Optimization of Capacitive MEMS Pressure Sensor for RF Telemetry

Prince Nagpal, Manish Mehta, Kamaljeet Rangra, Ravinder Aggarwal

Abstract — This paper describes the capacitive pressure sensor design for biomedical applications like blood pressure measurement. The described pressure sensors provide high sensitivity even at low pressure range suitable for biomedical applications. Effects of varying different parameters on the pressure sensor performance have been studied. From the results, the pressure sensors with compatible parameters can be selected for specific requirements. These compact pressure sensors are made up of biocompatible materials and can be implanted easily inside body to be used for RF telemetry purpose.

Key Words— MEMS, Capacitive, Diaphragm, Biocompatible, Biomedical

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1 INTRODUCTION

SENSORS are one of the most active applications of MEMS. With the achievements in miniaturization of MEMS devices, sensor's applications have expanded not only for industry purpose but also for biomedical applications. Pressure sensors are one of the various types of sensors, where pressure is to be measured. One of the types of pressure sensor is capacitive pressure sensor. The capacitive pressure sensing technique's performance in respect of sensitivity is better than rest all other microsensing techniques viz. piezoresistive microsensing, piezoelectric microsensing and resonant microsensing. And so is applicable to wide range of applications like automotive applications, industrial applications, biomedical applications and general & consumer applications. The capacitive microsensing technique utilizes the diaphragm-deformation-induced capacitance change to convert the information of pressure into electrical signals. The capacitance is computed in a 3D model using $C = \varepsilon * \int (1/h)\, dA$ [1]

As MEMS technology is promising to achieve compact sizes, here we have optimized the capacitive pressure sensor to be implanted inside the body for blood pressure measurement [2] like applications. MEMS technology offers the possibility to realize devices of hundreds of micrometers and diaphragms of thickness 1 micrometer only. Therefore these capacitive pressure sensors are required to respond very less changes in applied pressure. Some of the desired features to these capacitive pressure sensors include high sensitivity at low pressures, biocompatibility and low profile. Using contamination insensitive [3] manufacturing process, smooth contacts [4] and additional touch points [1] sensitivity of capacitive pressure can be further improved.

In this paper, effect of varying different paramaters of the capacitive pressure sensors for biomedical applications in pressure range from 0 to twice of atmospheric pressure has been studied.

In this paper we demonstate three different possible geometries for capacitive pressure sensor are circular, square & rectangular. These pressure sensors are designed by having a silicon substrate, a silica bridge and a biocompatible diaphragm [5]. Details of the pressure sensors design and effect of varying geometry, surface area of diaphragm [6], diaphragm thickness, diaphragm dimensions and diaphragm material are described.

2 PRESSURE SENSOR DESIGN AND SIMULATION RESULTS

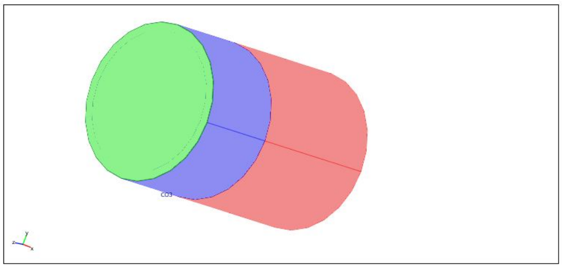

Fig.1 Subdomains of circular capacitive pressure sensor

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- *Dr. Ravinder Aggarwal is currently Professor at Thapar University, Patiala, India*

2.1 Design Specifications

The design of the circular capacitive pressure sensor analysed is shown in figure. On an silicon substrate of radius 283 μm and thickness 500 μm, a silica bridge has been mounted of thickness 300 μm on substrate perimeter of 30 μm width. A thin silicon diaphragm of 2 μm and 253.885 μm radius is than placed on mounted bridge to create a vaccum compartment beneath it.

The pressure sensor's performance with three different geometries is studied as shown in Fig. 2 in accordance with the following Table 1

TABLE 1
DIMENSIONS OF THE PRESSURE SENSOR

	Geometry		
Subdomain	**Circular**	**Square**	**Rectangular**
Substrate	Radius 283 Thickness 500	Side 500 Thickness 500	Length 860 Breadth 300 Thickness 500
Bridge	Width 30 Thickness 300	Width 25 Thickness 300	Width 25 Thickness 300
Diaphragm	Radius 253.885 Thickness 1	Side 450 Thickness 1	Length 810 Breadth 250 Thickness 1

2.2 Results

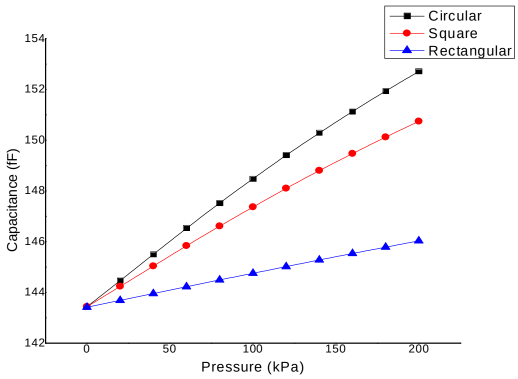

Fig. 2 Performance Graph of Capacitive Pressure Sensors

The Simulation is carried out by COMSOL Multiphysics 3.5 software, where capacitance is computed from the knowledge of deformation, induced by applied pressure, using expression C = (ε * 4)/(50μm + W2). Fig. 2 shows the comparative change in capacitance as applied pressure is varied for three geometries circular, square and rectangular of same surface area. Fig.3, Fig.4 and Fig.5 shows the Stress distribution for circular, square and rectangular geometry respectively. Here we can see that for the same surface area of diaphragm and silicon material used, the circular geometry performs best among all three, regarding sensitivity in the pressure range from 0 to 200kPa.

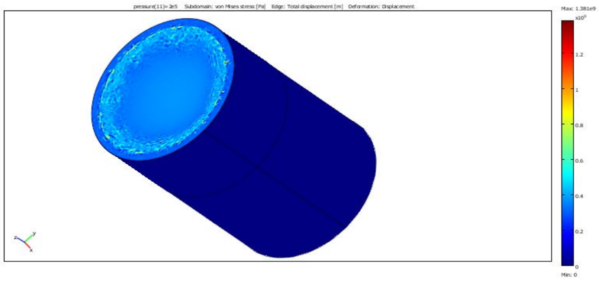

Fig. 3 Stress Distribution for Circular Geometry

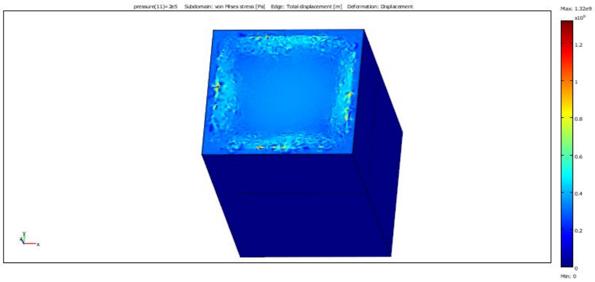

Fig. 4 Stress Distribution for Square Geometry

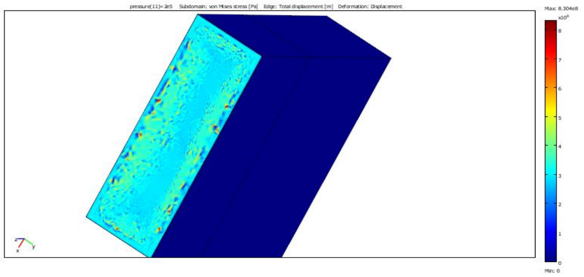

Fig. 5 Stress Distribution for Rectangular Geometry

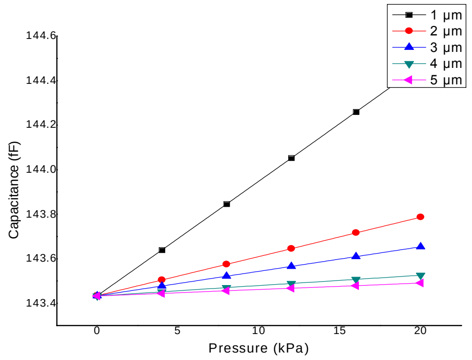

Fig. 6 Performance graph of circular geometry for diaphragm thickness variation

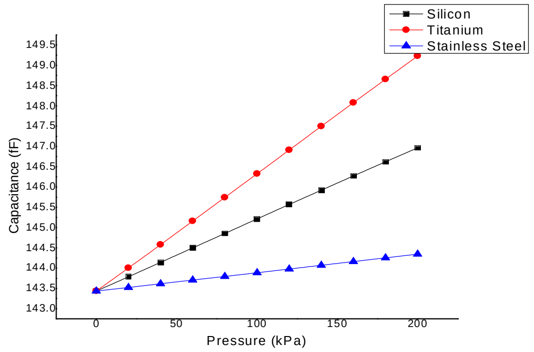

Fig. 9 Performance graph of circular geometry for diaphragm material variation

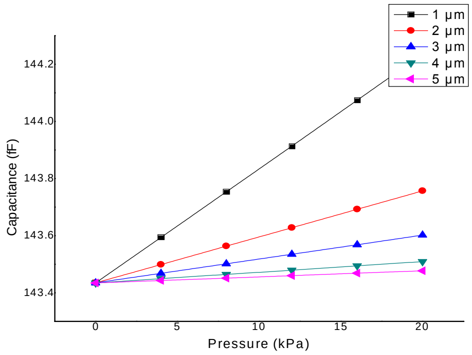

Fig. 7 Performance graph of square geometry for diaphragm thickness variation

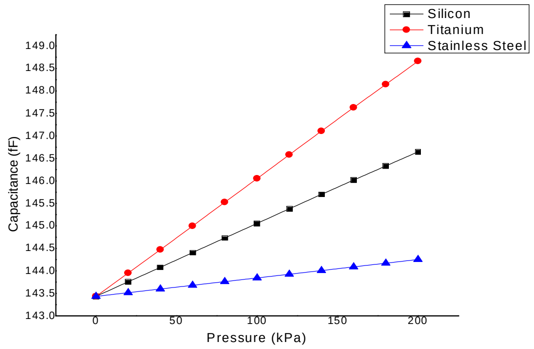

Fig. 10 Performance graph of square geometry for diaphragm material variation

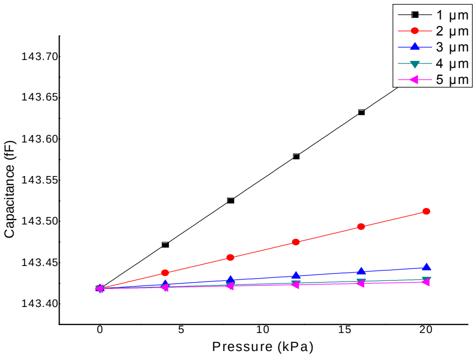

Fig. 8 Performance graph of rectangular geometry for diaphragm thickness variation

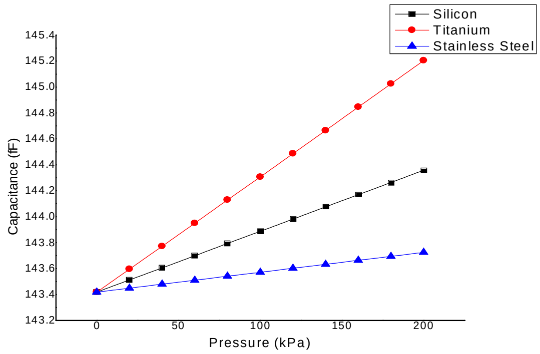

Fig. 11 Performance graph of rectangular geometry for diaphragm material variation

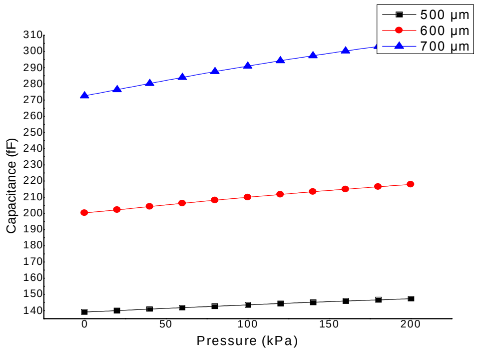

Fig. 12 Performance graph of circular geometry for diaphragm surface area variation

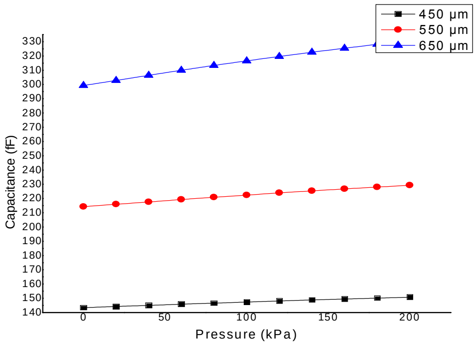

Fig. 13 Performance graph of square geometry for diaphragm surface area variation

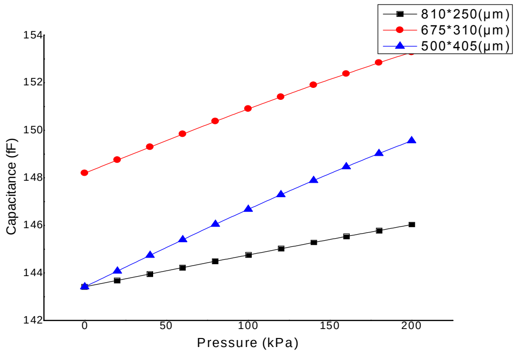

Fig. 14 Performance graph of rectangular geometry for diaphragm dimension ratio variation

Fig. 6, Fig. 7 and Fig. 8 shows the results of varying diaphragm's thickness from 1 µm to 5 µm for all three geometries considered.

Fig. 9, Fig. 10 and Fig. 11 shows the results of capacitive pressure sensor performance for four different biocompatible diaphragm materials for all three geometries considered.

Fig. 12 and Fig. 13 show the results of capacitive pressure sensor performance for different surface areas of circular and square geometry.

Fig. 14 shows the results of capacitive pressure sensor performance for different dimensions of rectangular geometry.

3 ACKNOWLEDGMENTS

I specially thanks to CEERI, Pilani and Thapar University, Patiala for providing their researches. Researches in [1], [2], [5] contributed great information for this paper.

4 CONCLUSION

Three different geometries of capacitive pressure sensor have been demonstrated. The capacitive pressure sensors are optimized regarding geometry, diaphragm material, diaphragm thickness, diaphragm surface area and diaphragm dimension ratio. The optimized sensors are suitable for biomedical applications in the low pressure range.

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