Fabrication of Micro Scale Triboelectric Microphone

CNF Project Number: 2929-21
Principal Investigator(s): Shahrzad Towfighian
User(s): Mohammad Alzgool

Affiliation(s): Mechanical Engineering, Binghamton University

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Contact: stowfigh@binghamton.edu, malzgoo1@binghamton.edu, mmalzgool14@gmail.com

Primary CNF Tools Used: Unaxis PT770, OEM AlN Sputtering, AJA Sputter Deposition, Heidelberg DWL-2000 Mask Writer, Oxford PECVD, Oxford 81 Etcher, PT770 Etcher, DISCO Dicing Saw, SÜSS MA6-BA6 Contact Aligner, YES Polyimide Curing Oven, Primaxx Vapor Etcher

MECHANICAL DEVICES

Abstract:

In our project, we are trying to fabricate and optimize a microphone that operates by using the mechanical structure and the triboelectric property of polyimide and aluminum with a back- etched wafer with aluminum nitride-aluminum layer as our diaphragm. The back-plate consists of polyimide, aluminum, and amorphous silicon. The motivation of this project comes from the promising results acquired from the MEMS triboelectric accelerometer that gave high signal-to-noise ratio, and the high and linear response of the output voltage [1]. The design from the previous work was optimized for sensitivity by manipulating the dimensions of the serpentine springs of the back-plate, and a back-etch was incorporated into the design to make the device act as a microphone.

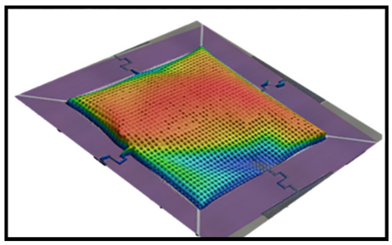


Figure 1: Fabricated triboelectric accelerometer.

Research Summary:

There are many advantages of triboelectric generators over piezoelectric generators such as lower cost, high flexibility, and superior electrical output. The operation of triboelectric generators depends on contact of a metal and a dielectric material with different affinity to electrons, the contact will result in charged conductive plates and separation with high impedance in between the plates will result in high voltage. In this work, we optimized our previous design of triboelectric accelerometers for maximum sensitivity with genetic algorithm [1]. The optimized triboelectric accelerometer was fabricated (Figure 1) and mounted on a shaker. The triboelectric excitation of 2-10 g was applied while the voltage was acquired. Frequency was swept from 0.5- 4 kHz and voltage produced was measured.

Fabrication:

The fabrication process (Figure 2) for triboelectric generator starts with 500 nm aluminum nitride, recipe used for this operation utilized the heater provided with the machine and required seasoning of the wafer for many depositions before continuing with the real wafer. The minimum stress from the nitride layer acquired with low-stress recipe was -50 MPa while it was more than 1 Gpa for the normal recipe. 500 nm of aluminum is sputtered and patterned for bottom electrode at 3 mtorr with titanium nitride adhesive layer. This is followed by high-rate silicon oxide PECVD layer that is one micron thick to create the gap between upper and lower electrode.

The process is then followed by back etching of the wafer to create inlet for the sound waves, the first aluminum nitride layer acts as a perfect stop-layer for the etching. This is done by cycling 200 loops of etching with five minutes of release to clean black silicon deposits, this process was finalized after 1000 loops. Then, polyimide spin-coating at 5000 rpm for one minute was done, curing by polyimide oven for one hour at 300°C is optimal, and patterning is carried out using RIE oxford 81 with CF_4/O_2 mixture of 15/45 sccm. Then, the top layer is finished by sputtering 200 nm aluminum, which is patterned by PT770 ICP machine, and depositing amorphous silicon for proof-mass with 200°C under 20 mtorr for 20 minutes to ensure stress is within tensile region, the amorphous silicon resulted is one micron thick and is etched with SF6/O2 mixture for one minute with RIE machine Oxford 81. Then, release of the top and bottom layers is done by vapor HF etching which is done using slow speed for 2 μm etch followed by 8 μm etch using faster recipe to etch oxide layer sideways. Finally, the wafer is diced and wire-bonded for testing.

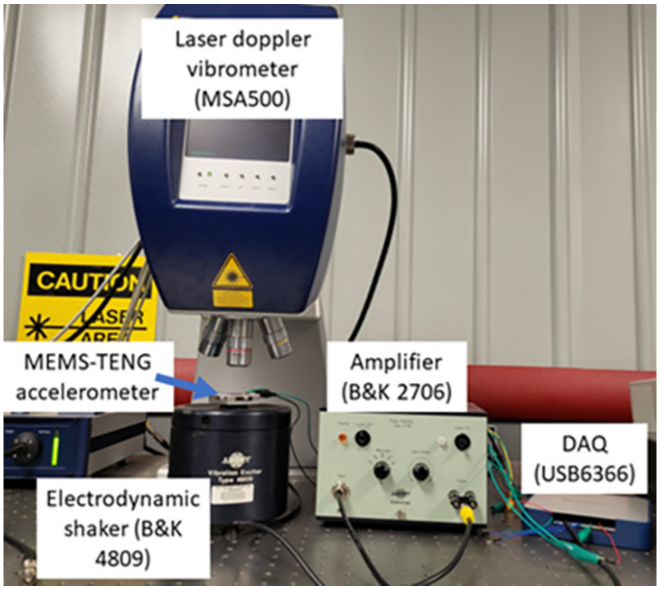


Figure 2: Fabrication process overview.

Results:

The accelerometer was tested at 0.5-4 kHz with excitation amplitude 2-10g with sinusoidal input. The frequency response (Figure 3) shows a noticeable resonance peak at 1.25 kHz with 1.8 V generated at the highest end as a response to excitation of 10g. The frequency response for the rest of the tested bandwidth is relatively flat for every tested acceleration amplitude. The residual stresses during deposition processes of spin-coating the polyimide and from the sputtering deposition of the aluminum layer caused shift in resonance between expected and acquired results. These stresses cause the released membranes to buckle up which creates undesired differences between the designed and the actual device.

Generated voltage-excitation amplitude (Figure 4) still shows linear relation with the highest sensitivity of 187 mV/g. The sensitivity is an improvement over our previous design which has 68 mV/g sensitivity with only 0.7 V as the highest produced voltage [1]. It is also noticed that there is a linear relationship between the measured acceleration and the produced voltage for the fabricated accelerometer at each frequency. Results present a promising design that can be suitable for self-powered MEMS motion sensors or microphones.

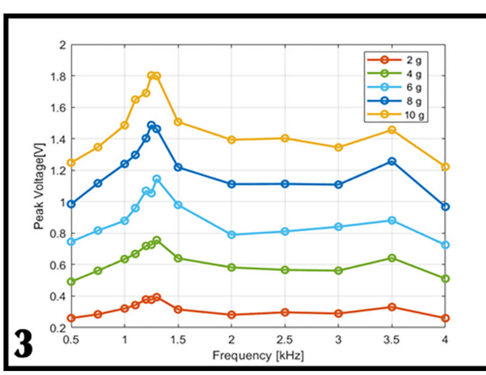
Conclusions and Future Work:

In this work, we were able to significantly enhance the performance of a triboelectric accelerometer by applying genetic algorithm to the design and by modifying the fabrication process. We targeted maximum sensitivity in our optimization and changed the placement of the dielectric layer from the bottom to top. The changes made to the fabrication process alongside the changes in the design have improved the device output.

Currently, we are trying to test the device with back-etched volume to act as a microphone. Such work requires complete investigation of both diaphragm and back-plate separately to understand their integration.

References:

[1] Alzgool, M., Tian, Y., Davaji, B., and Towfighian, S. (2023). Self-powered triboelectric MEMS accelerometer. Nano Energy, 109, 108282.



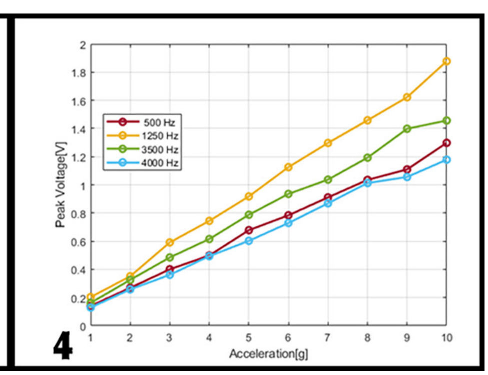


Figure 3: Frequency response of the triboelectric accelerometer.

Figure 4: Excitation amplitude-triboelectric accelerometer output voltage.