Wafer-scale Fabrication of High Quality Josephson Tunnel Junction Phase Qubits.

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It is well-known that the choice of materials and processes is essential for achieving long decoherence times in superconducting qubits and that one of the main loss mechanism comes from surrounding dielectrics[1]. We have investigated a way how to reduce this loss by utilizing a wafer-scale fabrication technology[2] to fabricate $Al/Al_2O_3/Al$ Josephson tunnel junction circuitry, *i.e.* phase qubits with SQUID read-out. The tunnel junctions are defined by a plasma-etched via through a dielectric layer covering the bottom Al electrode. The ex situ tunnel barrier is formed by oxidation of the bottom electrode in the junction area. As the dielectric layer, Si_3N_4 has been used and in addition to the tunnel junction stack, an Al layer for low-ohmic interlayer connections was added. As a final step we used the top Al layers as a hard mask for removing residual Si_3N_4 by plasma etching, and hence reducing the amount of dielectric surrounding the qubit. From decay time measurements of the phase qubits, we can show a four times increase of the relaxation time, T_1, after the dielectric removal, and measure a $T_1 = 130$ ns.

[1]A. D. O'Connell et al., Appl. Phys. Lett. **92**, 112903, 2008.
[2]Mika Prunnila, Matthias Meschke, David Gunnarsson, et al. J. Vac. Sci. Technol. **28**, 1026-1029, 2010.