Foundry-compatible fabrication processes for superconducting circuits

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Abstract

The implementation of algorithms that can provide an exponential speed-up over their classical counterparts in a fault tolerant superconducting quantum computer will require on the order of a million of physical qubits [1]. This will likely necessitate the use of industrial fabrication facilities that can provide the required circuit parameter control over large qubit counts. Currently, state of the art superconducting circuits uses fabrication processes such as shadow evaporation and lift-off techniques [2] that are incompatible with large-scale foundry capabilities. In this work, we therefore explore and develop novel approaches to manufacture high coherence superconducting circuits using foundry compatible fabrication processes and materials. We fabricated aluminium superconducting qubits with high coherence and relaxation times (up to 100 μs) and 99.94 % single qubit fidelity without the use of shadow evaporation or lift-off techniques [3]. For materials screening purposes and to characterize associated loss mechanisms, we developed a superconducting resonator platform for rapid testing and show high quality factor superconducting resonators using a variety of foundry-deposited materials such as niobium, tantalum, aluminium, niobium titanium nitride, niobium nitride and titanium nitride [4].

References

[1] Austin G. Fowler, Matteo Mariantoni, John M. Martinis, and Andrew N. Cleland Phys. Rev. A 86 (2012) 032324
[2] F. Arute, K. Arya, R. Babbush et al. Nature 574, (2019) 505–510.
[3] J. Verjauw, R. Acharya, J. Van Damme et al., arXiv:2202.10303 (2020).
[4] J. Verjauw, A. Potočnik, M. Mongillo et al. Phys. Rev. Applied 16 (2021) 014018.

Figures

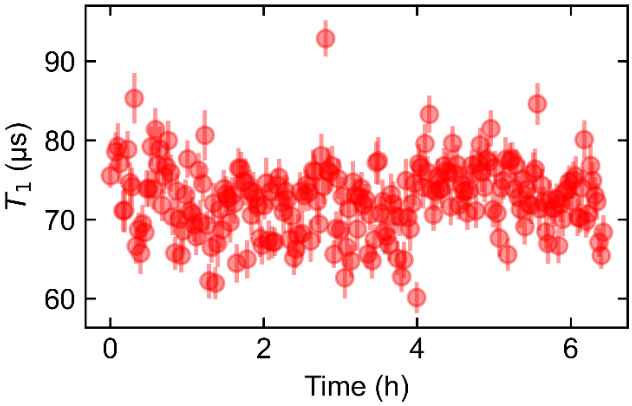

Figure 1: Qubit relaxation time measured over 6.5 hours. The highest T_1 corresponds to = 104 ± 5 μs

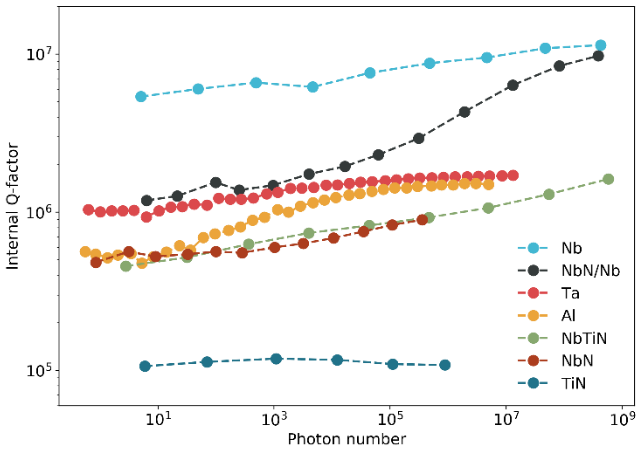

Figure 2: Resonator internal quality factor for a variety of materials as a function of photon number.