

Design and Simulation of MEMS-Based Two-Directional Capacitive Pressure Sensor



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Abstract In this paper, MEMS-based pressure sensor is designing using a parallel plate capacitor which can be broadly applied in the electronic technology enhancement circles, increase in pressure tends to equivalent increase in capacitance or reduction in the dielectric value. So, by varying pressure, the respective capacitance can be changed, the individuality of our design gives the analysis of change in capacitance with the respective increase in pressure along with displacement of the proof mass and combs can also be observed by stimulating COMSOL Multiphysics software our design will give more capacitance compared to the other proposed design which we proposed and our design has a huge range of application from jets to measuring the pressure.

Keywords Pressure · MEMS · COMSOL Multiphysics · Two-directional

1 Introduction

Micro Electromechanical Systems (MEMS) is a type of technology by which can extract various types of inputs and has wide range of applications in diverse sectors like: Automobiles, Industries and Biomedical. MEMS-based capacitive pressure sensors is to measure the change in capacitance by applying pressure of certain pascals on the proof mass which is an external force, and it can be used in the various types of systems like modern drone applications, industrial operations, military applications and biomedical applications [1–4].

For the present study, COMSOL Multiphysics® is a tool used for the design and simulation. It is a special software and is a platform for Multiphysics simulation using Finite Element Method (FEM) and with physical models. This software tool consists of many modules like Body, Fluid, Chemical for solving many unsolved issues and it also consists of solid mechanics this will give the stress analysis and

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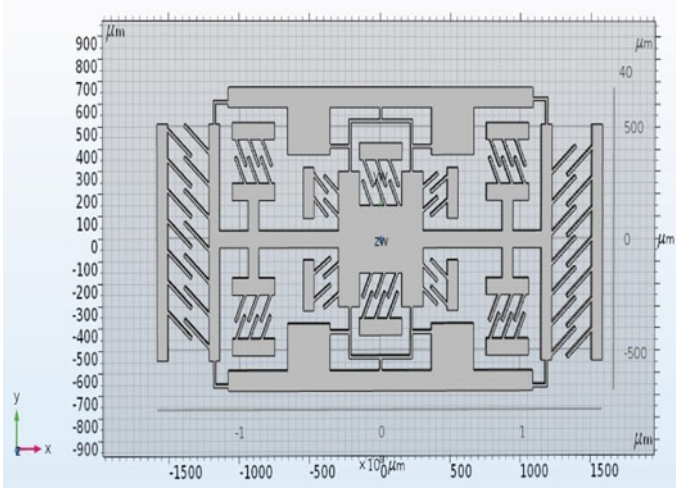


Fig. 1 Structure without air block

flow in solid this two physics solve the different problems in the designed sensor [5–8].

The present 2-dimensional capacitive pressure sensor design will sense pressure applied in two dimensions. When any external pressure is applied on the two dimensions. When external pressure applied to the device angular, linear displacement occur movement occurs 2 dimensionally in the sensor. This results in change in relative area between the electrodes of the capacitors in the device. This results in capacitance change with the help of two parameters. In this paper, stress analysis, capacitance and pressure measurement of the device will be described [9–12].

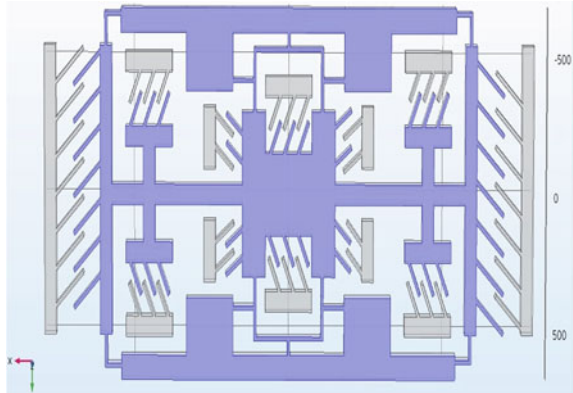
2 Design Concepts

The design has two sets of electrodes to act as capacitance, proof mass is the crux of the design. Where the total pressure is applied on the proof mass capacitance change occurred in the various positions of the design. Polysilicon (Si) are used as sensor material because of its mechanical stability in the fabricated devices of micro electromechanical sensors (Fig. 1).

3 Design of Electrodes

There are electrodes in this design on the inner side of the Base Substrate. Which are used to sense the mechanical changes happens within the design (Fig. 2).

Fig. 2 Enable electrodes in the design



As the area increases the capacitance increases.

$$C = E0A/d \tag{1}$$

The capacitance c_1 that is given in Eq. (1) is used to measure the capacitance between the plates. The parallel plate capacitance will depend on the following parameters: permittivity of the air, dielectric permittivity, area of cross section and distance between two plates.

$$c_1 = \frac{KA}{d} \tag{2}$$

where K is product of air and dielectric permittivity, A is area of cross section and d is distance between two plates. All the remaining capacitances of $c_{2..8}$ is also same as c_1 . Thus, the acceleration depends upon the change of capacitance that depends on the applied momentum.

4 Measurements of Displacement

The displacement is defined as the change in position of an object are the vectorial sum of the distances travelled by the body. The standard unit of displacement in the international system CF units is the kilometre, SI units is metre, CGS is centimetre.

SIMULATION PROCESS USING COMSOL

The simulation process in COMSOL Multiphysics based on the following steps: Selection of physics, Geometry design, Meshing and computation of study. The selection of physics will be determined based on user requirement and the type of step analysis. The selection of study is based on the requirements of the user. Here we study

the stress and capacitance of the materials. Design can be done on the work plane and our design is based on 2-dimensional and this software also supports 3-dimensional and various structures. The COMSOL Multiphysics® supports different kinds of materials such as Metals, Insulators, Semiconductors, Biomaterials and Liquids. If our desired material is not present in library, we can design our own material with material property. This software supports the following physics: It supports the Finite Element Method to simulate the corresponding device. It allows the mathematical analysis. And it simulates the partial differential equations. So, user can use the physics which will be suitable for the device. Meshes on the design is needed to track the changes in the design on applying external forces in very closed manner. Meshes are various types: They are tangential, finer, extra finer and coarse etc., which will be provided with the tool. The computation of study supports the different inputs to the proof mass such that desired results can be obtained for applying the different data analysis to the device. The COMSOL Multiphysics analysis are the 1-Dimensional, 2-Dimensional and 3-Dimensional characteristics with multiple expressions. The user can choose the multiple parameters like surface, points, or boundaries, etc. Here we adopted for the 3-dimensional approach based on our requirements.

5 Simulation Results

Total displacement (Fig. 3)

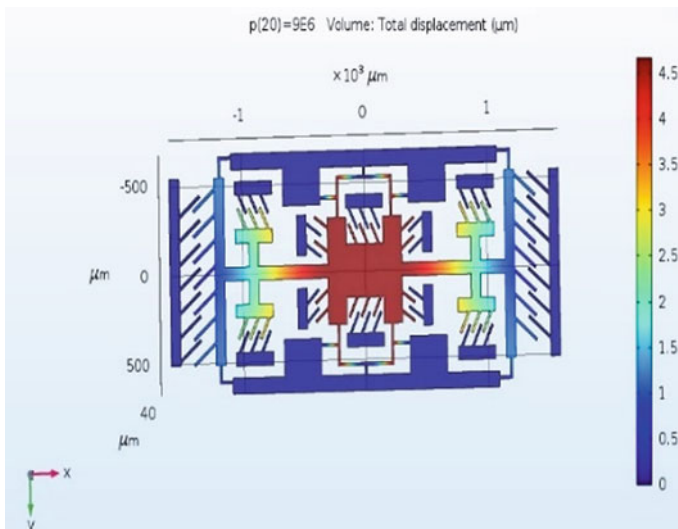


Fig. 3 Total displacement of proof mass

This analysis provides the information of displacement that occurs in the proof mass. The angular displacement is to be measured by either clockwise or anticlockwise direction. And linear displacement is measured along with x and y-direction. The angular displacement analysis is shown in (Figs. 3 and 5). The maximum angular displacement is 4.5×10^{-6} m. Figure 4 shows the surface capacitance for one set of electrodes. Then the value of a capacitance c_1 is 00.39pf (Table 1).

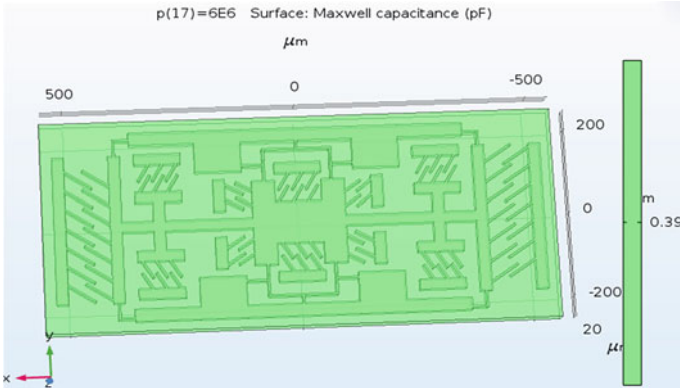


Fig. 4 The surface capacitance of a single electrode

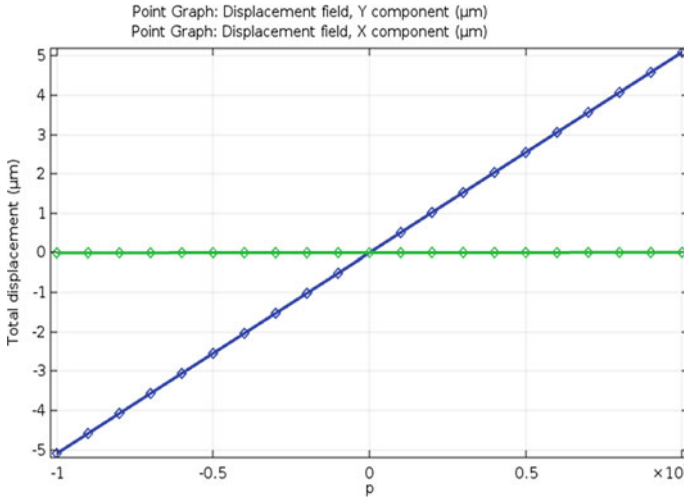


Fig. 5 Displacements versus pressure

Table 1 Measured parameters

S. No	Parameter	With zero displacement	With maximum displacement (pf)
1	Capacitance	0	0.39
2	pressure	0	4.5 μm

6 Conclusion

A new design approach demonstrated for MEMS inertial sensor, with capacitive electrodes. This structure has an eight set of electrodes, which supports to measure multi-directional inertia. High sensitivity for device can be used to determine the possible direction of moment. The simulation is done using the COMSOL Multiphysics®, which is a platform for designing and simulating multi-disciplinary domains. Stress and displacement analysis provide information on the rotational momentum of the proof mass. Then angular acceleration measured with suitable formulations and then capacitance and acceleration parameters are tabulated with boundary conditions. Finally, this design will be suitable to enhance the performance for further simulation of integrated rotational-linear inertial sensors in future.

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