Optimization of MEMS Fabrication for Electrical Detection

Joshua Ott

Electrical Engineering, Southern Methodist University

NNIN REU Site: Cornell NanoScale Science and Technology Facility, Cornell University, Ithaca, NY

NNIN REU Principal Investigator(s): Harold Craighead, Applied and Engineering Physics, Cornell University

NNIN REU Mentor(s): Darren Southworth, Josh Cross, Applied and Engineering Physics, Cornell University

Contact: hgc1@cornell.edu, drs59@cornell.edu, jdc47@cornell.edu

Abstract:

The much-celebrated potential of resonate microelectromechanical systems (MEMS) in sensing and electrical filter technologies has been limited by convenient methods of device readout. Our purpose is to optimize MEMS devices for electrical detection, enabling integration into real-world devices. We fabricated device arrays in which the parameters of etch orifice size, sacrificial oxide thickness, and device geometry were varied in order to maximize electrical coupling.

MECH

Introduction:

MEMS resonant technology is used for biological sensing and electric filtering technologies. These resonators have a certain resonance frequency. Shifts in resonant frequency from accretion of mass onto the device, for example, could indicate the presence of an analyte. We are developing an electrical method of resonance frequency detection. Historically, these resonators lack convenient methods of device readout. Some methods require large apparatus' such as superconducting magnets or aligned optics. With the advent of electrical detection we have a means for real-world integration of these devices since the simple circuitry required lends itself to packaging. All that is required is a capacitor and inductor.

In the past, electrical readout was limited by small signal detection. We fabricated device arrays with varied resonator geometries in attempt to increase the signal. The goal of these geometries was to reduce the motional resistance, which is the figure of merit in our experiment.

$$R_m = \frac{d^2 m \omega_o}{{V_g}^2 {C_g}^2 Q}$$

Figure 1: Motional resistance equation.

The motional resistance equation can be seen in Figure 1. Variable d is the sacrificial oxide thickness, m is the resonator mass, ω_0 is the angular frequency, V_g is the voltage applied to the resonators, C_g is the resonator capacitance, and Q is the quality factor.

We attempted to reduce motional resistance by changing the resonator geometries and etch hole orifices, which altered the variables m, ω_0, and C_g. We also grew varying oxide thicknesses, which reduced the distance (d) and increased the capacitance (C_g). The resulting correlations gave the oxide thickness a fourfold effect on the motional resistance, making it one of the most important aspects of our devices. However, if we created a thickness too thin, the devices would not resonate properly and stick to the silicon wafer.

Experimental Procedure:

An array of devices, including different geometries and different etch hole sizes, were fabricated on each die. The etch holes were created using a reactive ion etch. A buffered oxide etch was then used to release the resonators from the oxide.

The most important devices from fabrication were our "drums," a flat membrane with a single etch hole. This device can be seen in Figure 2. The light areas correspond to where the device is released from the wafer. The drums were created with etch hole diameter's varying from 2-10 μm, in 2 μm increments. Actual membrane diameters measured

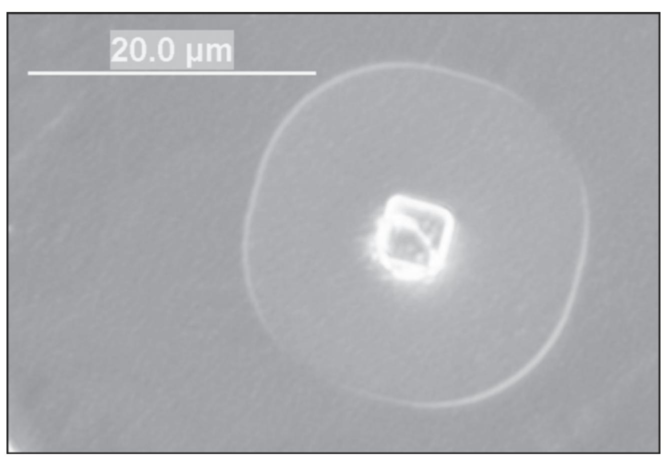

Figure 2: 4 µm etch hole drum resonator.

approximately 20 μm. The drums were comprised of polysilicon grown on silicon dioxide. The polysilicon was N^+ doped, made tensile (in order to create a flat membrane) and grown to approximately 330 nm. Oxide thicknesses of 645, 223, and 95 nm were the targets, with 223 nm being the only viable resonator.

An LC impedance matching circuit was used to detect the electrical signal. The resonators were placed under vacuum. By interchanging capacitors and inductors, the circuit was matched to the resonance frequency of each resonator. Using LabView, the quality factor and resonance frequency was then calculated. With these variables we did back calculations to get the motional resistance.

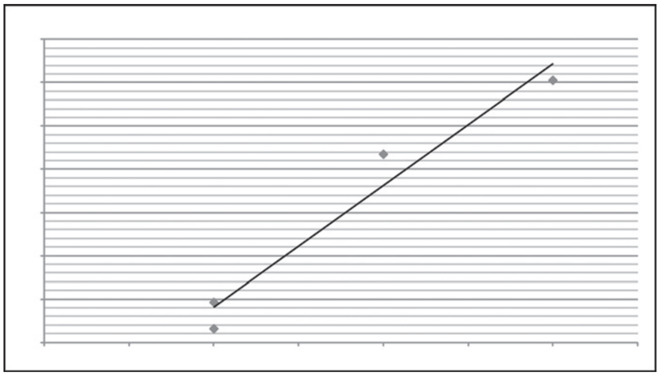

Figure 3: Motional resistance vs. etch hole diameter.

Results and Conclusion:

There was a definite trend when comparing etch hole diameter and signal strength. As etch hole size was decreased so did motional resistance (Figure 3), which indicates that a smaller etch hole produces a larger signal. We also discovered that the quality factor of our devices was independent of etch hole size. The actual drum diameter was independent of etch hole size as well.

Future Work:

Since the largest factor for motional resistance is oxide thickness, it is our greatest chance for increasing the signal. Therefore, going for an even smaller oxide thickness would increase the signal. Work could also be done to create an even smaller etch hole to see the results: a larger increase in signal power, no increase in signal power, or simply diminishing return in signal power. Lastly, multi-hole membranes should be studied to see how their geometries affect the electrical signal.

Acknowledgments:

I would like to thank the National Science Foundation and, in particular, the National Nanotechnology Infrastructure Network, for allowing me to be involved in this REU program, and the Intel Foundation for sponsoring my research. I would like to think Harold Craighead for his support, and Darren Southworth and Josh Cross for their assistance. Acknowledgment is also given to the Cornell NanoScale Facility Staff, especially Melanie-Claire Mallison.