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# Modelling and Simulation of Cantilever Sensor Using COMSOL Multiphysics

**R.S.Shaik shavali Malik**
M.Tech Student,
Department of Electronics and Communication Engineering,
Madanapalle Institute of Technologyand Science,
Madanapalle, India.

**V. Sai Kumar**
Associate Professor,
Department of Electronics and Communication Engineering,
Madanapalle Institute of Technology and Science,
Madanapalle, India.

**Sravanan kumar Reddy**
Department of Electronics and Communication Engineering,
Madanapalle Institute of Technology and Science,
Madanapalle, India.

**Logesh kumar S**
Asst Professor,
Department of Electronics and Communication Engineering,
Kumaraguru College of Technology, Coimbatore,
Tamil Nadu, India.

## Abstract:

This paper presents the design ofMEMS based micro-cantilevers.The microcantilever beam are made up of silicon substrate with gold-coated film. The simulations results comprise of stress, displacement, and Eigen frequency measurements, These micro-cantilevers were usefor many applications such as chemical sensors, bio sensors.

## Keywords:

Finite Element Method, MicroElectroMechanicalSystems(MEMS), COMSOL Multiphysics, Cantilever.

## INTRODUCTION:

A cantilever is rectangular bar which is fixed at one end and the other end of it is free to move when it got experiences some pressure or any stress. A Microcantilever sensor can be used as chemical,physical, or biological sensor by detecting the changes in deflections or vibrational frequency of a cantilever. These deflection of micro cantilever varies when a specific mass of an analyte is adsorbed on its surface. These microcantilevers are in microns and may be designed in different shapes. A rectangular micro-cantilever is show below in figure 1.

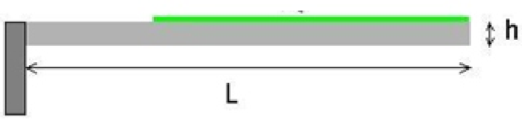


Figure 1. Basic Cantilever structure.

Micromechanical cantilevers are the most promising biosensors. Cantilever - based sensing is based on a significant deflection of the cantilever beam due to induced surface stress, Flow, added mass, Pressure or the transfer of heat chimps as indicated in figure 2.

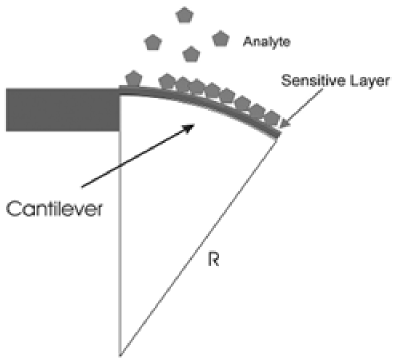


Figure 2: cantilever's deflections after experiencing load.

## CANTILEVER:

A structure with one end will be fixed end and the other side is allowed to move when it encounters any force these are defined as cantilever.

A Microcantilever is a device that could be utilized as physical, biological, or chemical sensor based on the changein cantilever's vibrational frequencies.

This deflections of microcantilever changes when a particular mass got adsorbed or deposited on its surface

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## CANTILEVER BEAM DESIGN PARAMETERS:

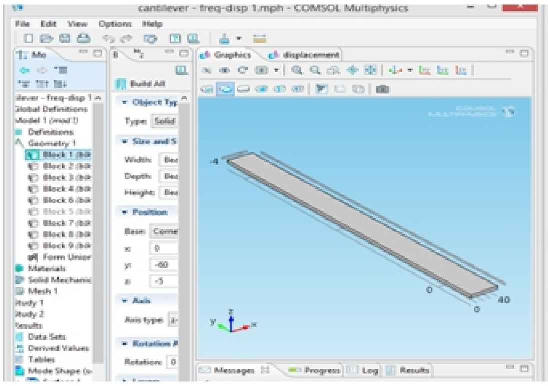


**Figure 3: A rectangular cantilever beam designed using COMSOL**

The suggested cantilever sensor is modeled to be highly sensitive for the detectionof physical changes or movements over the human body surface. The sensitivity of thestatic mode cantilever is best explained in terms of the spring constant as given by the following equation.

$$\text{Spring constant } k = \frac{E.w.t^3}{4.L^3} \qquad (1)$$

where, E - Young's Modulus of the piezoelectric
w - Width of the cantilever
t – Thickness of the cantilever
L – Length of the cantilever

Stoney's equation relates the stress caused overthe cantileverand the so produced deflection as below

$$\Delta g = \frac{E.\Delta h.t^2}{(1-v).L^2} \qquad (2)$$

where, Δg –Differential stress
Δh – Deflection of the cantilever
v – Poisson's ratio

The physics employed is Solid Mechanics.The total force is being applied to the cantilever is correlated with the number of analyte molecules attaching to the gold surface of cantilever. The dynamic working mode of the cantilever resonance frequency (f) in the is given by:

$$f = \frac{1}{2\pi}\sqrt{\frac{k}{m_{eff}}}$$

Where, 'k' is the spring constant,
'meff'effective or dynamic mass.

The Eigen frequency and stationary study were performed in order to get a best resulted cantilever. The result verifies the Hooke's law which states that stress is directly proportional to strain. Mathematically,
F= - kx
Here, x is displacement in Z-direction,
F is restoring force,
k is spring constant.

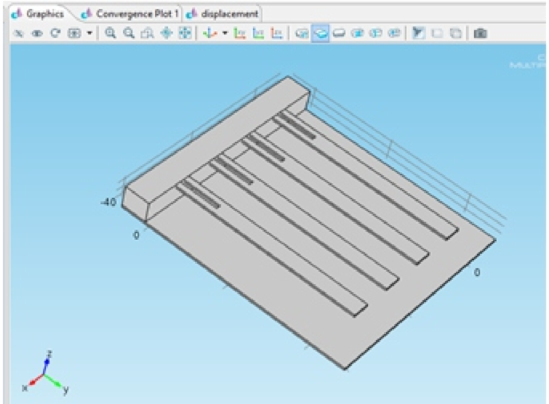

**Figure 4 Proposed Model.**

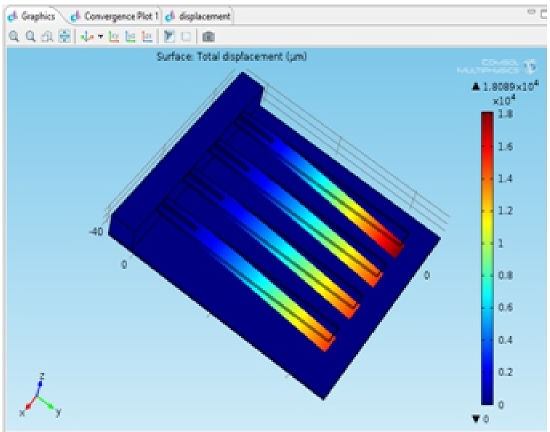


**Figure 5: Microcantilever model after simulation Using COMSOL.**

### Table 1 Material properties

| Parameters | Materials | |
|---|---|---|
| | Si | $SiO_2$ |
| Young's Modulus (MPa) | $1.30191*10^5$ | $7.0*10^4$ |
| Poisson's Ratio | 0.278 | 0.17 |

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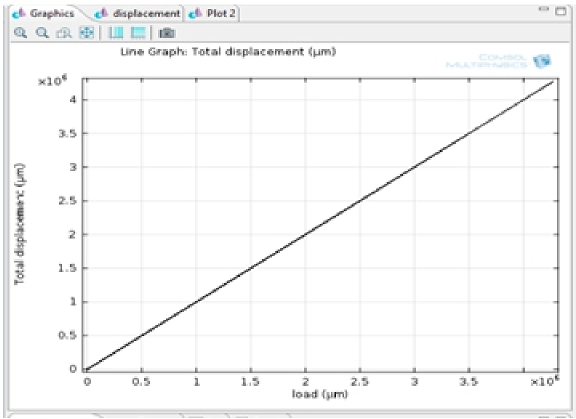
## RESULTS:

Recent advancement in MEMS technologiesresulted in the latest integrated circuit (IC) and also complementarymetaloxidesemiconductor (CMOS) technologies in producing extremely small cantilevers array. $SiO_2$, poly-silicon and Silicon Nitride $Si_3N_4$were used as layer on the Si crystal beam. Hence the graph shows the Displacement vs Load of cantilever designed in micro meters.




Graph 1: Displacement vs Load on cantilever.

## CONCLUSION:

The micro-cantilever array sensorswere having very advantages such as its selectivity towards an analyte, sensitivity towards small concentration. Hence it prove that the micro-cantilever array sensors to be a multipurpose tool in various fields. Hence a MEMS based micro-cantilever array sensor can be used as diagnostic tool, and also for biosensing, chemical sensing.

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