A high-throughput, single-step lithography process is discussed for fabricating on-chip capacitors using Manhattan-style double angle deposition utilizing *in-situ* plasma oxidation. Our AlOx thin film is incorporated as a dielectric between two aluminum electrodes to produce capacitors in superconducting LC circuits with intent to characterize microwave losses at single photon levels, a regime relevant for operation of superconducting qubits. The target capacitances require a trench width at 1 – 2 μm, which then need a 5-μm-thick resist stack for Manhattan style lithography. However, the thick resist structure results in artifacts for small capacitors with effective area variations between 4 – 16 μm^2. In order to preserve the controlled geometry for capacitors, while minimizing undesired shadowing effects, we have developed a specially designed pattern and compatible fabrication.

Our AlOx thin film fabrication process combines Manhattan-style double angle deposition with *in-situ* plasma oxidation to synthesize high stability AlOx dielectrics. Our *in-situ* plasma oxidation technique has previously demonstrated excellent stability in single-electron charge sensors. The specific resistance of our AlOx thin films tunes across more than 8 orders of magnitude (from 10^2 to 10^{10} Ohm·μm^2). This is achieved by varying the oxidation time to include very high specific resistance values. For the long-oxidation-time samples, we measure a specific capacitance of approximately 22 fF/μm^2, which remains stable for oxidation times exceeding 300 s. These efforts aim to produce lumped-element, low-loss parallel plate capacitors for use in superconducting qubits while maintaining the geometric flexibility needed to meet target capacitance values.

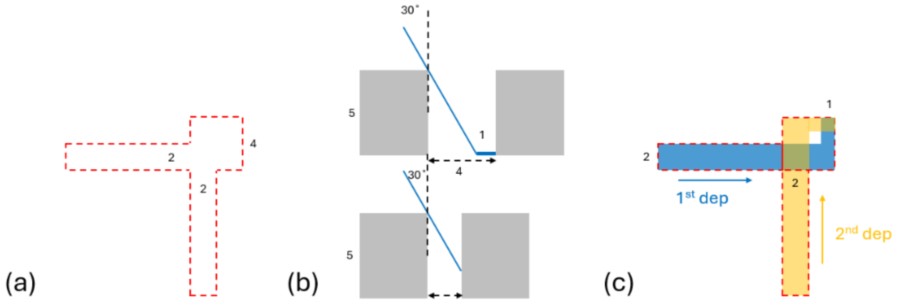

Figure 1 (a) Example resist pattern for capacitor fabrication. (b) Cross-sectional view that emerges from the double angle deposition. (c) Resulting deposited pattern from (a) which has a void in the center.

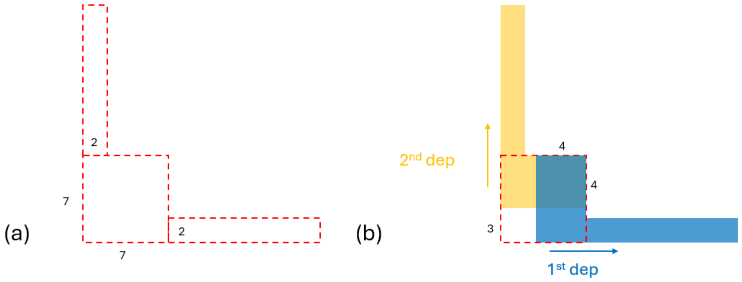

Figure 2 (a) Adjusted resist pattern that forms a contiguous (square) overlap for the capacitors. (b) equivalent deposited pattern from the designed mask with an effective overlap area at 16 μm^2.

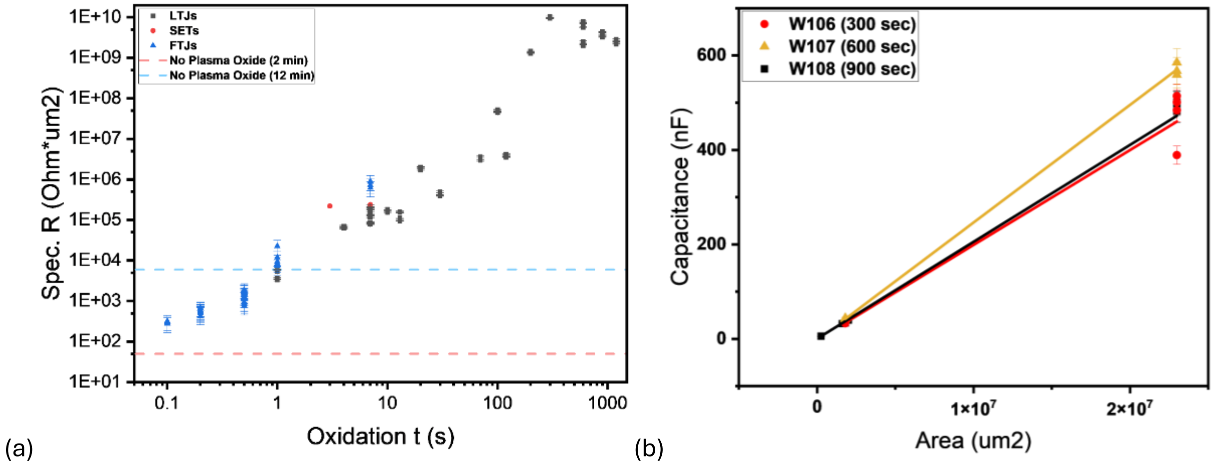

Figure 3 (a) Specific resistance due to varying plasma oxidation time for *in-situ* plasma-oxidized AlOx tunnel barriers at room temperature. (b) Measured capacitances as a function of area in the longer time regime of oxidation. The slope is the specific capacitance at 22 fF/μm^2.