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Design and Analysis of MEMS Based Micro-Cantilever Shapes for Sensitivity Improvement

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ABSTRACT:

In this paper we proposed the MEMS based piezoelectric micro-cantilever for different shapes of rectangular, single leg and double leg circular shapes to analyse their sensitivity using COMSOL MULTIPHYSICS. The analytical model of the cantilever beam will be analysed and the process of its construction will be discussed. Finally, the simulation results of applied force and the end displacement are observed. So that we have compared the changes in the sensitivity of a cantilever beam with respect to change in its shapes for the applied force.

Key words:

Mems, Micro cantilever, Comsol Multiphysics.

I. INTRODUCTION:

A Micro-cantilever is a device that can be used as physical, chemical or biological sensor by detecting the changes in cantilever bending or vibration frequency, which is fixed at one end and the other end, is free to move when it experiences some stress. For different sensing applications like Chemical and biological sensors, the MEMS based MICRO CANTILEVER are proven to be extremely sensitive. It is the miniaturized duplicate of a diving board that moves up and down at regular intervals. Micro-cantilevers are a million times smaller than the diving board having dimensions in microns and different shapes as shown in figure 1.

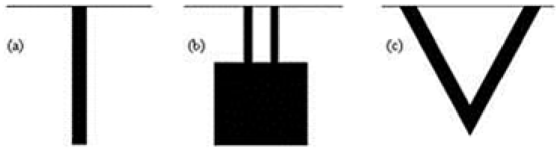

Figure 1: Different types of micro-cantilevers (top view) (a) Rectangular (b) Double-legged (c) Triangular

In order to understand the behaviour of MEMS cantilevers the two equations studied are

a. Stoney's formula, which relates cantilever end deflection δ to applied stress σ:

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

Where

ν = is Poisson's ratio,

E = Young's modulus,

L = the beam length and

t= the cantilever thickness.

b.Formula relating the cantilever spring constant, k, to the cantilever dimensions and material constants:

$$k = \frac{F}{\delta} = \frac{Ewt^3}{4L^3}$$

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Where

F= force and

Ш=cantilever width.

The movement of the cantilever is effected by its length, width, thickness and various properties of the material used to make the structure. The geometric shape, as well as the material used to build the cantilever determines the cantilever's stiffness. Figure 2 shows the view of the micro cantilever using piezoelectric devices physics of the structural mechanics application mode of MEMS module of COMSOL MULTIPHYSICS.

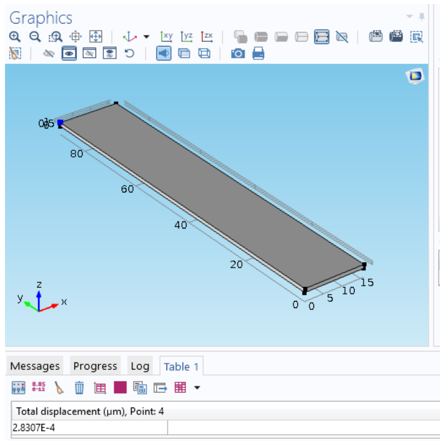

Figure 2: Design of the rectangular micro-cantilever

The analysis is done on the structure made up of silicon material having the following properties given in table 1.

Property	Name	Value	Unit
✓ Density	rho	2329[kg/...	kg/m³
✓ Young's modulus	E	170e9[Pa]	Pa
✓ Poisson's ratio	nu	0.28	1
Coefficient of thermal expansion	alpha	2.6e-6[1/...	1/K
Heat capacity at constant pres...	Cp	700[J/(kg...	J/(kg·K)
Relative permittivity	epsilonr	11.7	1
Thermal conductivity	k	130[W/(...	W/(m·K)

Table 1: material properties of the silicon structure

II. Micro-electromechanical Systems (MEMS):

MEMS as the name suggests is a Micro-electromechanical System which comprises of mechanical elements, actuators, sensors & (electronics & electrical) devices miniaturized on a single silicon substrate. It is an emerging field with a vast range of applications. Cantilever is a wide ranging used component in micro system devices. It has been proven as an excellent platform for acute sensitive biological and chemical sensors. Micro cantilevers has enhanced and very popular due to its high selectively and sensitivity, flexibility and ease of fabrication on chip circuits.

MEMS is a process technology used to create tiny integrated devices or systems that combine mechanical and electrical components. They are fabricated using integrated circuit (IC) batch processing techniques and can range in size from a few micrometers to millimetres. These devices (or systems) have the ability to sense, control and actuate on the micro scale, and generate effects on the macro scale.The Schematic representation of MEMS components is given in the figure 3.

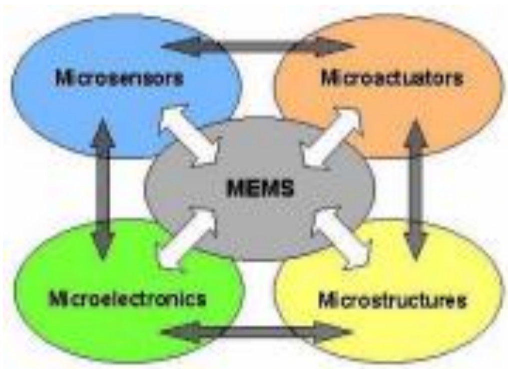

Figure 3: Schematic illustration of MEMS components

The critical physical dimensions of MEMS devices can vary from well below one micron on the lower end of the dimensional spectrum, all the way to several millimeters. While the functional elements of MEMS are miniaturized structures, sensors, actuators, and

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microelectronics, the most notable (and perhaps most interesting) elements are the micro-sensors and micro-actuators. Micro-sensors and micro-actuators are appropriately categorized as "transducers", which are defined as devices that convert energy from one form to another. In the case of micro-sensors, the device typically converts a measured mechanical signal into an electrical signal. The basic components of MEMS devices are shown in the figure 4.

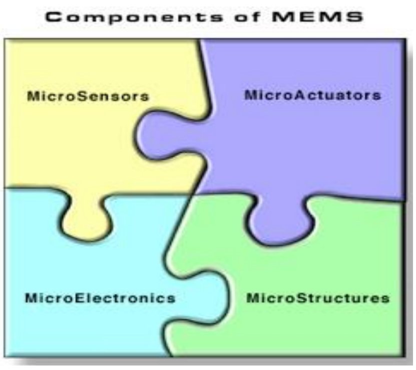

Figure 4: basic components of MEMS devices

III. COMSOL Multi-physics

COMSOL Multi-physics is a finite element analysis, solver and Simulation software / FEA Software package for various physics and engineering applications, especially coupled phenomena, or multi physics. With this software one can easily extend conventional models for one type of physics into Multi-physics models that solve coupled physics phenomena - and do so simultaneously.

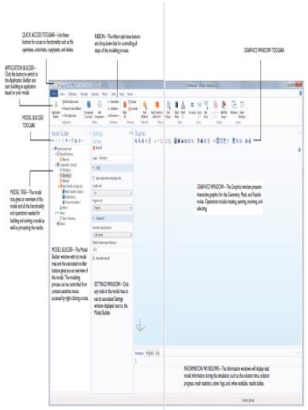

Figure 5: view of COMSOL desktop

Quick Access Toolbar

The Quick Access Toolbar gives access to functionality such as Open, Save, Undo, Redo, Copy, Paste, and Delete. You can customize its content from the Customize Quick Access Toolbar list.

Ribbon

The ribbon at the top of the desktop gives access to commands used to complete most modeling tasks. The ribbon is only available in the Windows® version of the COMSOL Desktop environment and is replaced by menus and toolbars in the OS X and Linux® versions.

Settings Window

This is the main window for entering all of the specifications of the model including the dimensions of the geometry, properties of the materials, boundary conditions and initial conditions, and any other information that the solver will need to carry out the simulation.

Plot Windows

These are the windows for graphical output. In addition to the Graphics window, Plot windows are used for Results visualization. Several plot windows can be used to show multiple results simultaneously.

IV.SIMULATION RESULTS AND ANALYSIS

RECTANGULAR CANTILEVER:

When we apply force of 0.5 to rectangular cantilever then deflections of rectangular cantilever with respect to Arc length is shown in figure 6.

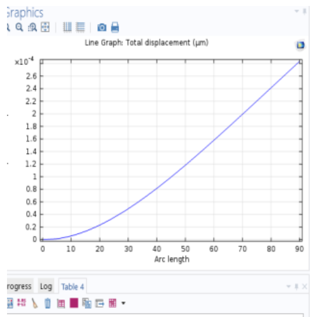

Figure 6: deflection of rectangular cantilever

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Deflections increases as length of cantilever increases .The total deflection value is shown in figure 7.

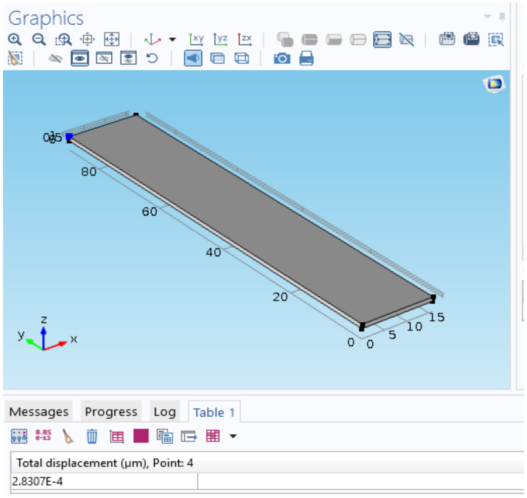

Figure 7 : A rectangular cantilever beam designed using COMSOL

SINGLE LEG CIRCULAR CANTILEVR:

When we apply force of 0.5 to Single leg circular cantilever then deflections of single leg circular cantilever with respect to Arc length is shown in figure 8.

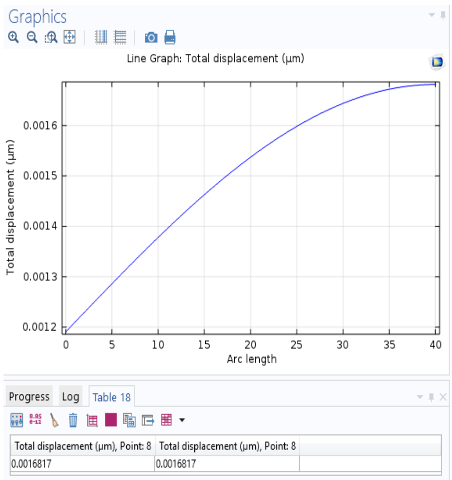

Figure 8: deflection of single leg circular cantilever

The total deflection value of single leg circular cantilever is shown in figure 9.

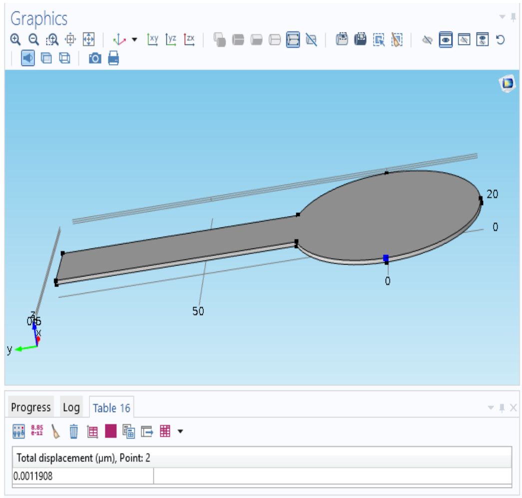

Figure 9: single leg circular cantilever designed using COMSOL

DOUBLE LEG CIRCULAR CANTILEVER:

When we apply force of 0.5 to Double leg circular cantilever then deflections of double leg circular cantilever with respect to Arc length is shown in figure 10.

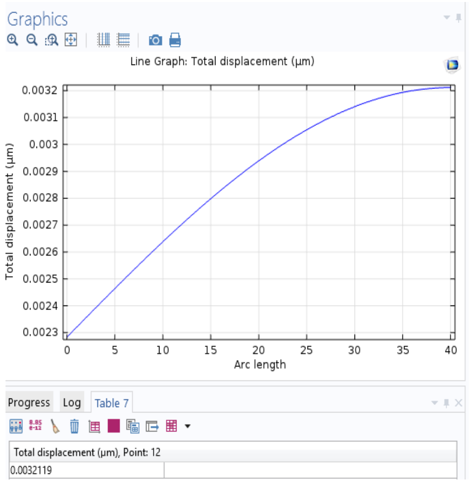

Figure 10: deflection of double leg circular cantilever

The total deflection value of Double leg circular cantilever is shown in figure 11.

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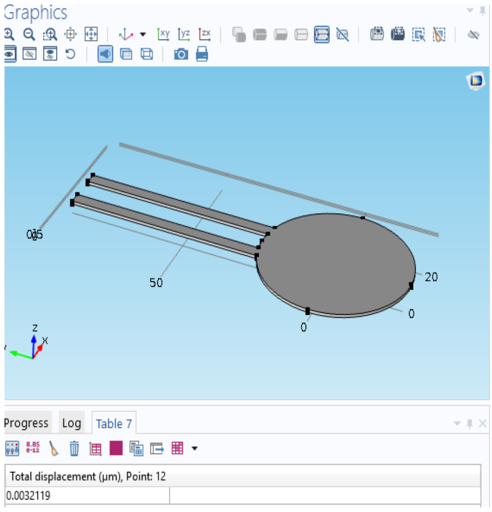

Figure 11: double leg circular cantilever designed using COMSOL

V CONCLUSION

For analysing the sensitivity of Micro-cantilevers we have designed various shapes such as rectangular, single leg circular shape and double leg circular shape Micro-cantilevers with the same amount of force is applied. From the results we obtained we conclude that the microcantilever with double leg circular shape is more preferable as a sensor as it have more sensitivity when compared to other designs.

VI. ACKNOWLEDGMENT

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