Modeling and Simulation of Dual Application Capacitive MEMS Sensor

A. Ravi[1], R. Krishna[1], J. Christen[1]

[1]Arizona State University, Tempe, AZ, USA

Abstract

Capacitive sensors offer high spatial resolution, sensitivity and good frequency response. A capacitive MEMS device that finds use both as a pressure sensor and capacitive micro-machined ultrasonic transducer (CMUT), thus opening up a wider market, is the idea behind this project. The device is designed to operate at about 5 MHz acoustic frequency. Frequencies around 5 MHz find numerous applications which include non-destructive evaluation of materials used in navigation vehicles, medical ultrasound imaging and therapy. A COMSOL Multiphysics® simulation is used to simulate the behavior of the two sensors - CMUT and pressure sensor.

A simplified 3D model of the MEMS structure is constructed using COMSOL software. The device is first modeled as a CMUT and using the Structural Mechanics Module, the resonant (Eigen) frequencies of the device are simulated. Figure 1 shows the results from the Eigenfrequency analysis. Further, with the addition of electrostatics to the Structural Mechanics Module, membrane deflections for various voltages are simulated. Figure 2 shows the membrane deflection at collapse voltage.

The device is then modeled as a pressure sensor. Membrane deflections for various pressure values are simulated. The maximum deflection observed at the centre of the membrane is compared with the theoretical values. Figure 3 shows the plot of simulated and theoretical membrane deflections for various applied pressures.

In conclusion, using the COMSOL simulation, we present a single capacitive MEMS structure that could be used both as a CMUT and a pressure sensor. While the CMUT operating at around 5 MHz acoustic frequencies finds application in medical imaging, non-destructive evaluation and navigation, the highly sensitive pressure sensor can find use as altitude, tactile and automobile pressure sensors.

Reference

1. S. Ergun, B. T. Khuri-Yakub, et. al., "Capacitive Micromachined Ultrasonic Transducers: Theory and Technology", Journal of Aerospace Engineering, 76, April 2003.

2. K.K. Park, B. T. Khuri-Yakub, et. al., "Fabrication of Capacitive Micromachined Ultrasonic Transducers via Local Oxidation and Direct Wafer Bonding", Journal of Microelectromechanical Systems, Vol. 20, No. 1, 2011.

3. W. P. Eaton, et.al., "A new analytical solution for diaphragm deflection and its application to a surface micromachined Pressure sensor", International Conference on Modeling and Simulation, MSM 1999.

Figures used in the abstract

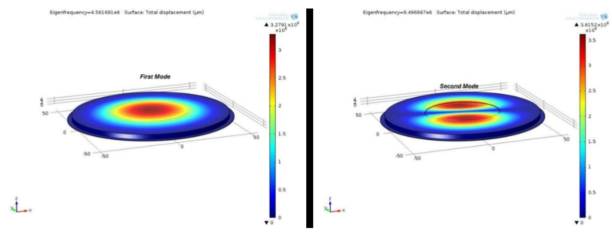

Figure 1: First and second mode Eigenfrequencies.

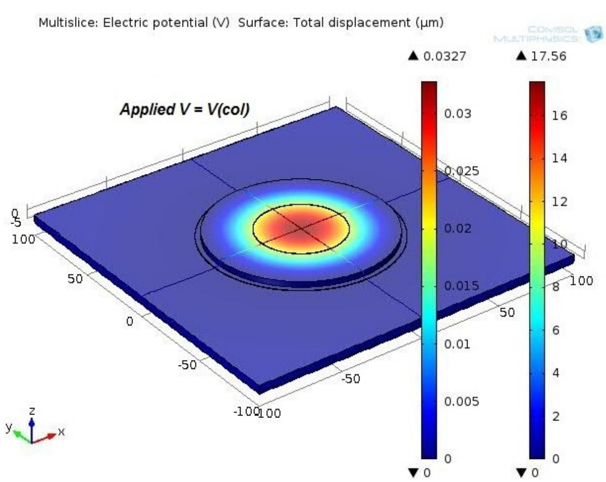

Figure 2: Membrane deflection at collapse voltage.

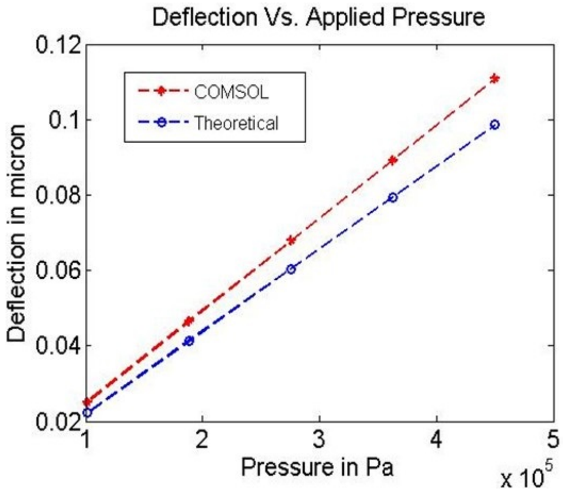

Figure 3: Plot of maximum membrane deflection versus applied pressure.