CMUT Based Free Membrane Intra-Cardiac Volumetric Blood Flow-Meter

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Introduction: A free membrane receiver is used to increase the capacitance and therefore the sensitivity of the flow meter[1]. For the current application, from the wavelength of sound wave in soft tissue (c= 1540 m/s) the resolution was calculated to be 0.48 mm. This gives the first Eigen frequency of the capacitive structure according to which the poly silicon membrane was designed. After applying the bias, kinetic and dynamic study was carried out. Acoustic coupling gives the receiver mode. Changes were made to the dimensions to increase the resolution for the same fundamental frequency. The percentage increase in capacitance in the free membrane was calculated.

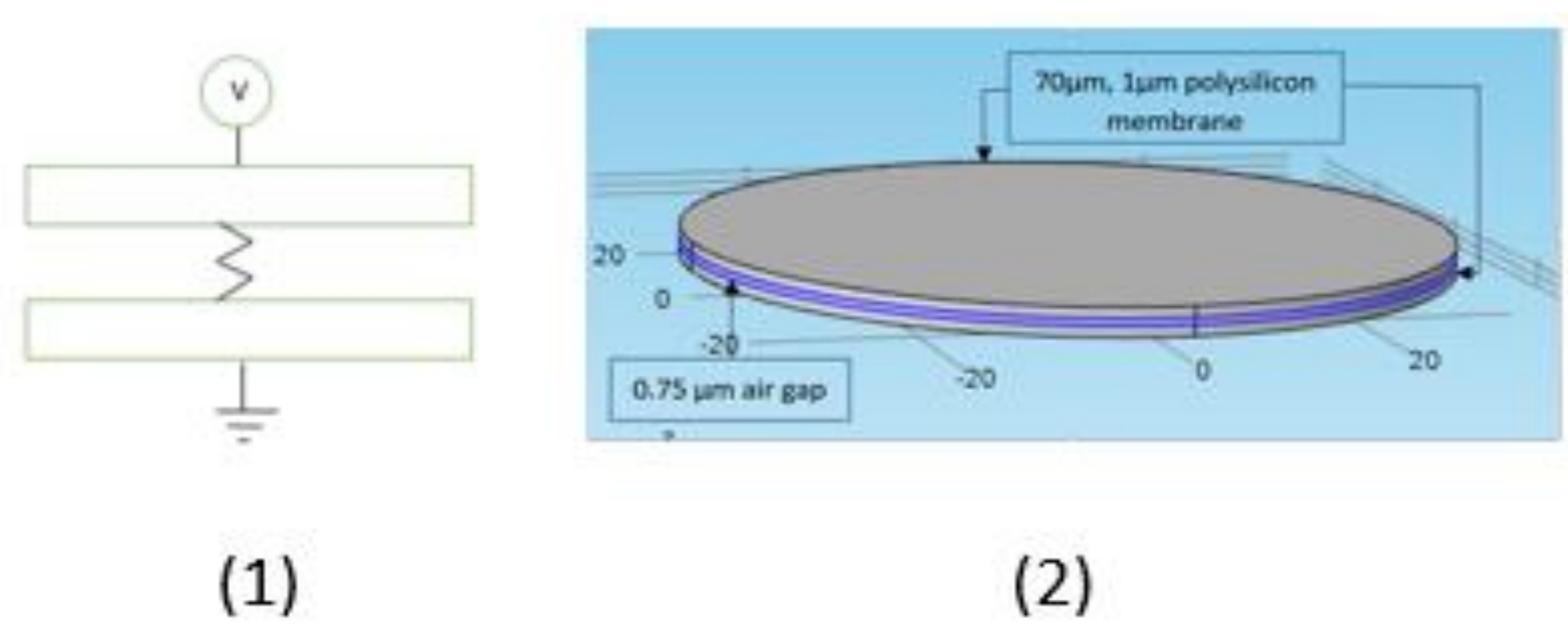


Figure 1. (1) Lumped model (2) Simulated CMUT

Computational Methods: The A.C. plus D.C. biased membrane creates an electrostatic stress according to the Poisson's equation (1). The force density acting on the electrode comes from the Maxwell stress tensor (2)[3]. The varying force from the alternating voltage generates ultrasonic waves which waves on striking the receiver generates an echo signal according to the voltage change. Blood flow meter works on the principle of Doppler shift (3) in the echo signal to measure the velocity of blood stream. This device works in the time domain so that the ultrasound angle (4)(z is found experimentally) and the diameter of flow (5) can be measured which gives the flow rate[2].

$$\nabla\cdot(\varepsilon\nabla V)=0 \quad .....(1)$$

$$Fes= -1/2[(E\cdot D)n+(n\cdot E)D] \quad ....(2)$$

$$V= c\,(T2-T1)/2T\cos\theta \quad .....(3)$$

$$\tan\,\theta=4zr\,/c\delta T \quad .....(4)$$

$$D = cT\,\sin\theta/2 \quad .....(5)$$

Results: The transmitter membrane biased at (135 + 15 sinωt) V (f=1.66 MHz) resulted in a displacement amplitude of 0.29 μm. than the maximum allowable strain of LPCVD polysilicon of 0.018. The inward normal acceleration was coupled to the membrane acceleration and displacement amplitude of 0.23 μm was observed. This was increased to 0.46 μm for the same fundamental frequency by changing the h/r[2] ratio. The resulting capacitance shows an increase of 10% when compared to bound.

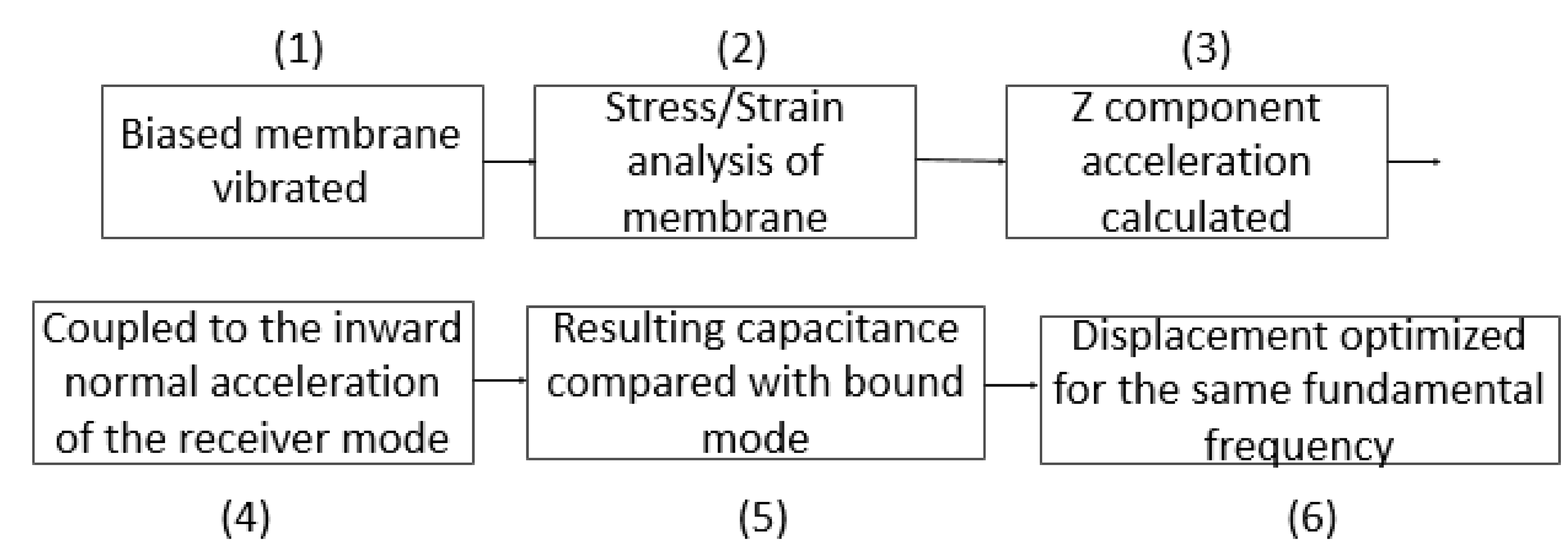
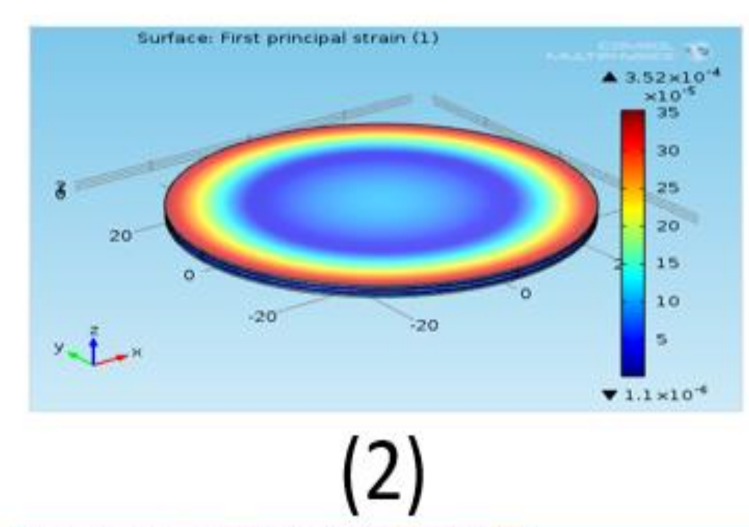
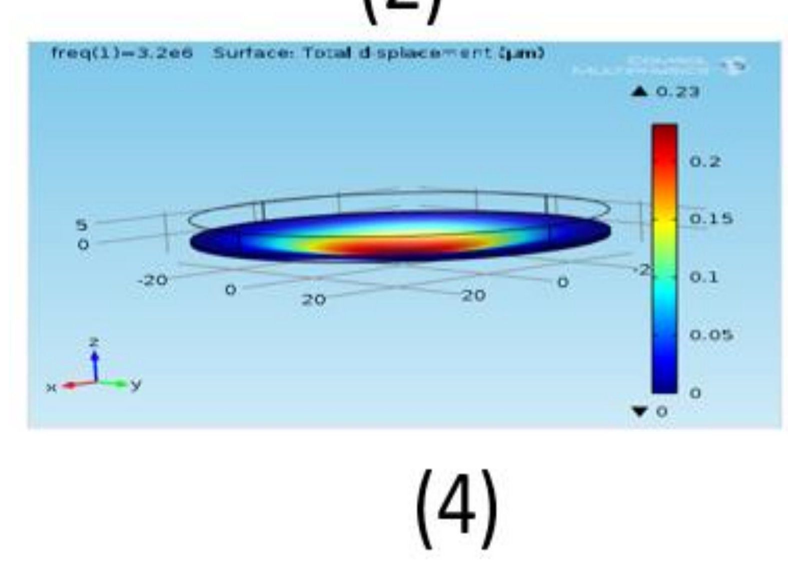


Figure 2. Process flow of results



Time (s)	Acceleration, Z component (m/s^2)
0	-1.1972961431149285E7
5.0E-8	-1.1972016184040923E7
1.0E-7	-5153192.570307183
1.5E-7	1.5214310753995202E7
2.0E-7	1.4297464245830195E7
2.5E-7	4028475.9192867684

(3)



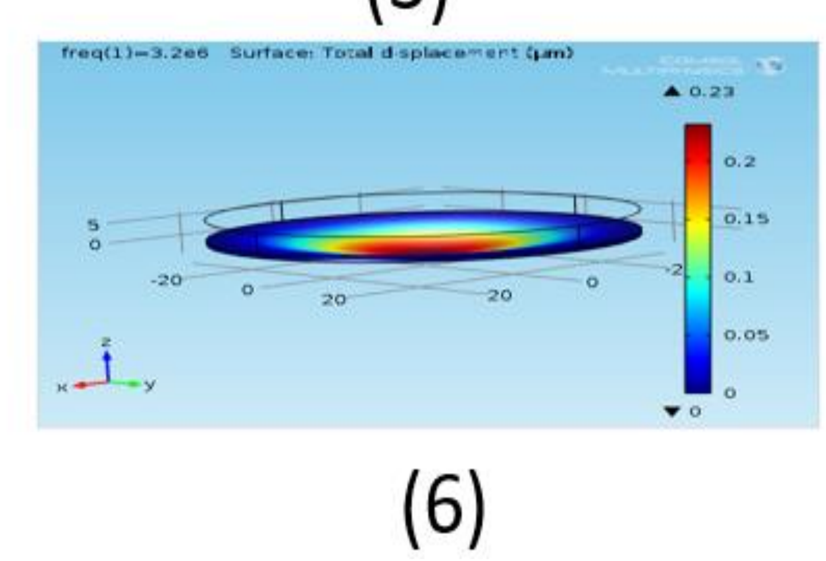


Figure 3. Results (in order of process flow)

Conclusions: The device is now proven to be more sensitive and is now ready for process modelling. Owing to the current silicon technology, this MEMS device can be easily mounted on a probe. Being minimally invasive it can be extremely useful for measuring the fetal cardiac blood flow. However, CMUT is a low frequency device and to further increase the resolution the device needs to be introduced inside the to-be measured body.

References:

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