Comparative Study of Rectangular and Trapezoidal cantilever Beam for Virus Detection

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Abstract – ***Cantilever sensors are mostly preferred as biosensors because of their highly sensitive sensor platform which gives high throughput for the detection of proteins and nucleic acids. In this paper a rectangular shaped cantilever beam was taken as the base and a trapezoidal cantilever beam was developed to increase the sensitivity of the mass that was given to the tip of the beam using MEMS technology. The model consists of a pit to trap the virus present in a given sample at the free end of the cantilever beam, and a piezoelectric material is attached at the fixed end to measure the mass of the virus in terms of voltage .Both the models of the cantilever beams were simulated in COMSOL MULTIPHYSICS software, a comparative study of both the models was done in terms of voltage which in turn determines the sensitivity of the mass at the tip.***

Key Words: *Cantilever, MEMS, Comsol Multiphysics, piezoelectric voltage*

1. INTRODUCTION

During the inception of Microelectro mechanical systems(MEMS),the application of MEMS in biomedical applications were realized[1].Cantilever beams is one of the commonly used structure because we can change its surface properties according to the biomolecule that is been detected[2].Binding of the biomolecule to be detected(Example: virus) on the surface of the cantilever can be done using various biomarkers that varies according to the properties of the virus to be detected.[3].It is possible to study the effects of this pathogen viral binding on the surface of the cantilever by observing the changes in the MEMS devices.
In this paper mechanical detection method is used to detect a virus, that is a biomolecule is detected due to mechanical motion of the cantilever[1]. So in the present work the mechanical vibrations are converted into voltage to measure the mass of the virus.The main principle of this paper is that a cantilever beam is placed in an oscillatory environment at its own resonance frequency. This produces strain, in turn produces stress at the fixed end and generation of electrical voltage across the piezoelectric material (PZT-5A)[2].When a sample of certain mass is given to the cantilever ,the resonance frequency of the cantilever decreases to a few hundred Hz therefore increasing the deflection of the cantilever and the stress across the fixed end of the cantilever.

2. DESIGN OF PIEZOELECTRIC CANTILEVER BEAM

The design consists of a cantilever beam whose one end is fixed and other end is free. In this paper we have considered two cantilever beams; one is the basic rectangular beam, the other is a trapezoidal cantilever beam.
The design is the same for both the beams, only the dimensions are varied for both the beams according to its shape. The schematic representation of both rectangular and trapezoidal beam is as shown in Fig-1 and Fig-2 respectively. The rectangular beam has dimensions 500µm*100µm*7µm and trapezoidal beam has dimensions (33, 0), (0,500), (100,500), (63, 0).A layer of polysilicon is taken as first block for the design. The second block is made up of SiO_2 which acts as the insulator. A pit of dimensions 200µm*80µm*4µm for rectangular beam and (37, 10), (30,150), (70,150), (57, 10) is placed at the free end of the cantilever to bind maximum number of virus. At the fixed end a piezoelectric material is placed which is of dimensions 500µm*100µm*7µm for rectangular beam and (5,420), (0,500), (100,500), (94, 420) for trapezoidal beam. The piezoelectric material is sandwiched between upper and lower platinum layers they act as an electrodes to measure the voltage across piezoelectric material.

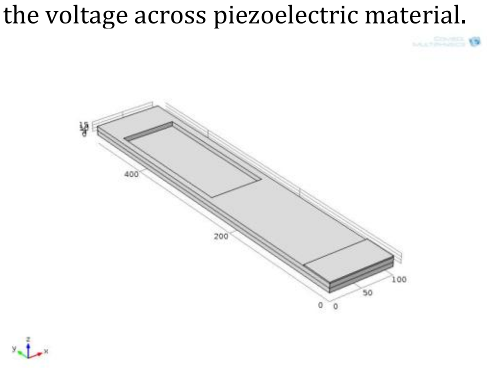

Fig -1: Rectangular cantilever beam

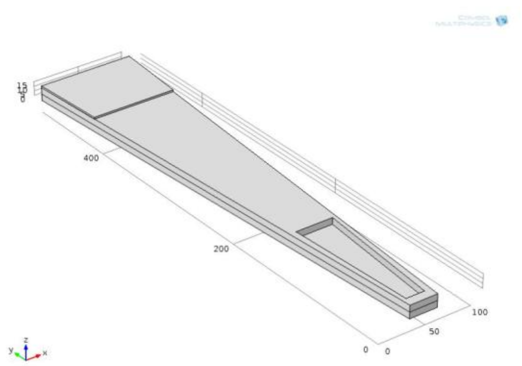

Fig -2: Trapezoidal cantilever beam

3. SIMULATION USING COMSOL

The simulation process of both the models is the same. For simulation of this model, three types of physics have been used. They are; Structural mechanics, Electromechanics and Piezoelectric devices. Different values of resonant frequency are obtained by using electro mechanics physics where an electromagnetic induction of 2 Volts is given. Meshing used for both the models is physics controlled courser mesh. At different eigenfrequencies, voltage is obtained for different samples of mass.The voltage variations for both the models for different samples of mass are obtained. Thus when mass=20ng,30ng and 40ng the voltage obtained for both the models is as shown in Fig-3,Fig-4,Fig-5 respectively.

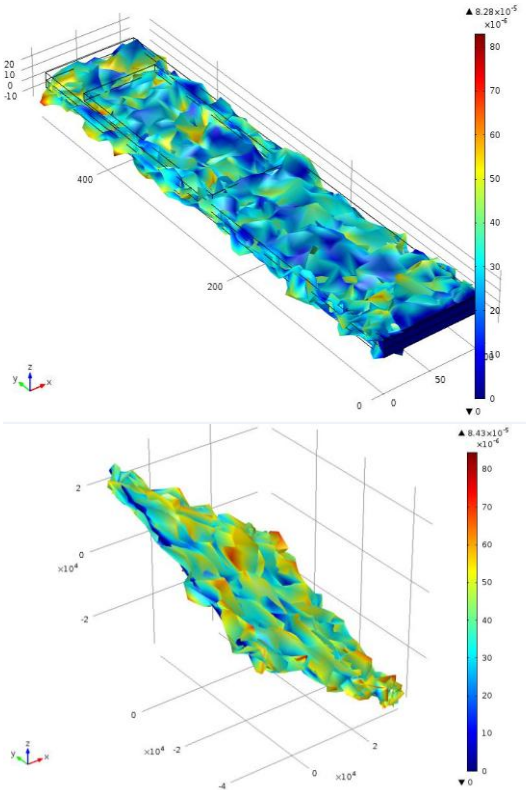

Fig-3: Simulation of rectangular and trapezoidal beam when mass=20ng

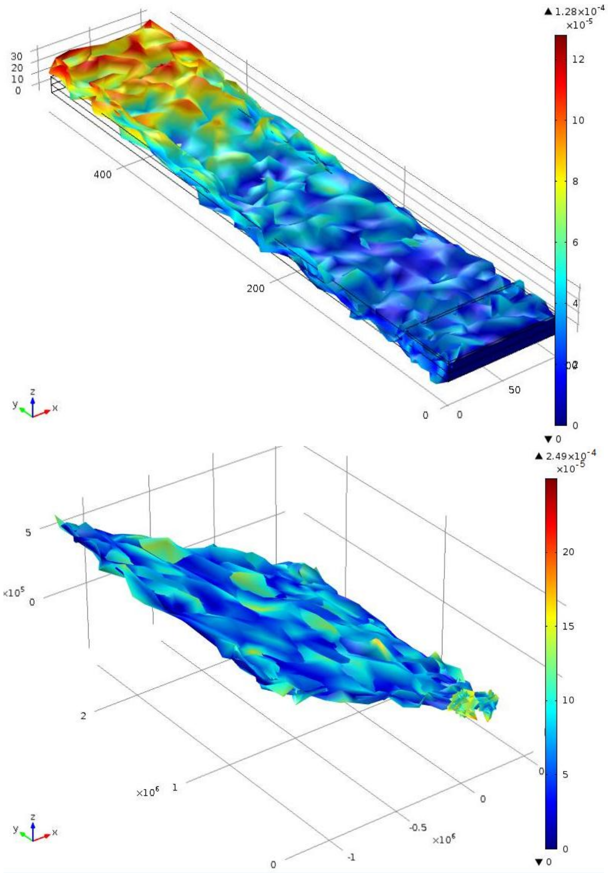

Fig-4: Simulation of rectangular and trapezoidal beam when mass=30ng

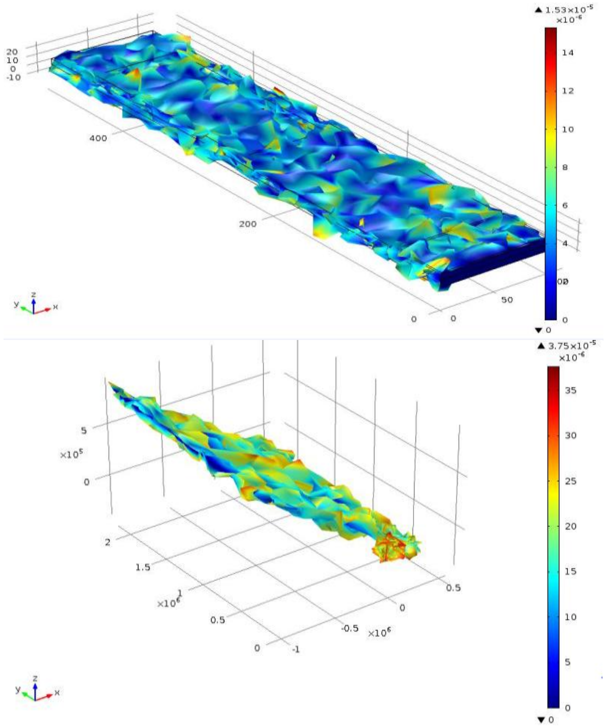

Fig-5: Simulation of rectangular and trapezoidal beam when mass=40ng

4. RESULTS

The results obtained from above simulation indicates that as the sample mass increases from 20ng to 40ng even the voltage increases from microvolt to millivolt through which detection of virus whose size is of the obtained range can be easily detected.

Also by comparing both the models we can infer that the trapezoidal model shows more deflection for the same mass that is given to the rectangular beam. The value of voltages for each Eigen frequency can be obtained by selecting the Eigen frequency analysis in the study option. The comparative study of both the beams for various Eigen frequencies and different mass is as shown in Table-1.

Table -1: Comparative study of both the models.

Rectangular model			Trapezoidal model		
Mass in g	Eigen freq in Hz	Voltage in μV	Mass in g	Eigen freq in Hz	Voltage in μV
20	3.225e5	$8.28*10^{-5}$	20	6.115e5	$8.43*10^{-5}$
	2.026e5	$4.54*10^{-5}$		1.065e5	$5.3*10^{-5}$
	0.248e5	$7.79*10^{-5}$		1.984e5	$6.85*10^{-5}$
	0.145e5	$6.17*10^{-5}$		6.747e5	$8.65*10^{-5}$
30	4.671e5	$1.28*10^{-4}$	30	2.625e5	$2.49*10^{-4}$
	6.890e5	$2.81*10^{-4}$		1.346e5	$3.37*10^{-4}$
	1.963e5	$5.81*10^{-4}$		2.588e4	$2.95*10^{-4}$
	2.225e5	$3.81*10^{-5}$		6.695e5	$4.56*10^{-5}$
40	1.701e4	$1.53*10^{-5}$	40	1.577e5	$3.75*10^{-5}$
	2.413e4	$1.87*10^{-5}$		2.700e4	$2.35*10^{-5}$
	1.603e5	$1.08*10^{-5}$		1.065e4	$2.27*10^{-5}$
	2.414e5	$2.2*10^{-5}$		9.644e5	$3.05*10^{-5}$

5. CONCLUSIONS

Thus a piezoelectric micro cantilever beam was modeled using COMSOL Multiphysics software for the detection of virus of size 100nm. Here two models of cantilever of different shapes were developed to compare the sensitivity in terms of voltage obtained. Sample mass of 20ng, 30ng and 40ng were given to both the models. The voltage obtained across the PZT-5A piezoelectric material increases from microvolt to millivolt as the mass increases. So the voltage obtained at each Eigen frequency is proportional to the number of virus present in the sample.

By comparing both the models we can conclude that trapezoidal model has more sensitivity than that of the rectangular model, this is because for the same mass the trapezoidal model shows more deflection than the regular rectangular model.

The maximum number of virus that can bind to the pit depends on the surface properties of the cantilever and the nature of the virus. The piezoelectric voltage obtained is associated with detection of a particular virus.

Further, a crosssection can also be introduced between the polysilicon and SiO_2 layer. Thereby we are not only changing the surface profile but also the cross section profile to optimize the stiffness and mass distribution[4].

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