Bridging the Gap for High-Coherence Superconducting Qubits

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Superconducting qubits are lithographically-defined electronic circuits containing Josephson tunnel junctions that behave as “artificial atoms” when cooled to milliKelvin temperatures. The superconducting qubit coherence time – which is a key metric to characterize their quantum mechanical performance – has improved significantly in the last 15 years. These improvements have been driven by advances in the materials, fabrication, and design of superconducting qubits.[1]

Here I will describe our work to fabricate high-coherence superconducting qubits. I will discuss a process for fabricating superconducting air bridge crossovers (as shown in Figure 1), a feature that improves qubit performance by (1) bridging gaps in the ground plane to reduce spurious electromagnetic modes and crosstalk and (2) increasing coupling strength between connected qubits by enabling large mutual inductances. The air-bridge fabrication process is fully compatible with the qubit fabrication process, and it includes mixed patterning using both photolithography and electron beam lithography. The process has led to working superconducting qubit circuits with superior performance.[2] In addition, we are working towards further scaling of our superconducting circuits using 3D integration with indium bump bonding between chips (see Figure 2).

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[1] Oliver and Welander, MRS Bulletin **38** (10), 816 (2013).
[2] Weber *et al.,* arXiv:1701.06544.

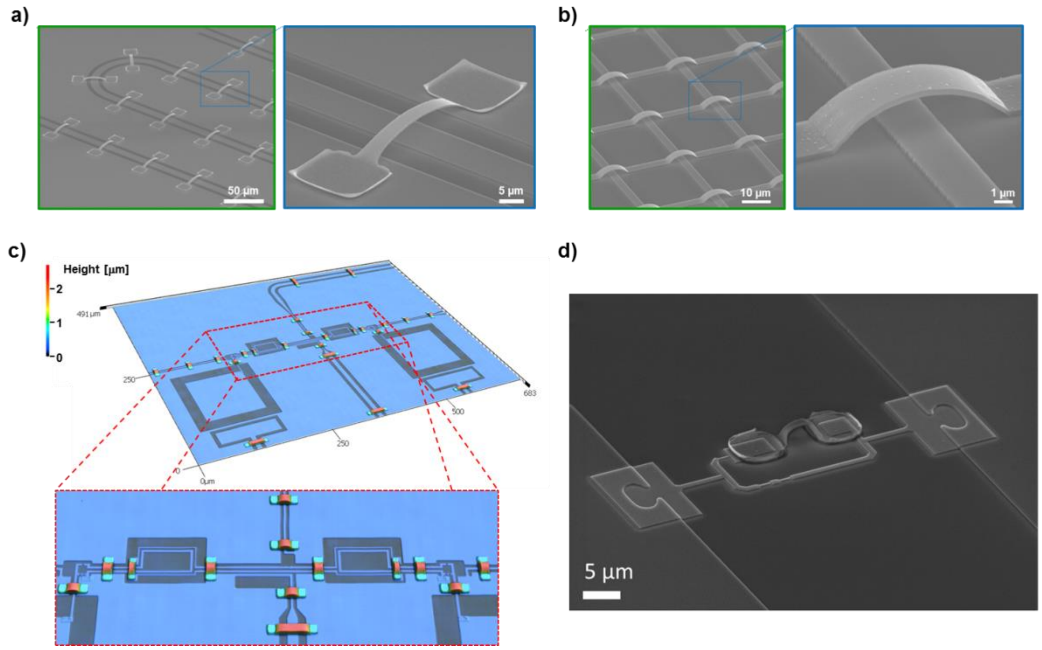

Figure 1: Superconducting air-bridge crossovers demonstrations. (a) SEM images of air-bridge crossovers connecting the ground plane of a coplanar waveguide resonator. (b) SEM images of a crossovers test structure with a low-resistance electrical path through 100 crossovers in series. (c) Confocal image of a fabricated coupled-qubit circuit with crossovers within the coupler qubit loop. (d) SEM image of a high-coherence qubit with an integrated air bridge.

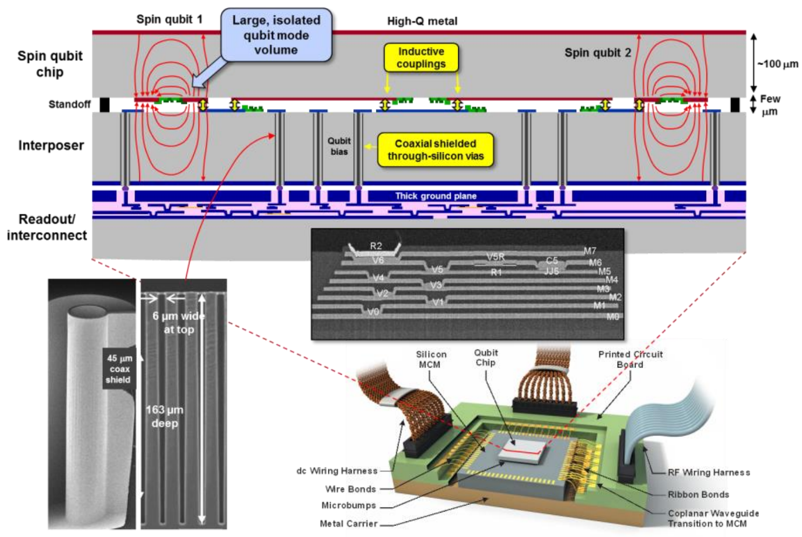

Figure 2: Cross-sectional views of the MIT-LL 3D integration approach. The spin qubit chip is fabricated separately from the readout / interconnect multi-chip module (MCM) to enable independent process optimization of each layer. The two layers are connected through an interposer layer with bump bonds for electrical connectivity. Control lines are routed to MCM edges for wire-bonding.