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MEMS HYDROPHONE SENSOR FOR LOW FREQUENCY DETECTION

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ABSTRACT: MEMS Cylindrical Hydrophone is a vectored hydrophone which uses Piezoresistive effect to detect low frequency. The structure consist of four beam microstructure and a cylinder which has same density of water. The entire structure is placed in symmetry with respect to x and y plane. The model is built using COMSOL. Wheatstone bridge circuit is used as read out circuitry. Experimental results shows that frequency response vary from 20Hz to 3 KHz with an added advantage of small size and high sensitivity. The fabrication of this structure is carried out using silicon based MEMS technology.
KEYWORDS: Vectored Hydrophone, Microstructure, and high sensitivity.

1. INTROUCTION.

MEMS (Micro Electro Mechanical Systems) has been identified as one of the most promising technologies in these century. MEMS sensors have wide applications because of their small structure and low cost. Hydrophones are devices which are used to detect sounds underwater. Hydrophone are used in submarine detection and to observe any disturbances in the medium. In water medium, sound waves are considered as pressure waves, hence most of the Hydrophone uses piezoelectric material so that an electrical output can be generated through these pressure waves. As the technology improves, noise level in the radiated signal decreases, hence hydrophone should be able to detect low frequencies.

Hydrophone which uses Piezoresistive materials have an advantage of detecting low frequencies. This advantage makes Piezoresistive hydrophone more useful for underwater applications when compared to piezoelectric hydrophones. Piezoresistive hydrophones produce change in there resistance when sound signals are applied to them. We require an additional circuit to convert this change in resistance to an electrical output (change in voltage or current). This circuit is generally considered as readout circuitry.

The work in this paper is divided in to three stages 1) developing and analysing the model on COMSOL 2) defining the fabrication steps in CoventorWare 3) Readout circuitry.

2. STRUCTURE DESIGN.

The structure of MEMS Piezoresistive hydrophone consist of two parts 1) micro beam structure and 2) cylinder. Micro beam structure consist of 4 rectangular beams, 8 piezoresistors, and square mass [1]. The Piezoresistive material which act like resistors are placed on the beam where stress is maximum. Cylinder is the important part of the entire structure as it effects the sensitivity and the resonant frequency.

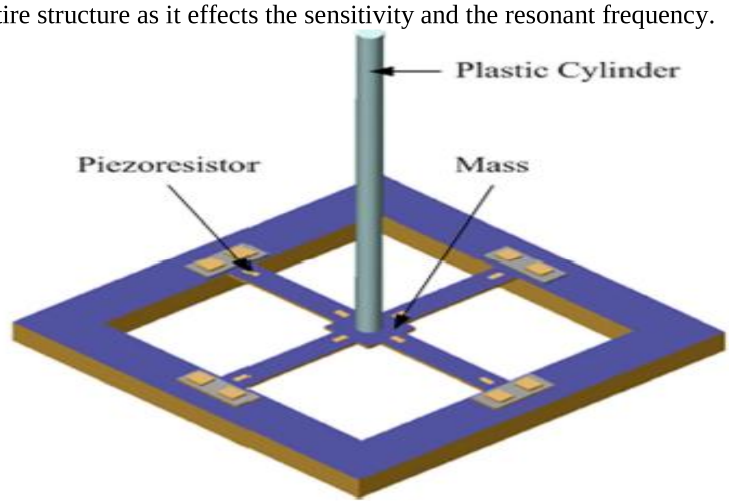


Figure.1: 3D structure of cylindrical hydrophone.

The density of cylinder should be same as that of water. Both mass and beam should have same thickness. The cylinder is fixed at the centre of mass. When the pressure wave alias sound wave strikes the cylinder there will be angular rotation and horizontal displacement in mass, which causes strain in the beams. Piezoresistive materials are placed at the places where maximum strain is experienced. The height of the cylinder is indirectly related to the resonant frequency.

The mass of the structure is 500µm wide and 500µm length with 10µm thickness. The four beams have 1000µmx120µm in dimension with 10µm thickness [1]. Since the edges of the beam are fixed, maximum stress is observed at the edges of the beam as shown in the fig2. The entire model as described above is built using COMSOL Multiphysics tool and analysed.

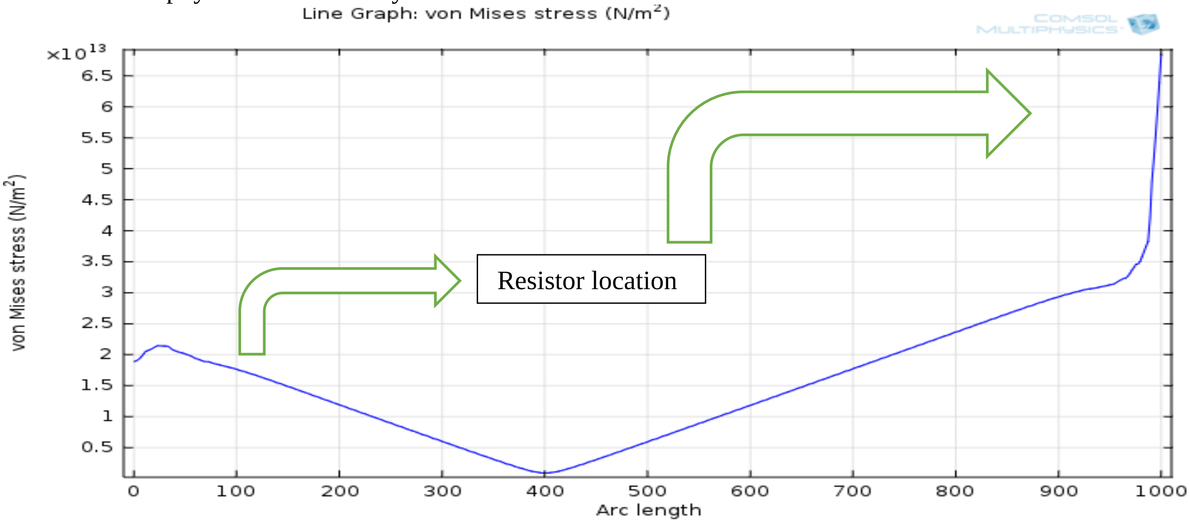
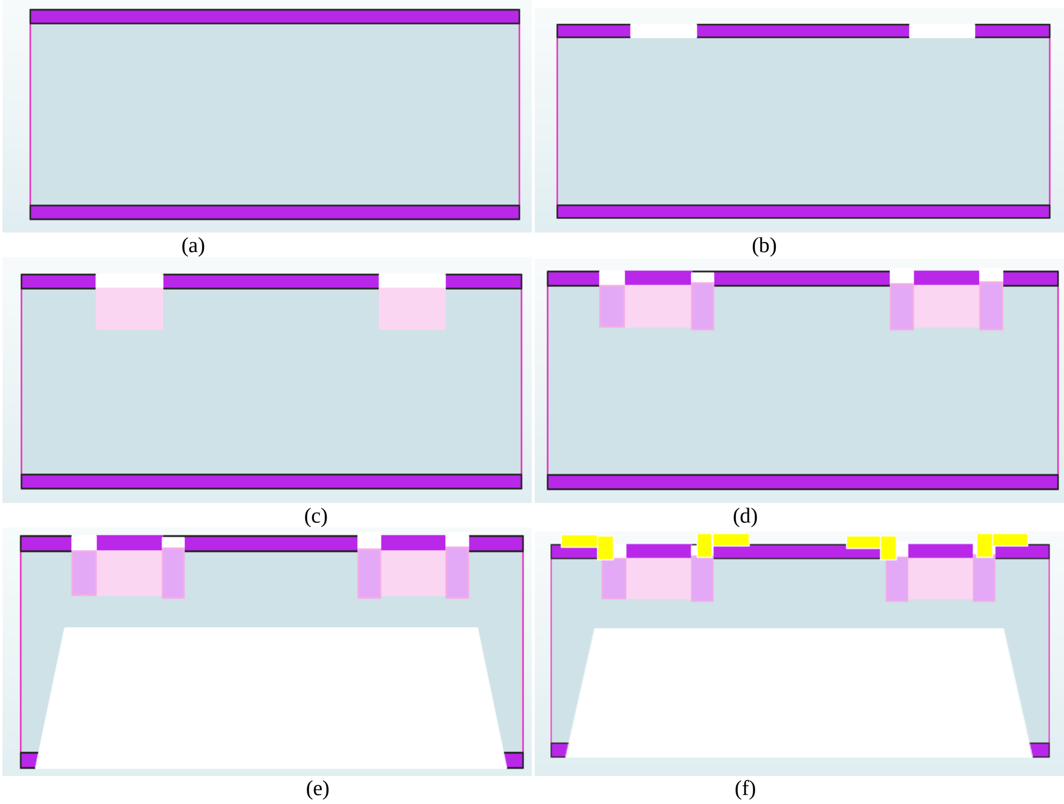


Figure 2: The curve of stress distribution along the beam length.

3. FABRICATION

MEMS Piezoresistive cylindrical hydrophone consist of two parts which are manufactured using two different technologies. Microbeam structure is manufactured with silicon based MEMS technology using thesteps described in fig 3. Plastic cylinder is manufactured using plastic moulding technology.



Silicon (n type) SiO_2 resistor (p type) ohmic contact TiPtAu

Figure 3: (a) Silicon wafer of thickness 100µm thickness (b) DRIE etching to remove the oxide layer (c) Boron ION implantation to form p-type resistance (d) formation of ohmic contact by increasing the ion concentration €Back side DRIE etching (f) TiPtAu evaporation and lift out

4. READOUT CIRCUITRY.

As described above when the pressure wave is applied to cylinder, the stress generated on the beam changes the resistivity of the Piezoresistive material placed which in turn changes the resistance. This change in resistance should be converted to change in voltage or current.The circuit best used for this is Wheatstone bridge. The structure consist of two simple series and parallel resistor with two input terminal and two output terminal as shown in the fig 4. The output is given to the subtractor to get the change in voltage. If needed the output can be amplified and used for the required purpose.

Pressure waves may arrive in any of the directions say, x or y, thus we require two Wheatstone bride for each direction. The four resistors in x-direction will form one Wheatstone bridge and the other four in y-direction forms the other. This will provide directional analysis. The resistor terminal of the Wheatstone bride should be connected to the resistor contact of the hydrophone.

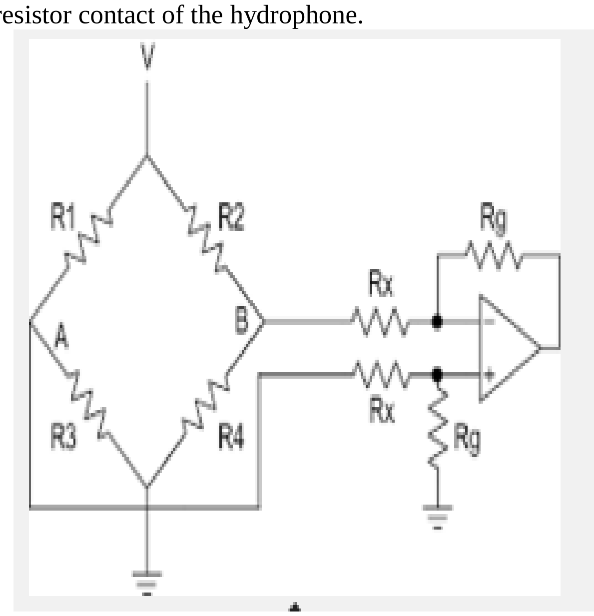
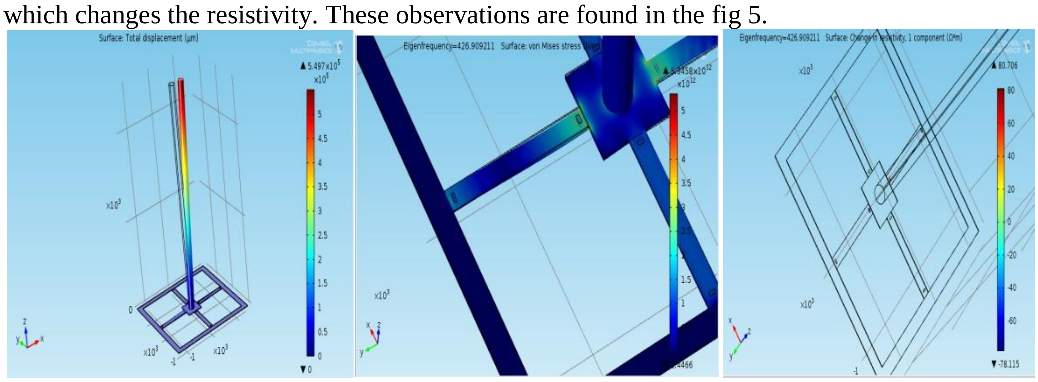


Figure 4: Wheatstone bridge with subtractor.

5. RESULTS.

COMSOL uses fine element analysis, by dividing the entire structure in to finite number of small elements. When directional pressure (force) is applied, the cylinder gets displaced causing stress on the beam which changes the resistivity. These observations are found in the fig 5.



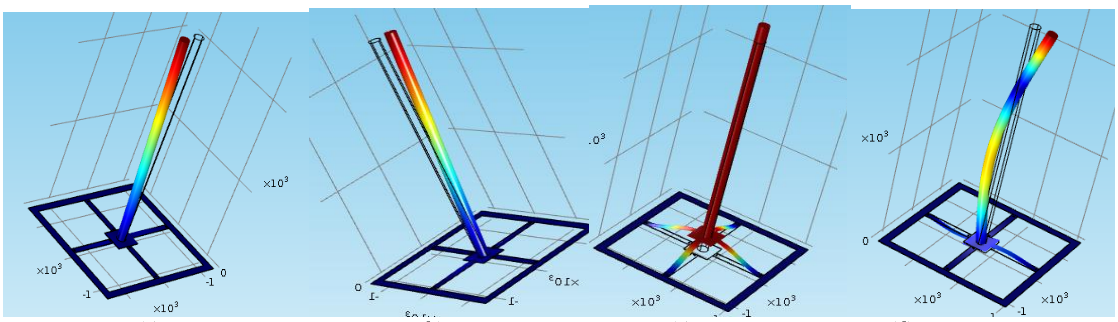
(a) (b) (c)

Figure 5: (a) Displacement of cylinder. (b) Stress in x-directional beam. (c) Change in resistivity.

Table 1 gives the natural frequency for 6 modes of operation. Displacements for these frequencies has been plot in fig 6. Displacement is minute after 3 KHz thus the structure works well between 20Hz to 3 KHz. The highest displacement is obtained at 1st model frequency 426.90Hz.

Table I: Natural frequency of hydrophone

Mode	Frequency (Hz)
1	426.9
2	434.7
3	1954.09
4	36383
5	36384
6	66691.98



(a) (b) (c) (d)

Figure 6: Displacement for first 4 mode frequency (a) 426.9 (b) 434.7 (c) 1954.09 (d) 36383

6. CONCLUSION

We have implemented cylindrical hydrophone using MEMS technology which is small in size and detects low frequency with sensitivity ranged from 20Hz to 3 KHz. The readout can be independently used as ASIC. It is used to observe any change in the particle velocity of the medium in which it is placed.

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