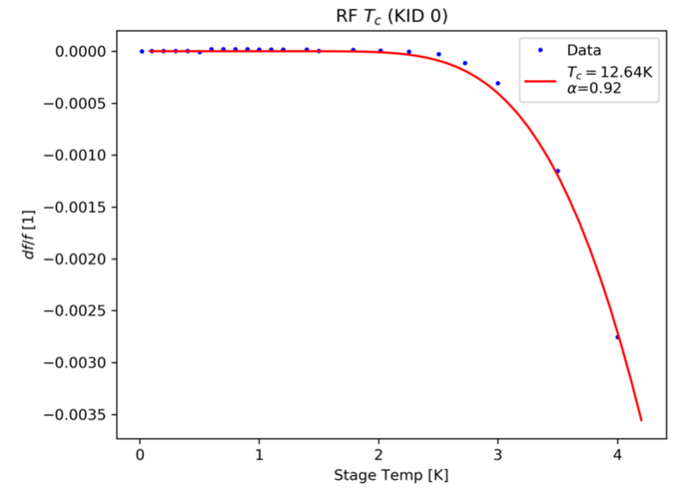


Fabrication

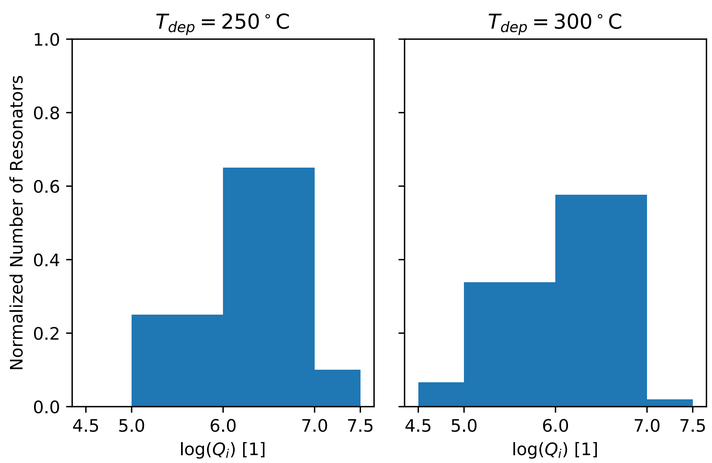
Process Step	Machine	Notes
Deposition	Ultratech Fiji Plasma Enhanced Atomic Layer Deposition	Temperature: 250-300 C 100 cycles≈6 nm
Lithography	Heidelberg MLA150 Maskless Aligner	Defoc: 0 Dose:125 mJ/cm^2 375nm laser
Etch	PlasmaTherm Inductively Coupled Plasma Chlorine Etcher	Etch time: 5-10 min CF_4 Flow: 40 sccm CHF_3 Flow: 10 sccm Ar Flow: 10 sccm

RF Characterization

To measure the microwave properties of the ALD NbN films, we construct single-layer microwave resonators and test them to obtain the RF critical temperature $T_C^{(RF)}$ and quality factor Q. This is done with a simple fabrication process described on the bottom left.

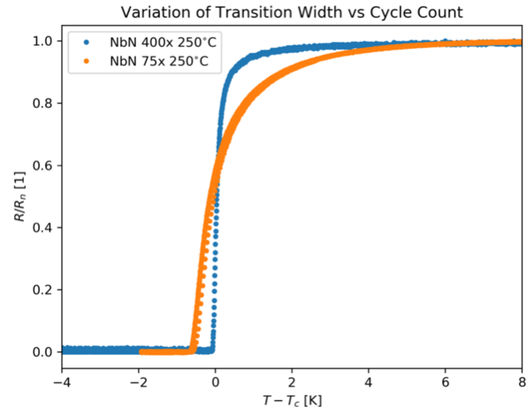


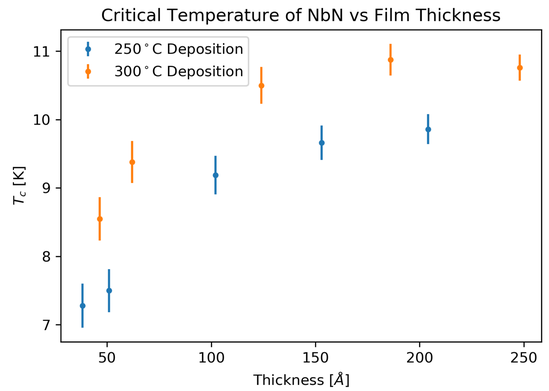
To find $T_C^{(RF)}$, we measure the frequency shift as a function of stage temperature, and fit to Mattis-Bardeen curves and extrapolate Tc. A sample resonator fit is shown above.



We find all Q values above 10^4, with most above 10^5 and many above 10^6. The quality factor performance is maintained as the deposition temperature changes.

DC T_c and Thickness





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