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Design of Mems Based Rectangle Cantilever Using Comsol

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ABSTRACT : This paper presents the design and simulation of MEMS based rectangular cantilever made up of polycrystalline silicon using FEM (COMSOL MULTIPHYSICS).The clamping is provided at one end while the load is applied on the other end. The effect of change in length, width and thickness is studied.
Keywords: MEMS, FEM, Polycrystalline silicon

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I. INTRODUCTION

Research in MEMS is an interdisciplinary activity involving various engineering disciplines like mechanical, materials science, electronics and instrumentation. It is an integration of mechanical and electronic systems on the same chip at micro-scales. The MEMS systems are replacing other conventional systems because of their unique advantages like, IC technology with integrated multi-functioning, precision and improved performance, batch fabrication leading to reduced manufacturing costs and time. Miniaturization which results in portability, ruggedness, low-power consumption, developed on a mass scale, easily maintained and repaired, and less harmful to environment. The researchers of MEMS focus on different fields like design, MEMS materials, processing, fabrication, testing & calibration. Microcantilevers are popular as sensing elements in bio-MEMS applications. A bio-MEMS sensor consists of a bio receptor and transducer. A biosensor utilizes chemical and biological reactions to detect and quantify a specific analyte. A biosensor, which uses mass based transduction, is called a mass sensor. Mass sensors are used to detect extremely small masses of biomolecules such as proteins, viruses or even parts of DNA in the range of femtograms (10-15 gm.) to zeptograms (10-21 gm.). In all applications one of the key points for a successful solution to the problem is the availability of a detector with high sensitivity, selectivity and reproducibility to the chemical and biochemical parameters of interest. The sensitivity or minimum detectable mass depends on the ratio between the mass and the resonant frequency of the beam. Generally, the resonant frequency increases and the mass decreases when the dimensions are decreased. Thus, a straightforward approach to enhance sensitivity is to decrease the dimensions of the beam. In microcantilever biosensors, the cantilever transduces the recognition event from its receptor - immobilized surface (for example, a DNA probe and an antigen or antibody) into a mechanical response (for example, static displacement and resonance frequency). Microcantilever provide an alternative technology that overcomes this limitation. One face of the cantilever is coated with a functionalizing layer, which is highly specific to a particular analyte. This layer acts as the sensing element. When the cantilever is brought into contact with the corresponding analyte, the interaction between the functionalizing layer and the analyte causes a change of free energy, which results in a change of surface stress. The difference between the stresses of the functionalized and non-functionalized layers causes the cantilever to deflect. Thus, the cantilever transduces a chemical reaction into a mechanical response. Measurement of this deflection provides a rapid indication of the analyte concentration.

II. DESIGN PARAMETERS

When the molecules are deposited on the surface of a cantilever they not only exert some mass but also generate a surface stress due to interaction between the molecules and the cantilever surface. To measure the deflection due to this surface stress stoney,s formula is generally used which is given by

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

Where,

σ is the maximum stress applied on beam,
v is the Poisson's ratio of the material
L is the cantilever length,
E is the young's modulus of the material

t is the thickness of the beam.
A rectangular cantilever is designed. The load is applied on the free edge of the cantilever. The material used for simulation is polycrystalline silicon. The dimensions and the material properties are given in table below.

Dimensions	**Value**
Length	**200μm**
Width	**100μm**
Thickness	**2μm**
Young's Modulus	**160GPa**
Poisson's Ratio	**0.22**
Density	**2320kg/m^3**
Load applies	**10pN**

The fig.1. Shows the view of microcantilever using Structural mechanics application mode of MEMS module of COMSOL multiphysics.

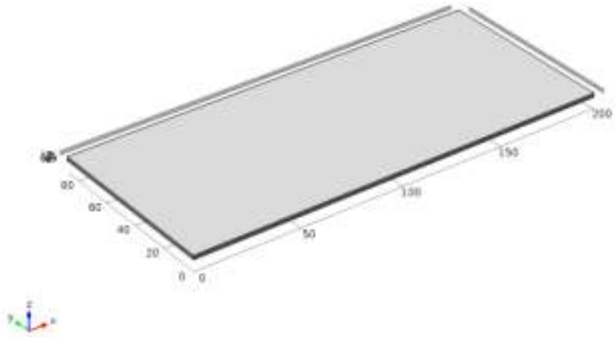

Fig. 1.

III. SIMULATION RESULTS

The rectangular cantilever considered and its FEM simulation using COMSOL Multiphysics is shown in fig.2.

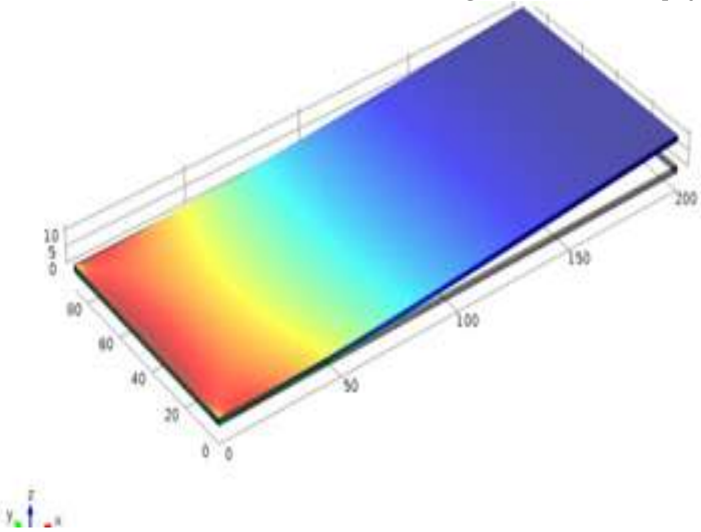

Fig. 2.

<u>Effect of Change in Length</u>

The effect of change in length is discussed. As seen from equation, the deflection is varying proportionally with the length of the cantilever as shown in table 1. It can be observed from table that even though the deflection is increasing with the increase in the length the stiffness is decreasing.

Table 1

Length (µm)	Deflection(nm)	Sensitivity	Stiffness
20	0.0138461538	23.43195266	0.10985
40	0.0553846154	46.86390533	0.01373125
60	0.1246153846	70.29585799	0.004068519
80	0.2215384615	93.72781065	0.001716406
100	0.3461538462	117.1597633	0.0008788
120	0.4984615385	140.591716	0.000508565
140	0.6784615385	164.0236686	0.000320262
160	0.8861538462	187.4556213	0.000214551
180	1.121538462	210.887574	0.000150686
200	1.384615385	234.3195266	0.00010985
220	1.675384615	257.7514793	8.25319E-05
240	1.993846154	281.183432	6.35706E-05

The graph for length vs stiffenss is shown in fig.3. It is observed that the length of the cantilever is increased, the sensitivity is increasing but, the stiffness is reducing simultaneously. Thus, an optimum condition has to be reached where the length has to be fixed to an optimum condition. This will be achieved after the FEM studies of varying with thickness and width of a cantilever.

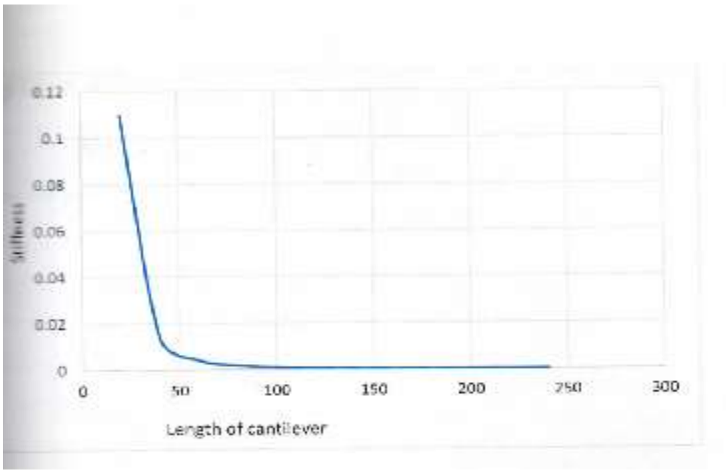

Fig. 3.

Effect of Change in Width

If the width is increasing sensitivity and stiffness both are increasing. Thus the width is optimized with respect to length and thickness. The width of the cantilever is maintained half of the length of the cantilever it tends to gives maximum sensitivity and thickness. The change in width is shown in table 2.

Table 2

Width (µm)	Deflection(nm)	Sensitivity	Stiffness
20	0.124615385	21.0887574	0.00027462
40	0.498461538	42.17751479	0.00054925
60	1.121538462	63.26627219	0.00082387
80	1.993846154	84.35502959	0.00010985
100	3.115384615	105.443787	0.00013731
120	4.486153846	126.5325444	0.00016477
140	6.106153846	147.6213018	0.00019223
160	7.975384615	168.7100592	0.0002197
180	10.09384615	189.7988166	0.00024716
200	12.46153846	210.8875674	0.00027462
220	15.07846154	231.9763314	0.00030208
240	17.94461538	253.0650888	0.00032955

The graph for Width vs stiffenss is shown in fig.4.

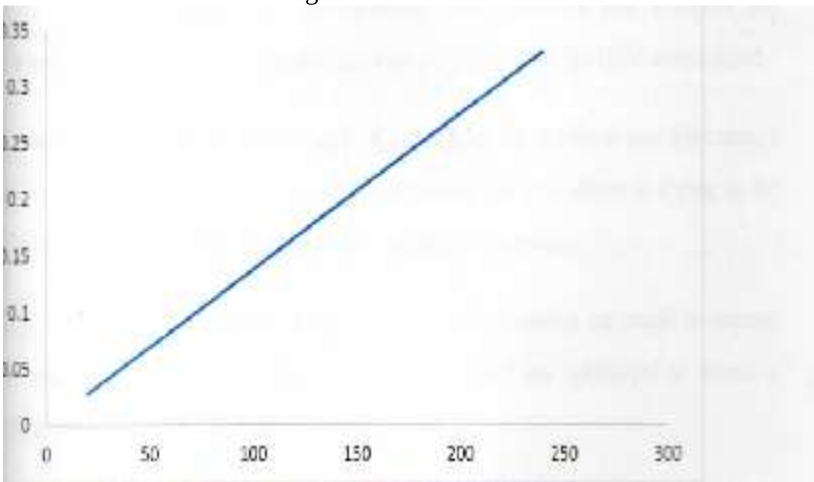

Fig.4.

Effect of Change in Thickness

As the thickness of the cantilever is increasing the sensitivity decreases but stiffness increases. The change of thickness is shown in table 3.

Table 3

Thickness (μm)	Deflection(nm)	Sensitivity	Stiffness
0.35	4.775510204	0.808163265	0.00001715
0.40	3.65625	0.61875	0.0000256
0.45	2.888888889	0.488888889	0.00003645
0.50	2.34	0.396	0.00005
0.55	1.933884298	0.327272727	0.00006655
0.60	1.625	0.275	0.0000864
0.65	1.384615385	0.234319527	0.00010985
0.70	1.193877551	0.202040816	0.0001372
0.75	1.04	0.716	0.00016875
0.80	0.9140625	0.1546875	0.0002048
0.85	0.809688581	0.137024221	0.00024565
0.90	0.722222222	0.122222222	0.0002916

The graph for Thickness vs stiffenss is shown in fig.5.

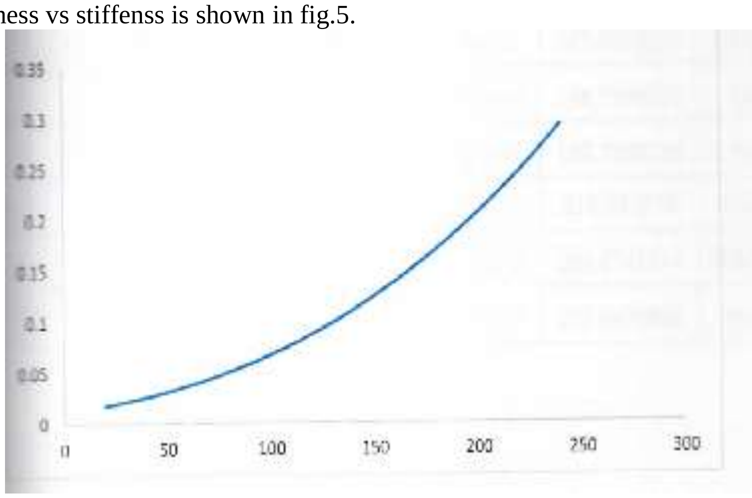

Fig.5.

IV. CONCLUSION

The MEMS based rectangular cantilever has been designed and the deflection properties have been studied. This cantilever application is in determining VOC's. The senstivity of a sensor is very crucial and this is dependent on the dimensions of the cantilever.

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