Comparative Analysis on Design and Simulation of Perforated Mems Capacitive Pressure Sensor

Kirankumar B Balavalad*, Bhagyashree Mudhol*, B G Sheeparamatti*, Praveenkumar B. Balavalad**
*Department of Electronics & Communication Engineerign,
Basaveshwar Engineering College Bagalkot- 587103.
**VPM Polytechnic, Bagalkot-587103.

***Abstract*-MEMS sensor has gained popularity in automotive, biomedical, and industrial applications. In this paper, the design and simulation of conventional, slotted and perforated MEMS capacitive pressure sensor is proposed. Polysilicon material is used as diaphragm material that deflects due to applied pressure. Better sensitivity is the main advantage of conventional pressure sensor as compared with other two sensors and perforated pressure sensor achieves large operating pressure range. The proposed MEMS sensor demonstrated with diaphragm length 50um, gap depth 3um is being modelled. The simulation is carried out for different types of MEMS capacitive pressure sensor using COMSOL Multiphysics and Coventor ware.**

Keywords: ***MEMS, Conventional pressure sensor, slotted and perforated diaphragm, COMSOL Multiphysics, Coventor ware***

I.INTRODUCTION

Micromachined pressure sensors have been developed because of their small size, high performance, high reliability and low cost. MEMS pressure sensors measure the pressure interms of deflection of sensing plate. Micro Electro Mechanical Systems[MEMS] are the integration of mechanical elements, actuators, sensors and electronics on a common substrate using integrated circuit process sequences. Micro pressure sensors are widely applied in automotive, biomedical, space, military and various industrial applications. The capacitive pressure sensor uses a pair of parallel plates which forms a capacitor. The upper plate act as movable plate which is fixed from four sides. When pressure is applied on the upper plate it deforms which changes the distance between two plates of capacitor. This change in capacitance can then be observed to sense the pressure. This paper explores the design parameters of MEMS based capacitive pressure sensor using COMSOL Multiphysics and Coventor ware before actual fabrication. The objective of analysis are first, verify the deflection of the diaphragm due to the applied pressure between the diaphragm and substrate. Second, to verify the deflection and capacitance between the diaphragm and the substrate.

II. SENSOR MODEL

Conventional pressure sensor, Slotted pressure sensor, Perforated pressure sensor has been modelled using COMSOL Multiphysics and Coventor ware tools. The designed MEMS capacitive pressure sensors consist of a square polysilicon diaphragm of 50um side length and 1.5 um thickness. This diaphragm deflects due to applied pressure. The diaphragm is suspended over the substrate by a air gap of 3um. The capacitance is given by

$$C = \frac{\varepsilon_0 \varepsilon_r A}{d} --(1)$$

Where C = Capacitance value of the system, ε_0 = Relative permittivity of free space, ε_r = Relative permittivity of free dielectric medium, A = Effective surface area, d = Separation distance between the membrane.

2.1 *Conventional pressure sensor*

The diaphragm is kept distance away from the bottom electrode in conventional mode of operation. Here four ends of diaphragm are fixed. Figure 1 show the geometry of Conventional pressure sensor.

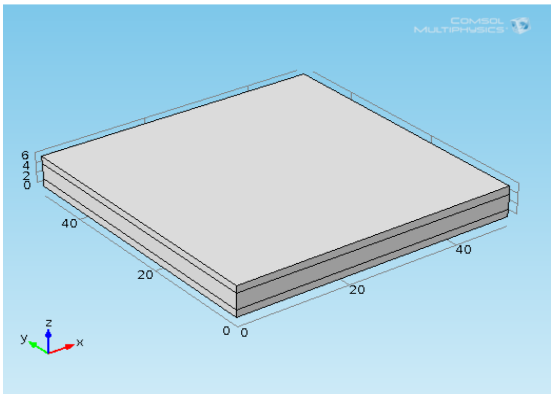

Figure 1. Conventional pressure sensor

2.2 Slotted Pressure Sensor

Four ends of diaphragm are fixed in slotted pressure sensor. When external pressure increases on top electrode, the sensitivity of pressure sensor increases. For achieving more sensitive device and reducing the effect of residual stress and stiffness of the diaphragm, slotted diaphragm is proposed as shown in figure 2 because of this slots sensor will become more sensitive

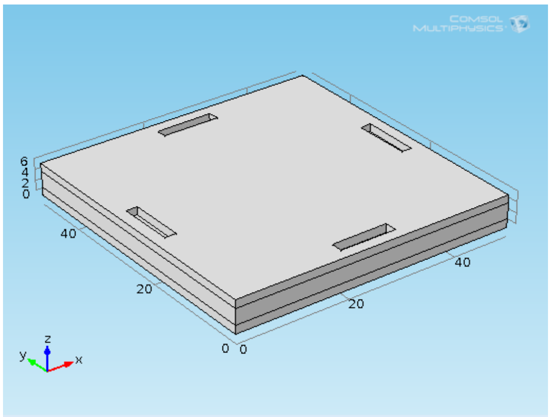

Figure 2. Slotted pressure sensor

2.2 Perforated pressure sensor

Holes are added to the top electrode in order to reduce the residual stress and stiffness of the diaphragm as shown in figure 3. This will make more sensitive than the slotted pressure sensor.

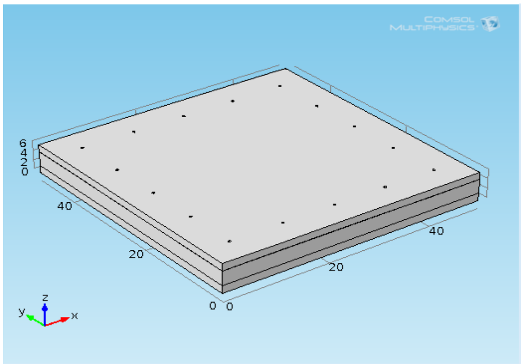

Figure 3. Perforated pressure sensor

The design of capacitive pressure sensor includes three layers , diaphragm, dielectric medium, substrate with polysilicon, air and polysilicon respectively.

Table 1: Material Properties

Name	Polysilicon
Density(kg/m3)	2320
Young's modulus(GPa)	169
Poisson's Ratio	0.22
Relative Permittivity	4.5

III. MATHEMATICAL BACKGROUND OF CAPACITIVE PRESSURE SENSOR

The design consists of side of 50um*50um and h of 1.5um The maximum centre displacement w_{max} for the square diaphragm is given by

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

Capacitance is calculated using

$$C = C_0(1+\frac{12.5pl^4}{2025dh}--(3)$$

Where p=Applied pressure, l = Length of diaphragm, d=Distance between electrode, h=Height of diaphragm, C_0=Initial capacitance

Sensitivity: -Sensitivity of the diaphragm is defined as the change in the capacitance to the change in the applied pressure. The equation used to find the sensitivity of the designed models is given in equation

$$S = \frac{\Delta C}{\Delta P}--(4)$$

Where ΔC=change in capacitance=$(C-C_0)/C_0$

IV. PERFORMANCE PARAMETERS

The following parameters are used for the analysis of designed capacitive pressure sensor models. **1.Total displacement**: Displacement of the diaphragm changes with the change in applied pressure. **2.Capacitance**: Capacitance of the model against the pressure applied. **3.Sensitivity**: the ratio of change in capacitance with respect to per unit change in the pressure applied.

V RESULTS AND DISCUSSION

Figures 4 & 5, 9 &10, 14 & 15 show simulation of conventional, slotted and perforated capacitive pressure sensors using Comsol and Coventor ware respectively. For conventional capacitive pressure sensor the displacement of diaphragm is achieved for 0 to 8Mpa.Similarly for slotted and perforated capacitive pressure sensor the displacement of diaphragm is achieved for 0 to 12 Mpa and 0 to 16 Mpa respectively. The change in capacitance is observed due to deflection of the diaphragm.

Figure 4,5 shows the total displacement of diaphragm for applied pressure of 8 Mpa as 1.0189um and 1.2800um. Figure 9,10 shows the total displacement of diaphragm for applied pressure of 12 Mpa as 1.0449um and 1.0784um. Figure 14,15 shows the total displacement of diaphragm for applied pressure of 16 Mpa as 1.0407um and 1.300um. Figures 6,11,16 show the graphs of applied pressure v/s total displacement. Figures 7,12,17 show the graphs of applied pressure v/s capacitance. Figures 8,13,18 show the graphs of applied pressure v/s sensitivity. As the applied pressure increases there is linear increase in capacitance.

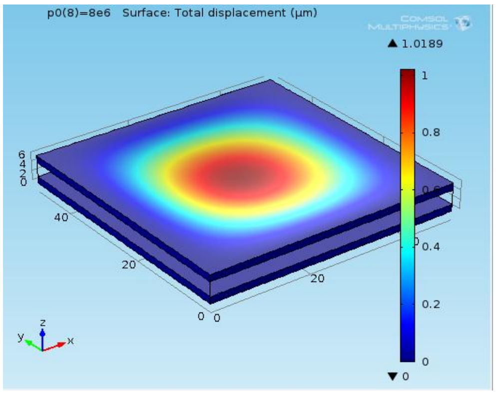

Figure 4.Conventional pressure sensor using Comsol multiphysics

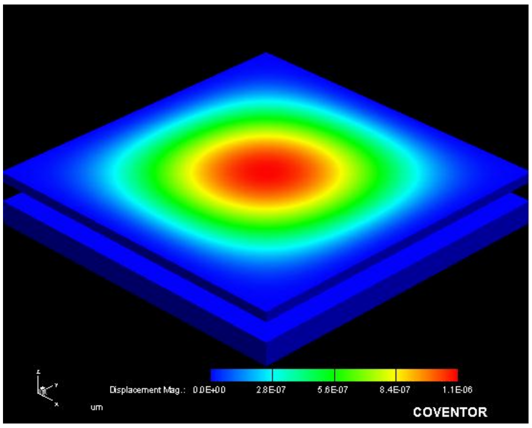

Figure 5.Conventional pressure sensor using Coventor ware

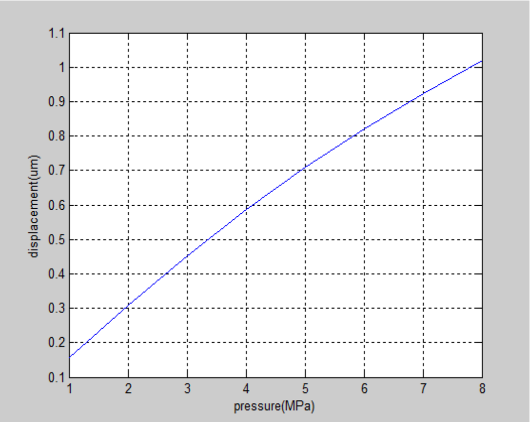

Figure 6. Graph Of Applied Pressure V/S Displacement For Conventional Pressure Sensor

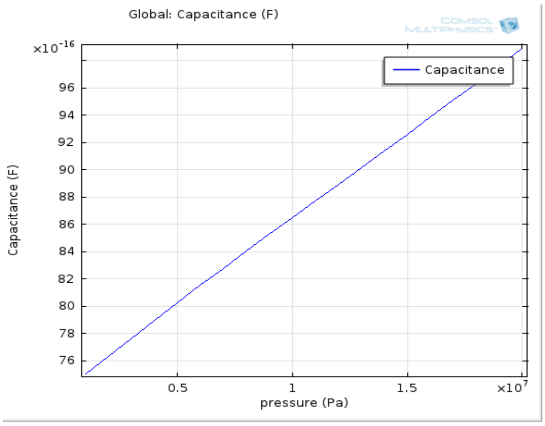

Figure 7 graph of pressure v/s capacitance for conventional pressure sensor

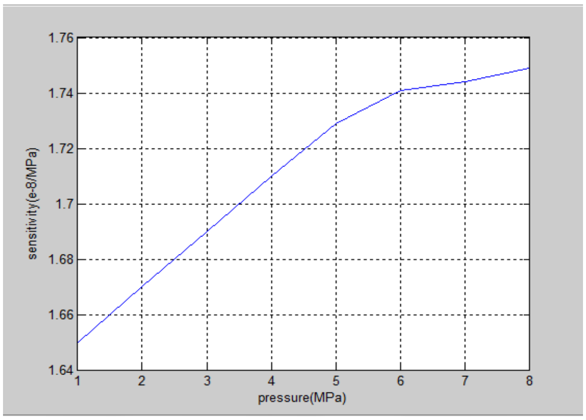

Figure 8. Graph of applied pressure v/s sensitivity for conventional pressure sensor

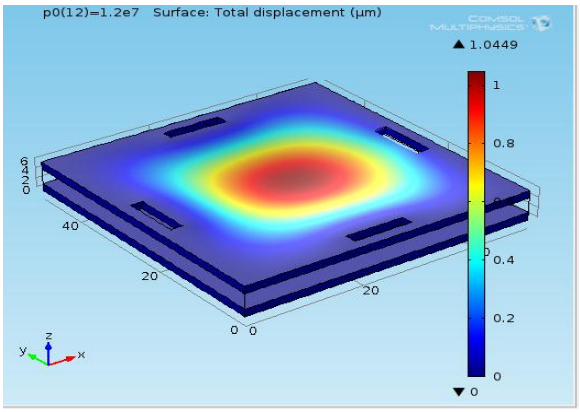

Figure 9.Slotted Pressure Sensor Using Comsol Multiphysics

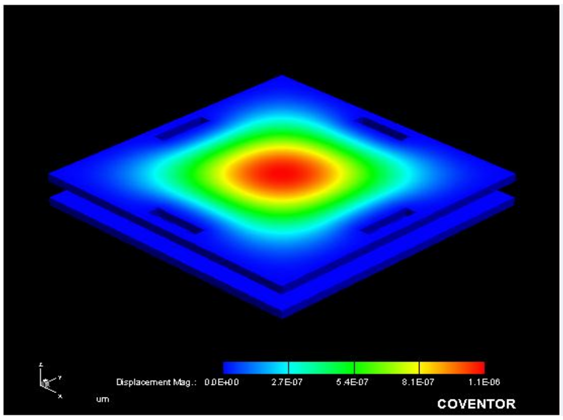

Figure 10.Slotted pressure sensor using Coventor ware

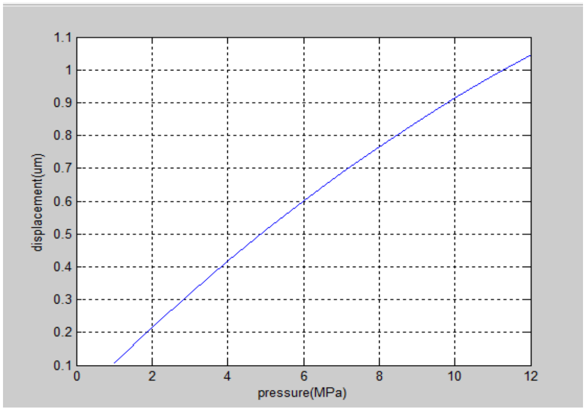

Figure 11. Graph of applied pressure v/s displacement for slotted pressure sensor

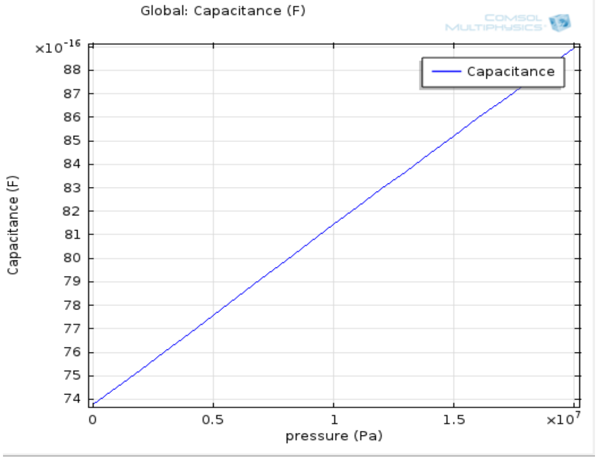

Figure 12. Graph of applied pressure v/s capacitance for slotted pressure sensor

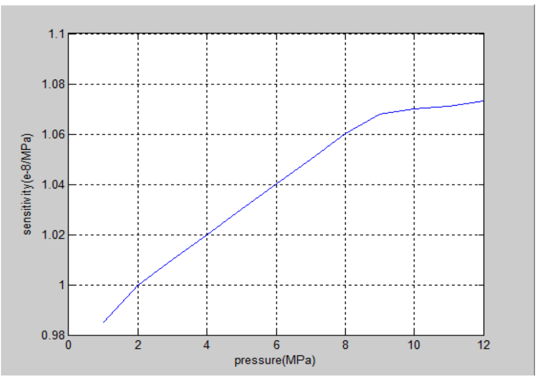

Figure 13. Graph of applied pressure v/s sensitivity for slotted pressure sensor

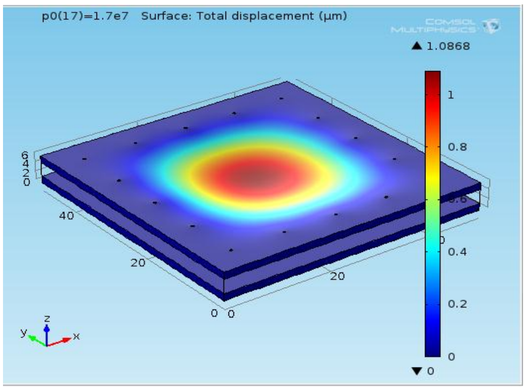

Figure 14.Perforated pressure sensor using Comsol multiphysics

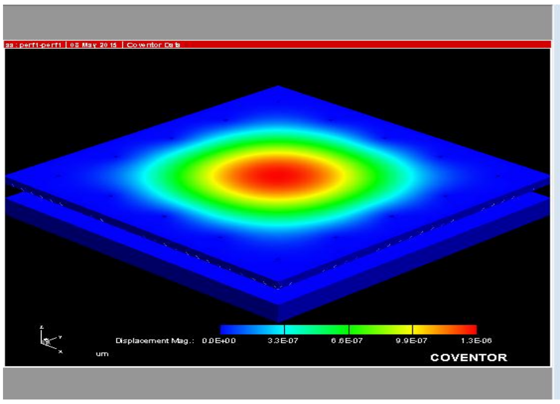

Figure 15.Perforated pressure sensor using Coventor ware

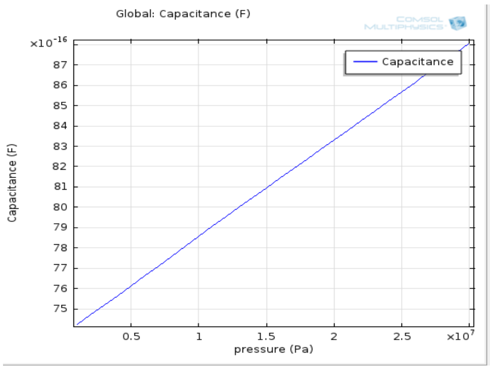

Figure 16. Graph of applied pressure v/s capacitance for perforated pressure sensor

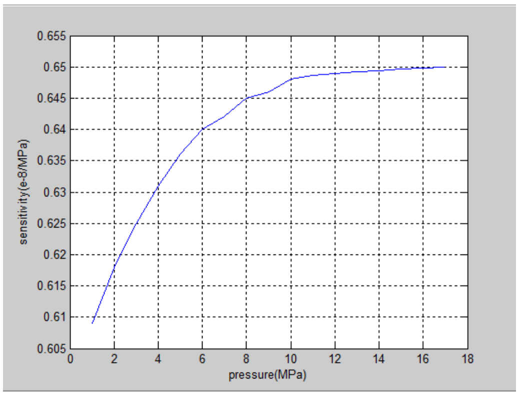

Figure 17 Graph of applied pressure v/s Sensitivity respectively for perforated pressure sensor

VI. CONCLUSION

Conventional, slotted and perforated MEMS capacitive pressure sensors are designed and simulated using COMSOL Multiphysics and Coventor ware tools. The simulation results show that the conventional capacitive pressure sensor achieves good sensitivity where as perforated capacitive pressure sensor achieves large operating pressure range. Hence the conventional pressure sensor can be used for high sensitivity applications. Perforated capacitive pressure sensor is used in harsh environment (16Mpa).

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