Performance analysis of FEM simulated LTCC diaphragm

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Outline

1. **MEMS Pressure Sensor**
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2. **Low Temperature Co-Fired Ceramic (LTCC)**
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    b) LTCC diaphragm based Pressure sensor design

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    b) Frequency

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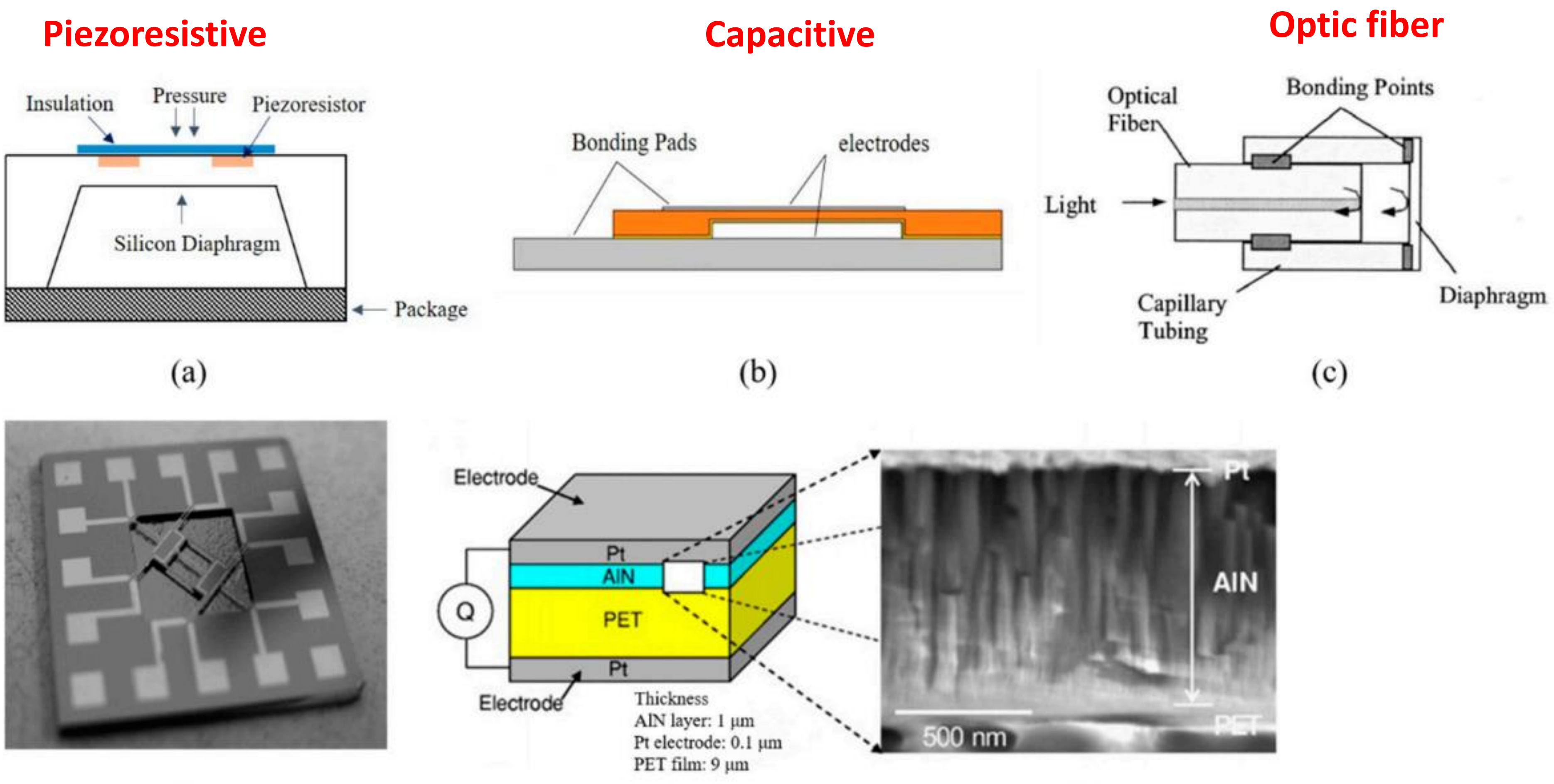
1.MEMS Pressure Sensor

- **Type of Sensors**

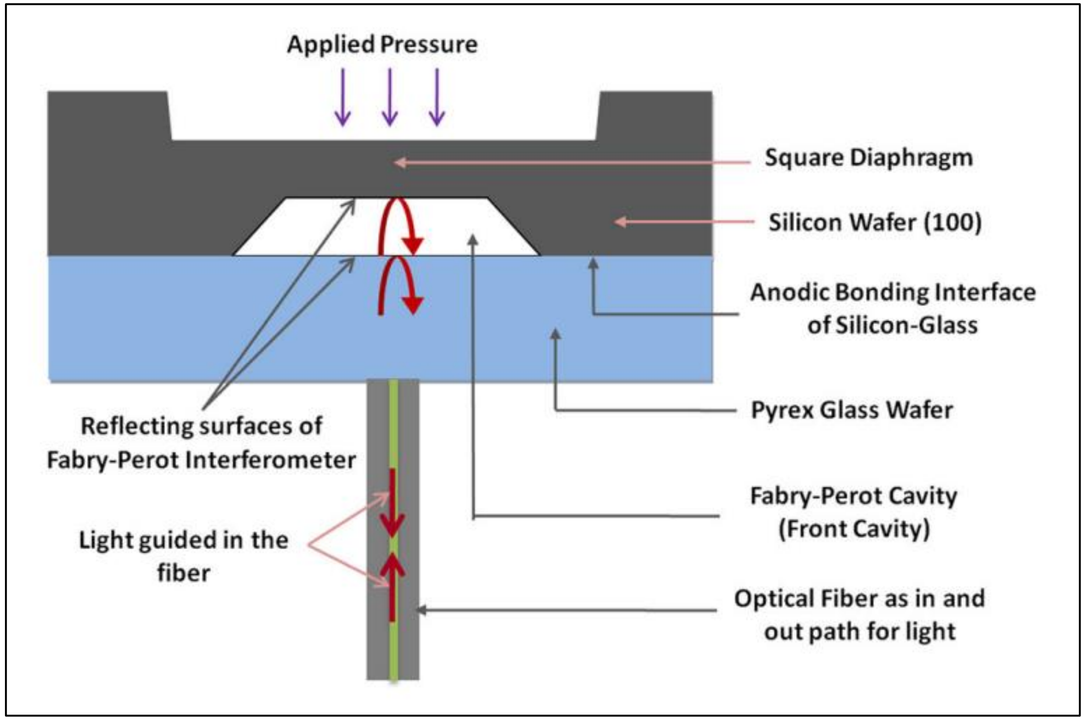


(a) (b) (c)

(d) (e) (f)

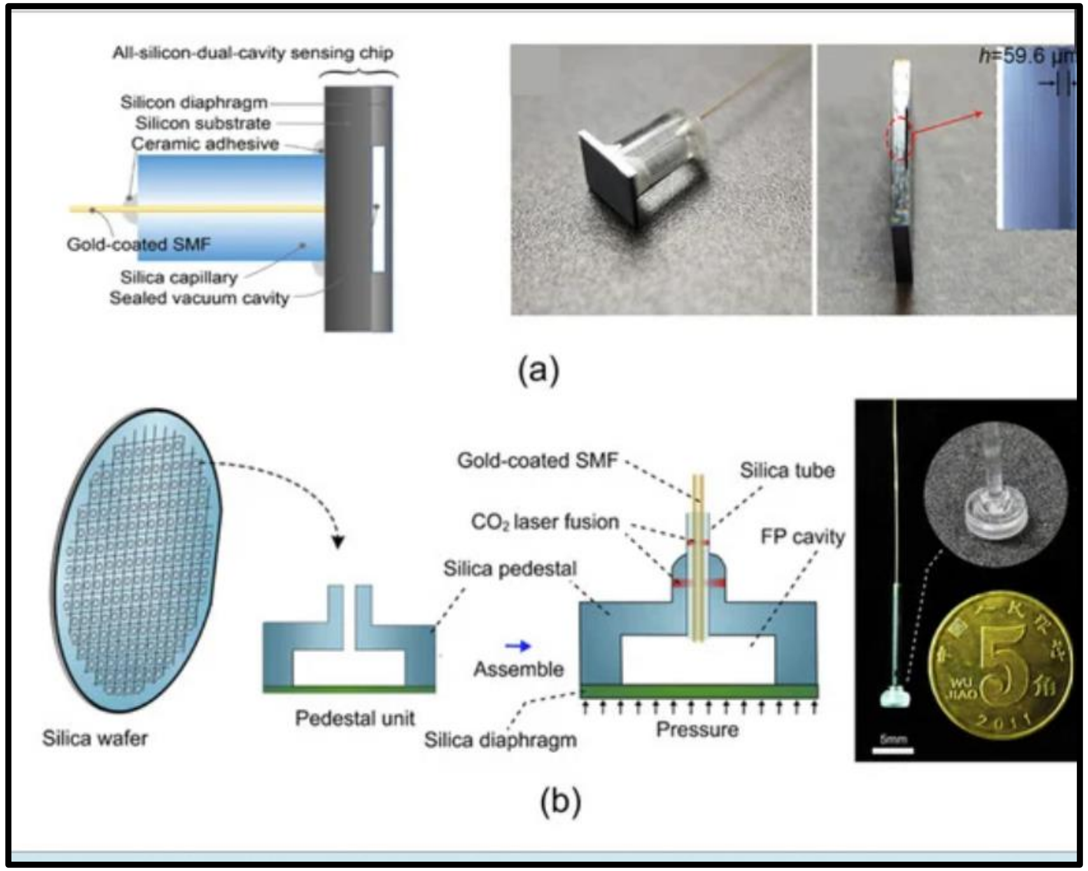
Song, P.; Ma, Z.; Ma, J.; Yang, L.; Wei, J.; Zhao, Y.; Yang,F.; Zhang,M.; Wang, X. Recent Progress of Miniature MEMS Pressure Sensors. *Micromachines,2020, 11*(56).

• Diaphram Based Fiber-Optic Sensor



<u>A sealed microcavity pressure sensor based on the principle of a Fabry–Perot interferometer (FPI) fabricated using MEMS technology</u>

Mishra, S., Balasubramaniam, R. & Chandra, S. Finite element analysis and experimental validation of suppression of span in optical MEMS pressure sensors. Microsyst Technol 25, 3691–3701 (2019). https://doi.org/10.1007/s00542-019-04333-2



Chen, Y.; Lu, D.; Xing, H.; Ding, H.; Luo, J.; Liu, H.; Kong, X.; Xu, F. Recent Progress in MEMS Fiber-Optic Fabry–Perot Pressure Sensors. *Sensors* **2024**, *24*, 1079. https://doi.org/10.3390/s24041079

Diaphragm Materials: Single crystal silicon (Si), polysilicon (PolySi), graphene, Si3N4

<u>***LTCC (low temperature co-fired ceramic) is a good candidate as a diaphgram for the high temperature applications.**</u>

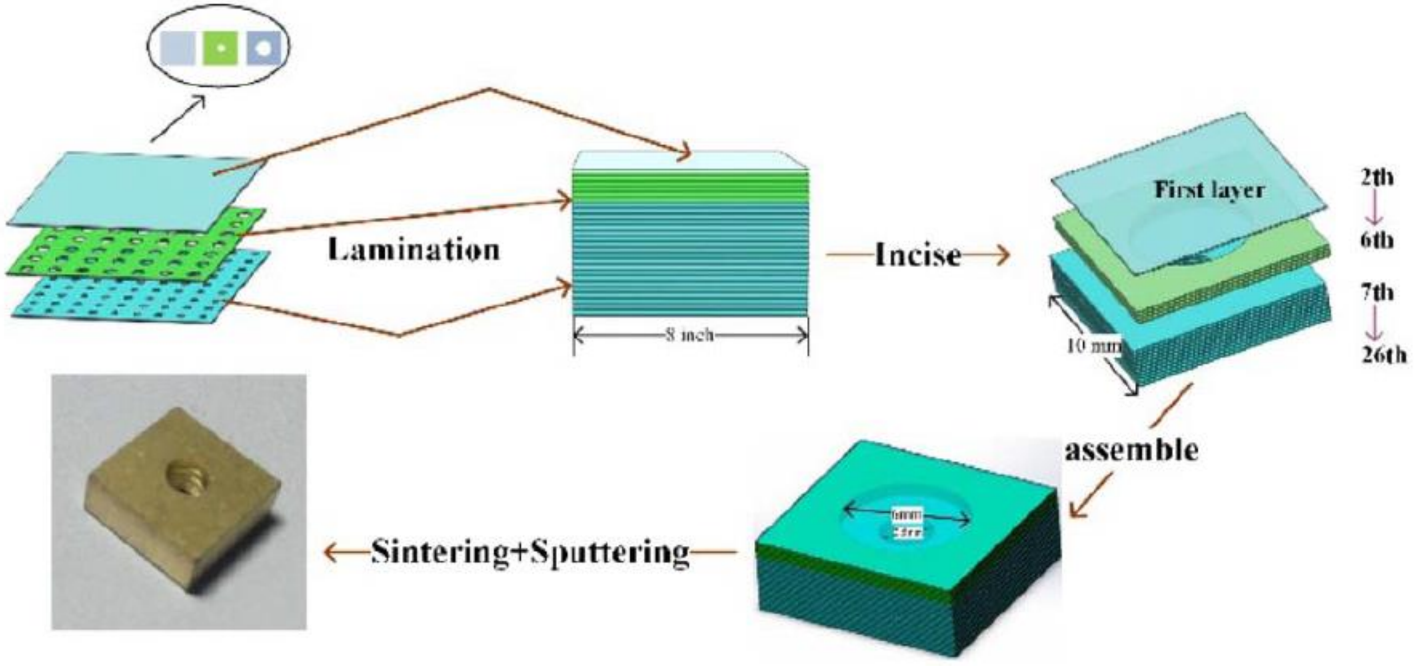
2.Low Temperature Co-Fired Ceramic (LTCC)

- **Fabrication**

i. a multilayer ceramic substrate that consists of an alumina–cordierite ceramic powder and Na_2O-Al_2O_3-B_2O_3-SiO_2 glass powder

<u>**Fabrication Steps**</u>

- Via formation
- Inner wiring
- Stacking
- Firing
- Polishing

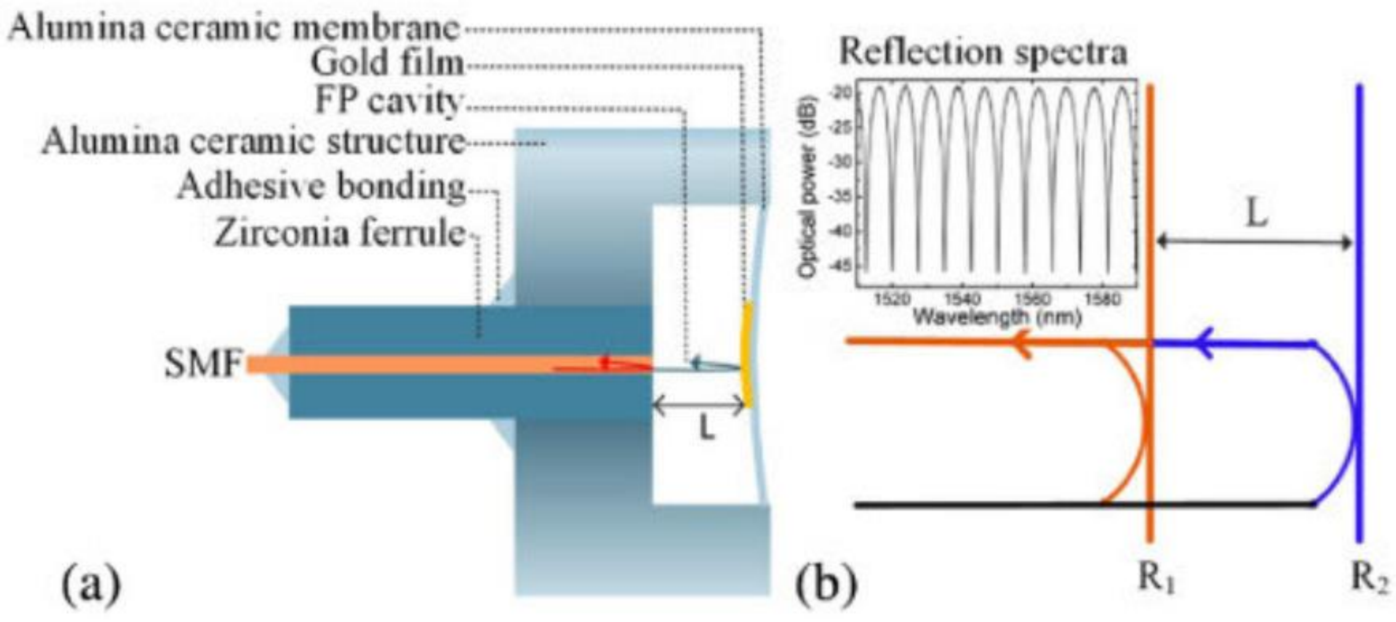


Liu, Jia & Jia, Pinggang & Zhang, Huixin & Tian, Xiaodan & Liang, Hao & Hong, Yingping & Liang, Ting & Liu, Wenyi & Xiong, Jijun. (2018). Fiber-optic Fabry–Perot pressure sensor based on low-temperature co-fired ceramic technology for high-temperature applications. Applied Optics. 57. 4211. 10.1364/AO.57.004211.

Yıldız Fikret (2021). “Anodically bondable Low Temperature Co-Fired Ceramic (LTCC) based Fabry-Perot Interferometer (FPI) pressure sensor design”, Optik, 247, Doi:10.1016/j.ijleo.2021.167755

2.Low Temperature Co-Fired Ceramic (LTCC)

- **Design**



Sensor configuration and principle of operation. (a) Schematic of the fiber-optic FP pressure sensor for a high-temperature environment. (b) FP cavity interference in the sensor.

Liu, Jia & Jia, Pinggang & Zhang, Huixin & Tian, Xiaodan & Liang, Hao & Hong, Yingping & Liang, Ting & Liu, Wenyi & Xiong, Jijun. (2018). Fiber-optic Fabry–Perot pressure sensor based on low-temperature co-fired ceramic technology for high-temperature applications. Applied Optics. 57. 4211. 10.1364/AO.57.004211.

Design parameters: Thickness of LTCC diaphragms were selected **50 µm, 75 µm and 100 µm** with the diameter of **3 mm, 4 mm and 5 mm**, respectively.

Naturel Frequency (circular shape)

$$f = \frac{10.2}{2\pi}\sqrt{\frac{E}{12(1-\nu^2)\rho}}\frac{t}{a^2}$$

Central Displacement

$$\omega(r=0) = \frac{Pa^4}{64D}$$

Sensitivity

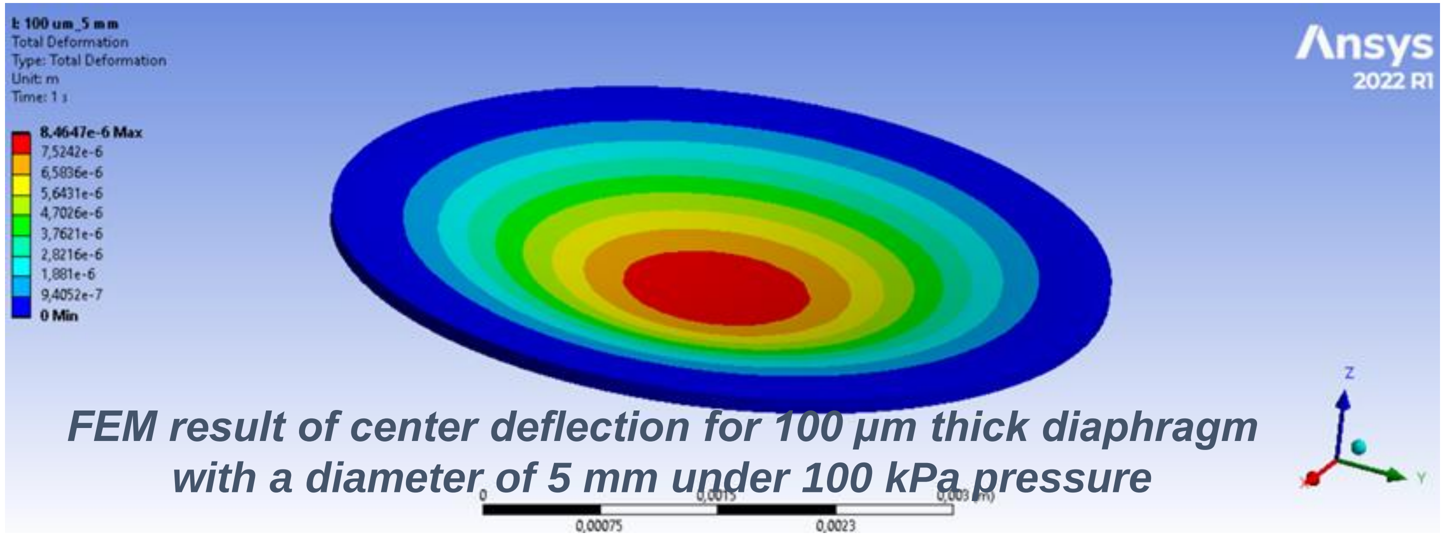
S=ω/P

3.Results

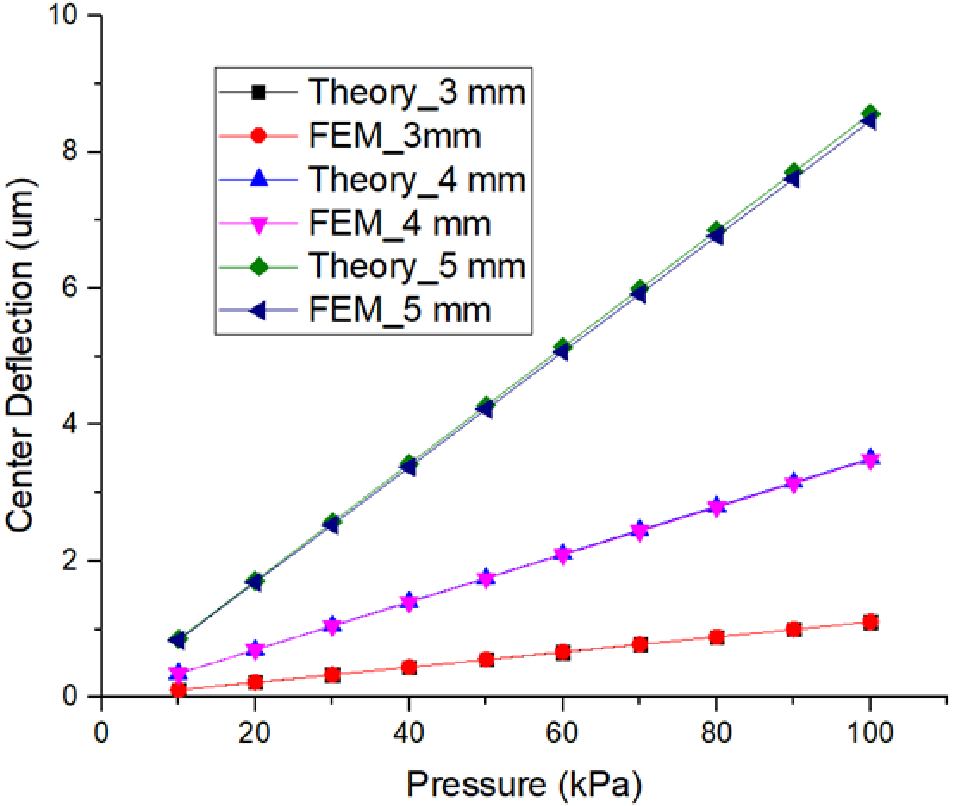
- Sensitivity (nm/kPa)

Table 1 Sensitivity (nm/kPa)

	t (μm)=50		t (μm)=75		t (μm)=100	
Diameter (mm)	Theory	FEM	Theory	FEM	Theory	FEM
3	88.79	88.00-88.29	26.31	26-26.17	11.10	11.12
4	280.62	278.33-279.00	83.15	82.33-82.56	35	34.90
5	685.1	680-681.2	203	201-201.8	85.6	84-84.6



FEM result of center deflection for 100 μm thick diaphragm with a diameter of 5 mm under 100 kPa pressure

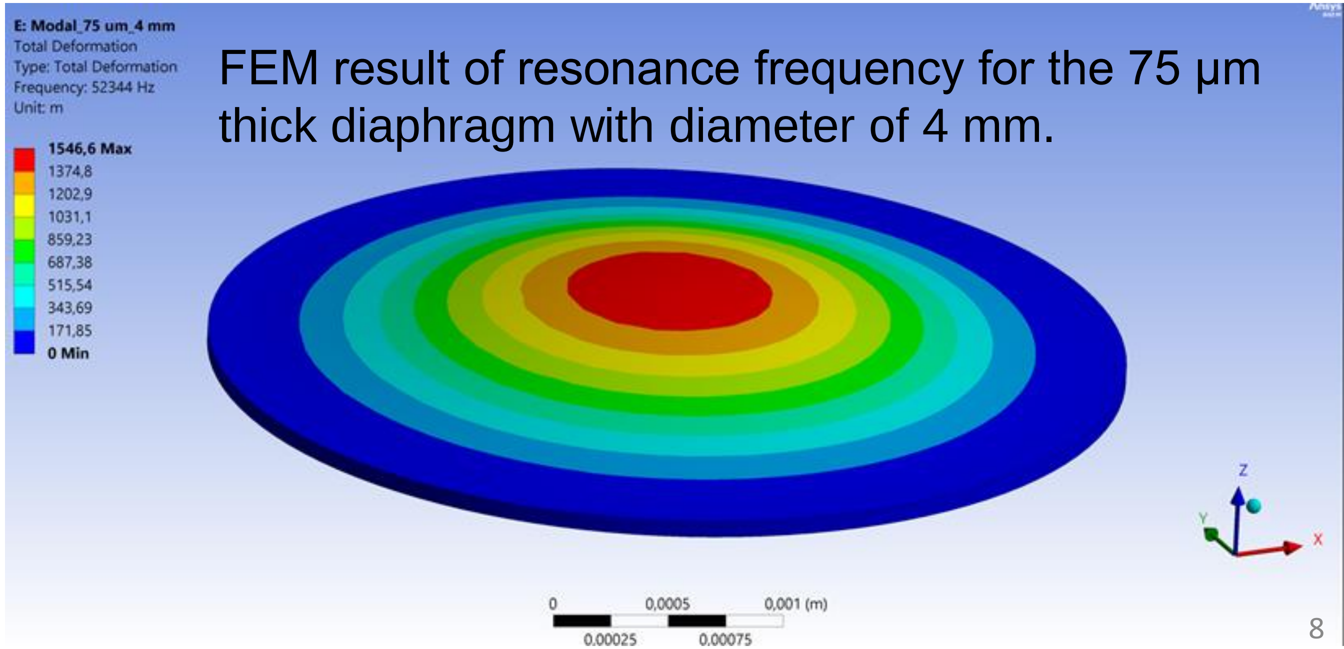


Comparison of theory and FEM results

3.Results

- Frequency (kHz)

	t (μm)=50		t (μm)=75		t (μm)=100	
Diameter (mm)	Theory (kHz)	FEM (kHz)	Theory (kHz)	FEM (kHz)	Theory (kHz)	FEM (kHz)
3	61.78	62.00	92.67	92.89	123.56	123.32
4	34.75	34.89	52.13	52.34	69.50	69.67
5	22.24	22.32	33.36	33.49	44.48	44.64



FEM result of resonance frequency for the 75 μm thick diaphragm with diameter of 4 mm.

4.Conclusion and Future works

- The effect of diaphragm thickness and radius on sensitivity and naturel frequency for circular LTCC diaphragms proposed and studied.

- FEM analysis and analytical results were obtained and compared for circular diaphragm.

- Future work of this study is performance analysis (numerical and analytical) of LTCC diaphragm with different geometry (circular, square, hexagon, etc.).

Thank You…