# Fabricating Superconducting Quantum Interference Device Nanostructures for Single Spin Detection


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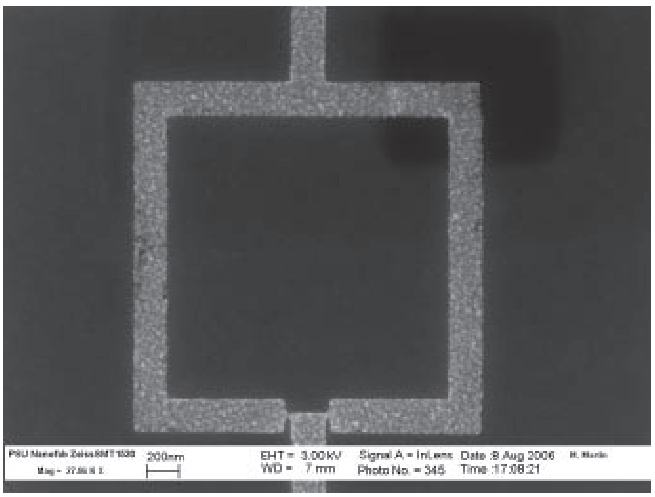


*Figure 1: FESEM image of a SQUID ring.*


## Abstract:

The overall goal of this project was to fabricate extremely sensitive microbridge superconducting quantum interference devices (SQUIDs) [1] using two high resolution electron beam resists stacked in a bi-layer. The geometry of the microbridge SQUID is needed because this particular type of SQUID will be used to detect the spin of single molecule magnets. In order for the SQUID to be more sensitive than current microbridge SQUIDs, the specific goal and main focus was to create lines 20 nm in width in the junction of the SQUID rings (see Figure 1). The SQUID rings were created using the Leica EBPG-5HR electron beam lithography tool.

In the making of the SQUID devices two types of metal were used; niobium and aluminum. Niobium was deposited through sputtering, and aluminum through thermal evaporation. Images of the SQUID rings were then taken using a field emission scanning electron microscope (FESEM). Finally, the SQUID samples were sent to the University of California, Berkeley, for characterization.


## Experimental Procedure:

The project began with a 3″ bare silicon wafer that was cleaned with de-ionized water, acetone and isopropyl alcohol to remove any undesired residues. The wafer was then prepared by spinning and baking two high resolution electron beam resists in a bi-layer configuration. The wafer was then exposed to the electron beam lithography tool (e-beam) to make a dose array. From the dose array, the proper dose needed for the 20 nm lines in the SQUID rings would be determined. After exposure to the e-beam, the wafer was developed. Different developing schemes were used to determine the correct developing times in the three different chemicals used in the developing process. The wafer was developed in n-amyl acetate, methyl-isobutyl ketone:isopropyl alcohol (8:1), and de-ionized water. Metal was then deposited onto the wafer and a lift-off process took place. The final step was imaging the SQUID rings with FESEM. From the images obtained, the proper dose and developing scheme were determined.

Another 3″ bare silicon wafer was cleaned, prepared, and processed with the determined dose from the e-beam and developing times. For the metal deposition step in the procedure, the wafer was cleaved in half to create two samples of SQUID rings. Niobium was sputtered onto one half and aluminum was thermally evaporated onto the other. For each sample, the thickness of the metal deposited was 10 nm. During the lift-off procedure, ultrasonic agitation was used to promote the lifting-off of the metal. The two samples were then imaged with field emission scanning microscopy and sent to the University of California, Berkeley, for characterization.

## Results and Conclusions:

From the dose array, an exposure of 180 $\mu C/cm^2$ was found to be sufficient for the formation of the 20 nm lines in the junction of the SQUID ring. The determined

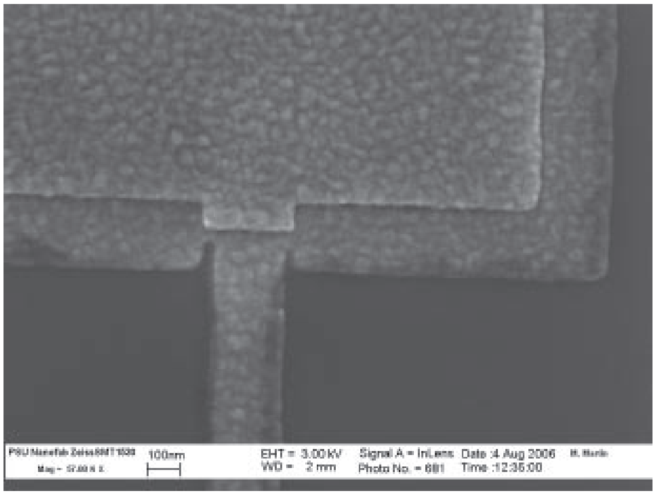


*Figure 2: FESEM image of niobium SQUID with poor lift-off.*

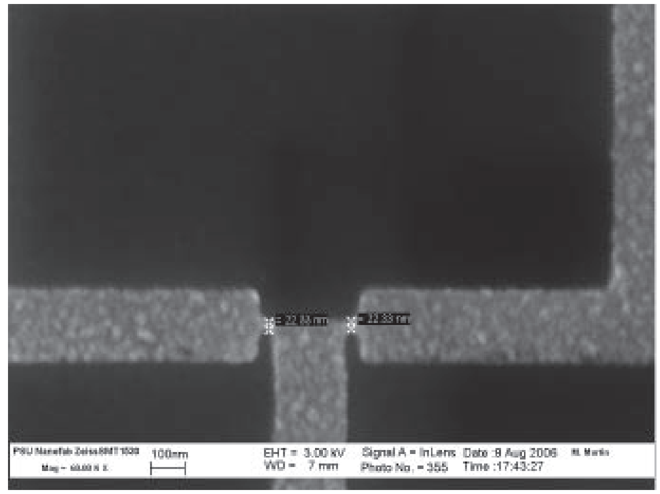


*Figure 3: FESEM image of junction of SQUID with 20 nm lines.*

developing scheme was 90 seconds in n-amyl acetate, 30 seconds in methyl-isobutyl ketone:isopropyl alcohol (8:1) solution and 30 seconds in de-ionized water. The niobium SQUID sample did not lift-off as well as the aluminum (see Figure 2). This may possibly be due to the fact that sputtering is less collimated than thermal evaporation. Ultrasonic agitation did help promote the lift-off in both of the samples. Using the determined exposure and developing scheme from the dose array, SQUID rings having junction lines approximately 20 nm in width were successfully created in the final sample (see Figure 3).

## Future Work:

The future work for this project includes testing that will be conducted at the University of California, Berkeley. At this location, the SQUID rings will be tested to determine whether they are more sensitive than current microbridge SQUID devices, and whether they are capable of detecting single spins or not. They will then be used to study spin dynamics in single molecule magnets. Other future work includes the "fine tuning" of the recipe to create the microbridge SQUID devices.

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## References:

[1] K. Hasselbach, C. Veauvy, and D. Mailly, Physica C: Superconductivity 332, 140 (2000)