IOP Conference Series: Materials Science and Engineering

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To cite this article: Samridhi *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **594** 012045

Finite Element Analysis of Circular Silicon Diaphragm

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Abstract. Miniaturization of sensing devices not only reduces the size, but also enhances the performance and reliability in sector of automation, space, weather monitoring and forecasting. It has become important for scientist and researchers working in the field of micro-electro-mechanical system area to simulate the structure before actual fabrication. This paper reports about the performance of proper meshing required to lead the exact results of simulated circular silicon diaphragm with the help of finite element method. In this paper, we have shown that the proper meshing of the circular silicon diaphragm has shifted the vibrating frequency of the diaphragm under different pressures applied.

Keywords: Sensors, Meshing, Frequency, Displacement

1. Introduction

Circular plates are employed in many applications like biological analysis, energy harvesting and silicon sensing device [1]. Therefore, silicon is still proving itself to be a good quality material for the sensing device [2]. MEMS sensing devices based on this material were fabricated, firstly in form of transducer to generate a signal as a function of pressure. These sensing devices have undergone a significant growth in the area of industries as well as in the commercial sector [3, 4]. They are cheap due to batch fabrication and are in small size, consume low power and gives enhanced performance. The era of MEMS fabrication allows miniaturization of complicated systems in a way of controlling, actuating and has integrated sensing capabilities on a single chip. These sensors have changed the mindset of designers and engineers the way they measure the sensitivity of the pressure sensor. Therefore, it is necessary to understand the complex structure of the sensor on a single microchip before its actual fabrication. Finite Element Analysis is a valuable tool for the designing purpose of a sensor since it gives more accurate and precise results up to high level of accuracy and it tells the physical behaviour like the structural mechanics of a sensor [5].In this article, the simulated results show how frequency response of diaphragm is changing with meshing size. The proper meshing is carried out by finite element analysis which enables us to obtain the displacement of the diaphragm under a different range of applied pressure. Finer the meshing, the solution converges near to the real behaviour of a diaphragm with a very high level of accuracy.

IOP Conf. Series: Materials Science and Engineering **594** (2019) 012045 doi:10.1088/1757-899X/594/1/012045

2. Modelling and Theory

According to the literature review, it has been found that the maximum displacement of circular diaphragm occurs at the center, while stress is minimal at the edges of circular diaphragm. The maximum stress of the diaphragm is given by the formula [6].

$$\sigma_{max} = 1.25Pa^2\,/t^2 \tag{1}$$

Also, the maximum deflection at the center of circular diaphragm can be given as:

$$\boldsymbol{w_{max} = (1-\nu^2)Pa^4/4.13Et^3} \tag{2}$$

Where t is thickness, ν represents Poisson's ratio, and P is pressure, a refers the dimension, and E is young modulus. In the present paper, we have performed displacement and stress analysis of circular diaphragm geometry with Silicon as a substrate material using COMSOL package.

3. RESULT AND DISCUSSION

The finite element analysis has been performed for the silicon circular diaphragm and the simulated results have been shown in figure 1. Fig.1 (a) and (b) shows the geometry of a circular diaphragm with radius of 1mm and diaphragm thickness 50 µm, which is supported by a fixed region having radius of 2mm. A fine and normal meshing is carried out by FEM (finite element method) on the same substrate with same dimension and geometry.

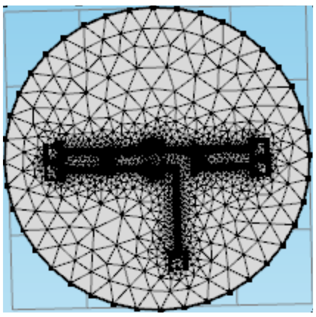
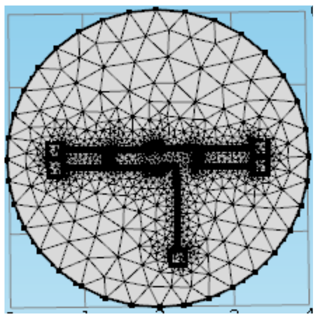
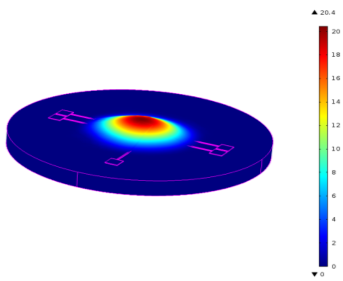
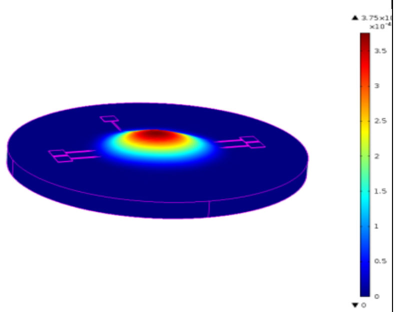
Modes [mn]	**Fine Meshing**	**Normal Meshing**
	Displacement of Diaphragm at 275KHz frequency	**Displacement of Diaphragm at 350 KHz frequency**
	 **(a)**	 **(b)**
[11]	 **(c)**	 **(d)**

Fig.1 Displacement Profile under Fine meshing and Normal Meshing

For fine meshing, the vibrating frequency of circular silicon diaphragm is noted ~ 275KHz, as shown in Fig.2 (a) at pressure about 60 KPa with step size of 10 KPa. The maximum displacement of the silicon diaphragm is about ~ 16μm under this pressure. The deflection so induced by this pressure is shown in Fig.1(c) and it shows that the displacement is maximum at the centre of circular diaphragm. Similarly, for normal meshing, the vibrating frequency of circular silicon diaphragm is noted as ~350KHz, as shown in Fig.2 (b) at pressure about 26 KPa with step size of 5KPa and. Here, the maximum displacement of the silicon diaphragm is about ~ 6.5 μm under this pressure. The deflection so induced by this pressure is shown in Fig.1(d).

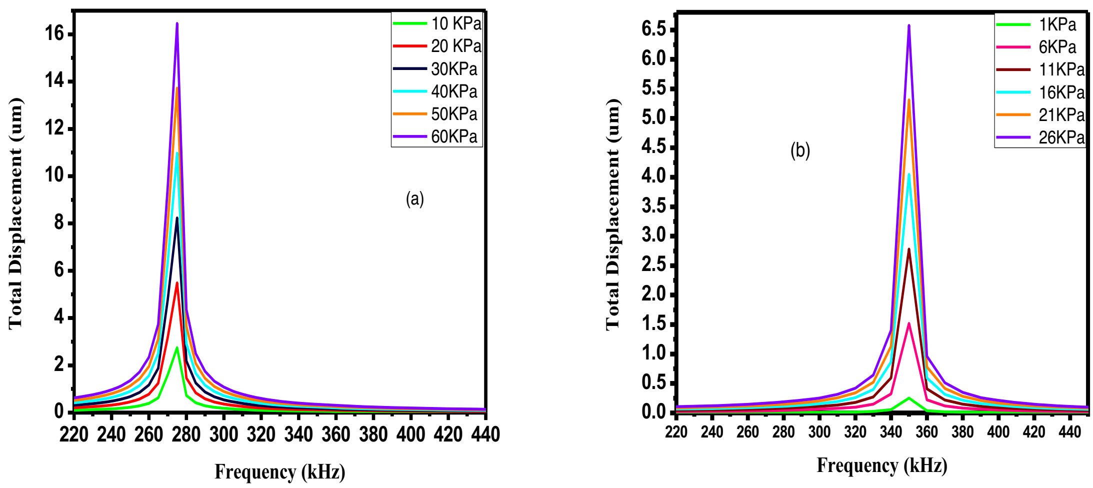


Fig. 2 Frequency Vs Displacement of Si diaphragm at (a) Fine Meshing having ~275KHz frequency and (b) Normal Meshing having ~350KHz frequency

Conclusion

A proper meshing has been carried out by finite element analysis within the framework of the COMSOL package to find the real behaviour of the vibrating diaphragm which can be applicable for the various sensing devices and micro-structures. Finer the meshing, the solution converges near to the real behaviour of a diaphragm with a very high level of accuracy.

Acknowledgement

Samridhi and P. A. Alvi are grateful to DST, Government of India, New Delhi, for providing the facilities thorough "Banasthali Center for Research and Education in Basic Sciences" under CURIE programme.

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