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Barometric Pressure Sensor with Air Pockets fabricated by CMOS Process Technology

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Abstract

In this work, we propose a novel barometric pressure sensor which has air pockets. Air pockets are connected around the barometric sensor to increase the sensitivity of the sensor. The barometric sensor has a 0.5 μm thin diaphragm, which can reduce the size of the sensor. All fabricated processes are compatible with the CMOS process technology. The results indicate that the proposed barometric sensor produces a reasonable response to different atmospheric pressures.

1. Introduction

Recently, barometric pressure sensors for measuring atmospheric pressure have played an important role in the sensor market [1]. These sensors have become an integral part of many applications such as weather forecasting, altimeter and control system. In addition, it is expected that a barometric sensor capable of measuring the height corresponding to atmospheric pressure will be installed in various smart devices.

Microelectromechanical system (MEMS) barometric pressure sensor has been widely used because of their high sensitivity, small size and low cost for fabrication. However, fabrication processes of most MEMS barometric pressure sensors are not compatible with Complementary Metal-oxide Semiconductor (CMOS) process technology and MEMS barometric sensors are too large in size to integrate with semiconductor devices. It is quite difficult to form a cavity under the silicon substrate of MEMS barometric sensors. Conventionally, the cavity can be built by back-side etching process of a substrate or a substrate etching process using KOH solution. However, these processes can result in a thick diaphragm, which increase the size of the barometric sensors.

In this paper, we adopt CMOS process technology to fabricate a barometric pressure sensor. A thinner diaphragm is built by front-side etching process of the substrate through the line-shaped etching holes, thereby reducing the size of the barometric sensor. In addition, the sensitivity of the barometric sensor is increased by connecting the air pockets and the barometric sensor.

2. Fabrication

6-inch *p-type* (100) silicon wafer was used to fabricate the barometric pressure sensor. Key fabrication processes of the barometric sensor are shown in Fig.1. Line-shaped SiO_2 etching holes are patterned on the silicon substrate. Fig.2 (a) is the top SEM view taken after patterning of line-shaped etching holes. A cavity with a depth of 2.5 μm was formed by isotropic etching process using sulfur hexafluoride (SF_6) gas through the etching holes. Note that anchors are formed at a large distance between line-shaped etching holes during the isotropic etching process. Plasma Enhanced Tetraethyl Orthosilicate (PE-TEOS) was deposited to seal the etching holes. The deposited PE-TEOS layer became the diaphragm of the barometric sensor, and its thickness is 0.5 μm. Fig.2 (b) shows the cross-sectional SEM view after sealing the etching holes. Next, undoped polycrystalline silicon (Poly-Si) was deposited. Boron ions with a dose of 5×10^{15} cm^{-2} are implanted into the Poly-Si layer. The Poly-Si layer was patterned as the piezoresistor of the barometric sensor after annealing at 1050 ℃ for 5 seconds. Then SiO_2/ Si_3N_4/ SiO_2 (ONO) passivation layers and metal wiring layer were patterned. All processes were fabricated using the conventional CMOS process technology.

3. Results and discussion

It is important to form a thin diaphragm to make a small-sized barometric sensor. The sensitivity of the barometric sensor is inversely proportional to the square of the thickness of the diaphragm. The stress applied by the diaphragm on the external pressure can be expressed by the following equation Eq.(1)

$$\sigma = \frac{0.308PL^4}{H^2} \tag{1}$$

where σ, P, L, H are the surface stress on the diaphragm, external pressure, length of the diaphragm, thickness of the diaphragm, respectively. Therefore, if the thickness of the diaphragm is reduced, the sensitivity of the sensor increases and the size of the sensor can be reduced. Table 1 compares the size and the thickness of diaphragms several barometric sensors. Our barometric sensor has a diaphragm with a thickness 0.5 μm. Compared to those of other sensors, our sensor has a thinner diaphragm thickness and a smaller size.

Fig.3 (a) shows the placement of air pockets. Air pockets were placed around the barometric sensor to increase the sensitivity of the sensor. Anchors are repeatedly placed at all air pockets and the sensor except the central region of the sensor where piezoresistors are placed, so that the stress due to the pressure difference concentrated only in the central region. Air pockets increase the sensitivity of the barometric sensor by increasing the total volume of the cavity.

The displacement of the diaphragm with external pressure changes the resistance of the Poly-Si piezoresistor. As shown in the Fig.4 (a), two fixed piezoresistors and two variable piezoresistors are composed of Wheatstone bridge circuit. Since the fixed piezoresistors are on the oxide layer on the silicon substrate and the variable piezoresistors are on the diaphragm, only the resistance values of variable piezoresistors change to the external pressure.

Fig.5 shows measured output voltage of Wheatstone bridge circuit with the change in atmospheric pressure. The barometric sensor with air pockets has a sensitivity of 1.2 μV/hPa, and the barometric sensor without air pockets has a sensitivity of 0.8 μV/hPa. The sensitivity of the barometric sensor increased as air pockets are added to the sensor.

4. Conclusions

We have proposed a barometric sensor with air pockets that can be implemented with conventional CMOS process technology. Due to the thin diaphragm thickness (0.5 μm), the sensor was fabricated in small size, and the air pockets effectively increased the sensitivity. Our sensor is expected to be integrated with CMOS devices.

Acknowledgements

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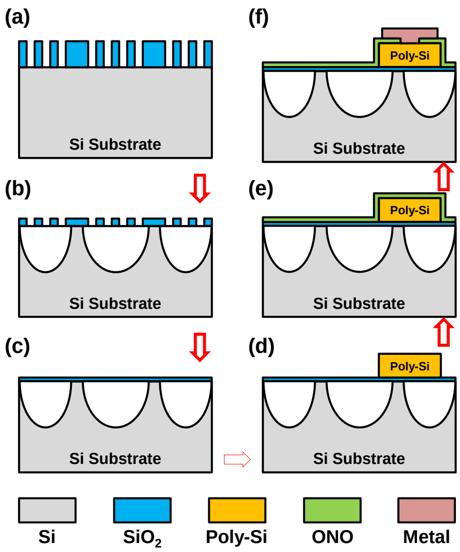

Fig.1 Schematic cross-sectional views of key fabrication process steps of barometric sensor.

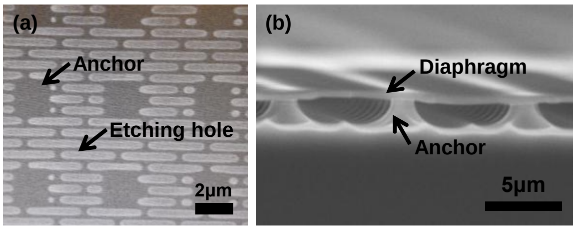

Fig.2 (a) Top SEM view taken after patterning etching holes and anchors, (b) cross-sectional SEM view taken after sealing the cavity.

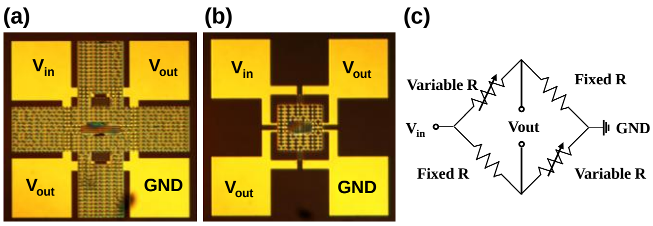

Fig.3 (a) Top view of barometric sensor with air pockets, (b) top view of barometric sensor without air pockets, (c) equivalent circuit of the Wheatstone bridge circuit.

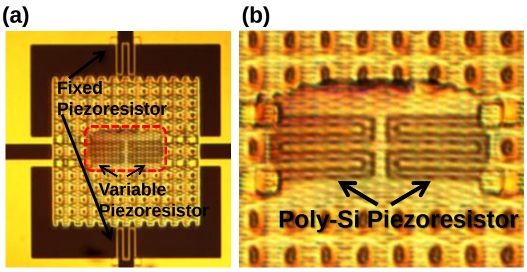

Fig.4 (a) Top view showing the arrangement of piezoresistor, (b) magnified top view of the central region of the diaphragm.

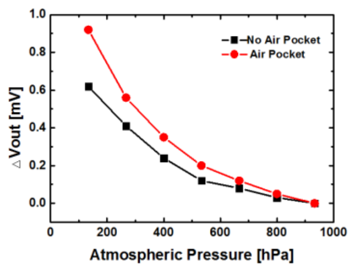

Fig. 5 Measured output voltage change of the Wheatstone bridge circuit with the atmospheric pressure depending on presence of the air pocket

Table.1 Comparison of size and diaphragm thickness of barometric sensors in published papers and this work.

Reference number(s)	This Work	[2]	[4]
Sensor Size (μm)	300×300	680×680	500×500
Diaphragm Thickness (μm)	0.5	3~6	3

* The size of the sensor in this work includes four pads (4×100 μm×100 μm).