Fabrication of High Inductance Nano Coils with a Neon Focused Ion Beam

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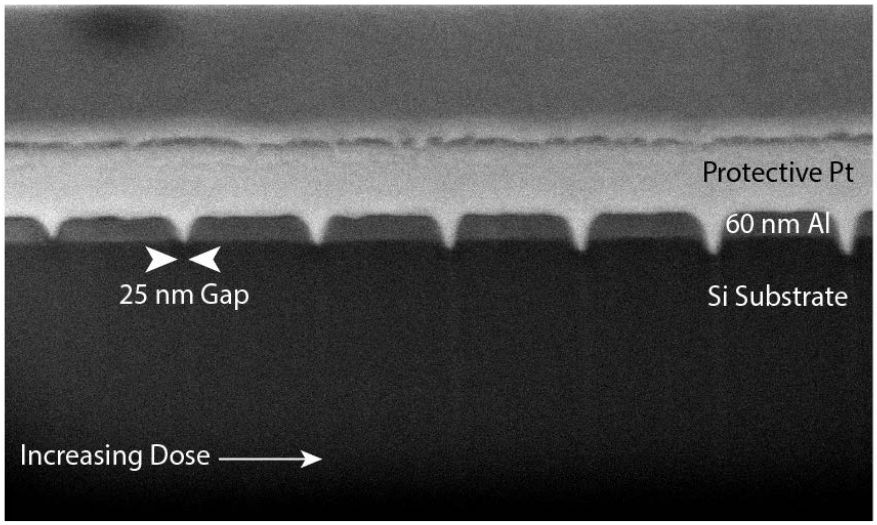
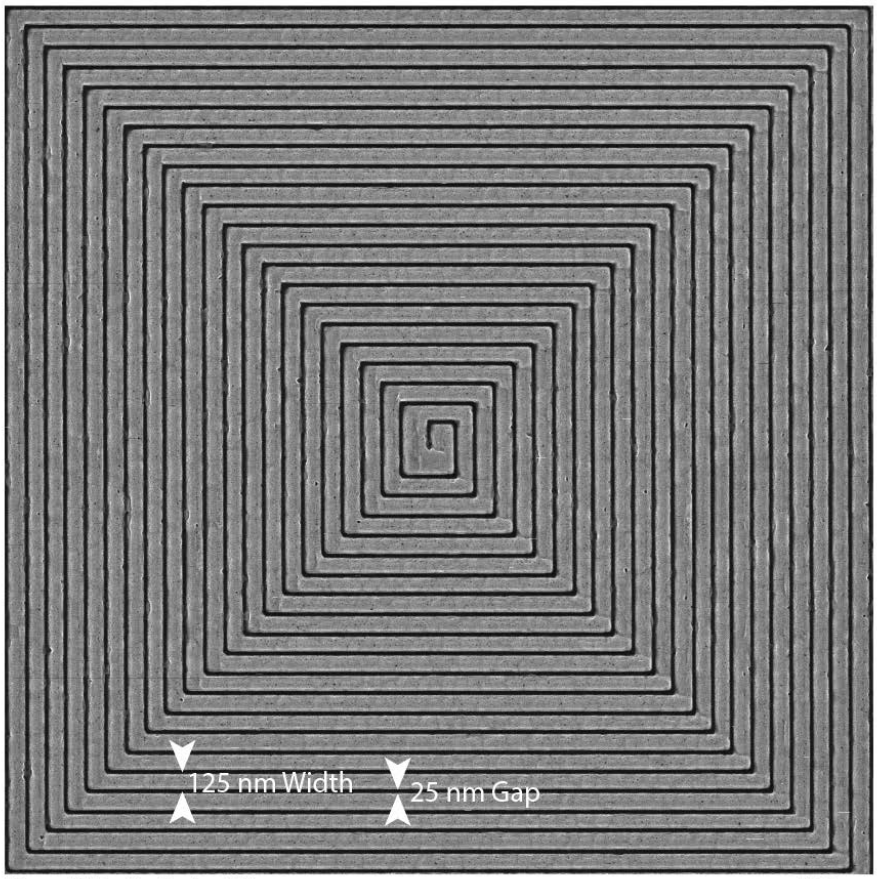
In the field of quantum information processing, interconversion between disparate photon wavelengths is an important part of connecting distant systems operating at different frequencies; electro-opto-mechanical quantum superconducting LC (inductor-capacitor) circuits provide one means of interconversion from microwave to optical frequencies. The aim of this study was to improve the inductor by fabricating a more tightly wound wire coil with a smaller pitch, increasing inductance according to the modified Wheeler formula. The previous benchmark, a 3 mm long aluminum coil with a 500 nm pitch, was achieved on a silicon substrate using electron beam lithography, metal evaporation, and liftoff. Improvements were sought here using two different neon focused ion beam techniques to etch a spiral pattern into a 60 nm aluminum pad, resulting in a coil: (1) direct ion beam etch and (2) hard mask ion lithography on an atomic layer deposition (ALD) film followed by reactive ion etch. Both techniques are capable of achieving a 150 nm pitch (e.g. 125 nm wire width, 25 nm gap), better than a threefold improvement over the previous benchmark. The merits and drawbacks of the two methods are discussed. Hard mask neon ion lithography on ALD films shows particular promise for etching relatively large areas of nanostructures with minimal ion beam damage to the underlying material.

[See two graphics on next page]



Cross-Section of Neon Dose Array — 200 nm

Scanning electron microscope image of cross-sectioned neon ion beam dose array, used to determine the requisite dose for fully etching through the 60 nm aluminum layer, leaving isolated wires in between; this method yields as small as a 25 nm gap between wires.



Neon-Milled Inductor Wire — 500 nm

The center of a 500 μm long wire created by directly etching a spiral pattern into aluminum with a neon focused ion beam; a 125 nm wire width and 25 nm gap comprise the 150 nm pitch.