MBE-Grown Germanium Quantum Well Planar Josephson Junction

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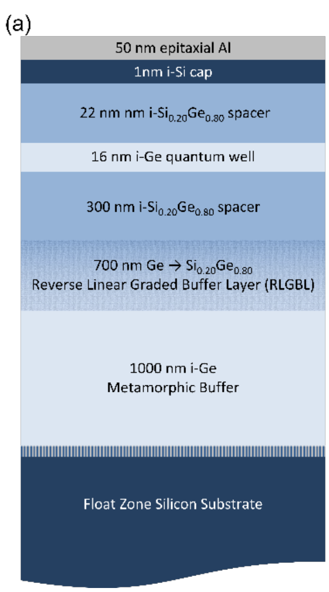
At the heart of a transmon qubit is the Josephson junction (JJ) which is engineered to create the anharmonic energy spacing needed to individually populate the two lowest energy levels in the system. Transmon qubits can incorporate two such JJs in a SQUID arrangement to achieve flux tunning of the qubit but require on-chip, current carrying flux lines. This presentation will discuss the characterization of undoped germanium quantum wells (Ge-QW) in a SiGe heterostructure and the fabrication of planar JJs for future integration into voltage tunable transmon qubits.

Strained Ge-QWs host heavy holes with high mobility and low effective mass. When combined with highly transparent superconducting contacts, they create a promising platform for combining voltage-controlled semiconductor materials with high fidelity superconductor qubit circuitry. The Ge-QW with SiGe spacer material is grown using Molecular Beam Epitaxy (MBE) and has a carrier mobility greater than 60,000 cm^2/Vs with a hole density less than $1x10^{12}$ cm^{-2}. Using a series of lithography and etching techniques, 100-nm to 500-nm long JJs are formed on a 2.5 µm tall SiGe mesa that is necessary to isolate the lossy SiGe from the rest of the superconducting circuit. Device design, fabrication challenges, and preliminary junction performance will be shown.



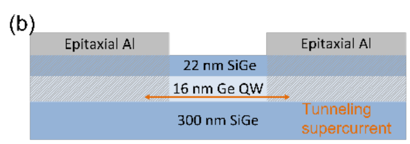


Figure 1. Cross-section of the MBE grown heterostructure (a) with two metamorphic layers, the first between the Ge buffer and Si substrate, and the second between the SiGe spacer and Ge buffer. Cross-section of the lateral Josephson junction device (b) with a tunnel gap of a few hundred-nanometers defined by e-beam lithography and anisotropic etching of the post-growth deposited aluminum.

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Supplemental Material to MBE-Grown Germanium Quantum Well Planar Josephson Junction

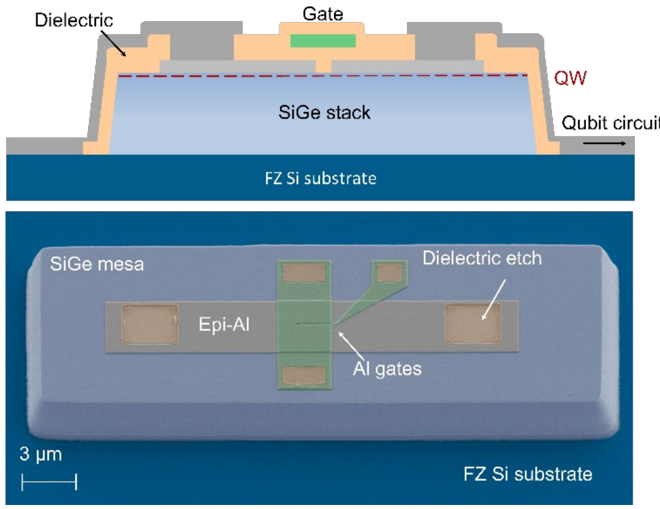

Figure S1. Cross section and false color oblique SEM image of a mesa toped nanowire Josephson junction prior to electrode deposition.

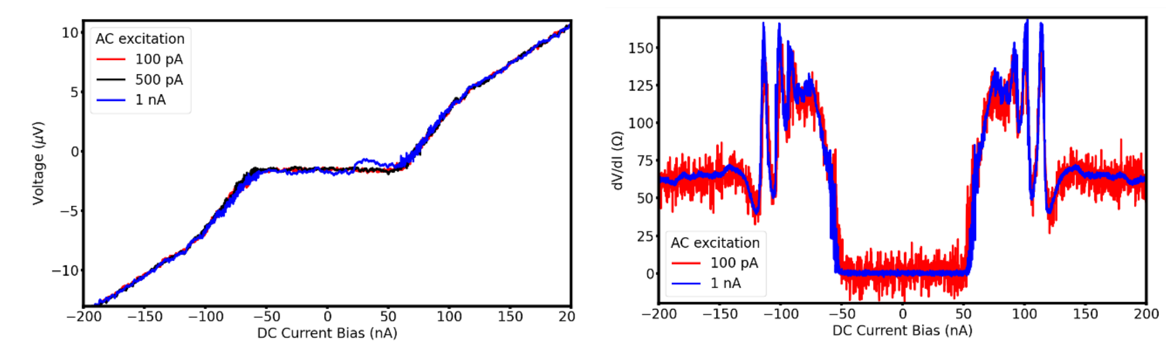

Figure S2. Current-voltage measurement (a) and differentia resistance, dV/dI, (b) of a lateral germanium quantum well Josephson junction with various values of applied excitation showing a Josephson junction critical current of 60 nA.

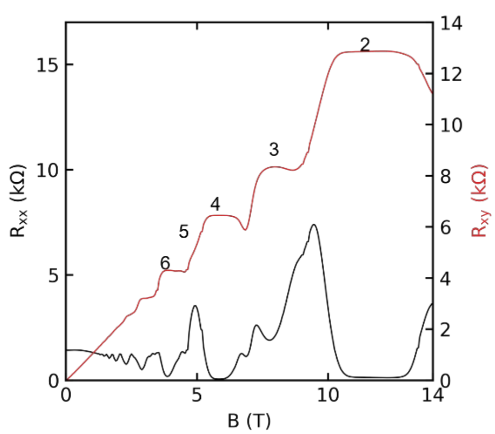

Figure S3. Ungated quantum Hall oscillations of the germanium quantum well material:
density = 6.13×10^{11} cm^{-2}, mobility = 69,800 cm^2/Vs.