DESIGN OF VARIOUS SHAPED MEMS BASED CANTILEVERS EXECUTED IN COMSOL MULTIPHYSICS

T. Saran Kumar

Research Scholar, Department of ECE, University of Technology, Jaipur.

Dr. G Kumar

Professor, Department of ECE, University of Technology, Jaipur.

I.Rama Satya Nageswara Rao

Assistant Professor, Department of ECE, B V C Engineering College (A), Odalarevu.

Y.Satya Vinod

Assistant Professor, Department of ECE, B V C Engineering College(A), Odalarevu.

Abstract: In this paper we have designed, simulated and analyzed various shaped MEMS based cantilevers like rectangular, T-shaped, Π-shaped and cone shaped cantilevers. The simulation of these MEMS based cantilevers are executed in COMSOL Multiphysics Tool. From the analysis, the T-shaped cantilevers with width W=300μm, length L=50μm and thickness t=20μm with paddle width W=20μm and length L=300μm produces maximum displacement of 7.2515×106μm.

Keyword: MEMS, Cantilever beam, Eigen frequency, Displacement, COMSOL Multiphysics.

1. Introduction

A normal single defended beam, acknowledged as a cantilever, a canonical mechanical structure with well accounted strain and bending characteristics. Cantilever based MEMS sensors offers a very assuring succeed for the evolution of biological, chemical and physical sensors. They have been employed in respective fields such as transducer, accelerometer and sensor etc., and have been proven to be very versatile [1, 2, 3]. MEMS cantilever sensors leans or banks upon the mechanical deformations of the constructions.

In the MEMS cantilevers two working modes are available, they are the dynamic and static modes. In static mode, bending of the cantilever is caused by induced surface stress due to the binding of target molecules on the surface of the cantilever induces a surface stress change across cantilever surface. Depending upon the molecular forces this can be either positive or negative direction bending. In dynamic mode, shift in cantilever resonance frequency caused by the change in the total mass due to the binding of the molecules on the cantilever surface changes total mass [4, 5].

The responses of the MEMS cantilever sensor working in static or dynamic mode can be monitored by piezoresistive, piezoelectric, optical and capacitive methods. The optical method is the most ordinarily used method and is sensitive but it has many disadvantages like requirement of external devices, not being portable to work within microarray format [6]. All the drawbacks in the optical method are not available in the piezoresistive method.

MEMS cantilever sensors offers high in sensitivity, low in cost fabrication, ease of use, mass production, label-free detection and parallel processing within a microarray format. Hence these MEMS cantilever sensors are ideal for sensing applications [7].

The electronic mechanical cantilevers are one in every of the foremost anticipating and trustworthy biological sensors. Cantilever provides an excellent platform for terribly sensitive method like biological sensing, chemical sensing occasions. Popularly micro cantilevers are well-known for its selectivity and sensitivity. It conjointly furnishes the compatibility options wishes the flexibility of the chip or circuit, simply deployable into IC. It's well-liked due to solace of fabrication like alternative typical devices there is no separate external modules for detecting or sensing, cantilevers fabricated using aggregated production.It yields a legion quantity of economical options like low price, tractability in production. Both the selectivity and therefore the sensitivity play a key role in accountancy of standards of the device [8].

In this paper the design, simulation and analysis of the various shaped MEMS based cantilevers are reported by FEM tool.

2. Computational Procedure

The spring constant and the resonance frequency are the two basic mechanical quantities based on which a cantilever is characterized. The displacement of MEMS cantilevers can be derived as a in terms of differential surface stress by using Stoney’s equation as $\delta = \frac{3L^2(1-\vartheta)}{\mathrm{E}t^2}(\sigma_1 - \sigma_2)$

Where, δ is the cantilevers displacement, E is the Young’s modulus, ϑ is the Poisson’s ratio, $(\sigma_1 - \sigma_2)$ is the differential surface stress,t and L are the thickness and length of the cantilevers beam respectively.

The stress in the beam can be varied by linearly with the varying distance along the centerline and maintaining the stress zero at the centerline. The high sensitivity value can be achieved by having the cantilever with piezoresistor at the base. The stress can be calculated by using $\sigma_{max} = \frac{6L}{Wt^2}F = \frac{3Et}{2L^2}\delta$

Where. W is the width and F is the applied force of the cantilever beam.

The highest sensitivity can be obtained by making the thickness of the cantilevers beam as minimum as possible.

2.1 MEMS cantilevers Design

The MEMS cantilevers design can be done by

i) *Building Geometry*: In this design step, we define the geometric parameters of the desired design.

ii) *Defining the material*: In this step, we define the material to build the cantilevers i.e., silicon, silicon dioxide, Polysilicon etc., with their different properties like Poisson's ratio, young's modulus, density.

iii) *Generating Mesh*: With respect to the size and shape of the elements to accomplish the results that are reliable we have to use an acceptable element mesh. The free meshes cannot give more accuracy than compared to the mapped meshes. The control over shape and size of the element is given bythe mapped meshes.

3.Results and Discussions

3.1 Simulation of various MEMS based cantilevers

Here, the analysis is performed for rectangular, T-shaped, Π-shaped and cone shaped MEMS cantilevers. The simulations are carried out considering the cantilevers by piezoresistivity materials (n-si, p-si (single crystalline), n-si, p-si (polycrystalline)) having the young's modulus of 160×10^9Pa, Poisson's ratio of 0.22 and density of 2320kg/m^3.

S.No.	Parameter	Value
1.	Young's Modulus	160×10^9Pa
2.	Poisson's Equation	0.22

3.	Density	2320

Table 1: Piezoresistive Properties of cantilevers

3.1.1 Rectangular Shape

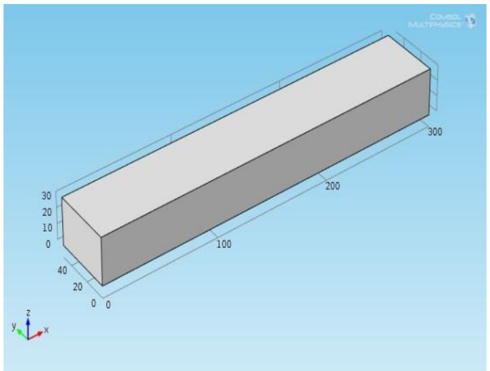

Fig 1: Design of rectangular MEMS cantilever

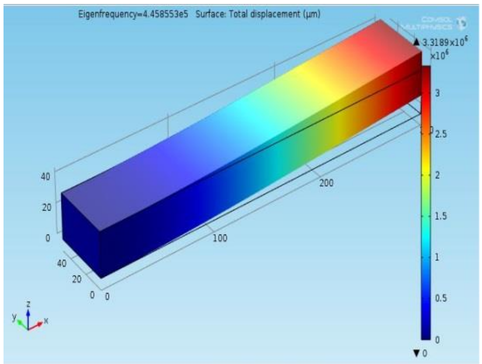

Fig 2: Displacement of a rectangular MEMS Cantilever

Figs. 1&2 Shows the rectangular shaped MEMS based cantilever. The rectangular MEMS based cantilever is performed with the geometric parameters as width=300µm, length=50µm and thickness=20µm and the total displacement of MEMS cantilever is simulated by using COMSOL Multiphysics.

3.1.2 T-shapedcantilever

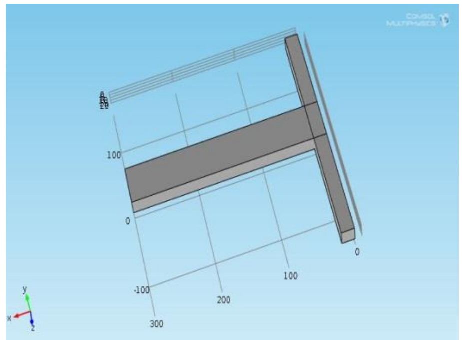

Fig 3: Design of T-shaped MEMS

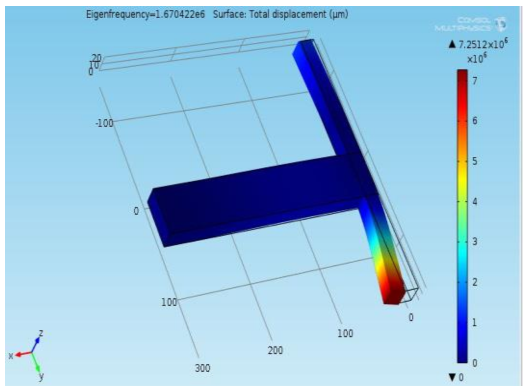

Fig 4: Displacement of T-shaped MEMS cantilever

Figs. 3&4 show the T-shaped MEMS based cantilever. The T-shaped MEMS based cantilever is performed with the geometric parameters as base width W=300μm, length, L=50μm and thickness t=20μm with the paddle width W=20μm and length L=300μm and the total displacement of MEMS cantilever is simulated using COMSOL Multiphysics.

3.1.3 π -Shaped

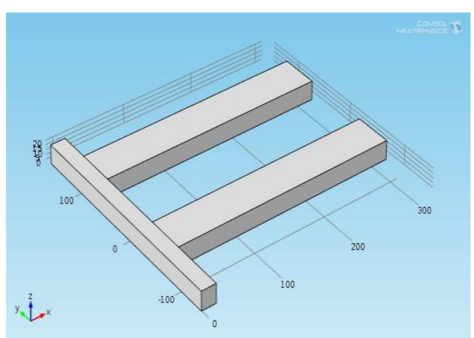

Fig 5: Design of Π-shaped MEMS cantilever

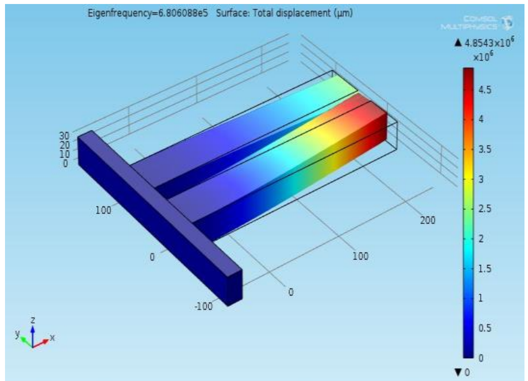

Fig 6: Displacement of Π-shaped MEMS cantilever

Figs. 5&6 show the parabola shaped MEMS based cantilever. The Π-shaped MEMS based cantilever is performed with geometric parameters as width W=300μm, length L=50μm and thickness t=20μm with the paddle width W=30μm and length L=300μm and the total displacement of MEMS cantilever is simulated using COMSOL Multiphysics.

3.1.4 Cone Shaped

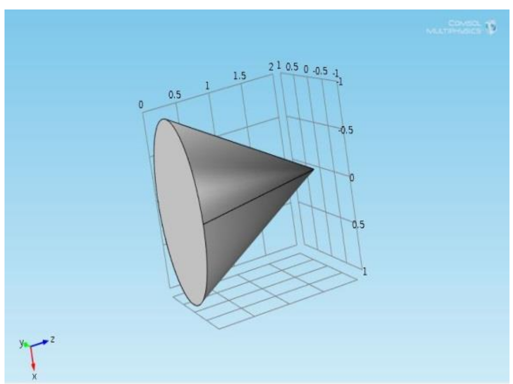

Fig 7: Design of a cone shaped MEMS cantilever

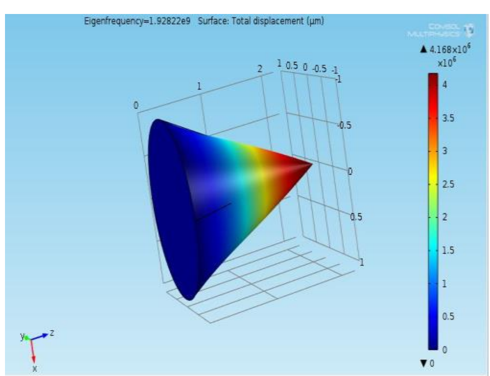

Fig8: Displacement of cone shaped MEMS cantilever

Figs. 7&8 show the cone shaped MEMS based cantilever. The cone shaped MEMS based cantilever is performed with the geometric parameters as radius=1μm and height=2μm and the total displacement of MEMS cantilever is simulated using COMSOL Multiphysics.

As per the analysis performed for different shapes of MEMS cantilever is given in the table-2. Of the different shapes of the MEMS cantilevers, the T-shaped MEMS cantilever produces the maximum displacement of 7.2512×10^{6}.

S.No.	MEMS cantilevers	Eigen Frequency	Total Displacement
1.	Rectangular	4.458553×10^{5}	3.3189×10^{6}
2.	T-Shaped	1.670442×10^{6}	7.2512×10^{6}
3.	Π-Shaped	6.806088×10^{5}	4.8543×10^{6}
4.	Cone Shaped	1.92822×10^{9}	4.1680×10^{6}

Table 2: Total Displacements of various MEMS cantilevers

4. Conclusion

The MEMS cantilever sensors are mostly used as physical, chemical and biological sensors in various applications. Of all MEMS based cantilever sensors biosensors plays the major role in MEMS. Here, the T-shaped MEMS cantilever with base width W=300μm and length L=50μm and thickness t=30μm, for a paddle length L=300μm and width W=20μm and thickness t=30μm produces the total displacement of 7.2512×10^{6}. The simulation is executed using COMSOL Multiphysics and the variation of rectangular, T-shaped, Π-shaped and cone shaped MEMS cantilever is studied by considering the piezoresistive materials. Further the high sensitivity and the displacement can be obtained by introducing the stress concentration region (SCR).

Acknowledgement

"The authors would like to thank NPMASS scheme for establishing national MEMS design center in AP, which is supported by IISC Bangalore for providing the necessary design facilities".

References

[1].T. Thundat, P. I. Oden, and R. J.Warmack, "Microcantileverssensors,"Microscale Thermophysical Engineering, volume 1, pp. 185–199, 1997.

[2].V. M. Reddy, G.V. S. Kumar, "Design and Analysis of Microcantilevers with various shapes using Comsol Multiphysics Software", IJETAE, Volume.3 Issue 3, March 2013.

[3].S Arora, Sumati, A Arora, P.J George, "Design of MEMS based Microcantilevers using Comsol Multiphysics", Applied Engineering Research, Volume.7 Issue 11, 2012.

[4].Ibrahim Ethem SACU, Mustafa ALCI, "Design of basic piezoresistive microcantilever biosensor", IU-JEE, Vol.13, 2013.

[5].TanviChandel, Balwinder Singh, "The state of art survey on microcantilevers for MEMS Devices", IOSR-JEEE, Vol.9, Issue 5, 2014.

[6].H.F. Hawari, U. Hashim, Y. Wahab, M.T. Azmi,Shakaff, S. Johari, , A.Y.Md."Design and analysis of various microcantilevers shapes for MEMS based sensing", ScieTech 2014, IOP Publishing.

[7].Rudresha K J, Girisha G K, "Microcantilevers Optimization for MEMS Biosensor Applications", IJECER, Vol.1 Issue 1, June 2013.

[8]M.G.G.JithendraPrasad, Syed Shameemm, "Design and Analysis of Micro-CantileverBased Biosensor for Swine Flu Detection"IJECE, *Vol. 6, No. 3, June 2016.*