A capacitive pressure sensor for MEMS

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ABSTRACT

Pressure sensors have widespread applications in medicine and automotive industry. Specific designs and mounting arrangements vary considerably, ranging from small, sensitive catheter-tip transducers used within the heart to the bigger, rugged devices needed for industrial process control. A capacitive type of pressure sensor has been made using bulk silicon micromachining. It converts the diaphragm deformation, corresponding to pressure, into a change of capacitance. The total change in capacitance is the integral of the change of capacitance of each small area on the diaphragm. The change of capacitance $\delta C/C$ is measured as a function of deformation or pressure. The diaphragm deflection has been modelled using Intellisuite software.

1.0 INTRODUCTION

MEMS based silicon pressure sensor [1,2,3] has the advantage of low cost, small volume and high sensitivity. In addition, batch production is possible with on chip circuitry. Main uses are bio-medical applications, robotics and automobiles.

Blood pressure sensor is the most popular device used in medical applications. This device used as the part of the patient's intravenous system monitors blood pressure, which is transmitted to the pressure sensor through the column of saline intravenous solution. The sensor is meant to have an operating lifetime of 24-72 hours and is then discarded to minimize the possibility of infection. The annual production of these units is more than 17 million and the price for the basic hospital kit including the sensor and inter-connecting plastic tubing and valves is less than 10 dollars. Other applications include intrauterine pressure (IUP) sensors for monitoring pressure during child delivery, angioplasty pressure sensors, catheter tip pressure sensors and infusion pump pressure sensors.

Capacitive structure has been widely used in traditional pressure sensors. They feature high stability, high sensitivity and low temperature drift. They have an advantage over piezo-resistive type of device which requires extensive calibration and compensation procedures due to their small output signal swing (10-100mV) and large thermal drift. Capacitive pressure sensors are also known to have robust structure and are less sensitive to side stress and other environmental effects.However, its output is nonlinear with respect to the input changes and the sensitivity in the near linear region is not high enough to ignore many stray capacitance effects.

2.0 DESIGN

The main component of the pressure sensor is a thin flexible membrane or diaphragm as shown in Fig.**1.** On application of pressure, the membrane deflects and this deflection is a measure of the applied pressure. For a circular membrane of radius r and thickness t, deflection d can be expressed as a function of applied pressure P as[1]:

$$d = 0.662\, r^3\, (P\, r/E\, t)^{1/2}$$

Where E is the young's modulus.

This equation indicates that the sensitivity of deflection to pressure is mainly determined by membrane radius, which can be designed to match a prescribed measurement range . The membrane deflection can be directly measured using capacitive techniques or the deflection –induced stress is measured using integrated piezo-resistors.

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It is difficult to get circular membrane experimentally with wet etching so we fabricated square diaphragms and simulated results for the same. Table 1 shows the diaphragm deflection for different diaphragm areas, thicknesses and applied pressures using intellisuite software(for MEMS design). Fig 2 shows deflection for different applied pressures which is observed to be linear. Fig. 3 shows deflection for different membrane thicknesses.

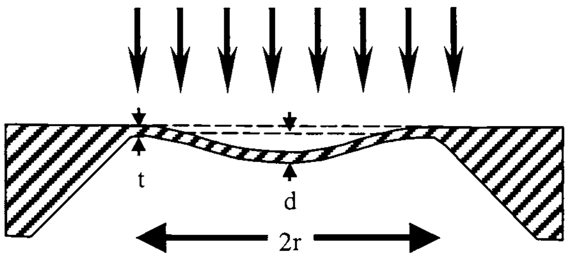

Fig 1: Structure of the bulk-micromachined membrane

Table 1: Simulated results for different sensor parameters using intellisuite software

Area (mm^2)	Pressure (Pascal)	Deflections for various thickness (Microns)				
		5□m	**10□m**	**15□m**	**20□m**	**25□m**
7x7	10	19.44	2.53	.76	.32	.16
	40	78.01	10.10	3.31	1.29	.66
	100	194.4	25.21	7.62	3.21	1.65
	200	390.10	50.38	15.41	6.43	3.31
6x6	10	9.785	1.328	.40	.17	.088
	40	39.143	5.312	1.60	.682	.35
	100	97.85	13.28	4.00	1.69	.87
	200	195.75	26.56	8.01	3.39	1.72
2x2	10	.006	.0024	.0013	.0007	.00048
	40	.023	.0100	.005	.0028	.00200
	100	.610	.0201	.013	.0071	.0048
	200	1.20	.0402	.025	.015	.0096

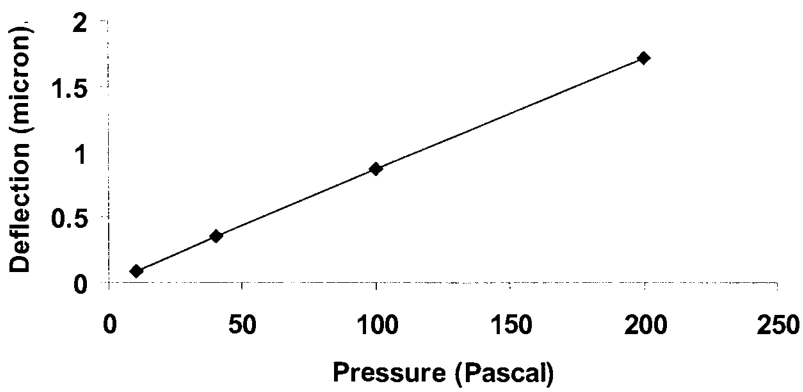

Fig 2: Pressure Vs Deflection for diaphragm (6mm X 6mm X 25 micron)

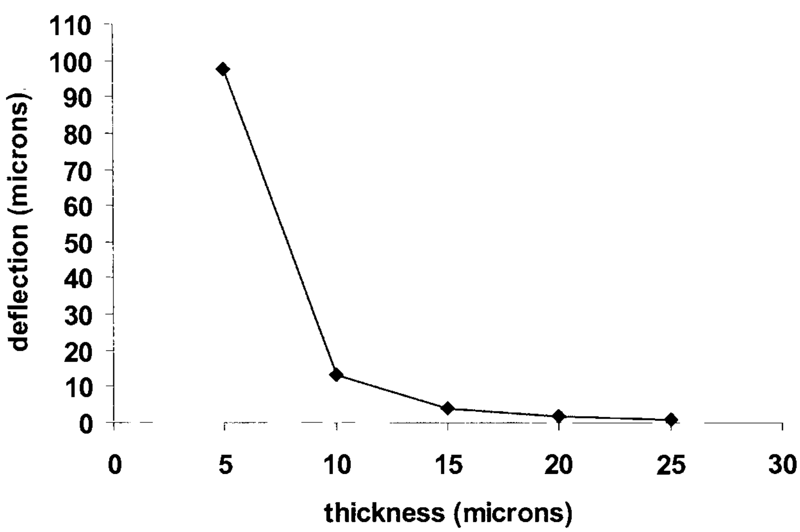

Fig 3: Thickness Vs deflection at 100 Pa for (6 mmx 6mm) diaphragm

3.0 FABRICATION

The sensor structure was fabricated using bulk micro-machining techniques. Thin square membranes were formed by removing silicon in the selected areas. KOH based etchant was used for this purpose. A thin layer of aluminium was evaporated in vacuum coating unit. This structure was mounted over metallized glass forming a parallel plate capacitor as shown in fig.4.

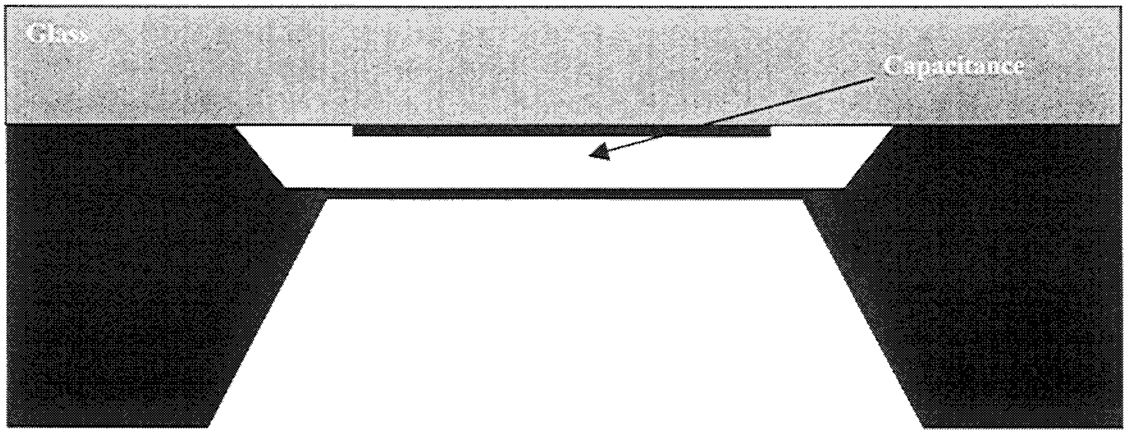

Fig 4: Structure of a typical silicon-glass Sensor

4.0 RESULTS AND DISCUSSIONS

The static capacitance when no pressure was applied was measured to be around "4pf". The change in capacitance was measured after applying pressure on the membrane. These results are shown in the Figs. 5 and 6 for two different membrane thicknesses 24μm and 15μm respectively. As shown, the sensitivity is better in the second case whereas range is more in the first case. These membranes were mounted using epoxy on bottom electrode. We have carried out experiments on bonding techniques and will be using these for bonding the sensors. These sensors will be tested in the vacuum system.

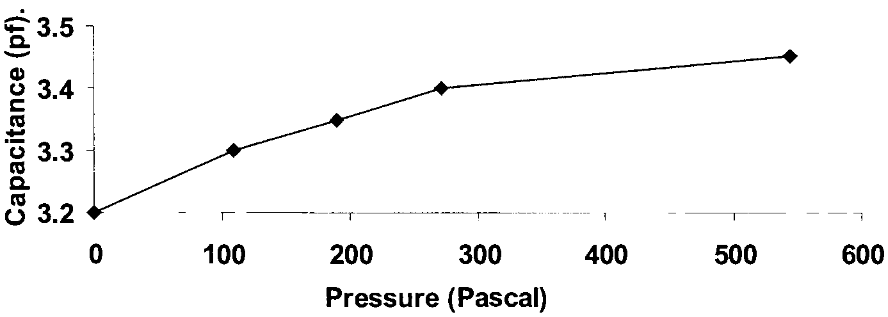

Fig 5: Capacitance Vs Applied Pressure for Sensor 1 Diaphragm (6 mm X 6 mm X 24 micron)

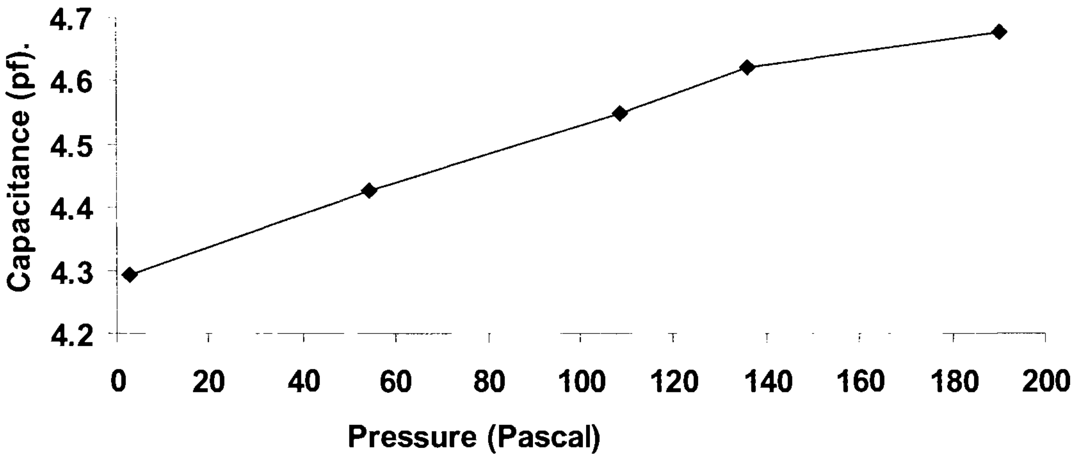

Fig 6: Capacitance Vs Applied Pressure for Sensor 2 Diaphragm (6 mm X 6 mm X 15 micron)

5.0 REFERENCES

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