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# Study of Enhanced Mass Detection Using Cantilever Beam

**J. Gayathri[1], B. Rajesh Kumar[2]**

Department of Electronics & Instrumentation Engineering, GITAM University, Vishakhapatnam, Andhra Pradesh, India

**Abstract:** ***Cantilever, one of the most common forms of MEMS. Using Cantilever one can make highly sensitive sensor. Moreover to design a mass based sensor sensitivity plays a vital role. In this paper, micro-cantilever was designed whose sensitivity was enhanced. The strengthened sensor is now used to detect minimal changes in mass. Study was carried out in experimental and analytical analysis. Experimental analysis was executed using COMSOL MULTIPHYSICS (simulation software). This paper demonstrates the use of Stoney's formula for analyzing the analytical variations of micro-cantilever sensor. Obtained analytical and experimental outcomes of the sensor in both static and dynamic modes were compared.***

**Keywords:** Cantilever, COMSOL, Stoney's Formula, Sensitivity

## 1. Introduction

Working operation of MEMS sensors is generally based on mechanical motion and deformity of their micro machined components, such as single-clamped suspended beams like cantilevers, double clamped suspended beams like bridges. Cantilevered beams are the most present structures in the field of microelectro mechanical systems (MEMS). The use of cantilever based sensors is improving these days due to its high sensitivity and easy fabrication. The sensitive cantilever sensor can be used to detect minimum changes in the target molecule. Mass in micro range can be detected using micro cantilever so that they can be used for cancer cell detection, monitoring food supply etc. In this paper, the sensitivity of the sensor was enhanced and further the sensor was used to detect changes in applied mass in both static and dynamic mode.

## 2. Sensitivity Analysis

The sensitivity of a sensor always plays a key role in design parameter. To increase the overall sensitivity of micro cantilever biosensors, both the deflection and resonant frequency of the cantilever should be increased. The overall sensitivity of a micro cantilever biosensor depends on the design sensitivity of the cantilever and the measurement sensitivity of the deflection measurement system. A sensitive cantilever design should efficiently convert the bimolecular stimulus into a large cantilever deflection. The improvisation of sensitivity mainly depends on two factors. One is to increase the cantilever deflection by changing the shape of the cantilever. Therefore, dimensions and geometry have modified to increase the sensitivity. Deflection depends on length and thickness of the cantilever so the two parameters are varied to increase the sensitivity of the sensor. The other factor depends on the material taken in to consideration. As we change the material its young's modulus changes and sensitivity depends on it. In order to analyze it, three materials have taken in to consideration. They are Silicon, Silicon di-oxide, Silicon nitride.

**Table 1:** Chosen Materials

| *Sl. No* | *Material* | *Young's Modulus(Gpa)* |
|---|---|---|
| **1** | Silicon Di-oxide($SiO_2$) | 70 |
| **2** | Silicon(Si) | 170 |
| **3** | Silicon Nitride($Si_3Ni_4$) | 250 |

As different materials were applied corresponding deflection was calculated. The deflection for $SiO_2$ is more which implies it shows more sensitivity towards target molecule.

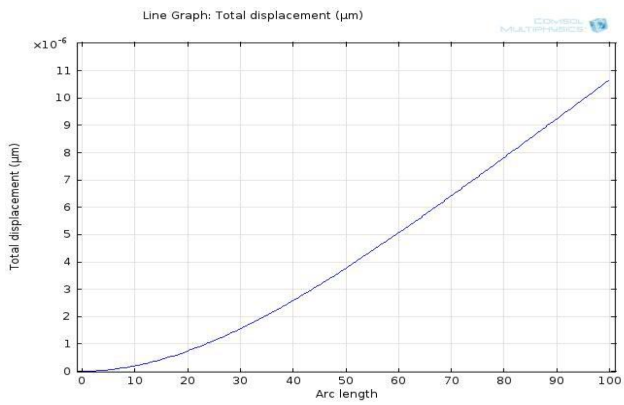


**Figure 1:** Deflection graph for Silicon Di-oxide Material

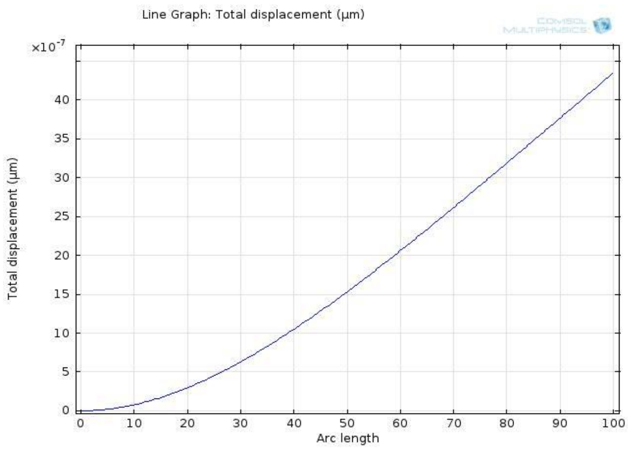


**Figure 2:** Deflection graph for Silicon Material

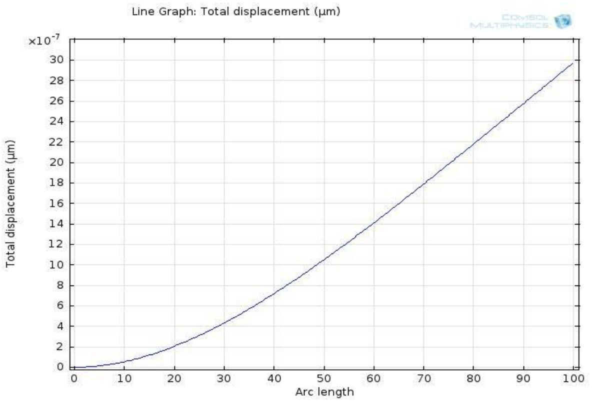


**Figure 3:** Deflection graph for Silicon Nitride Material

## 3. Analytical Analysis

Two equations are key to understand the behavior of MEMS cantilevers. The first is Stoney's formula, which relates cantilever end deflection ‘d’ to applied stress ‘σ’:

$$\mathbf{d} = \frac{3\sigma(1-\upsilon)}{E}\left(\frac{L}{t}\right)^2 \ldots\ldots \text{(1)}$$

Where ‘υ’ is Poisson's ratio, ‘E’ is Young's modulus, ‘L’ is the beam length and ‘t’ is the cantilever thickness. The second is the fundamental resonant frequency ‘f’ of a rectangular cantilever is given by

$$\mathbf{f} = \frac{1}{2\Pi}\sqrt{\frac{E}{\rho}\frac{t}{L^2}} \ldots\ldots \text{(2)}$$

Where ‘ρ’ is density of the material, ‘E’ is Young's modulus, ‘L’ is the beam length and ‘t’ is the cantilever thickness. Micro-cantilever beam geometry is an important parameter where one has to use the optimized values. Molecules adsorbed on a micro-cantilever cause vibrational frequency changes and deflection of the micro-cantilever. Another way of detecting molecular adsorption is by measuring deflection of the cantilever due to adsorption stress on just one side of the cantilever. Depending on the nature of chemical bonding of the molecule, the deflection can be up or down.

**Table 2:** Chosen Material Properties

| *Sl. No* | *Material properties* | *Values* |
|---|---|---|
| 1 | Young’s modulus | 170e^9 pa |
| 2 | Applied stress | 10N/m² |
| 3 | Poison’s ratio | 0.28 |

**Table 3:** Cantilever Deflection Readings of Varying Length

| *Sl. No* | *Length(µm)* | *Deflection(nm)* |
|---|---|---|
| 1 | 100 | 12.98 |
| 2 | 90 | 10.51 |
| 3 | 80 | 8.30 |
| 4 | 70 | 6.36 |
| 5 | 60 | 4.67 |
| 6 | 50 | 3.24 |
| 7 | 40 | 2.07 |
| 8 | 30 | 1.16 |
| 9 | 20 | 0.51 |
| 10 | 10 | 0.12 |

Table(3) shows the measurement of cantilever beam deflection using equation (1) by varying length (L) and keeping thickness (t) constant as 2µm. Table (1) shows the material properties used to find the deflection. The below table (4) shows the measurement of cantilever beam deflection using equation (1) by varying thickness (t) and keeping length (L) constant as 100µm.

**Table 4:** Cantilever Deflection Readings of Varying Thickness

| *Sl. No* | *Thickness(µm)* | *Deflection(nm)* |
|---|---|---|
| 1 | 2 | 12.98 |
| 2 | 1.5 | 23.07 |
| 3 | 1 | 51.93 |
| 4 | 0.5 | 207.7 |

Vibrational frequency change of micro-cantilever is calculated using equation (2). The below table (5) shows the calculated results of change in frequency using equation (2) by varying length (L) and keeping thickness (t) constant as 2µm.

The below table (6) shows the measurement of cantilever frequency using equation (2) by varying thickness (t) and keeping length (L) constant as 100µm.

**Table 5:** Resonant Frequency Shift Readings of Varying Length

| *Sl. No* | *Length(µm)* | *Frequency(µHz)* |
|---|---|---|
| 1 | 100 | 7.74 |
| 2 | 90 | 9.55 |
| 3 | 80 | 12 |
| 4 | 70 | 15.7 |
| 5 | 60 | 21.5 |
| 6 | 50 | 30.9 |
| 7 | 40 | 48.3 |
| 8 | 30 | 86.01 |
| 9 | 20 | 193.53 |
| 10 | 10 | 774 |

**Table 6:** Resonant Frequency Shift Readings of Varying Thickness

| *Sl. No* | *Thickness(µm)* | *Frequency(KHz)* |
|---|---|---|
| 1 | 2 | 7.74 |
| 2 | 1.5 | 5.805 |
| 3 | 1 | 3.8706 |
| 4 | 0.5 | 1.935 |

## 4. Experimental Analysis

Experimental analysis were executed in comsol multiphysics. Comsol software provides platform to perform analysis in different physics streams. Simulation in comsol involves several steps which includes selecting physics,defining geometry,defining materials,setting up physics,meshing,simulation,analysis of results.

By selectig required physics for MEMS followed by defining geometry a micro-cantilever can be formed. In this paper si(c) is considered as the material on the surface of the cantilever.A cantilever is a beam supported on only one side.On the surface of the beam force can be applied.This can be attained by setting up physics.

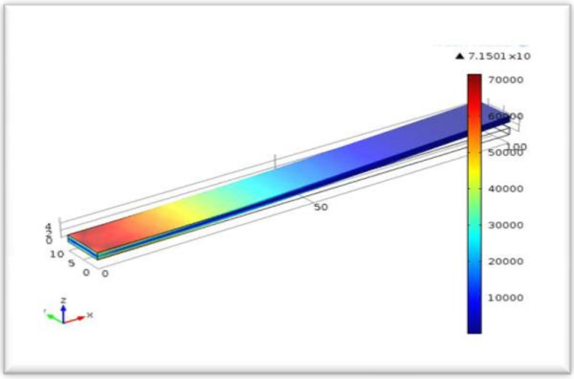


**Figure 4:** View of the Design

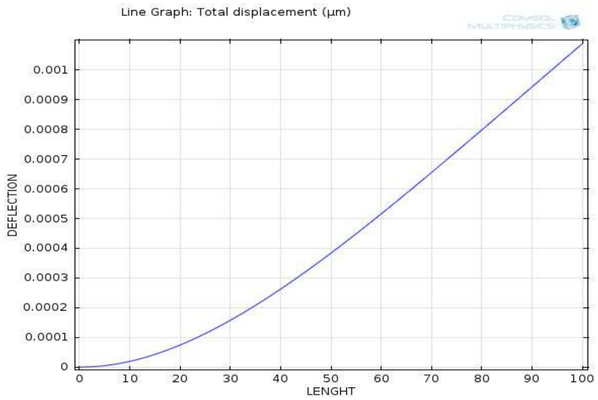


**Figure 5:** Cantilever Deflection Measurement

Fig.5 describes the value at which cantilever deflects when the length is 100(μm) and thicness(2μm).Besides one can obtain results at different dimensions and examine cantilever deflection.

Fig.6 exibits frequency at different modeswhen the length is at 100(μm) and thickness 2(μm). The frequency has to be set at certain range. Aforesaid in deflection one can obtain results at different dimensions and study frequency change of cantilever beam.

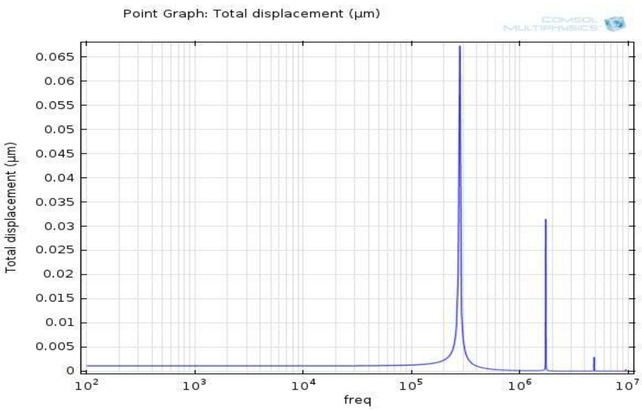


**Figure 6:** Frequency Response Curve

## 5. Conclusion

From this paper we have withdrawn the below outcomes. It was observed that as length and thickness varies, the deflection and frequency of cantilever beam alters. At specific applied stress we have observed changes in deflection and frequency as we change stress applied, the following changes were distinguishable.

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