MSA PROJECT REPORT

MEMS based Piezoelectric Sensor System for Virus Detection(HIV)

Submitted by

GROUP No. 1

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As per the requirement for the course on

Micro Sensors and Actuators

1. PROJECT TITLE

MEMS based Piezoelectric Sensor System for Virus Detection (HIV)

2. ABSTRACT

Designing a piezoelectric MEMS sensor for virus detection, including HIV and herpes. For cantilever construction, PZT-5A is employed as a piezoelectric material with a 500 um length. The PZT-5A microcantilever structure was modeled in order to transform mechanical vibrations into voltage, which is then utilized to detect viruses at the nanoscale. Due to the microscopic size of the viruses, a sample is often in the nanogram range. They are being taken up by the biomarkers, which put some pressure on the free end of the cantilever. So, at the platinum electrode, voltage is produced at various eigenfrequencies.

3. INTRODUCTION

Reference paper 1

A PZT-5A piezoelectric micro cantilever structure that may detect viruses by converting mechanical vibrations into electricity.Modeling of this piezoelectric sensor device based on MEMS, which exhibits remarkable sensitivity to variations in attached mass at the cantilever tip.Understanding material parameters like relative permittivity, young's modulus, density, and poisson's ratio can be accomplished by analyzing the cantilever with Eigen frequencies.An increase in stress created causes an increase in the output voltage since the fixed end of the cantilever has a PZT layer.There are a variety of soluble HIV biomarkers that depend on immunological activation markers, coagulation markers, tissue fibrosis and inflammation markers, enterocyte damage markers, and monocyte activation markers.

Reference paper 2

Less power is needed by MEMS-based sensors, which has solved the problem of having to change batteries for regular gadgets by creating a way for devices to run on their own power.With the use of MEMS technology, numerous methods—including electrostatic, electromagnet, and piezoelectric materials—have been created to capture the available mechanical power and transform it into the necessary electric power for electronic devices. Due to their low resonance frequency, ease of manufacture, and ability to produce a superior strain and, thus, a higher power, cantilever beam structures attract more attention than other types of structures.

Reference paper 3

MEMS typically exhibit mechanical behavior that is connected with electrical behavior. They can range in size from a few micrometers to a few millimeters, on average. Most MEMS actuators and sensors, including switches, capacitive pressure sensors, accelerometers, filters, and resonators, start with a structure with a cantilever form.The shock caused by electrical actuation may result in cantilever failures that produce significant cantilever displacement. Therefore, designers are interested in finding ways to avoid these issues.The displacement of the cantilever is unaffected by that weight.

Reference paper 4

Electrostatic forces and the 3D static bending of a beam caused by applied loads combine to produce the best electric potential distribution for a given area.Some fascinating aspects of this work have come to light, such as the peculiar behavior of displacements in the absence of load and without an applied voltage.There are various materials being used. piezoelectric sandwich cantilever beam that evaluated how voltage and displacement relate to one another.When subjected to voltage, piezoelectric material experiences stress.

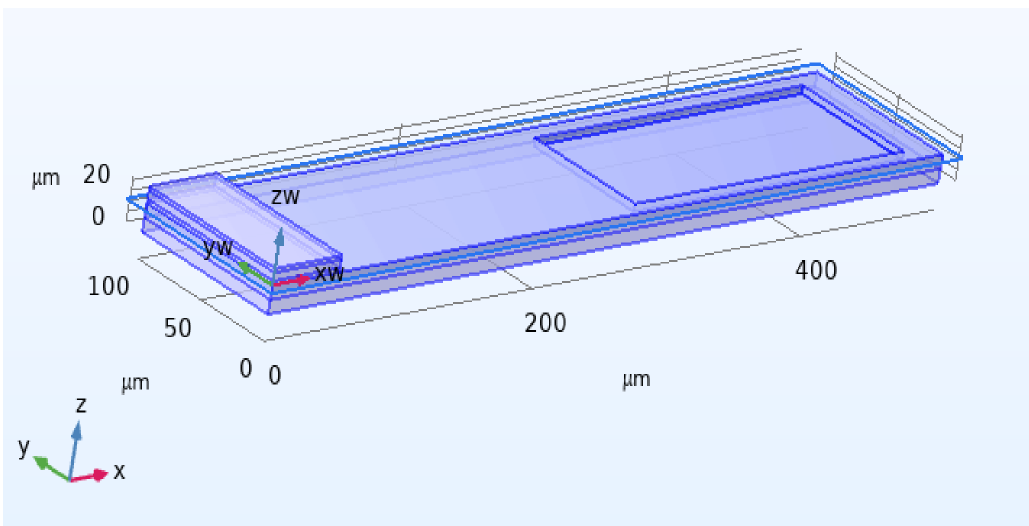
Reference paper 5

Enhance the conversion of mechanical energy to electrical energy. The first piezoelectric energy harvester could only generate a little quantity of power—between a few milliwatts and tens of microwatts which was insufficient for the electronic circuits independent operation.a comparison of the energy obtained from the BPF-built variable width beam and the other constant width piezoelectric cantilever beam for the same volume of substrate, piezoelectric material, and natural frequency. In comparison to the voltage generated by a constant width piezoelectric cantilever, it is discovered that the beam structure with piezoelectric element layered as a distributed linear function in three steps employing BPFs is more effective.

4. PROBLEM STATEMENT

- Detection of HIV and Herpes.
- The weight of the sample is in nanograms.
- Cantilever dimension (**500 µm** x **100 µm** x **7 µm**).
- **Lead Zirconate Titanate** (PZT-5A) is being used as a piezoelectric material .
- Piezoelectric material is used to convert the mechanical vibration into voltage.
- Platinum electrodes are used to get the output of the cantilever.
- Observing Stress , pressure , displacement at the fixed end of the cantilever at different Eigen frequencies.

5. METHODOLOGY



A micro cantilever having dimensions 500µm x 100µm x 7µm made of polysilicon is taken as the first block for design. The second block is a 500µm x 100µm x 7µm SiO2 (silica glass) insulator with a 200µm x 80µm x 4µm pit positioned (380,50,14) to bind the maximum number of viruses.

At the fixed end, on top of the cantilever, a piezoelectric material Lead Zirconate Titanate (PZT-5A) having dimensions 50µm x 100µm x 2µm is sandwiched between an upper platinum electrode and a lower platinum electrode having same dimensions as PZT-5A. The purpose of platinum electrodes is to take out electrical terminals for measuring the generated output electrical voltage. Material properties are mentioned below.After preparation of cantilever click Add physics and then select Solid mechanics option that add fixed end and surface to apply pressure i.e. pit boundaries. Pressure applied was 12.5 pascals.

6. NEW FINDINGS

By computing the Eigen frequencies of a cantilever using a finite element analysis tool like COMSOL, you can identify the natural modes of vibration of the structure and the corresponding frequencies at which they occur.

Furthermore, the Eigen frequency analysis can help in designing the cantilever to avoid resonant vibrations that could lead to failure or damage. By knowing the natural frequencies of vibration, you can identify any external loads or vibrations that may cause the cantilever to vibrate at or near its resonant frequency.So we are verifying the behavior of the cantilever using five different Eigen frequencies and observing changes of stress, pressure and displacement.

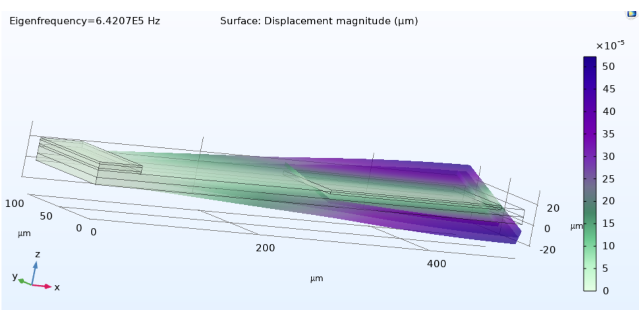


Fig 1 . Displacement magnitude of the cantilever

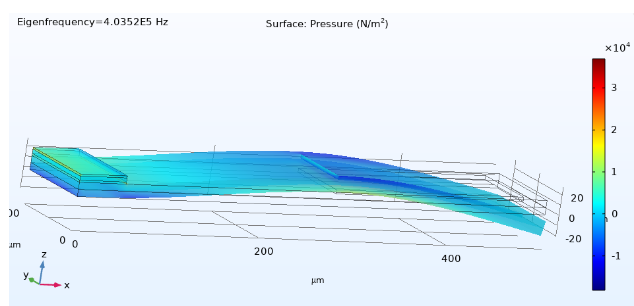


Fig 2. Surface Pressure of the cantilever

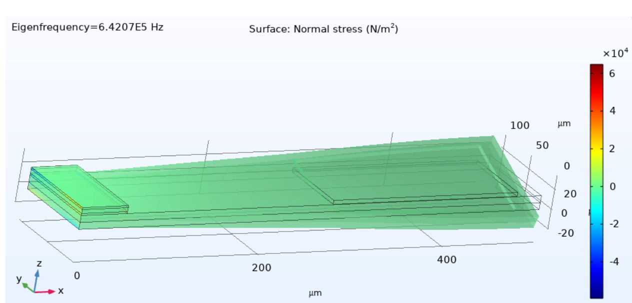


Fig 3. Surface Pressure of the cantilever

7. EXPERIMENTAL DETAILS

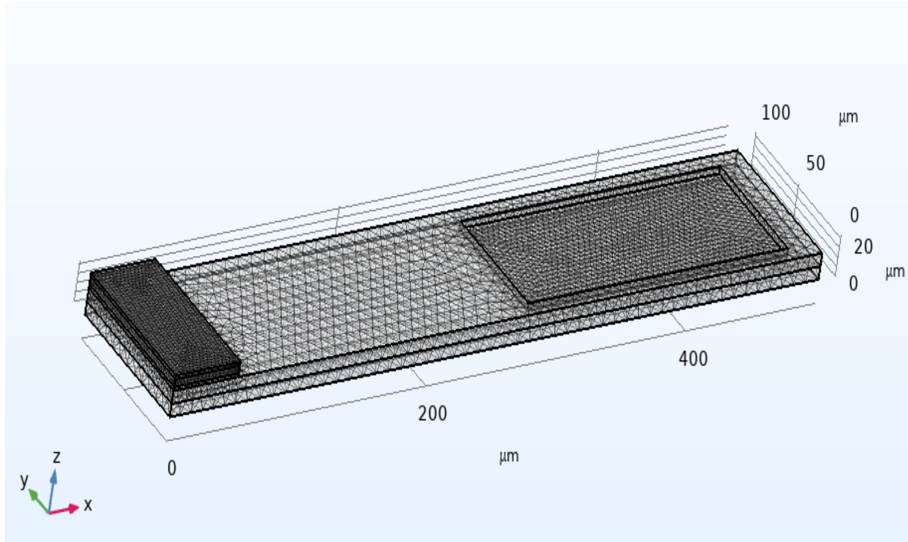


Fig 4. **Cantilever after applying Finer mesh**

Mesh profile : Finer mesh to all surfaces.

Material:

Block 1 - polysilicon [Relative permittivity = 4.5 : Density = 2320[kg/m^3] : Young's modulus = 169[GPa] : Poisson's ratio = 0.22]

Block 2 - Sio2 (Silica glass) [Relative permittivity = 3.75 : Density = 2203[kg/m^3] : Young's modulus = 73.1[GPa] : Poisson's ratio = 0.17]

Block 3,5 - Platinum [solid,annealed] [Relative permittivity = 0.5]

Block 4 - Lead Zirconate Titanate (PZT-5A) [Relative permittivity = 919.1 : Density = 7750[kg/m^3] : Young's modulus = 63[GPa] : Poisson's ratio = 0.2]

Physics and study :

Solid mechanics(solid) and study-1 , Electrostatics(es) and study-2(Eigen frequency)

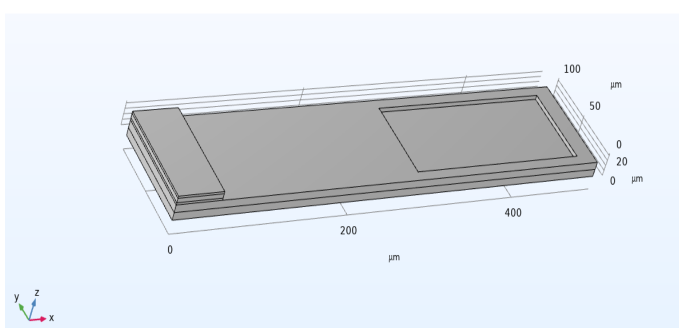


Fig 5. **Cantilever**

8. RESULTS AND DISCUSSION

Applying 12.5 pascals of pressure in the pit.

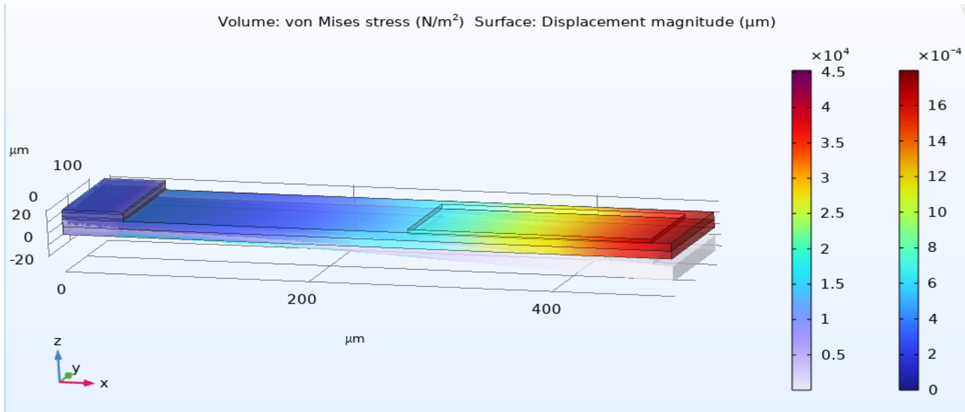


Fig 6. Displacement magnitude of Cantilever(Surface)

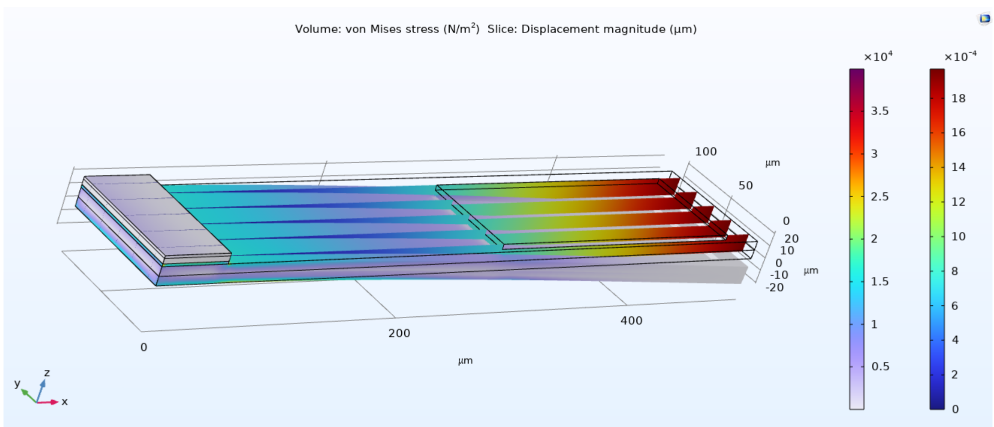


Fig 7. Displacement magnitude of Cantilever(Slice)

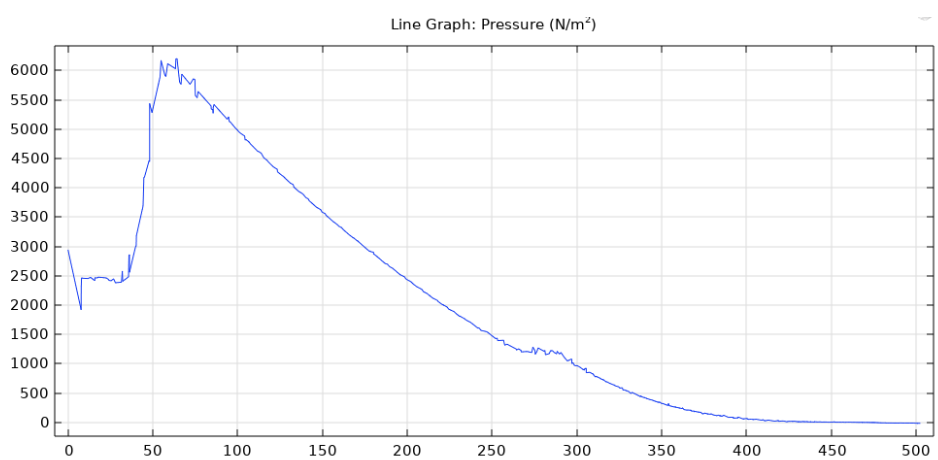


Fig 8. Pressure Distribution of the Cantilever

EIGENVALUES	X	Y	Z	STRESS
77809	199.12	5.1251E-4	9.2604	-22.560
4.0352e5	198.29	0.017794	20.406	-13.617
5.2238e5	196.83	4.2751	9.8468	-283.47
6.4207e5	199.21	8.3505	8.1029	-36.095
1.1066e6	197.67	0.068684	-10.673	7.6034

Table 1 . Comparison of Eigen frequencies with Stress

EIGENVALUES	X	Y	Z	PRESSURE
77809	198.37	0.0069732	5.2728	-906.06
4.0352e5	199.11	-0.030415	11.656	4171.7
5.2238e5	398.66	24.498	16.813	-888.09
6.4207e5	400.11	0.64705	-9.4623	466.47
1.1066e6	399.02	64.368	21.820	-15944

Table 2 . Comparison of Eigen frequencies with Pressure

EIGENVALUES	X	Y	Z	DISPLACEMENT
77809	390.63	-0.0024247	22.525	3.3610E-4
4.0352e5	382.93	0.038977	12.936	1.0667E-4
5.2238e5	431.17	15.950	13.326	4.1981E-4
6.4207e5	459.09	7.5754	-2.1616	4.0874E-4
1.1066e6	420.16	-0.026464	11.460	1.9250E-4

Table 3 . Comparison of Eigen frequencies with Displacement

9. APPLICATIONS

Medical diagnosis: MEMS based piezoelectric sensors can be used to detect viruses in clinical samples as blood. The sensors can detect the virus particles by measuring the mass changes on the sensor surface due to the specific binding of the virus to the sensor surface. This could be useful in the early diagnosis of viral infections.

10.FUTURE WORK

- At different Eigen frequencies, the cantilever's stress, displacement, and pressure are being measured. To learn more about the cantilever for detecting viruses, we can conduct additional observations based on electric potential (Surface potential and Slice potential).
- Binding of viruses can be done by using various biomarkers for a specific application.
- It is possible to bind viruses utilizing a variety of detection-specific biomarkers. There are a variety of soluble HIV biomarkers that depend on immunological activation markers, coagulation markers, tissue fibrosis and inflammation markers, enterocyte damage markers, and monocyte activation markers.

11.CHALLENGES FACED

1) We have tried to observe the Electric potential of Cantilever with respect to different Eigen frequencies .For all Eigenvalues, we received zero electric potential.

2) Placing the pit in silica glass drawing the desired shape of the pit on a work plane using silica glass proportions. Then create an Extrude with a distance of 4 micrometers in the direction of the negative Z axis, open booleans and partitions in ribbon, and add objects block 2 and Extrude 1 to difference. Therefore, block 2 will be subtracted from extrude. Pit will then develop.

12.CONCLUSION

For the purpose of detecting viruses with a diameter of 100 nm, a unique MEMS PZT-5A cantilever combined with a Si/SiO2/Pt/PZT-5A/Pt multilayer has been modeled and built using COMSOL Multiphysics. It has been discovered that a sample mass of 20ng at the tip may produce varying stress, pressure, and displacement with various Eigen frequencies. The produced piezoelectric voltage has been linked to the identification of a specific virus since the maximum number of viruses that may adhere to a pit surface of a given dimension depends on the virus's type.

13.REFERENCE

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e. Kumar, T., Kumar, R. and Chauhan, V.S., 2015, June. Design and finite element analysis of varying width piezoelectric cantilever beam to harvest energy. In *2015 International Conference on Energy, Power and Environment: Towards Sustainable Growth (ICEPE)* (pp. 1-6). IEEE.

14.CONTRIBUTIONS

E . JASWANTH KRISHNA - Verifying cantilever properties (stress, pressure, displacement) with different Eigen frequencies.

V . ROHITH - Preparation of cantilever and checking displacement of cantilever with different pressures