Equivalence Analysis on Design and Modelling Of Capacitive Pressure Sensors with Different Structure of Diaphragm

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***Abstract*—Sensors are becoming one of the inextricable parts of the human life. MEMS technology made this sensors error free and with overcoming the boundary of classical sensors. Pressure sensors are plays key role in many disciplines. Here in this paper we were designed and simulated capacitive pressure sensor with non-identical diaphragm structure with different measurements. We are using silicon as the material for the diaphragm because of its unique properties. In the design circular design has radius 36 um and the square with and keeping the areas of all designs are unique. The entire simulation is done using COMSOL multi physics.**

Keyword- Sensors, Boundary, MEMS, Pressure sensors, COMSOL

I. INTRODUCTION

In this present days we are making every filed as automatic to reduce the direct effort of human beings because human are not able deliver constant output to record or monitor because of physical reasons. So sensors are introduced to give a exact results for monitoring any kind of fields. But the classical sensors are not up to the mark because of their limitation. MEMS technology becomes the most popular for designing of sensors because here we are integrating electrical and mechanical system in a single wafer. So integration of this technology gives the desired results. Not only for this MEMS occupying the highest market share in sensor because of its unique qualities like very small in size and highly durability and low cost, less power dissipation. Pressure sensors are having application in many fields like automobiles and biomedical space as well as in military also. Here in this paper we are designing a capacitive pressure sensor in which the design is similar to normal capacitor. Here we are having the two plates which are separated by a distance and one end is fixed ant the other end is movable. We know that the capacitance is depends inversely on the distance between the two plates so we are varying the distance between the plates by using the amount of pressure we are apply on the moving plate and measuring the change in the capacitance. In this capacitive pressure sensor we are designing the diaphragm of sensor with different shapes but overall area is constant. The diaphragm is fixed at four corners at one end and allowed to move in one end. We are having circular, square and rectangular diaphragm structures. We make the comparison among the three models by measuring the displacement against the applied pressure and capacitance.

II. STRUCTURE OF THE INTENDED SENSOR DESIGN:

The general capacitor is consist is consist of two parallel plates separated by certain amount of distance. Here the capacitance is directly proportional to area and inversely to the distance between the two plates (d) which is in mathematical notion is given as

$$C = \varepsilon_0 \varepsilon_r A / d$$

Where $\varepsilon_0\varepsilon_r$ are the permittivity of free space and the relative permittivity of the dielectric layer C is the capacitance and A is area of the plates and d is the separation between the plates of the capacitor. Here in this paper we are designing three different models and their parameters like length, width and thickness are given below.

A. Square pressure sensor

In this mode the centre of the diaphragm is placed in a certain distance away from the fixed electrode. The diaphragm is fixed at the end of four corners and the centre part is a movable one. Not only the regular one we are given the slotted pressure sensor which will have the same dimensions like the first one but some portion is removed by using the tools of the COMSOL multi physics.

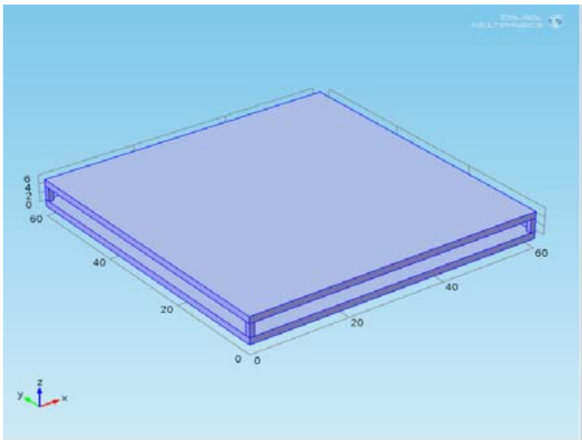

Fig1. Classical pressure sensor

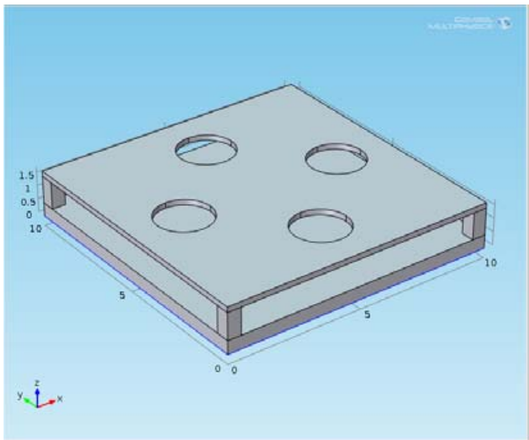

fig2: slotted pressure sensor

B. Circular pressure sensor

Here for circular model the radius of the diaphragm is taken from the centre point. The circle diaphragm is fixed at on end on the above of the base with the supporting arms. The air gap between the diaphragm and the fixed electrode is filled with dielectric metal which is nothing but the air gap. The length of the radius is given in the measurement. The sensitivity of the design is changes as the diaphragm changes its original position changes with the applied pressure.

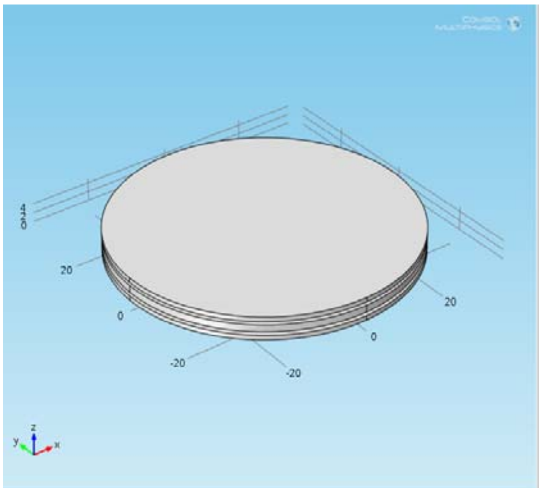

Fig 3: circular pressure sensor

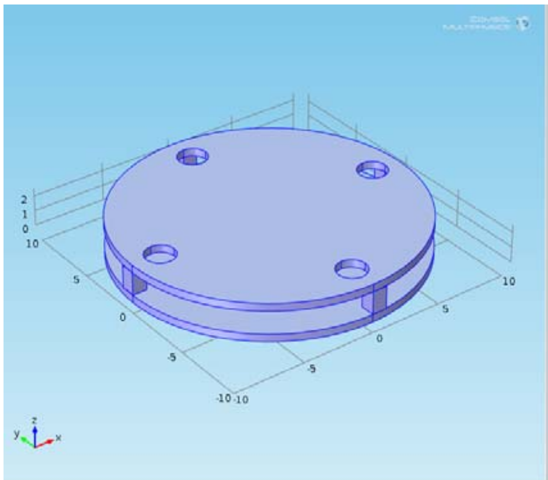

fig4: slotted pressure sensors

The above design of the circular capacitive sensor is is having 3 layers the primary layer is the diaphragm and the second layer is the dielectric layer and the final layer is the base of the base of the diaphragm.

TABLE I. Design Parameters of Square pressure

Design	**Square pressure sensor**		
	Length(um)	**Thickness**	**Area(um)**
Square	10	2	200
Square with slots	12	2	200

TABLE III. Design Parameters of Circular pressure

Design	**Circular pressure sensor**		
	Radius (um)	**Thickness**	**Area(um)**
circular	5	1.8	200
circular with slots	5	2	200

TABLE IIIII. Materials and its property for poly silicon

Property	**Value**
Density	2329[kg/m^3]
Young's module	$170e^9$
Poisson's ratio	0.28

III. Mathematical Methods for Computation of Capacitance

The design is consist of 10*10 um side length and thickness of 2 um and the deflection at the centre of the square diaphragm W_{max} is given by the following mathematical notation which is given as follows,

$$W_{max=} 0.01512(1-v^2)\, pL^4/Eh^3$$

Where L= length of the square diaphragm and h is the height of the diaphragm and E is the young's module and p is the pressure that is applied of the sensor.

For the circular diaphragm the measurement of the displacement is some watt different it is having the radius 6 um and the thickness is 1.8 um is given by the following mathematical notation

$$W_{max}=3\, w\, (m^2-1)a^2/1611m^2h^2$$

Where a is the radius of the diaphragm and h is the thickness of the design. By using the above two notation the respective capacitance is calculated, the capacitance is calculated by using the basic formula is given by

$$C = E_0E_rA/d$$

Where c is the overall capacitance measured with respect to the displacement of the pressure sensors diaphragm for all designs.

IV. Results and Discussion

The above figures 1,2 & 3,4 are designed and simulated by using the COMSOL and their respective simulations figures are given below

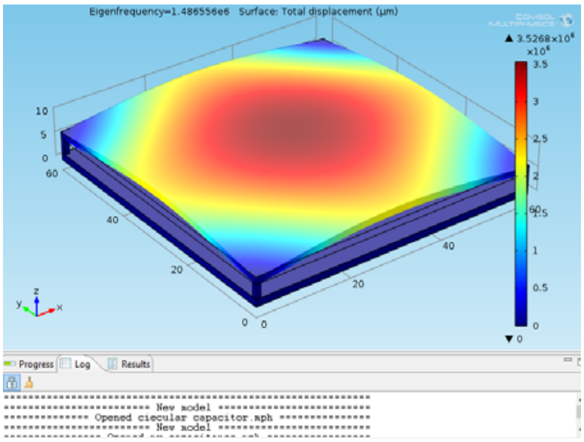

Fig: 5 square simulation

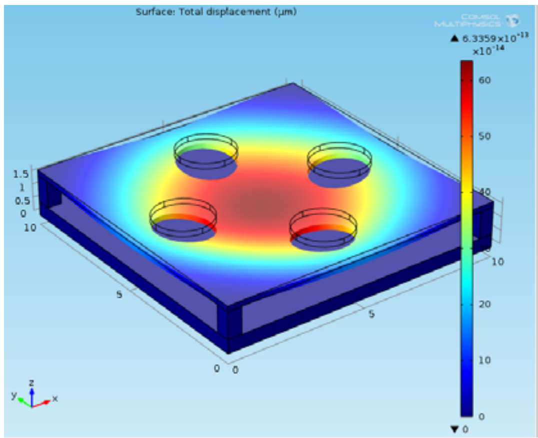

Fig 6: square with slots

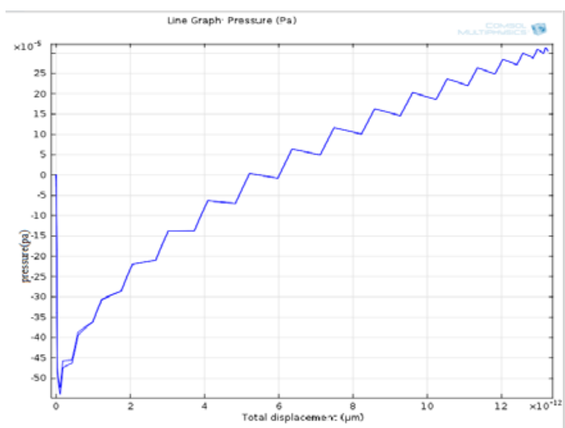

Fig7:pressure vs disp of normal sensor

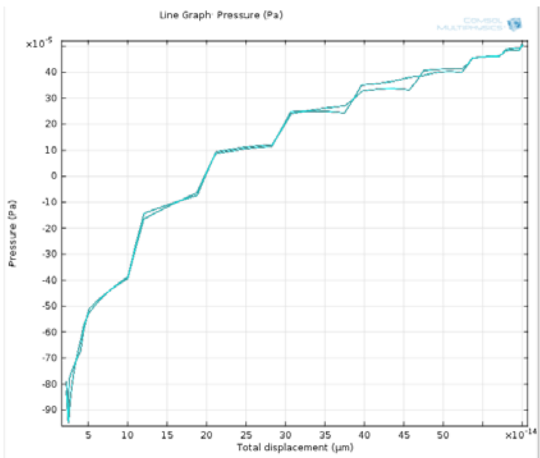

fig8: pressure vs displacement of slotted sensor

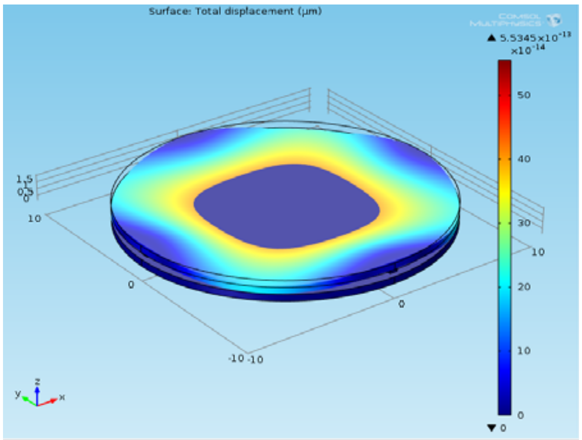

Fig 9: circular pressure sensor

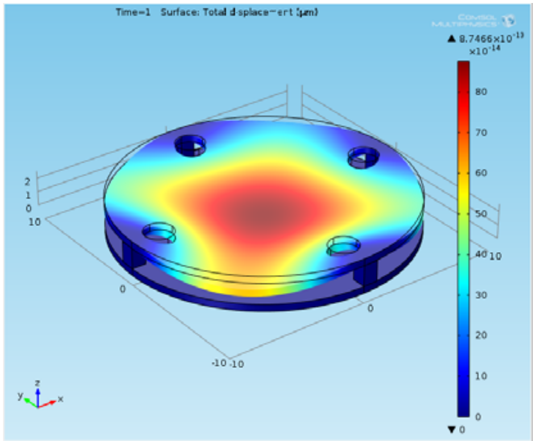

Fig10: circular with slots

The above two figures are the simulations diagrams of the square and the circular capacitive pressure sensor. Here we can observe the common thing that happened is the movement of the both sensor is observed with respect to the load is applied. For the circular capacitive sensor for the applied load the respective change in the displacement of the arc is varied for applying distinct pressure. It is also absorbed that the change in the displacement is more in the slotted one when compared with the normal sensor. The respective results are also given after the simulation schematic of the sensors. The circular capacitive sensor are also simultaneously under gone all the load conditions that are applied for the square shape capacitive sensor. The simulation schematic of the circular capacitive pressure sensor is shown in the figures 9 and 10. The figure 10 is the slotted one and is having the maximum displacement when compared to the regular one. The simulation results are given below,

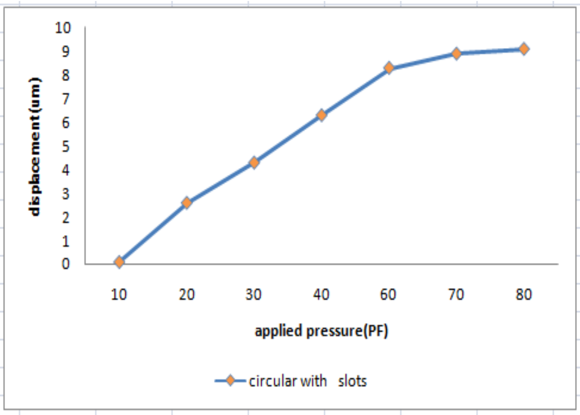

Fig11: pressure vs displacement without slots

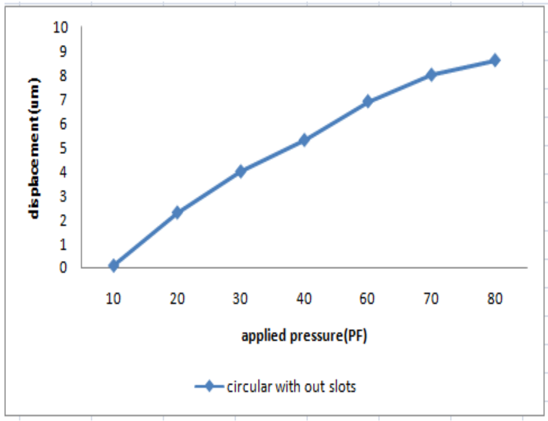

Fig12: pressure vs displacement with slots

The above two figures are represents the simulation results for the circular pressure sensor with out and with the slots. For the applied pressure in pf the respective displacement is come in um for these sensors. This displacement is directly deflected in the measurement of the capacitance of the sensor. Now we will make the comparison between the square and the circular type sensor based on the displacement and change in capacitance with respect to the change in applied pressure and ect. The comparison results are given below,

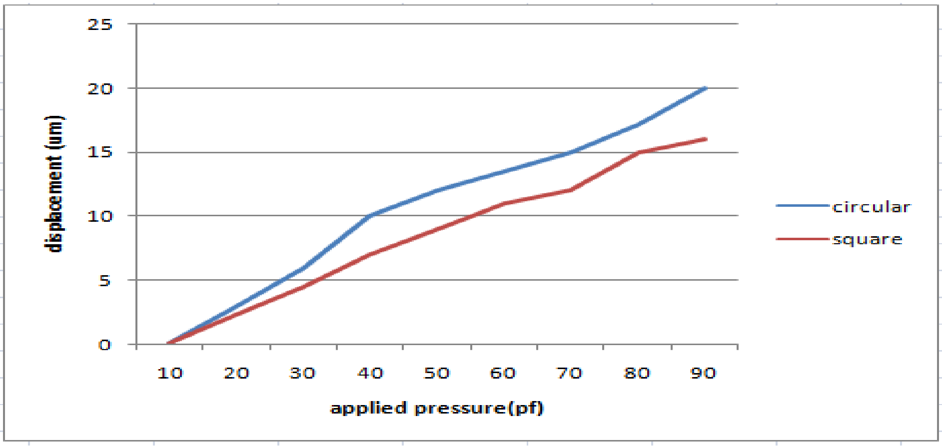

Fig13: Displacement vs applied pressure

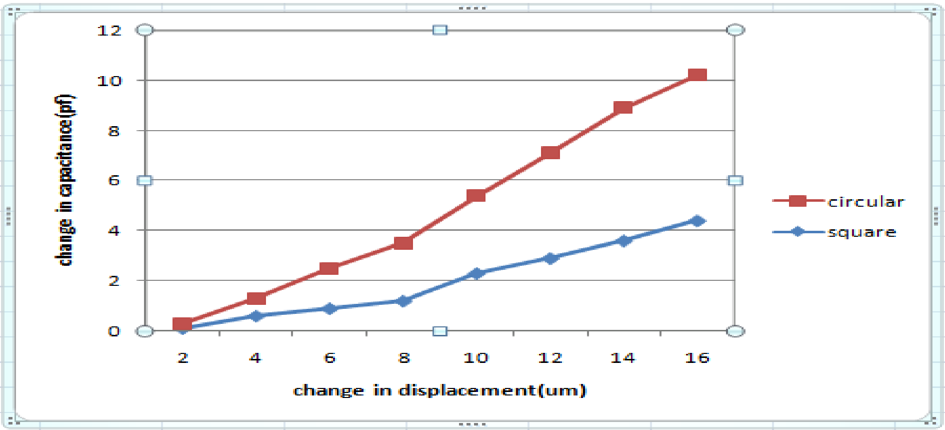

Fig14: Change in displacement vs change in capacitance

The above figures 13, and 14 are show the comparison between the circular and the square type diaphragm of the capacitive pressure sensors. The capacitance is measured in pF and the displacement is measured in the um with the applied pressure in pf. By observing the all the simulated results between the sensors the circular diaphragm sensor is having more sensitivity the compared to the square type sensor, we are not saying this only depend on the above we made no of iterations on the both and then finally we can say that the sensitivity is more for a circular diaphragm when compared to the square type sensor. The below figure gives the comparison between the two sensors.

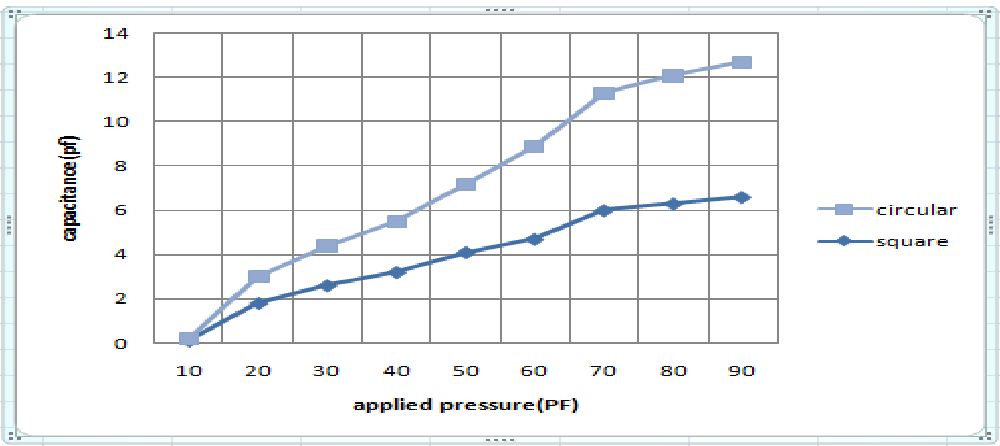

Fig 15: Applied pressure vs capacitance

V. CONCLUSION

The different types of MEMS capacitive pressure sensors are designed and simulated using the COMSOLE multi physics software and the respective simulation results are given. From the above all the discussion and the results we know that the circular diaphragm pressure sensor with the slots is having the more sensitivity the others. So for implementing the capacitive pressure sensor for any application with the circular will give the precision results and readings but we are having the conflict in the designing of the sensor. This type of sensors is very good in critical measurement where we required the high sensitivity and high accuracy. In future this sensor will play very important role in the field of pressure sensing because of its features and its precision but the implementation complexity is to be taken properly because it will reflect the entire performance of the sensor. So with the knowledge of above simulation results we will focus on this kind of sensors and improve its performance by the means of enhancing the technology.

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