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# Design and simulation analysis of a novel pressure sensor based on graphene film

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**Abstract.** A novel pressure sensor structure based on graphene film as the sensitive membrane was proposed in this paper, which solved the problem to measure low and minor pressure with high sensitivity. Moreover, the fabrication process was designed which can be compatible with CMOS IC fabrication technology. Finite element analysis has been used to simulate the displacement distribution of the thin movable graphene film of the designed pressure sensor under the different pressures with different dimensions. From the simulation results, the optimized structure has been obtained which can be applied in the low measurement range from 10hPa to 60hPa. The length and thickness of the graphene film could be designed as 100μm and 0.2μm, respectively. The maximum mechanical stress on the edge of the sensitive membrane was 1.84kPa, which was far below the breaking strength of the silicon nitride and graphene film.

## 1. Introduction

Pressure sensor is widely used in many fields, such as industry, agriculture, medical treatment, space flight, meteorology. At present, the mainstream device is the silicon piezoresistive pressure sensor, whose sensitive movable part is made of silicon thin film. The piezoresistive pressure sensor has a lot of advantages such as high sensitivity, fast dynamic response, high accuracy, good stability, wide working temperature range, small and easy to miniaturization[1-5]. However, the fabrication technology limits the size of traditional MEMS pressure sensor structures within micro scales, and according to the material characteristics, the silicon based pressure sensor is more suitable for medium and high measurement range. Once it reaches a low measurement range, the sensitivity of such sensor will decline. However, in many application fields such as breathing, small flow, unmanned aerial vehicle, the pressure sensor needs the high sensitivity to measure low pressure, the effective method to solve this problem is to reduce the thickness of the movable thin film of the sensor. But in actually, it is difficult to manufacture the movable film to nano scale by using silicon materials. Moreover, the electrical and material properties would be changed as the reduction of dimensions of the film structure.

Graphene can be fabricated to be a very thin film, which can reduce the size of the sensor structure to one tenth of the traditional one's. Graphene is arranged in SP2 hybrid, and C=C bond endows graphene with excellent mechanical properties. Each carbon atom and around three carbon atoms are combined by using a$\sigma$ bond, and the interaction of C - C bond is very strong. The connection between each carbon atom is very flexible which make it has high flexibility, and its elastic extension can achieve 20%. So, graphene film is one of the world's most hard and thin material with excellent mechanical properties, such as high coefficient of strain (about 1.8*104), which determines that it can has high sensitivity when it is used in devices[6-12].

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This paper proposed a novel pressure structure, graphene film and silicon nitride were used as movable sensing film and supported film, respectively. The proposed graphene based pressure sensor has small dimension and high sensitivity in very low measurement range.

## 2. Process flow design of the pressure sensor

The schematic diagram of the sensor structure is shown in figure 1(h), and the fabrication process is described in two parts:

Firstly, the main processes of the silicon substrate and the supported silicon nitride film are shown in figure 1(a)-(d):

(a) A thin layer of silicon nitride film was grown on silicon substrate;

(b) Etch holes were etched;

(c) Silicon dioxide was etched;

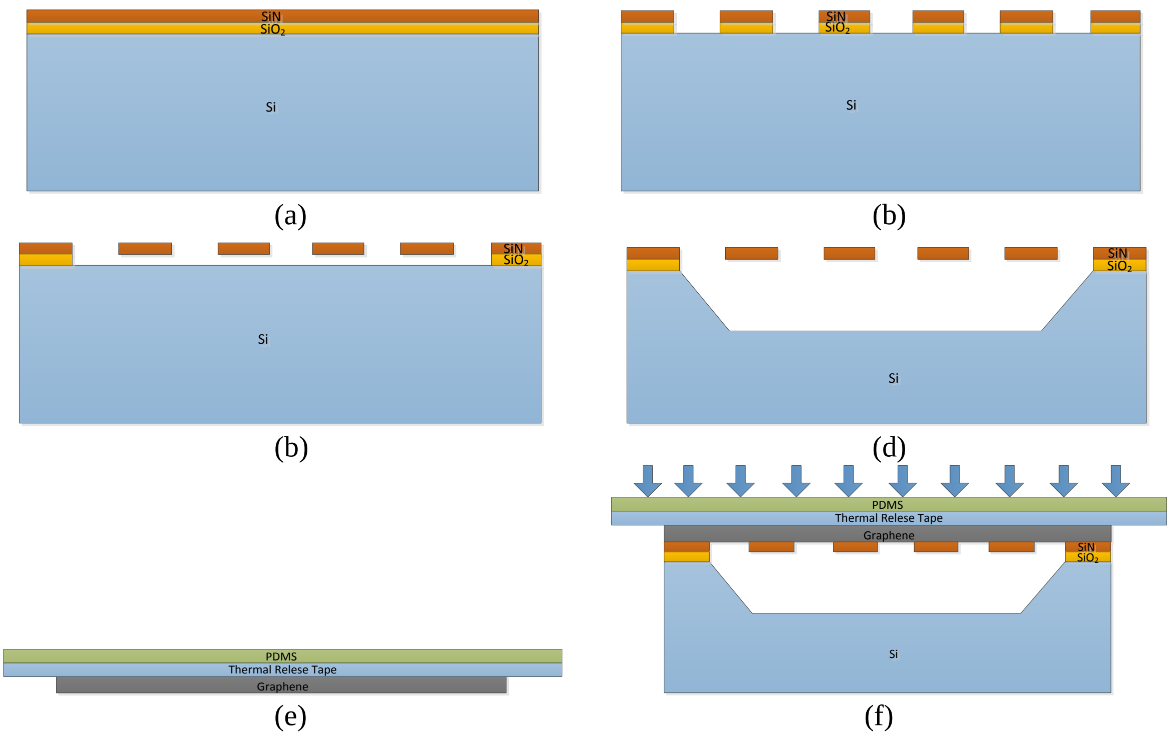
(d) Silicon substrate was etched by anisotropic etching to create the cavity in the front side of the substrate, and completed the support structure part of the silicon nitride film.

Secondly, the main process flow of graphene film transfer to silicon substrate is shown in figure 1(e)-(g):

(e) Put graphene film onto the substrate, such as slide, and taped the heat stripping on it, then coated with a layer of PDMS and made it solidified;

(f) Cut the graphene film into appropriate size and loaded a force on the surface of the substrate, then heated up to 80 ℃ to make the graphene film fully fitted to the substrate;

(g) Took away the adhesive tape at the peeling temperature (135℃), and left the transferred graphene film on the supported silicon nitride film. After the transfer, the whole sensor structure profile was completed, which was shown in figure 1(h).



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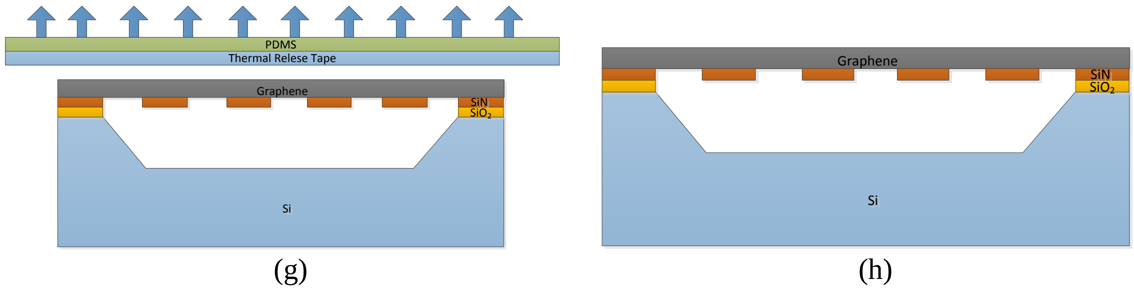


**Figure 1.** Overview of the fabrication process flow for the proposed graphene-based pressure sensor.

Compared with the traditional processing method of silicon based pressure sensor, the proposed fabrication process used the front etching method instead of the back etching method to get the cavity of the structure, which can reduce the chip area and save the cost. It is very convenient to use the hot stripping technology to transfer the graphene film to the silicon substrate, which is commonly used in microelectronics fabrication technology.

## 3. Simulation and analysis of the pressure sensor

ANSYS software was used to simulate and analyze the performance of the pressure sensor structure, the movable sensitive graphene film was square, the boundary conditions were fixed around the membrane, the Young's modulus of graphene was 280GPa, Poisson's ratio was 0.288. The thickness t of the film was 0.1μm, 0.2μm, 0.3μm, 0.4μm, 0.5μm, respectively. The length L of the film was 50μm, 100μm, 150μm, respectively. The pressure was loaded from 10hPa to 60hPa.The simulated results are shown in figure 2-5, which illustrate the relationships between the maximum displacement of movable film and the loaded pressure. It can be analyzed that when the movable film length was 50μm, the displacement of movable film was too small, which would get very low sensitivity; when the movable film length was 150μm, the displacement of movable film was too large, which would make the movable membrane too fragile; when the movable film length was 100μm, the displacement of movable film was suitable for low pressure measurement. Obviously, it can be obtained from figure 5 when the thickness of the film was 0.2μm, the maximum displacement of the movable film changed between several microns, which is quite suitable dimension to be designed for the structure. Furthermore, it is shown in figure 6 that the maximum stress generated in the edge area is 1.84kPa under 60hPa loaded pressure, which is far below the fracture strength of silicon nitride and graphene film.

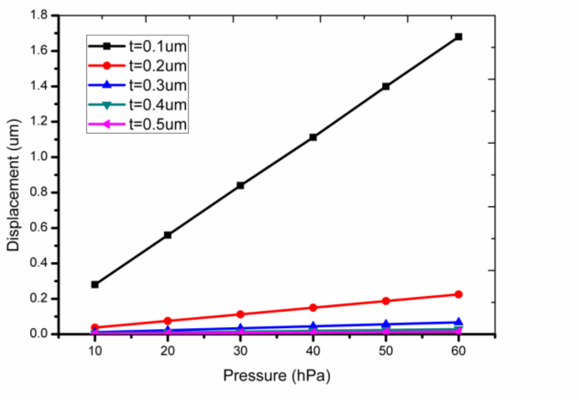


**Figure 2.** The relationship between the maximum displacement of movable film and the loaded pressure(L=50μm).

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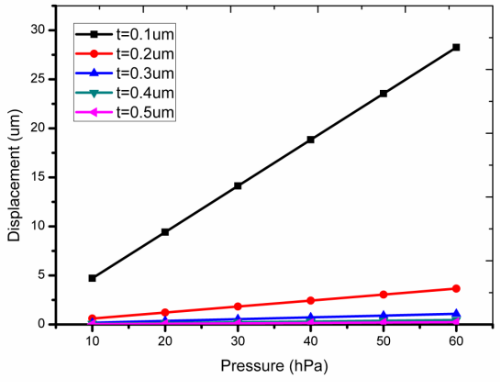


**Figure 3.** The relationship between the maximum displacement of the movable film and the loaded pressure(L=100μm).

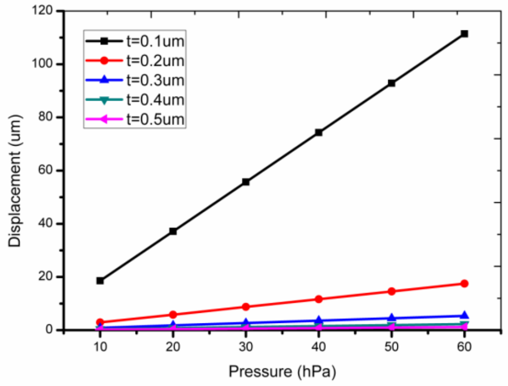


**Figure 4.** The relationship between the maximum displacement of the movable film and the loaded pressure(L=150μm).

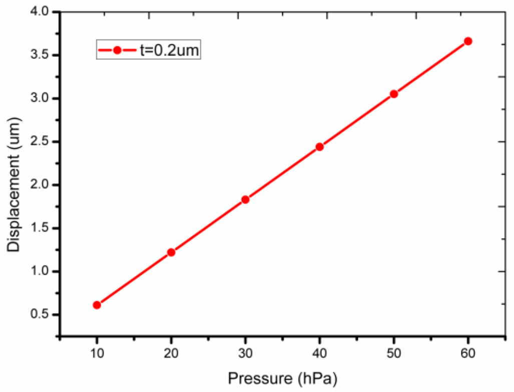


**Figure 5.** The relationship between the maximum displacement of the movable film and the loaded pressure(L=50μm, t=0.2μm).

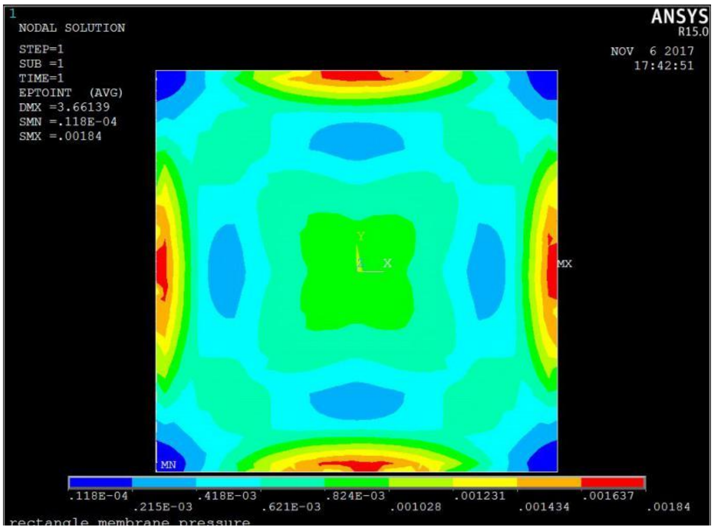


**Figure 6.** The stress distribution of the movable film(L=50μm, t=0.2μm).

## 4. Conclusion

In this paper, a novel pressure sensor structure based on graphene film as the sensitive membrane was proposed, and the fabrication processes was designed which was compatible with CMOS IC fabrication technology. The simulations have been given to analyze the maximum displacement of the sensitive film under the pressure from 10hPa to 60hPa, and an optimized structure dimension has been obtained. The design of the pressure sensor can give a meaningful guide to the low pressure measure field.

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