Fabrication of Micro Scale Triboelectric Generator

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

Affiliation(s): Mechanical Engineering, Binghamton University

Primary Source(s) of Research Funding: National Science Foundation Grant #1919608
Contact: stowfigh@binghamton.edu, malzgoo1@binghamton.edu, mmalzgool14@gmail.com
Primary CNF Tools Used: YES Asher, 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

Abstract:

Energy harvesting became of extreme importance as advances on internet of things are made. Although triboelectric generators (TEGs) are extensively researched in meso-scale as devices to harvest mechanical energy, research on downsizing TEGs to micro-scale is scarce [1]. In this project, we created and investigated the performance of a micro-scale TEG operating in contact-separation mode. The fabricated device was used as an accelerometer for accelerations in the range of 1-3 g.

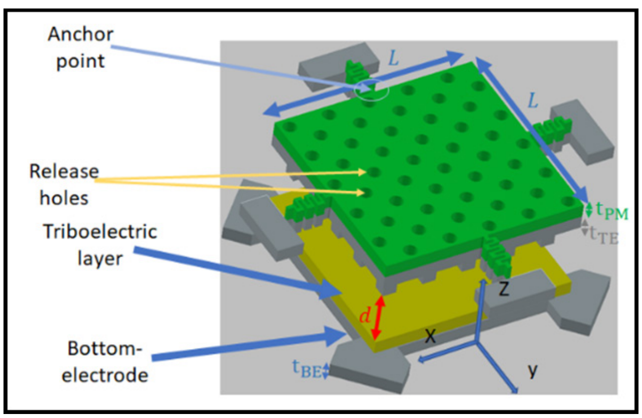

Figure 1: Micro triboelectric generator schematic.

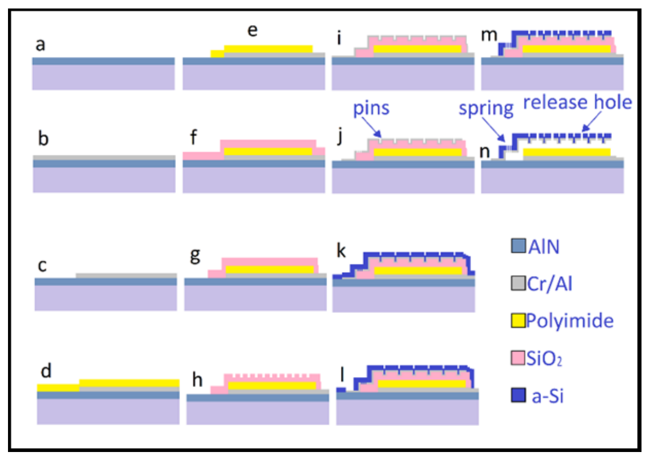

Figure 2: Micro triboelectric generator fabrication process flowchart.

Research Summary:

Triboelectric generators (TEGs) are researched nowadays because of their advantages over piezoelectric generators such as low cost, flexibility, and their high output. The triboelectric generator operating in contact-separation mode typically has three layers, two layers of which forms a triboelectric pair, and the third layer is a conductive layer that hits the substrate as shock is applied (Figure 1). Once the conductive electrode contacts the dielectric material, both layers in contact will gain\lose electrons which creates potential difference when these layers are separated. In our work, the triboelectric pair is made of polyimide (using HD microsystems PI2574 precursor) and aluminum, and the top electrode is made of aluminum too [2].

Fabrication:

The fabrication process started with sputtering 200 nm chrome/ aluminum on 1.5 µm aluminum nitride insulating layer (Figure 2 a, b). Then the chrome/ aluminum layer is patterned using PT770 etcher (Figure 2 c). Then polyimide layer was formed by spin-coating the precursor and baking it on a hot plate for 1 min followed by oven curing in the YES polyimide oven for 1.5 hours (Figure 2d). Then the polyimide was patterned using Oxford 81 etcher with CF_4/O_2 recipe (Figure 2e) [3]. This process was followed by PECVD film of SiO_2 deposited to create a gap (Figure 2f). This film was etched twice using Oxford 81 with different masks to create ditches on the top (Figure 2g,h). Then, another sputtered chrome/ aluminum film of 120 nm was deposited on top of the oxide layer (Figure 2i), this film will have pins when it fills the ditches created on the oxide layer. This layer was etched to form top layer and springs (Figure 2j). Then, a-Si layer is deposited on top to create a proof-mass and a structural layer on top of the chrome/ aluminum (Figure 2k).

Parameters for a-Si deposition were chosen such that the resulted film stress of a-Si and chrome/ aluminum is tensile and less than 180 MPa to avoid breakage in the serpentine springs. Then, a-Si on contact pads is etched using Oxford 81 (Figure 2l), and both a-Si and chrome/ aluminum are etched to form release holes for vapor hydrofluoric acid etching (Figure 2m). Finally, dicing and releasing of the chips with vapor HF etching to remove the oxide layer was done to create micro-scale triboelectric generator (Figure 2n).

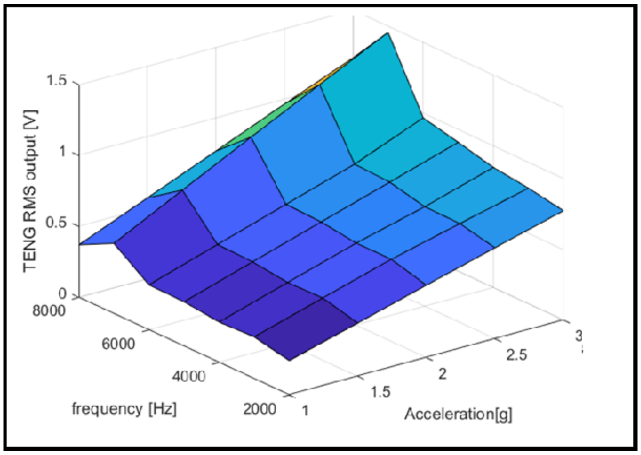

Figure 3: The relation between frequency, acceleration, and generated voltage.

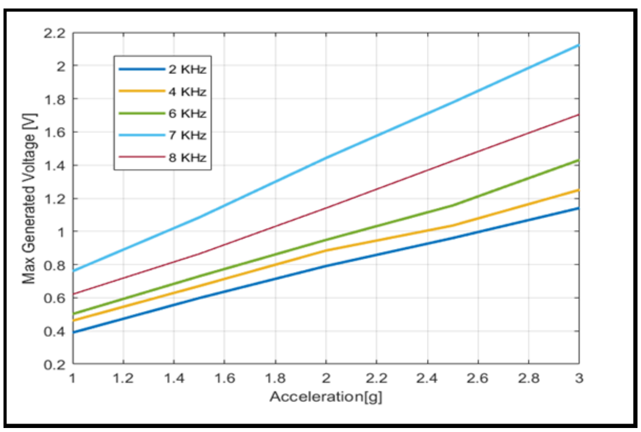

Figure 4: Generated output against acceleration with different input frequencies.

Results:

The fabricated device was mounted on a mini-shaker (B&K 4810) and an accelerometer was attached to the stage to measure the acceleration. Then the shaker was excited sinusoidally with acceleration in the range of 1-3 g. The output of the micro triboelectric generator as a function of acceleration and input frequency is shown in Figure 3. The generated voltage is noticed to be linear against acceleration at any given frequency as show in Figure 4. The sensitivity of the fabricated TENG varies as frequency is changed from ~0.4 V/g to ~0.65 V/g, which is higher than the sensitivity of the commercial accelerometer used. The highest sensitivity value is seen at the frequency of 7 KHz.

Conclusions and Future Steps:

There are plenty of parameters that could be optimized in this work. For instance, the polyimide was used here because it can withstand the 300-400°C temperature of the PECVD process while other materials like PDMS would evaporate, the output voltage might improve if we found a way to use PDMS instead of polyimide. Also, the amorphous silicon film was used here because the stress can be tuned to overcome the compressive stress of the chrome/ aluminum sputtered film. If we could swap the a-Si with a thicker conductive material and get neutralized film stress, it is possible to get higher voltage output from the reported device.

References:

[1] H. A. Hamid, Z. Celik-Butler, Design and optimization of a mems triboelectric energy harvester for nano-sensor applications, in: 2019 IEEE Sensors Applications Symposium (SAS), IEEE, 2019, pp. 1-6.

[2] H. Zhang, L. Quan, J. Chen, C. Xu, C. Zhang, S. Dong, C. Lu, and J. Luo, A general optimization approach for contact-separation triboelectric nanogenerator, Nano energy, vol. 56, pp. 700-707, 2019.

[3] G. Turban, M. Rapeaux, Dry etching of polyimide in o 2-cf 4 and o 2-sf 6 plasmas, Journal of the Electrochemical Society 130 (11) (1983) 2231.