

VLSI Layout Based Design Optimization of a Piezoresistive MEMS Pressure Sensors Using COMSOL Multiphysics

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Abstract

This paper focuses on the diaphragm design and optimization of a piezoresistive Micro Electro Mechanical System (MEMS) pressure sensor by considering Very Large Scale Integration (VLSI) layout schemes. The aim of these studies is to find an optimal diaphragm shape by Finite Element Method (FEM) using COMSOL Multiphysics, which is most suitable for VLSI layout. Optimal diaphragm shape is that shape which gives reasonable output stimuli with minimal deflection and stress. Three different shapes of diaphragms are considered in this study are circular, square and rectangular. In order to keep the pressure per unit area constant, the diaphragm area is fixed to be constant. Piezoresistors change their resistivity due to induced stress which results due to applied pressure and the change in resistivity can be sensed as a differential output. Four diffused polysilicon piezoresistors are placed on the surface of a diaphragm close to the edges and are arranged in a Wheatstone bridge configuration to achieve higher voltage sensitivity with reduced noise. The dimensions (μm) of the piezoresistor that are used on the diaphragm are $200 \times 10 \times 10$ (length \times width \times thickness) respectively. Given the device structure and shape of the diaphragm, its mechanical characteristics are theoretically studied[1] and compared with simulations by the finite element method (FEM) using COMSOL Multiphysics. All the three diaphragms are simulated using COMSOL Multiphysics and various results are compared. Figure 1 shows a comparison of stress in various diaphragm types with applied pressure. The rectangular diaphragm has maximum stress while the circular diaphragm has minimum stress. Figure 2 depicts a comparison of displacement of the diaphragm with applied pressure. The diaphragm deflection is maximum for circular diaphragm and comparable to that of square diaphragm while minimum for rectangular diaphragm. Figure 3 shows the comparison of Wheatstone bridge output as a function of pressure, which is almost same for rectangular and square diaphragms while minimum for circular diaphragm. Figure 4 shows the potential distribution across various piezoresistor at a given pressure. It is found that the simulation results using COMSOL Multiphysics are more reliable since the simulator uses localized parametric values at each position rather than averaged parametric values which are the case with analytical results. This design framework shows that the circular diaphragm has a larger deflection with smaller stress with a non-linear output voltage at high applied pressures. Even though the sensitivity of the rectangular diaphragm is more, it suffers from large stress with smaller deflections, thus the chances of diaphragm breakdown are more in rectangular diaphragm when compared to the square or circular diaphragm. From the structural mechanics point of view, circular diaphragm has better mechanical behavior. However, it is extremely difficult to design a layout and prepare a mask with

circular shapes and process control is extremely difficult. Thus, square or rectangular diaphragms are better suited from VLSI design and layout perspective. In these two, the square diaphragm is a better choice because it has less stress and more deflections.

Reference

[1]E. Ventsel, and T. Krauthammer, “Thin plates and shells”, Marcel-Dekker, NewYork, 2001.

Figures used in the abstract

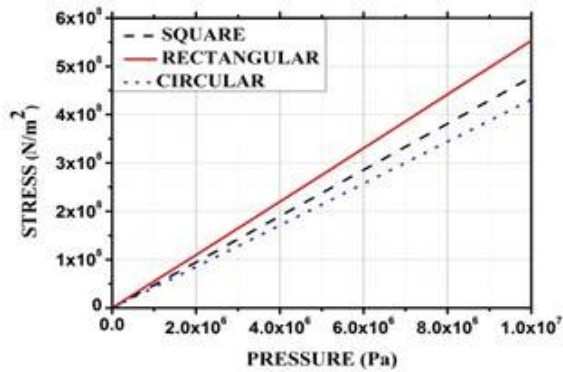


Figure 1: COMSOL simulation result for Stress Vs pressure.

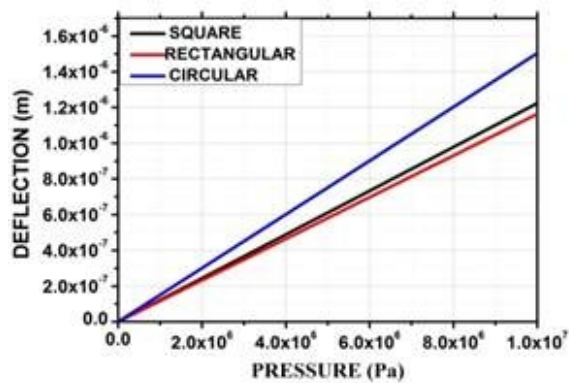


Figure 2: COMSOL simulation result for Displacement Vs. Pressure.

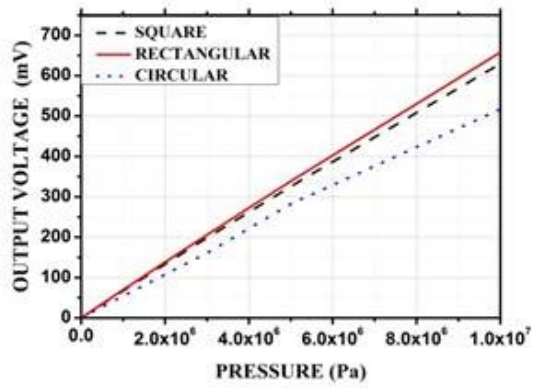


Figure 3: COMSOL simulation result for Output voltage Vs. Pressure.

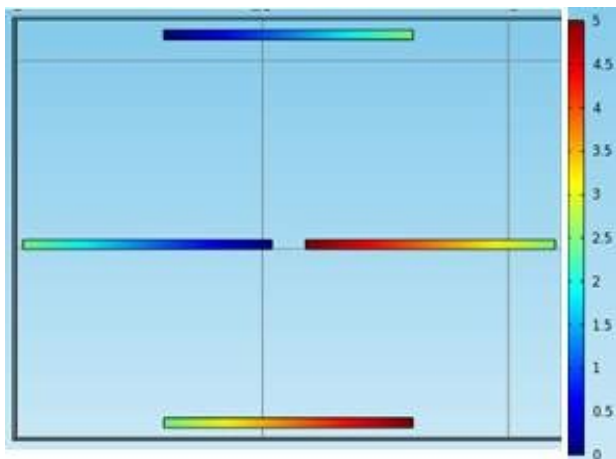


Figure 4: Potential distribution in a piezoresistor.