Modeling and Simulation of Piezoresistive Pressure Sensor for 2bar Application

M. Ramezani[1], M. El Barkouky[1]

[1]Melexis, Tessenderlo, Belgium

Abstract

Pressure sensors have the largest share in the global market of MEMS-based sensors. Among different types of pressure sensing techniques, piezoresistive transducers are the most conventional ones especially due to the advanced silicon micromachining techniques [1-2]. The variation in strain causes the change in electrical resistance of the piezoresistors. They are usually connected in the well-known configuration of Wheatstone bridge where the magnitude of the differential output voltage is proportional to the applied pressure.
Modeling helps suppliers to save a lot of fabrication costs by choosing the right design parameters. In this work we have used the Structural Mechanics Module of COMSOL Multiphysics® software to model the sensor and to make a comparative study of the MEMS pressure sensor with different shape and size of membrane. Note that the four rectangles shown in Figure 1 only represent the position of resistors and the complete layout of piezoresistors and the metal interconnections between resistors was skipped for simplicity. The sensor membrane is made of lightly n-doped single crystal silicon and the piezoresistors are made of lightly p-doped silicon. It consists of two longitudinal resistors and two transversal resistors to form Wheatstone bridge configuration. The thickness of silicon membrane, H, is 15µm and the length of membrane, L, was varied from 500µm to 1500µm. The supply voltage of 5V is applied to the bridge and the differential output voltage of the bridge was calculated over a pressure range of 0bar to 2bar. The most important parameters of sensor including sensitivity and nonlinearity of sensors with different sizes and shapes are then extracted from the output voltage.
Figure 2 shows the stress profile of two sensors with round and square shape membrane when a 2bar pressure is applied on top of it. The stress shows a peak around the edge of the membrane proving that the edge of the membrane is the best position to place the sensing elements and secondly it illustrates that the maximum stress for square membrane is bigger than the round membrane indicating the higher sensitivity of the square membrane (see Figure 3). The drop in sensitivity after including the passivation layer on top of membrane has been also taken in to account in the model. The accuracy of the model was verified with measurement results of three different families of sensors. All the measurement points are well distributed around the simulation points. The small variation in the measurement can be attributed to the process variations e.g. variation in the thickness of membrane across the wafer. Simulation results illustrates that nonlinearity of square membrane is worse than the round membrane which makes the calibration more complicated (see Figure 4).
It was shown that the sensitivity and nonlinearity of the square shape membranes are in

general larger than round ones. Therefore depending on the application, either round or square shape can be chosen for the sensor membrane and COMSOL modeling can help us to make a wiser choice for both the shape and the size of the membrane.

Reference

[1] L. Lin, W, Yun, MEMS pressure sensors for aerospace applications, In Aerospace Conference, IEEE, Vol. 1, pp. 429-436 (1998).
[2] KN. Bhat, Silicon micromachined pressure sensors, Journal of the Indian Institute of Science, Vol. 87, p. 115 (2012)

Figures used in the abstract

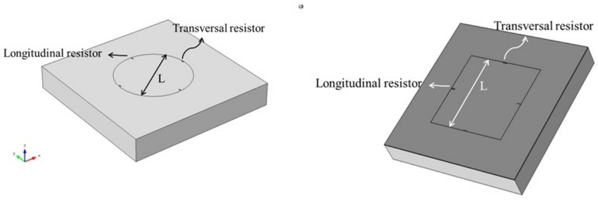

Figure 1: Comsol model of MEMS piezoresistive pressure sensor with round and square membrane.

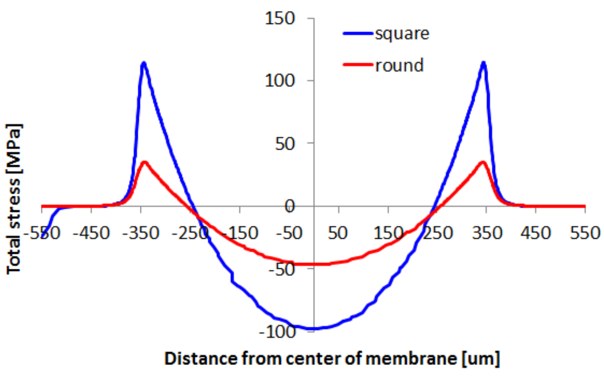

Figure 2: FEM analysis results of the stress profile of 700μm long square and round shape pressure sensors when a pressure of 2bar is applied.

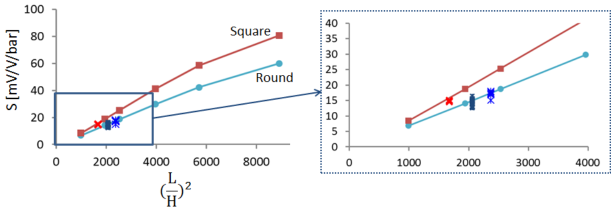

Figure 3: Comparison of FEM analysis results for sensitivity of sensor with different lengths with experimental data for three different sizes.

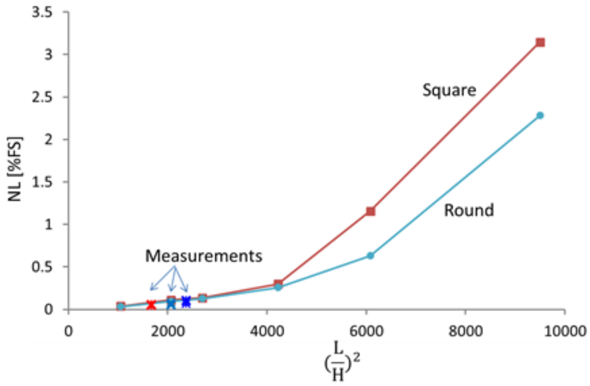

Figure 4: Comparison of FEM analysis results for nonlinearity of pressure sensor with square and round membrane shapes with experimental data for three different sizes.