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

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Abstract

MAIN BODY OF THE ABSTRACT:
In this paper a free membrane is used as a receiver to increase the capacitance and therefore the accuracy of the flow meter. 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.
INTRODUCTION:
CMUT consists of membranes with electrodes having A.C. plus D.C. bias. D.C. creates an electrostatic stress which is balanced by the spring force of the membrane (Figure 1). The alternating voltage varies the force generating the ultrasonic waves. These waves on striking the receiver generate an echo signal according to the capacitance change. The advantage of CMUT is improved bandwidth, ease of fabrication with silicon technology and integration with electronics [1]. Blood flow meter works on the Doppler shift in the echo signal to measure the velocity of blood stream (Figure 2). This device works in the time domain so that the ultrasound angle can be measured [2]. This also gives the diameter of flow and therefore the flow rate. It provides an edge over its laser counterpart since it can have a greater penetration depth owing to its low frequency when compared to laser making CMUT a minimally invasive device [1].
USE OF COMSOL MULTIPHYSICS:
Shell Interface from Structural Mechanics module in COMSOL Multiphysics was used to implement this model (Figure 3) to find out the Eigen frequencies of the vibrating membrane (Figure 4). A time dependent electro-mechanic study was set-up ([3]. To implement a free membrane only the sides of the membrane was fixed. The poly silicon membranes were modeled as a linear elastic dielectric material and all three domains had an electrical material model. The air domain was free to deform. To simulate the receiver mode, the inward normal acceleration was coupled to the membrane acceleration and displacement amplitude was observed.
RESULTS:
The transmitter has a diameter of 70 µm diameter and thickness 1 µm. The receiver is 49.50 µm in diameter and 0.5 µm thick (air gap 0.75 µm). The bias frequency needs to be 1.6MHz with a peak of 15V. The dc bias is 135V. The capacitance has a 10% increase for the free membrane.

CONCLUSION:
The device is ready for process modeling. 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 cardiac blood flow of newborns. 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.

Reference

1) Wang, Mengli, Capacitive micromachined ultrasonic transducer arrays for blood flow ultrasound doppler and photoacoustic imaging applications, Dissertation, University of New Mexico Albuquerque, New Mexico, December 2010.
2) Wang, Mengli; Chen, Jingkuang, Volumetric Flow Measurement Using an Implantable CMUT Array, IEEE TRANSACTIONS ON BIOMEDICAL CIRCUITS AND SYSTEMS, VOL. 5, NO. 3, JUNE 2011.
3) Electrostatically Actuated Cantilever, COMSOL Documentation.

Figures used in the abstract

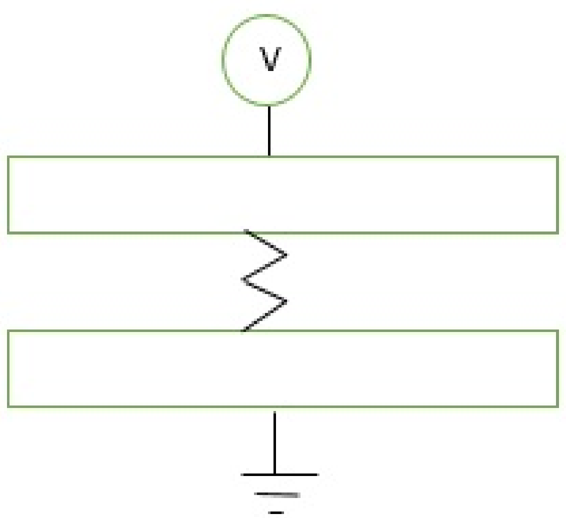

Figure 1: Lumped Model.

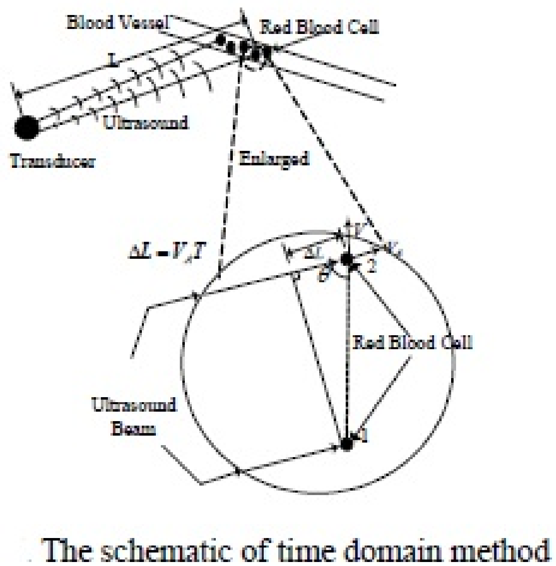

Figure 2: Principle of Operation.

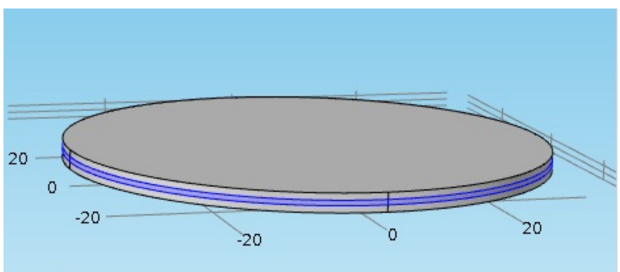

Figure 3: Solid Model.

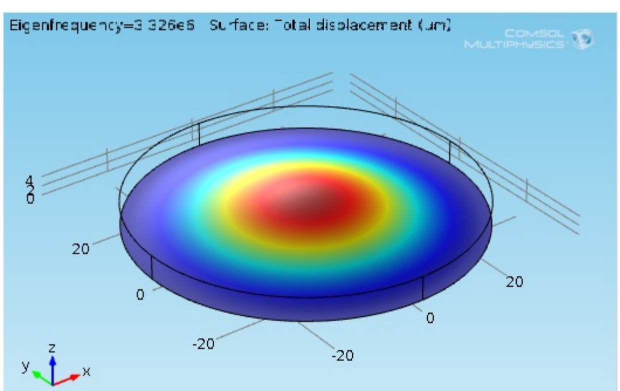

Figure 4: First Resonant Mode Shape.