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Study of MEMS Pressure Sensor for TPMS Using Graphene

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Abstract - ***In this paper TPMS(Tire pressure monitoring system) provides real time monitoring of the tires and plays an important role in vehicle safety. In this work we have investigate the MEMS pressure sensor structure, which is important in the successful of micromachined pressure sensor. MEMS pressure sensor structure based on graphene membrane has been designed using comsol finite element method software.Along with that design the stress distribution and deflection of rectangular and circular vacuum cavity for various pressure ranges and have been studied and compared. The width of the graphene membrane is 100 nm. The advantage predicts that it has a vastprobable for MEMS pressure sensor.***

Keywords: *graphene membrane; maximum deflection distance; MEMS pressure sensor; TPMS; COMSOL*

1.INTRODUCTION

MEMS (Micro electro mechanical system) refer to technologies which integrates the electrical and mechanical components. MEMS pressure sensor have gained major place in the sensor market during last decade due to various advantages of MEMS pressure sensor like small size, low weight, high pressure vulnerability ,and similarity it has become the first choice for extensive applications in medical, automotive, industrial and aerospace industries. The Automotive industries are the leading consumer of pressure sensor.

Graphene, exposed experimentally in 2014 [1],[2] has shown a number of extraordinary properties which make it is a very promising material for electronic devices.Some of the graphene`s incredible properties are its carrier mobility of up to 200,000 cm^2/Vs for pendant graphene,its high rupture strength of about 125GPa. The stiffness and strength of the graphene membrane are enough to withstand great pressure.These notable numbers will be clever to be explained with the electronic band structure of graphene which is result of the 2d honeycomb lattice of carbon atoms with two atoms in the ancient unit cell. Raman spectroscopy on fabricated devices indicates the viability of this approach.Ultimately,pressure induce band structure changes could be detect electrically,suggesting an application as ultra-sensitive pressure sensors

Graphene can be synthesized using variety of techniques, Mechanical exfoliation of graphene was the initial method to obtain single layer graphene sheet. However, this method has no control over the number of layers and also chemical vapour depositions are of two of the most promising technique for bottom-up synthesis of high quality,graphene sheets.

Classically applications are tire pressure monitoring system in gasoline direct injection system in automotive industries. Tire pressure monitoring system is highly significant automotive safety equipment required for measuring correct inflation of tire on road. It consists of a pressure sensor assembled with micro controllers and an electronic circuit mounted inside the tire which continuously monitor the tire pressure and the information is send to the driver whether the tire is correctly inflated or not.In most of the direct TPM system, MEMS pressure sensors are used.

In this work,based on the study of literature [4],on MEMS pressure sensor structure the stress distribution and deflection of rectangular and circular vacuum cavity for various pressure ranges has been applied to the graphene membrane. it has been observed and compared

2.SENSOR STRUCTURE AND FABRICATION

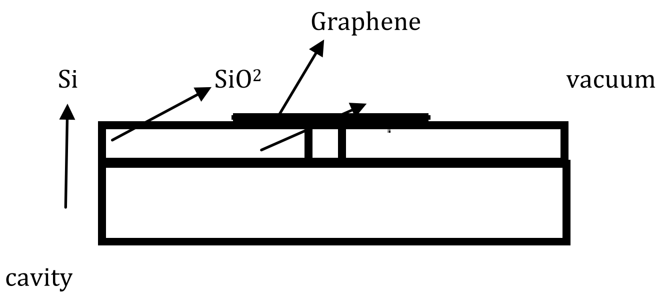


Fig-1:schematic of graphene-based pressure sensor

The graphene based pressure sensor structure is shown schematically in Fig .1. In this structure, the graphene membrane will be strained if there is a pressure distinction between the cavity and outside area. The strength and stiffness of graphene membrane are adequate to withstand great pressure. Wheatstone bridge connects four metal electrodes to measure the resistance change of the membrane and so gain the pressure disparity value. The structure is small, further, its sensitivity is higher and graphene has the would-be applied for MEMS pressure sensor

The fabrication processes of the pressure sensor are as follows, place a silicon wafer that had been cleaned and dried in thermally oxidized surroundings and its surface would form a SiO_2 thickness of 1μm.wet etching was used to make a rectangular vacuum cavity and the depth was 1μm. Then graphene membrane with certain layers which covered the cavity was transferred to the SiO_2 layer. Finally, polymethylmethacrylate (PMMA) was spun onto the graphene membrane as carrier layer, Metal electrode patterns by electron beam disappearance..

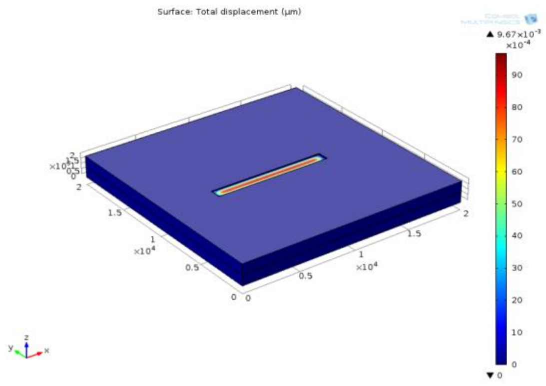
3.SIMULATION AND DISCUSSION

In order to analyze the deflection and stress distribution, we recognized a COMSOL model for the pressure sensor structure described above.the applicable material parameters of the simulation in the model are shown in table 1.the size of the rectangular vacuum cavity of width-10μm,depth-1μm,height-1μm,the radius of circular vacuum cavity is 1μm and the graphene membrane thickness is 100 nm and the applied pressure ranges is 0-45psi, therefore extrapolated by running simulations is on micron scale and nanometer scale we could calculate the maximum deflection distance for single layers.

TABLE -1

Material	Young modulus (GPa)	Poisson ratio	Density (kg/mg³)
Si	190	0.281	2.3×10^3
SiO_2	170	0.17	2.7×10^3
Graphene	1000	0.17	2.2×10^3

(a)



(b)

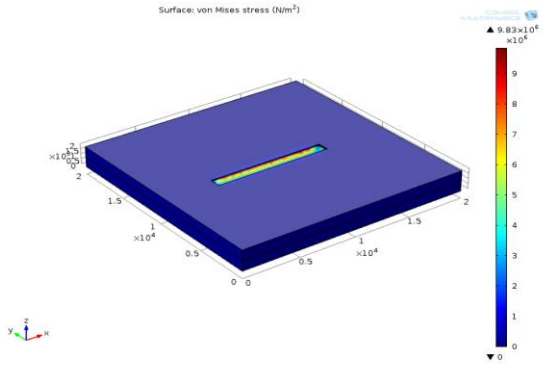


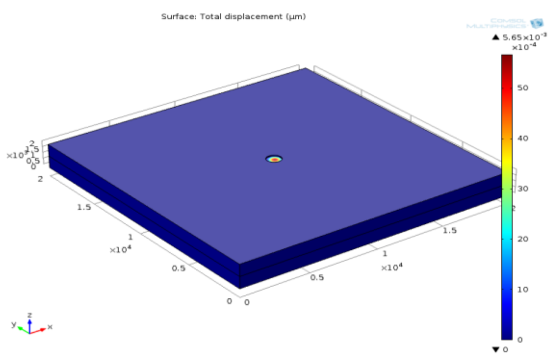
Fig-2(a) deflection distribution applied pressure is 45psi(b)Stress distribution in the graphene membrane of pressure sensor for rectangular vacuum cavity the applied pressure is 45 (psi).

TABLE -2

Pressure (psi)	Deflection(μm)	Stress (μm)
45	$9.67\times10^{-3}\times10^{-4}$	$9.83\times10^{6}\times10^{6}$
35	$7.52\times10^{-3}\times10^{-4}$	$7.64\times10^{6}\times10^{6}$
25	$5.37\times10^{-3}\times10^{-4}$	$5.46\times10^{6}\times10^{6}$
15	$3.22\times10^{-3}\times10^{-4}$	$3.28\times10^{6}\times10^{6}$
5	$1.07\times10^{-3}\times10^{-4}$	$1.22\times10^{6}\times10^{6}$

As shown in table 2, the deflection and stress distribution in the graphene membrane of pressure sensor for rectangular vacuum cavity by using applied pressure.

(a)



(b)

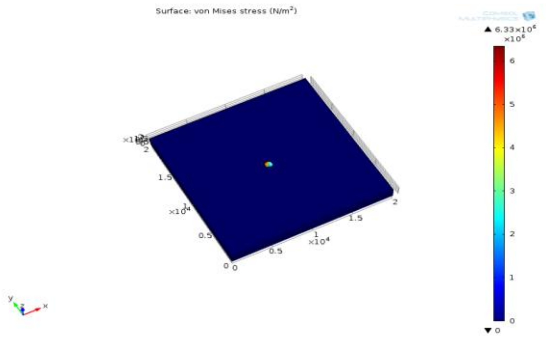


Fig-3(a)deflection distribution applied pressure is 45psi. (b) Stress distribution in the graphene membrane of pressure sensor for circular vacuum cavity, the applied pressure is 45psi.

Table -3

Pressure (psi)	Deflection(μm)	Stress (μm)
45	$5.65\times10^{-3}\times10^{-4}$	$6.33\times10^{6}\times10^{6}$
35	$4.4\times10^{-3}\times10^{-4}$	$7.64\times10^{6}\times10^{6}$
25	$3.14\times10^{-3}\times10^{-4}$	$5.46\times10^{6}\times10^{6}$
15	$1.88\times10^{-3}\times10^{-4}$	$3.28\times10^{6}\times10^{6}$
5	$6.28\times10^{-4}\times10^{-5}$	$1.22\times10^{6}\times10^{6}$

As shown in table 3, the deflection and stress distribution in the graphene membrane of pressure sensor for circular vacuum cavity by using applied pressure.

As shown in Fig.2 and Fig.3,we could get the stress and deflection distribution of two sensor structure, though the maximum stress occurs in the middle of the graphene membrane,the maximum stress occurs edge of the cavity. The maximum stress and deflection of graphene membrane for rectangular vacuum cavity are about thrice times that for circular vacuum cavity.

4.CONCLUSION

For TPMS the two pressure sensor structure of rectangular and circular cavity are studied, while the maximum deflection is occurs in middle of the graphene membrane and the maximum stress occurs along the edge of the vacuum cavity. The maximum deflection and stress of graphene membrane for rectangular vacuum cavity are about thrice times of that for circular vacuum cavity. The single layer of graphene membrane can deflect greatly under a large pressure shows high sensitivity.

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