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

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Introduction: From the VLSI layout perspective, to study the relation between shape of the diaphragm versus better sensitivity and reliability.

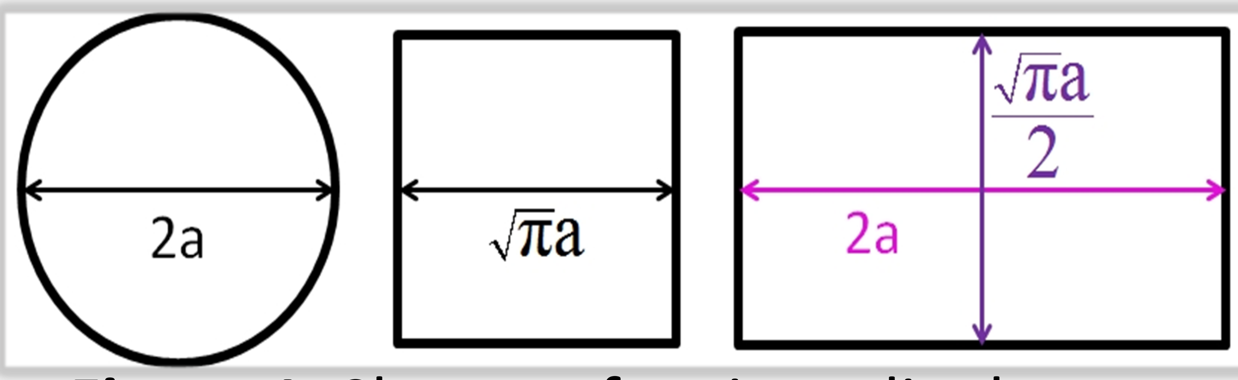

Figure 1. Shapes of various diaphragms

Diaphragm type	Dimension (μm)
Circular	250
Square	443
Rectangle	396×500

Table 1. Dimensions

Thickness of the diaphragm 30μm.

Sensor Diaphragm Design: Deflection is given by

$$\frac{\partial^4 w(x,y)}{\partial x^4} + 2\alpha_{si}\frac{\partial^4 w(x,y)}{\partial x^2 \partial y^2} + \frac{\partial^4 w(x,y)}{\partial y^4} = \frac{P}{Dh^3}$$

$$D = \frac{Eh^3}{12(1-\vartheta^2)}$$

P: Differential pressure
h: Membrane of thickness
D: Rigidity parameter

Application Mode Using COMSOL

Structural Mechanics: Used for structural design of the model which includes pre-setting of sub-domain consists of silicon as substrate/diaphragm and polysilicon as piezoresistor. Resultant deflection and stress are also studied.

Material System: Uses anisotropic models that include local and global coordinate systems.

Conductive Media DC Module: Used to investigate the changes in electrical connectivity when the piezoresistors are arranged in Wheatstone bridge configuration.

Results: Deflection Analysis:

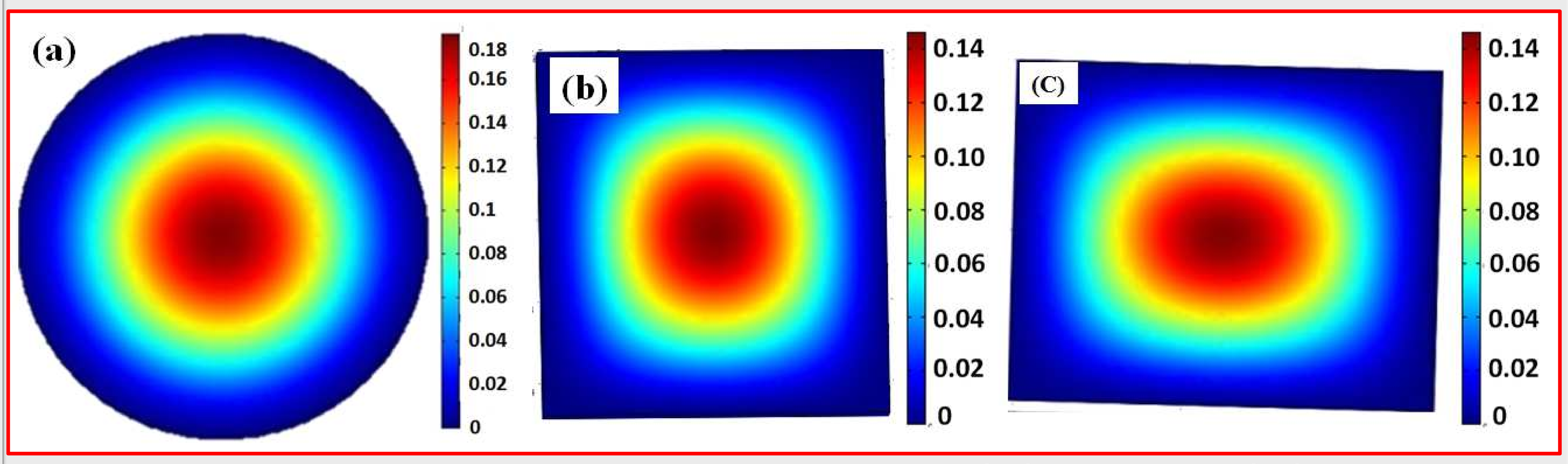

Figure 2. Comparison of deflection in **(a)** circular **(b)** square **(c)** rectangular diaphragms at an applied pressure of 1MPa.

THE AUTHORS WOULD LIKE TO THANK THE NPMASS PROGRAM FOR FUNDING THE SOFTWARE TOOLS USED IN THIS STUDY.

Results: Stress Analysis:

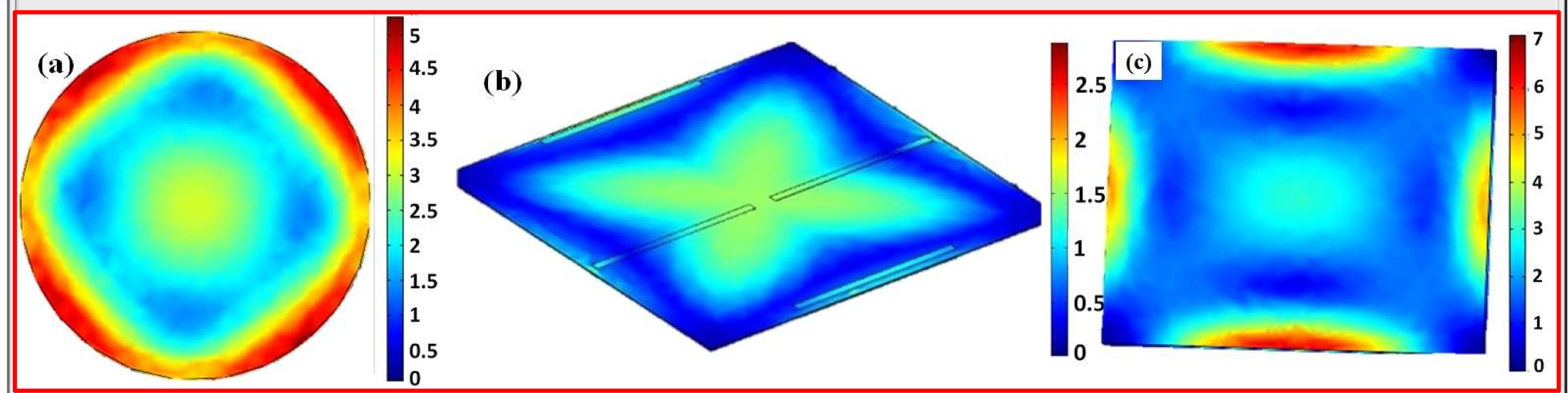

Figure 3. Comparison of stress in **(a)** circular **(b)** square **(c)** rectangular diaphragms at an applied pressure of 1MPa.

Results: Electrical Analysis:

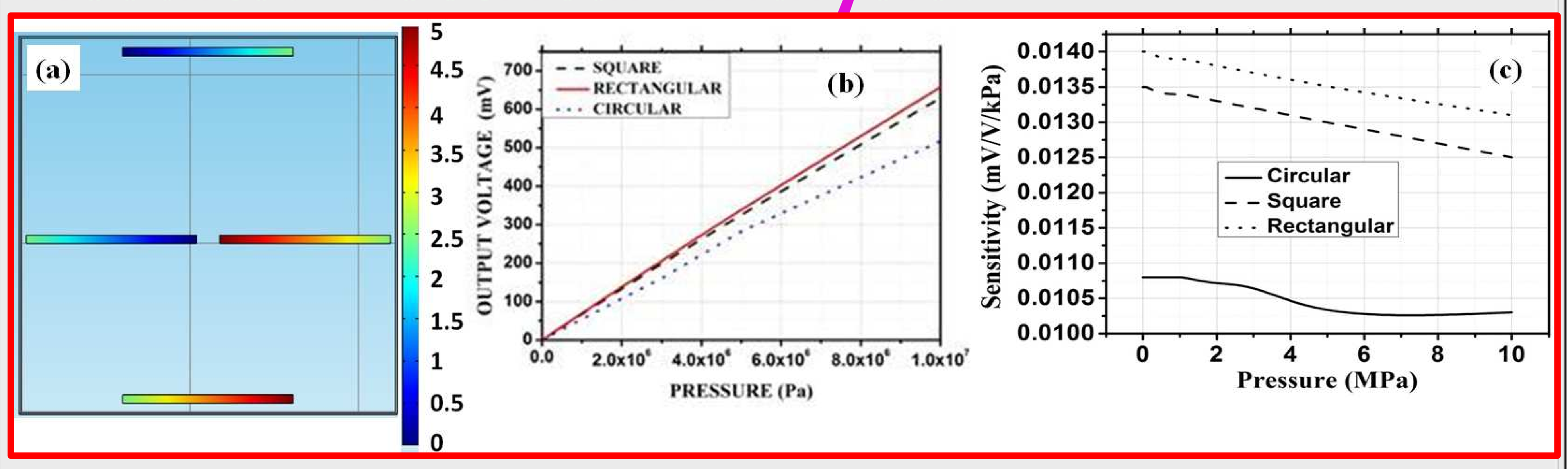

Figure 4. (a) Potential distribution in a square diaphragm (b) Wheatstone bridge output voltage and (c) Sensor output voltage sensitivity

Conclusions:

(i) Deflection is maximum at the center of the diaphragm and minimum at edges.
(ii) Maximum deflection is more in case of circular diaphragm when compared to the square and rectangular diaphragms.
(iii) maximum stress position is at the edge of the diaphragm.
(iv) Stress is much larger in a rectangular diaphragm
(v) Sensor output voltage is smaller in the case of circular diaphragm. For square and rectangular diaphragms, the output voltage is almost same.
(vi) From layout aspects, square or rectangular shapes are better.
(vii) Due to more stress compared felt by rectangular diaphragm, the probability for the sensor breakdown is more.
(viii) Square diaphragm is preferable.

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