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# Internal stress effect on nonlinearity of absolute pressure sensor fabricated with single-sided surface-micromachining processes

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With the development of silicon micromachining technology, the silicon pressure sensors offer wide use in automobile, industrial, biomedical and consumer applications [1-3]. Surface micro-machined pressure sensors show advantages, such as miniature size, good compatibility with integrated circuit and low cost. Along with the current development of testing technology, greater requirements have been developed that need low range, high reliability and high precision. However, surface micro-machined pressure sensors usually induce various stresses into structure layers during the process of fabrication diaphragms, which will affect the performance of the sensors, especially to the high accuracy, low range sensors. This work demonstrates the effect of the fabrication-induced internal stresses on the novel structure absolute pressure sensor.

The pressure sensor chip was accomplished by single-sided surface micro-machining process. Double polished silicon wafer with thickness of 420 μm and a resistivity of 3-8 Ω·cm was used as substrate. The sacrificial layer with thickness of 2.25 μm was released to produce the vacuum cavity and the absolute pressure sensor was performed. The LS SiN (Low Stress Silicon Nitride) diaphragm, manufactured by mean of LPCVD (Low Pressure Chemical Vapor Deposition) for pressure sensing, is designed as long rectangular diaphragm, and its thickness is 1.2 μm. B-doped polysilicon resistors with thickness of o.4 μm serve as stress sensing component and are defined on top of the LS SiN elastic diaphragm. Four polysilicon resistors are configured into a Wheatstone bridge through the metal interconnection. Parts of a pair of resistors are placed outside of the diaphragm to make full use of longitudinal piezoresistance effect of polysilicon resistors. The turn-around of the resistors are covered by Al. (Fig. 1). When a uniform pressure is applied on the diaphragm, deflection occurs and the strain of the polysilicon resistor changes. With a supplied voltage, the output signal in proportion to the applied pressure can be read out from the Wheatstone bridge.

In this paper, FEA (Finite Element Analysis), a numerical approach, was proposed to investigate the output-input characteristics of the pressure sensor under various internal stresses. The LS SiN elastic diaphragm was selected to be molded. The width of the membrane is designed as 80 μm and the length is 360 μm (Fig. 2). The Young's modulus $E$, Poisson's ratio $\upsilon$ and coefficient of thermal expansion $\alpha$ of the model are defined as 2.24e11 Pa, 0.23 and 2.1e-6 /k, respectively. Stoichiometric $Si_3N_4$ diaphragm is generally with high tensile stress. Therefore, we chose the internal stress states at 0 MPa, 50 MPa and 135 MPa. By comparison, the compressive internal stress is also concluded, at level of -135 MPa. The stress of the LS SiN membrane, with applied pressure of 60 KPa and selected internal stresses were performed (Fig. 3). The simulated applied pressure range is chosen from 0 to180 KPa to remove the positive nonlinearity caused by the large deflection effect.

LS SiN diaphragm with internal stress of 135 MPa was used in our experiments. The measured output nonlinearity is -2.18 %FSO, where the experimental applied pressure range is 16-300 KPa. The simulated nonlinearity with internal stress level at 135 MPa is -2.60 %FSO, slightly larger than the experimental value. Apparently, the higher the internal stress is, the larger the nonlinearity. Moreover, in certain internal stress range, the tensile stress induces a negative nonlinearity problem and compressive stress induces a positive nonlinearity (Tab. 1).

## References

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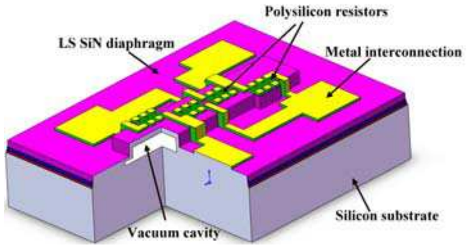

Figure.1. 3-D draft of the designed absolute piezoresistive pressure sensor

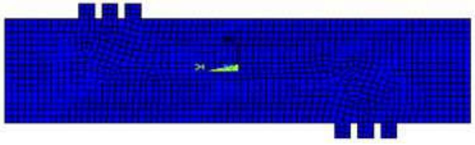

Figure.2.The finite element model of the structure diaphragm with LS SiN

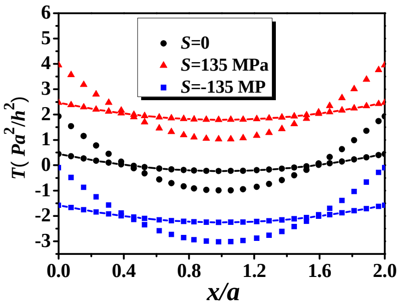

Figure.3. Stress on the LS SiN diaphragm under internal stresses of 0 MPa, 135 MPa and -135 MPa with applied pressure of 60 KPa. The dotted line shows $T_y$, and the scatter shows $T_x$.

Table.1.The nonlinearity of the absolute pressure sensor with various internal stresses.

| Internal stress (MPa） | Nonlinearity （%FSO） | |
|---|---|---|
| | FEA | experiment |
| -135 | 2.46 | |
| 0 | 0.00082 | |
| 50 | -0.94 | |
| 135 | -2.60 | -2.18 |