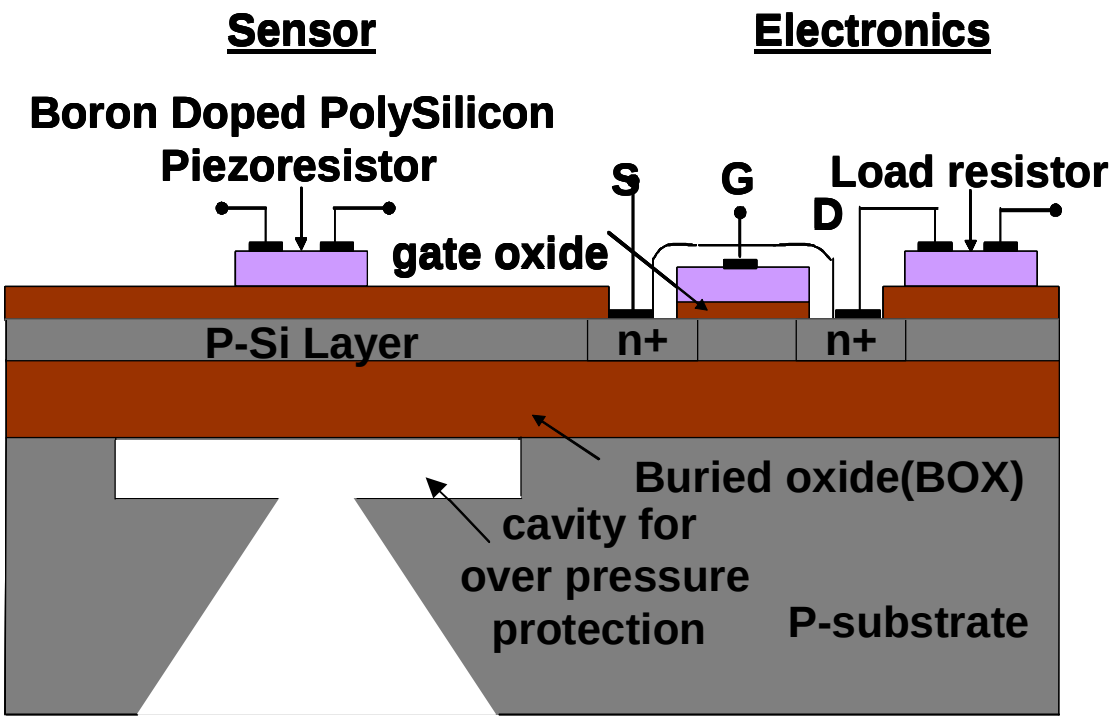
National Program on Smart Materials

Design and Development of MOS Integrated Piezoresistive Pressure Sensors



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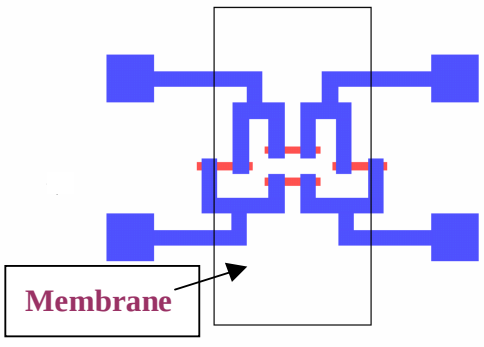
Pressure Sensor Details and the Novel Features

Polycrystalline Piezoresistive Pressure Sensors have been designed for two pressure ranges (1)10^3 – 3 x 10^5 Pascal (0.01 bar to 3 bar) (2) 10^4 – 10^6 Pascal (0.1bar to 10 bar) and fabricated at IIT Madras using Silicon On Insulator (SOI) layer as membrane and substrate for incorporating electronics as shown on the front cover page.

Significant / Novel Features : The pressure sensors designed and fabricated in this project have several novel features. (i) The devices are fabricated using Silicon On Insulator (SOI) approach to realize the pressure sensor membrane and the electronics. Diaphragm thicknesses ranging from 5 microns up to several tens of microns can be realized with this method. (ii) With the SOI approach over-pressure-protection cavity has been incorporated to prevent the diaphragm from further deflecting when the pressure is 2 P_{max} where P_{max} is the maximum pressure of operation. (iii) The piezoresistors are realized with polycrystalline resistors fabricated using LPCVD polysilicon deposited on the oxide grown over the SOI wafers prepared at IITM. These Polycrystalline resistors have shown virtually zero temperature coefficient when the boron doping concentration is suitably adjusted. (iv) The polysilicon piezoresistors are connected in the form of Wheatstone bridge. The resistor layout and the membrane aspect ratios are optimized and modified using ANSYS simulator so that the resistors located on the adjacent arms of the bridge experience maximum longitudinal tensile stress and longitudinal compressive stress respectively to achieve best sensitivity. (v) Pressure sensors have been fabricated with diaphragms of different aspect ratios to demonstrate the effect of the membrane aspect ratio on the sensitivity and linearity. (vi) The electronics consisting of an amplifier has been designed and proposed to be incorporated within the package, monolithically / in hybrid mode to achieve the full scale output voltage of 1 volt for 10 bar pressure.

Fig.1 Wheatstone bridge layout of the Pressure Sensor on the Membrane



The resistors are shown red and the metal connections and pads are shown blue. The resistors at the membrane edges experience a longitudinal tensile stress and the resistors in the middle undergo a longitudinal compressive stress. The Membrane width is 0.5 mm and the length is optimized.

Results achieved

The Microphotograph of the devices and the cut away view of the proposed device are shown in Fig.2 and Fig.3 respectively. The packaging was done at BEL, Bangalore. The devices have been tested at I.I.T. Madras by subjecting them to N_2 gas pressure through the pressure port shown in Fig.4. Typical test result obtained on the devices with 15µm membranes is shown in Fig.5.
Table – 1 gives the summary of the results.

Fig.2

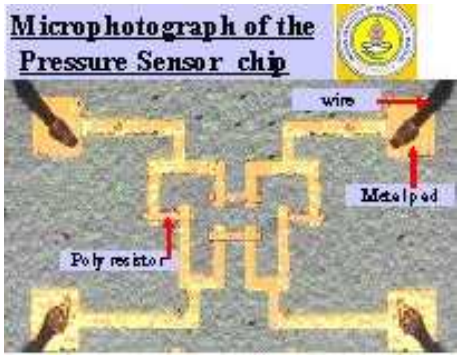


Fig.3

Fig.4

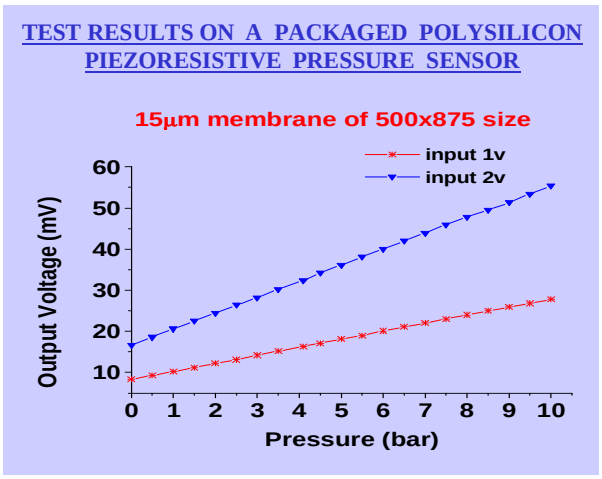
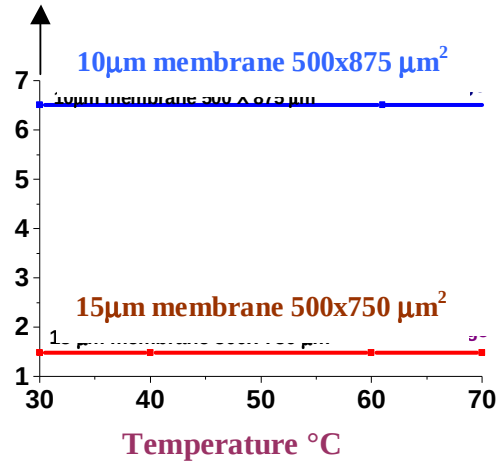


Fig.5

Table – 1: Summary of Results on the packaged pressure sensors

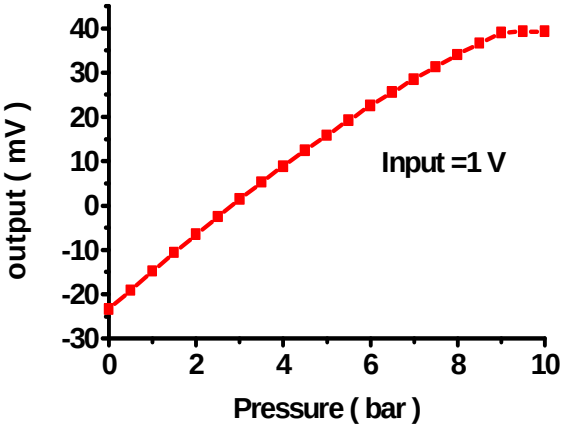
Membrane thickness, and aspect ratio	Offset Voltage for 1Volt input (mV)	Sensitivity (mV/Volt/BAR)	Maximum deviation in Linearity (% age)
10 µm, 500 µm x 750 µm	8.7	5.81	0.06 up to 3 Bar
10 µm, 500 µm x 1125 µm	8.7	10.3	2.90 up to 3 Bar
15 µm, 500 µm x 875 µm	8.4	1.8	0.36 up to 10 Bar



The packaged Pressure sensors have been tested up to temperature 70℃ and the sensitivity is found to be changing marginally only. (eg) in the case of devices fabricated with 10micron membrane the sensitivity changed by about 2 to 3% when the temperature was varied from 30℃ to 70℃

Results on the Pressure Sensors with Over- Pressure protection cavity

10µm membrane of 500x1125 µm² sizes with over-pressure protection



Specifications achieved for Packaged Pressure sensors having 6 µm cavity depth and membrane size of 500 µm x 1125µm:

Sensitivity S = 8.2mV/V/bar with **linearity** within **2 percent** up to **P_{max} = 3 bar** with the over-pressure cavity functional at a pressure of **3 P_{max} = 9 bar.**
Burst pressure P_B= 15 bar =5 P_{max} estimated using Rupture stress of silicon = 2GPa = 20kbar

Application Potential: The pressure sensors designed and fabricated in this project are suitable for an enormous range of application areas for sensing pressure in liquids and gases. Examples include automotive, aerospace systems, medical for blood pressure etc. The chip remaining the same in all the cases, modifications in the package need to be designed and implemented to suit to the particular application. For instance, a flat pill type package will be necessary for aerospace and biomedical applications. This packaging work can be taken up at BEL, Bangalore. The devices presented in this pamphlet have indeed been packaged at BEL, Bangalore.