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COUPLED CANTILEVER SENSORS FOR BIO APPLICATIONS-A COMPARITIVE STUDY

*[1&2]N.SIDDAIAH ,[1]G.R.K PRASAD, [2]D.V.RAMA KOTI REDDY, AND [3]Dr. B. MAHENDRAN

[1] *Department of ECE, K.L University, Green Fields, Vaddeswaram-522502, A.P, India*
[2]*Department of Instrument Technology, College of Engineering,Andhra University, Visakhapatnam, A.P, India*
[3]*Associate Professor, Department of Biotechnology, K.L University, Green Fields, Vaddeswaram-522502, A.P, India.*

ABSTRACT

In last decade, arrival of Micro-electromechanical systems (MEMS) have been immense and ever growing. In this paper, we have proposed a new T-shape and disc shape MEMS based triple coupled Cantilever sensors. We have designed and simulated a T-Shape and disc shape MEMS based triple coupled cantilever sensor made up of P-Silicon (Polycrystalline, Lightly doped) .Both coupled sensors have same effective area. The simulation results like displacement, Eigen-frequency, surface stress, temperature, measurements of the both triple coupled cantilever sensors are compared .This paper gives relative study of two different shape coupled micro-cantilevers.

KEYWORDS : **MEMS, T-shape, Disc shape, Eigen frequency, Sensor, Triple coupled cantilever(TCC)**

***N.SIDDAIAH**
Department of ECE, K.L University, Green Fields, Vaddeswaram-522502, A.P, India.
Department of Instrument Technology, College of Engineering,Andhra University, Visakhapatnam, A.P, India

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INTRODUCTION

Micro electro mechanical systems(MEMS) is the technology, which combines various disciplines like electronics, electrical, materiel science and mechanics , as a result, this technology introduces miniaturization[1].In MEMS sensors, actuators and many components are fabricated in one silicon substrate. Cantilever is a mechanical component, its one end is free and other end is fixed and is used widely in medical diagnosis. Due to high sensitivity, throughput the cantilever sensors plays vital role in the detection of target elements[2].The below diagram shows bending of the cantilever due to load, pressure or molecule adsorption. The working principle of cantilever is that the sensor responds mechanically when there is change in external parameters like temperature, load, pressure and molecule adsorption. In this paper the focus is on coupled cantilevers, which is array of cantilevers have many advantages over single cantilevers. The advantages includes mass localization, sensitivity and more adsorption area.

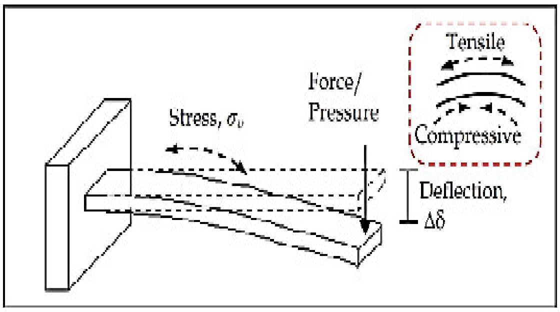

Figure1
static deflection of cantilever

CANTILEVER MODES OF OPERATION

The cantilevers are operated two different modes of operation, static mode and dynamic mode.

Static mode

Static deflection occurs due to surface differential stress. In this mode, the cantilever static deflection is measured caused by external force or by molecular specific binding on the surface[3].

Dynamic mode

Mechanical system responds to external oscillating force with different oscillating amplitudes. When the external force or pressure is applied on one surface of the cantilever the oscillating frequency of this sensor should be changes .This change in frequency is used in the detection of the amount of force or pressure applied. This type of measurement is termed as dynamic mode operation[4].There are different mode measurements like static mode, dynamic mode, heat mode, photo thermal spectroscopy, detection of changes, and detection of magnetic forces. Mainly focused on static and dynamic modes. In the static mode, during the adsorption of molecule or any target particle on the surface layer, there will be stress on the surface layer. In the dynamic mode, according to the molecule or target particle adsorption or desorption from the surface of the cantilever beam, beam gets oscillated at its resonance frequency and is monitored with the changes in the resonance frequency. The response of MEMS cantilever sensor can be monitored by using different methods like piezoelectric, piezo-resistive, optical etc. Cantilever sensors can find its applications in many sensing applications like chemical and biological detections due to their high sensitivity, low cost. In this paper a new shape coupled cantilevers named as T-shape and disc shape coupled cantilevers are designed, simulated and analyzed with the help of MEMS simulation software.

DESIGN PARAMETERS OF CANTILEVER

To understand the behavior of the MEMS cantilever sensors two basic equations are necessary. The first is *Stoney's formula*, which gives the relation between cantilever free end deflection and applied stress σ is

$$\delta_{max} = \frac{PL^3}{3EI}$$

Where, *P* is the applied force, E is young's modulus, L is the beam length and *I* is the moment of inertia
The moment of inertia for rectangular cross-sectional beam is given by

$$I = wt^3/12$$

The resultant deflection is given by

$$\delta_{max} = \frac{4PL^3}{Ewt^3}$$

DESIGN METHODOLOGY

Selecting Physics
In this step, required physics is selected i.e., solid mechanics, thermal stress etc.

Defining geometry
In this step, dimensions and required shape is defined to make coupled cantilevers i.e., T-shape, disc shape etc., with required dimensions in micrometers.

Assigning materials
In this step, material is assigned to make a cantilevers i.e., silicon(c), sio_2, P-silicon, n-silicon etc., with their different properties like young's modulus (E), Poisson's ratio(nu), density (n_d) etc.,

Setting up physics
In this step, required physics is selected i.e., Fixed Constraint, Body load, Point load etc.

Meshing
In order to achieve the results accurately we need to use an element mesh with respect to the dimensions of the elements i.e., Fine, Finer, Coarse, Coarser etc.

Simulation
In this step simulation is done according to the desired specifications.

Post processing* or *Analysis of results
In this step results are analyzed through graphs like point graph, line graph ete.

SIMULATION OF MEMS BASED COUPLED CANTILEVERS

T-shaped coupled cantilever
In coupled cantilevers, three identical cantilevers are coupled with one common fixed beam. Therefore, one cantilever resonant frequency depends on other two cantilevers. The three cantilevers free ends are T-shaped. The various coupled cantilever shapes have different operating modes and different resonant frequencies[5].Basically we consider three modes, in which first mode all three cantilevers are resonates with same resonant frequency and same phase, second mode the lateral cantilevers are oscillates in different phase but the central cantilever stationary, but in third mode the middle cantilever oscillates out of phase with the lateral cantilevers. The second mode is used to detect biological molecules. In this mode, when any biological substance is deposited on the surface of the middle cantilever then immediately lateral cantilevers starts oscillations[5].If the mass of the biological substance is increased on the middle cantilever then the oscillation amplitude increases in lateral cantilevers. Here, the modelling is performed for T-shape triple coupled cantilever and disc shaped triple coupled cantilevers.

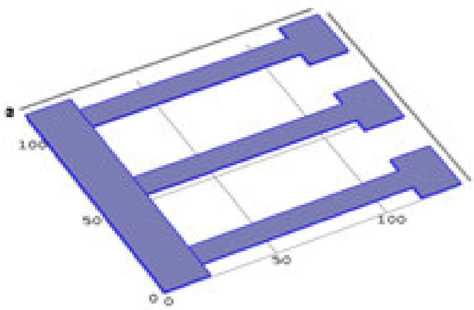

Figure2
Schematic diagram of T-shape TCC

Finite element method
The name finite element method is meant to suggest the technique; we apply all problems. The whole geometry is divided into smaller sub regions. The idea is we are going to use simple approximation method. We measure the computation of small region and to integrate all sub regions to get whole geometry computation results[14]. As the bio-sensing entities are highly sensitive, requires and equivalent coordinating devices as bio sensors. Various biocompatible materiel's are used as bio-receptors in coupled cantilever sensors[15].

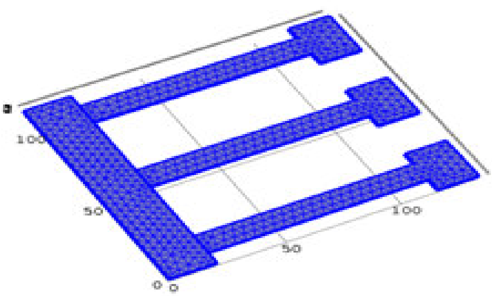

Figure3
Mesh model of T-shape TCC

Eigen frequency modes of T-shape TCC

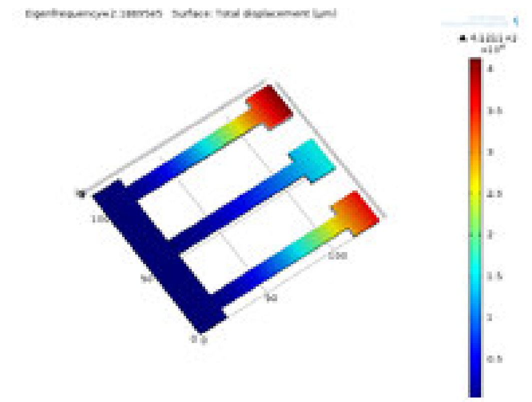

Figure 4
Simulation model of first mode

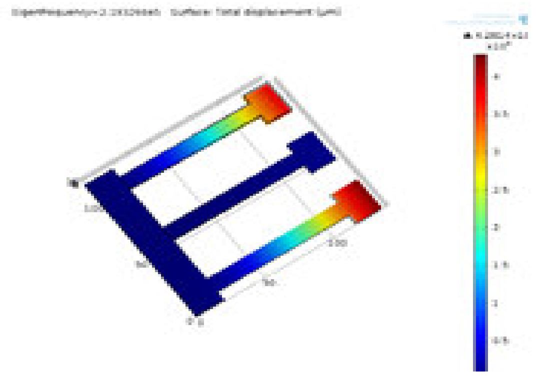

Figure 5
Simulation model of second mode

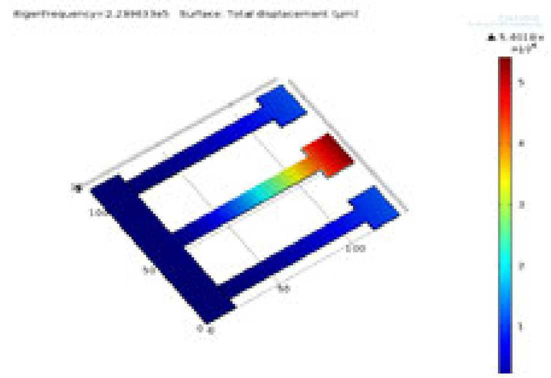

Figure 6
Simulation model of Third mode

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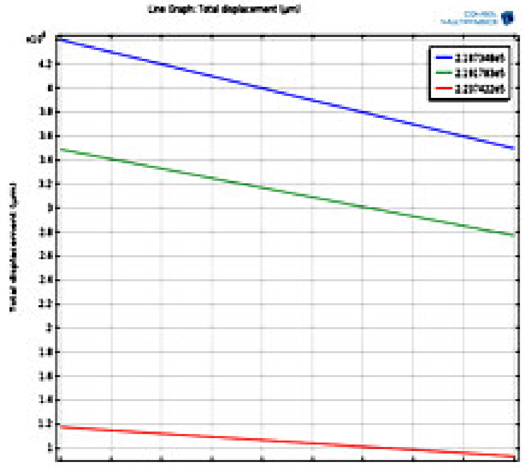

Figure 7
Total displacement Vs T-shape

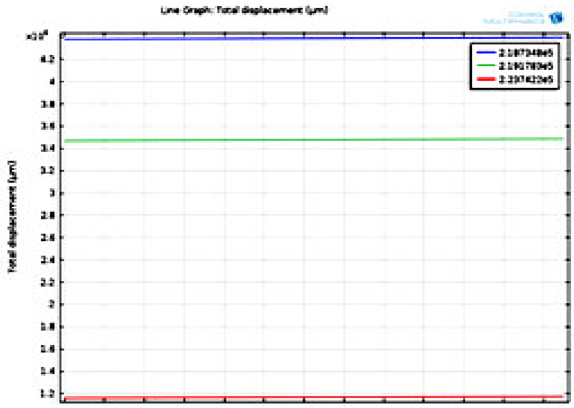

Figure 8
Total displacement Vs T-shape width

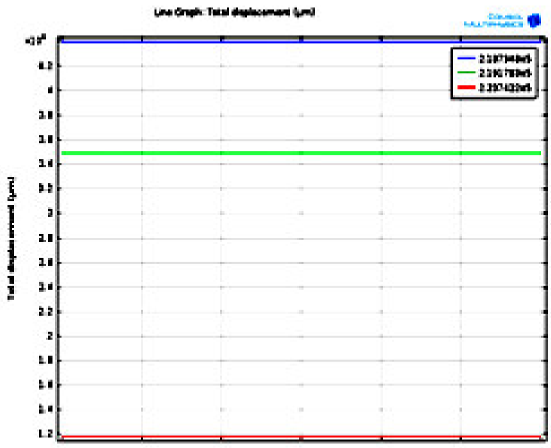

Figure 9
Total displacement Vs T-shape thickness

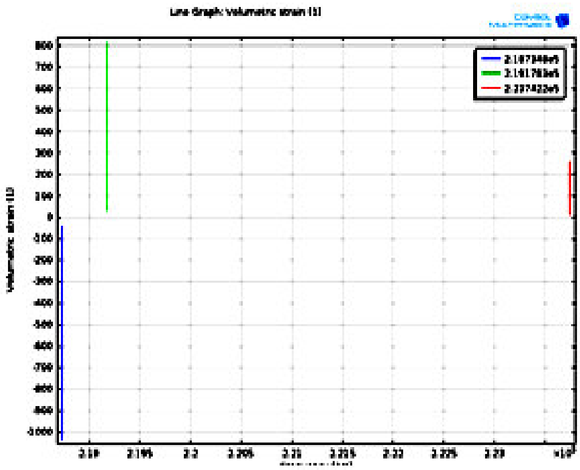

Figure 10
Volumetric strain Vs frequency

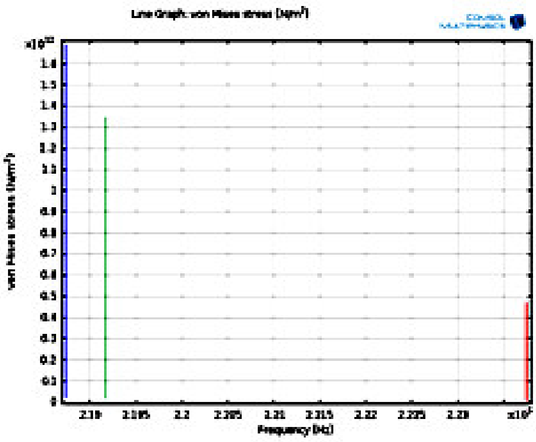

Figure 11
Stress Vs frequency

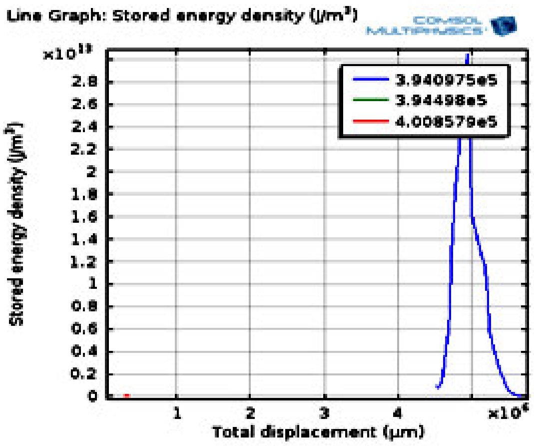

Figure 12
Stored energy density Vs displacement

Eigen frequency modes of disc shape TCC

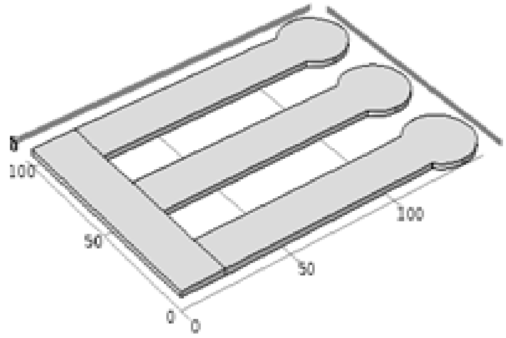

Figure 13
Schematic model of disc shape TCC

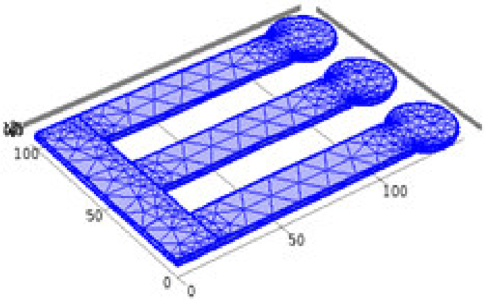

Figure 14
Mesh model of disc TCC

Simulation model of disc shape TCC

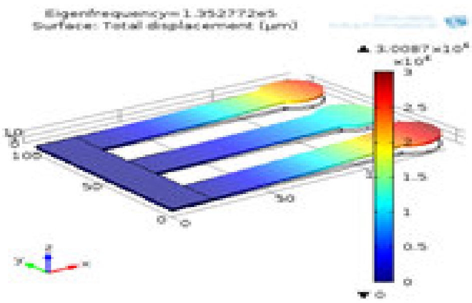

Figure 15
first mode

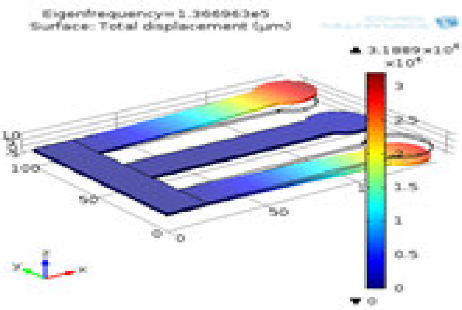

Figure 16
Second mode

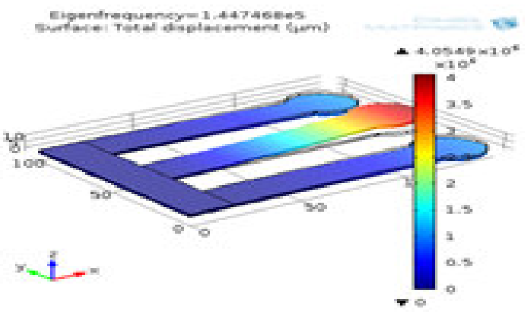

Figure 17
Third mode

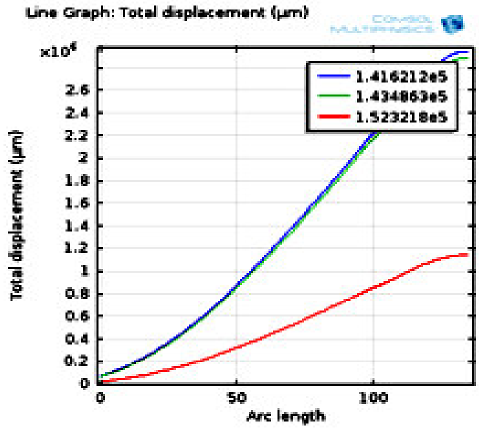

Figure 18
Total displacement Vs length

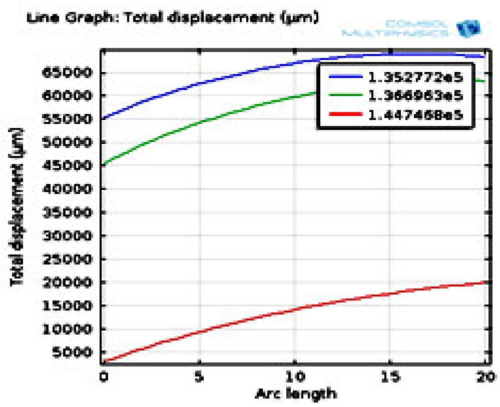

Figure 19
Total displacement Vs width

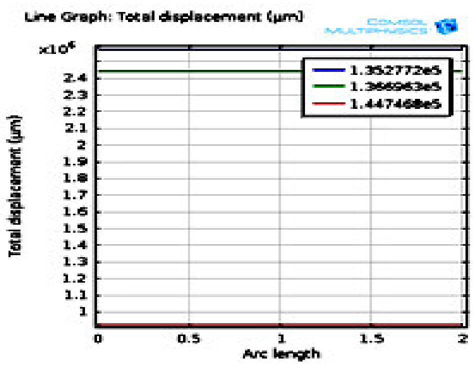

Figure 20
Total displacement Vs width

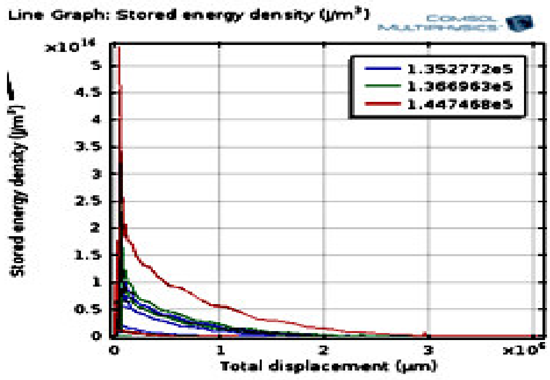

Figure 21
Stored energy density Vs total displacement

CONCLUSION

The different structural stabilities of Triple couple cantilever are verified for their sensitivity increase and optimization of these structures is very much essential while incorporating them as the bio sensing devices. In this paper a T shaped and Disc shaped TCC are analyzed for different materials and added mass, which determines the T shaped as more sensitivity than compared to Disc shaped cantilever.

CONFLICT OF INTEREST

Conflict of interest declared none.

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