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MEMS MICROPHONE SENSOR FOR DEFENSE APPLICATIONS

Priyanka Ashok Kamthane[1], Dr R Sundaraguru[2]
PG Student, Dept. of Electronics and Communication Engineering, Sir M Visvesvaraya Institute of Technology, Bengaluru Karnataka, India[1]
H.O.D, Dept. of Electronics and Communication Engineering, Sir M Visvesvaraya Institute of Technology, Bengaluru Karnataka, India [2]

ABSTRACT: A Directional microphone is a device which has the intelligence to sense the direction of the acoustic pressure falling on its diaphragm. In this work MEMS directional microphone inspired by Ormia ochracea fly has been designed and simulated. The Directional microphone with comb structures are designed using SOIMUMPS process and simulated to know the impact of structures on sensitivity; frequency response. The symmetric solid wing directional microphone is designed of different thickness for defense applications. In this work will be looking in detail on the design aspects of different directional microphone structures and comparison of their sensitivities to obtain the Directional microphone structure with best sensitivity. The frequency responses vary from 22 kHz to 26 kHz for 30um thickness of device 30um and 13 kHz to 17 kHz for 15 um thickness of device. The fabrication of this device is carried out using SOIMUMPs process using CoventorWare tool.

KEYWORDS: MEMS Microphone, Microstructure, high sensitivity.

1. INTROUCTION.

A Microphone is a device which will converts pressure variations in the environment to electrical signal. Electromagnetic transducers convert acoustic signals into electrical signals. Etymologically, the word microphone has its origin from Greek word micro that means „small and phone resembling „sound .
Microphones occupy a insidious space among acoustic sensors, various applications have imprinted for specific requirements that are needed for designing the microphones for specific consumer need; however, microphones that are built using metal –film, and capacitance based measurement means are generally accepted as the vital regulatory devices in terms of size and detection capability.

A MEMS microphone having applications in many areas for example audio applications in which minute size, quality of the sound should be high, consistency and every one can afford, these are the main requirements. One of the miniaturized device is microphone, has enabling high quality usage that are being designed but still the techniques used for designing microphones are unable to meet the expected performance required in the market so most of the microphone products are limited to standards with low performance. Hearing aid is an example of one such standard where in the performance parameter is quality dependent and how far the device can be miniaturized as possible. The invent of MEMS as made possible to overcome the most of the challenges that results as an outcome of performing miniaturization and also this has led to the improvements for capacitive microphones. Microphones are used in many electronic gadgets such as computers, cell phones, digital cameras, hearing aids, mp3 players, motion pictures, non-acoustic sensors for ex ultrasonic checking’s or knock sensor and public address systems. Design of microphone is application oriented, so all the dimensions of microphone are specified according to the consumer need applications. High frequency response of the microphone has applications in military as compared to the previous other microphone.
The work in this paper is divided in to two stages 1) developing and analysing the model on COMSOL 2) defining the fabrication steps in CoventorWare.

2. STRUCTURE DESIGN.

To design a structure of MEMS Directional microphone consists of two diaphragms (wings) with comb drive structure. If the sound wave incident from distant source on wings then the amplitude of pressure will be identical on both the wings because they are small in size. The amplitude of pressure incident on both the wings will be constant approximately, if source is placed far away distant from receiver.

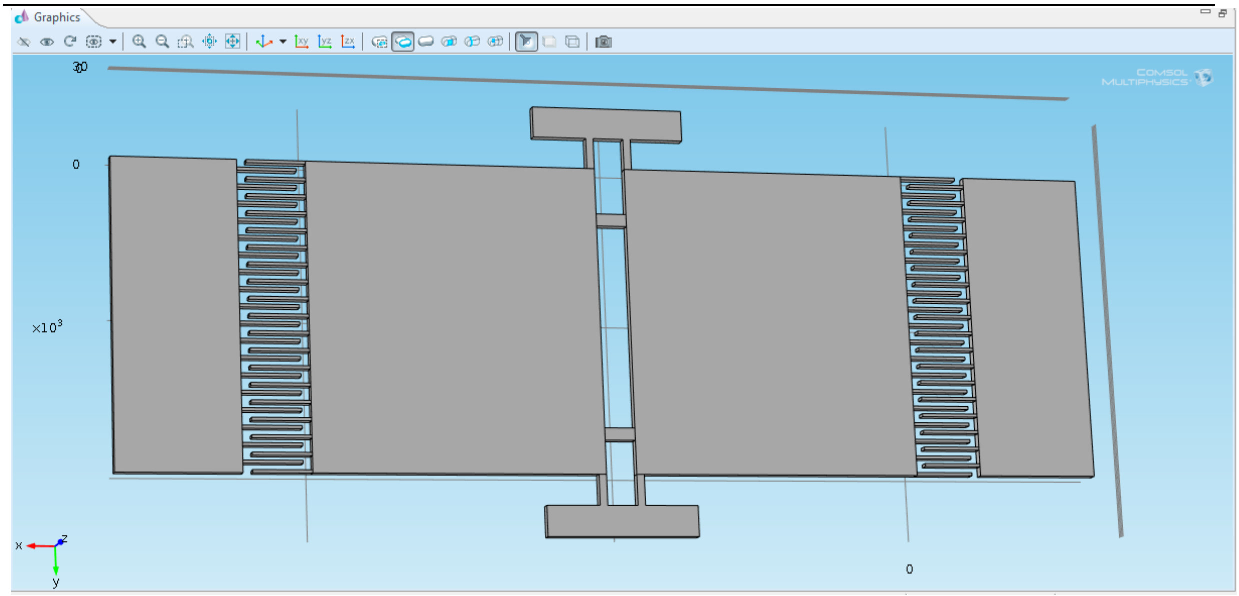


Figure1: Structure of MEMS directional microphone.

The above shown figure 1 has solid wings with dimension 2mm*1mm and having thickness of 30µm and also designed for thickness of 15µm. The type of construction material utilized is silicon because it will provide property of wings stiffness K. While considering the physical dimension and properties of the plate gives rise to total mass of the plate, which will help to find frequency factor for rocking mode is represented by ω rocking mode. The two solid wings linked each other through coupler that is called beam which is flanking at both the ends. The torsion stiffness of the beam dimension will account for coupling stiffness that is Ks. The resonance frequency of bending mode is controlled by this beam and this is given by ω bending.

The direction of arrival of sound wave is called as angle of arrival (AOA). In large creature the distance separation between the hearing organs is smaller. When pressure incident two ears then animal should have capability to recognize the small pressure differences because that will indicate directionality of that signal. Figure 1 represents that every wing has a movable brush fingers and those are integrated with fixed fingers connected to pads on both the side of structure. These fingers look similar as shown in parallel plate capacitor. By applying voltage on both the pads and pressure on both the wings due to the movement of both movable and Fixed fingers capacitance can be determined. By detecting the capacitance adjustment client can determine and differentiate deflection of device. Silicon is the material used for microphone structure.

Table 1.1 Design parameters for MEMS directional microphone.

Dimension	Value	Unit
Wings width	950	µm
Wings height	1000	µm
Comb width	190	µm
Comb height	10	µm
Coupling width	100	µm
Coupling height	40	µm
Thickness	30	µm

3. FABRICATION

The MEMS Directional microphone structure with comb drive is built using SOIMUMPs process that consists of four layers, the silicon structural layer, insulating oxide, substrate and blanket metal layer. SOI wafer is used as a starting substrate. Handle wafer thickness is 400µm. Oxide layer is deposited above the substrate layer. Oxide layer thickness is 6um, 1µm. Next silicon layer of thickness 30µm and 15um is doped and patterned using mask level SOI and etched down to oxide layer. This layer can be used to build mechanical structures. The wafers are reversed and the substrate layer is lithographically patterned from bottom side using mask level TRENCH to release the structure from the substrate. The blanket metal layer consisting of 50nm gold and chromium are deposited using shadow mask technique.

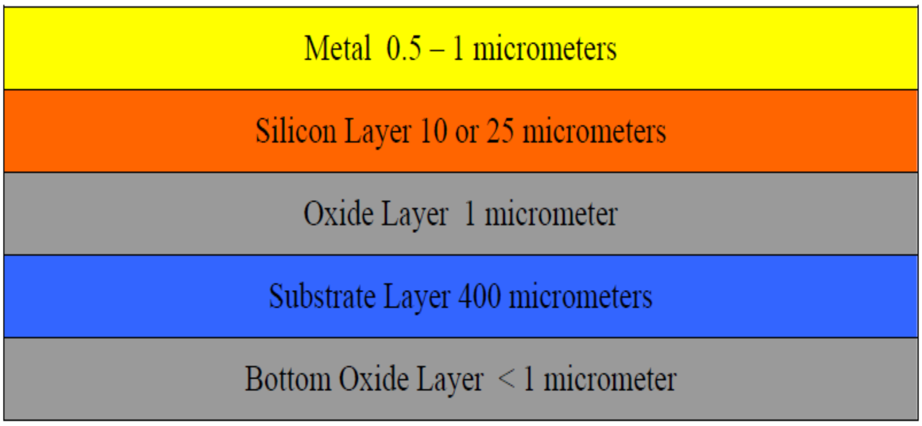


Figure 2: SOI MUMPS features.

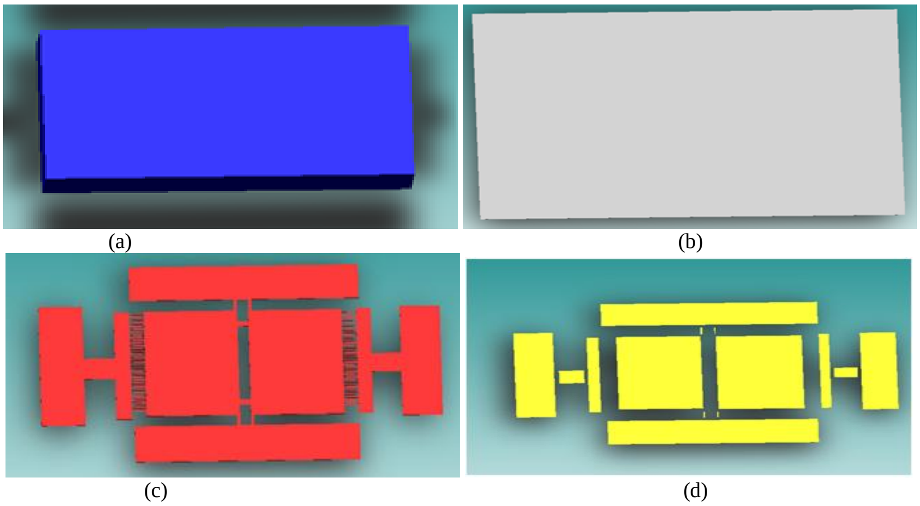


Figure 3: a) Silicon substrate b) Oxide layer c) SOI layer d) Blanket metal layer.

IV. BIOLOGICAL INSPIRATION.

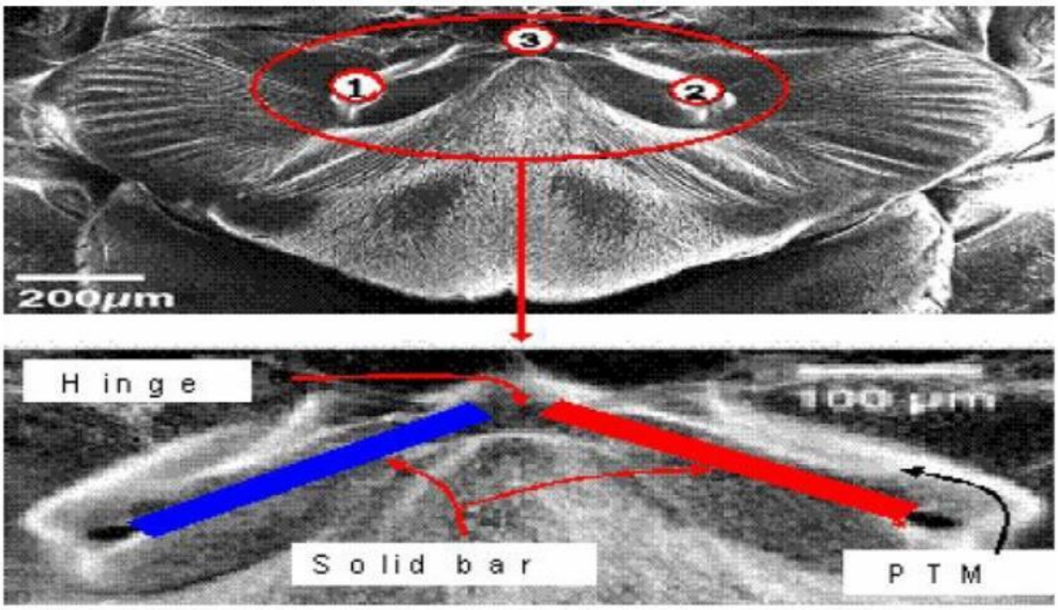


Figure 4: Auditory system of fly.

Ormia ochracea is having long wavelengths compared to the dimensions of the fly's hearing system and also the hearing system of the Ormia ochracea is astonishing mainly due to its acute directional sensitivity to sounds. The direction of low frequency sources (f < 500 Hz) of humans is determined primarily by sensing the intraoral time difference (ITD). In human the difference in arrival times is ranges from zero when the source is straight ahead, to several hundreds of microseconds when the source is directly to one side. Human can detect minimum of 10 µs [15] ITD, which is an approximate value and having minimum of 1 degree angular resolution. Humans have an even greater advantage at higher frequencies, as the head creates an acoustical shadow at the contra lateral ear due to which an intraoral intensity difference (IID) between the two ears is determined. Figure 1.2 given below shows the fly's auditory organ, the ear structure consists of two mechanical bars connected by a hinge membrane. In picture Parts 1 and 2 are the bars, part 3 is the hinge.

PTM is prosternal tympanal membrane; ear drum of the fly is for all intents and purposes and is the mechanism that drives the solid bars via the sound input. By Estimating the mechanical response of the Ormia fly it is determined that the ear nearer to the direction of arrival path of sound when it is approaching from one direction reacts with superior amplitude in comparative with the ear that is farthest away from the sound source. Intraoral difference is created by the mechanical response of the fly due to the coupling of the ears movement by a cuticular structure that connects the two tympana, that is being named as the intertympanal bridge. The achievement of directional sensitivity by using mechanical link as a coupler between two ears is first reported in this work. Implicating the fly structure as combined structure with damped harmonic oscillators the combined structure as two attached, damped harmonic oscillators showed that the movement of the structure is a combination of two principal modes. In the rocking mode, in which the two sides oscillate like a see-saw accounting 180º out of phase, is often envisioned as a rocking motion. In bending type mode, the coupling two sides are oscillating in phase and the structure bends in the middle by generating a bending approximating motion, this type of motion produced can be termed as another mode. The rocking motion resembles due to the difference developed in acoustic pressure arriving through different paths. The rocking motion acoustic pressure is represented by notion Pr (t), is given by $Pr(t)=Pi(t)-Pc(t)$,where Pi is the pressure incident on ipsilateral side of tympana which is in close proximity and Pc is the pressure incident on contralateral side of tympana and it is the farthest side from the sound source (contralateral). The mode that resembles the bending motion is determined by summation of acoustic pressure arriving through multiple paths and summation of two pressure inputs represented by notion Pb(t), $Pb (t) =Pi (t) +Pc (t)$. Bending type motion is having greater amplitude compared to the movement.

V. RESULTS

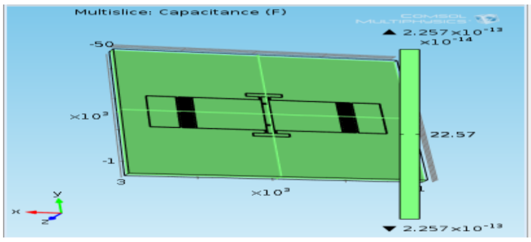
Both COMSOL and CoventorWare use fine element analysis by dividing the entire structure in to finite number of small elements. When directional pressure (force) is applied, on the wings of directional microphone it bends. Where we can observe two modes one is rocking mode and another is bending mode by doing Eigen frequency analysis. These observations are found in figure 5.

a

b

a) Frequency: 26.196 KHz.
Displacement: 3.2417 e6 µm.

b) Frequency: 24.264 KHz.
Displacement: 3.2262 e6 µm



c

Capacitance = 0.2257pf.

Figure 5 a) Bending mode b) Rocking mode c) Capacitance.

6. CONCLUSION

We have implemented Microphone using MEMS technology which is small in size and detects frequency with sensitivity ranged from 24 KHz to 26 KHz. It is used in military applications for landmine detection.

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