DESIGN AND SIMULATION OF HIGH SENSITIVITY MEMS CANTILEVERS

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Abstract

This paper presents design, analysis and simulation of MEMS based micro cantilevers of various shapes, to analyze their sensitivity. The analysis is done using FEM Tool (Comsol Multiphysics 4.3).The analytical model of Cantilevers of various shapes are analyzed and the construction process is discussed in this paper. The change in sensitivity with the change in shape is observed.

Keywords: *MEMS, Cantilever, Sensitivity.*

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1. INTRODUCTION

Cantilever is one which is fixed at one end and other end bends when a force is applied or due to an attatched load. These Micro cantilever beams are highly used in fabricating Chemical and biosensors for detection of explosives, harmful chemical and biological species. These Micro cantilevers have a wide range of applications in defense and medical fields. Micro cantilever based sensors have two types of application modes widely used in sensing applications: i) static mode, where the cantilever bends due to the application of force or due to an attached load. ii) Dynamic mode, where the resonant frequency is monitored which shifts due to the mass getting attached to the structure. The difference in resonance is correlated to amount of mass on cantilever or force applied to it.

Micro cantilever sensors can be operated in air, vacuum or in liquid. To serve as a sensor cantilever is coated with the sensing layer; [3]it should be able to collide with target molecules. When the target molecules start colliding with sensing layer the weight of the analyte increases and as a result stress on cantilever increases and cantilever bends. These interactions may be physical, chemical or both. By using different materials for functionalisation layer; this can be used in wide range of applications.In this Paper we designed Rectangular, Triangular, Pi shape and T-shape Cantilevers with high Sensitivity.

1.1 Optical Beam Deflection

This is the simplest way to measure micro cantilever deflection[3]. In this method, a laser diode is focused at the free end of the micro cantilever. The reflected beam is monitored using position-sensing detector (figure: 1). Displacement of the order of 0.1 nm can be measured by this technique.

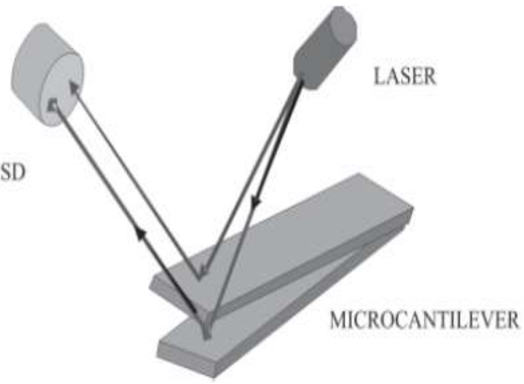

Fig: 1 Position Sensing Detector

2. DESIGN CONSIDERATIONS

For Micro cantilever to operate in both static and dynamic modes dimensions of the structure play an important role so cantilevers of different shapes and different geometries were designed with different thicknesses and their sensitivities were measured.

In this paper rectangular,T shape and pishape cantilevers were designed .For rectangular cantilever analysis is done for different dimensions ,we found that rectangular cantilever with l=70um,w=9um and h=1um has maximum deflection. For this Silicon is used as substrate which has a density of 2329kg/m^3,Young's modulus of 170e^9 Pascal and possions ratio of 0.28.

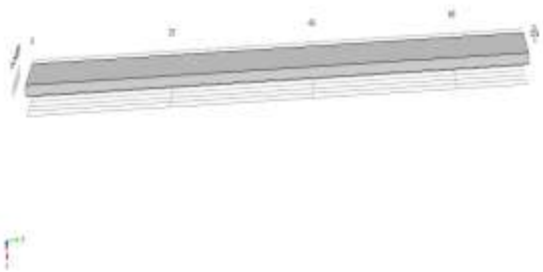

Fig: 2 Rectangular Cantilever with L=70um, w=9um, h=1um

Fig: 3 Rectangular cantilever with sio2 layer with a thickness of 0.5um

Mainly two equations are important to understand the behavior of MEMS Cantilevers[2]. First one is stoney's equation, Here δ,deflection at the end of the cantilever is directly proportional to stress σ ,L is the length of the Cantilever ,T is thickness of cantilever and E is the Youngs modulous of the material.

$$\delta = \left(\frac{3\sigma(1-\vartheta)}{E}\right) * \left[\frac{L}{t}\right]^2$$

$$k = \frac{F}{\delta} = EWt3/4L3.$$

The second equation is related to dimensions of material. Here K is the spring constant of the material.F is the Force, E is the Young's Modulus of Material.W is width of Cantilever, Deflection of the material is inversely proportional to thickness of material as thickness increases deflection of cantilever decreases. Spring Constant also depends on dimensions of the cantilever. In all the shapes si is used as substrate and sio2 is used as layer. From the stoney's equation it is clear that deflection at the end of the Cantilever "δ" is inversely proportional to Young's modulus of the material "E".So compared to SiN_3,SiO2and polysilicon sio2 gives more deflection. The following table 1 gives details about the material

Table1: Material Properties

Material Properties	Material Name	
	Si	Sio_2
Young's Modulus(pa)	$170e^9$	$70e^9$
Density(Kg/m^3)	2329	2200
Poisson's ratio	0.28	0.17

3. SIMULATION RESULTS:

3.1 Rectangular Cantilever

Rectangular cantilever is designed using Si substrate with dimensions of l=70um, w=9um, t=1um.The following is the deformed shape when stress is applied on it. In all the shapes one end is fixed. The deflection at the end of cantilever is shown in figure 4

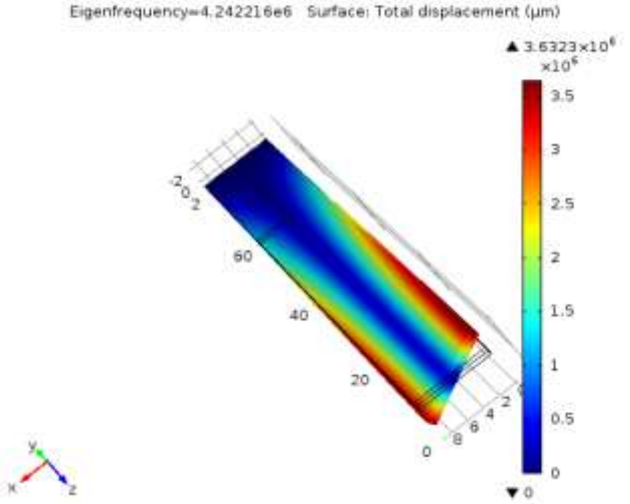

Fig: 4

3.2 Pi-Shape

In pi-shape all the three segments are taken as l=70um, b=9um, h=1um.The deflection at the end of cantilever is shown in figure 5.

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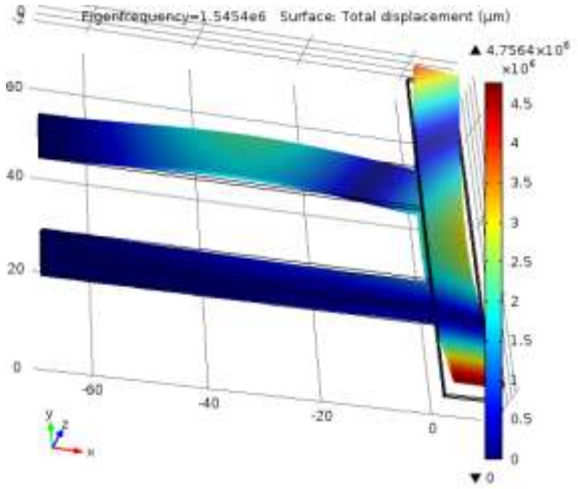

Fig: 5

3.3 T-Shape

In T-shape both paddles are of same size l=70um, w=9um, t=1um.The deflection at the end of cantilever is shown in figure 6.

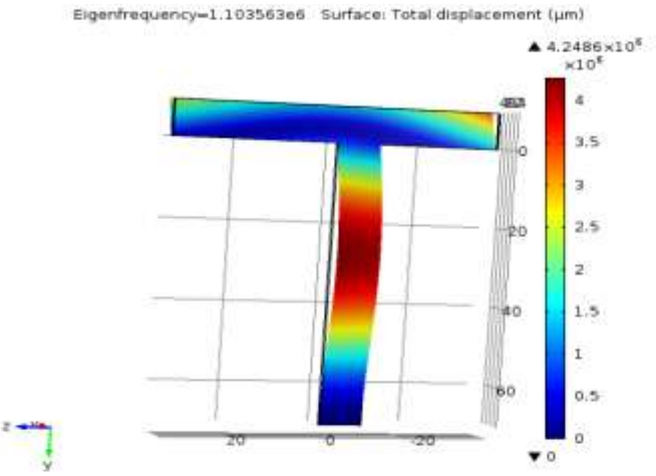

Fig: 6

Table 2: Comparison of Sensitivities of Cantilevers of different Shapes

Shape of Cantilever	Deflection in um
Rectangular	$3.6*10^6$
T-Shape	$4.24*10^6$
Pi-Shape	$4.7*10^6$

4. CONCLUSION

Cantilevers of different shapes have been designed and their sensitivity is analyzed under uniform conditions of stress and found that Pi-Shape Cantilever has high Sensitivity. The Sensitivity of the material changes with change in geometry and material properties, so one can chose definite geometry and definite material based on the site of application to be used. As the dimensions of the Cantilever decreases Sensitivity increases but fabrication of such smaller structures becomes complex. So using Cantilevers of different Geometry complexity of fabrication can be reduced.

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