A NOVEL MICROFABRICATION METHOD FOR SU-8 BASED PRESSURE SENSOR

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Abstract- This paper describes the novel development of SU-8 based MEMS capacitive pressure sensors. The device is inexpensive, simple to fabricate, lightweight, and accessible. This method is based on photolithography, but does not need an ultra-clean room and high precision mask production equipments. We demonstrated that the proposed pressure sensor can measure pressure with 22 pF/kPa sensitivity. The fabricated micropressure sensor has circular diaphragm with 2.5mm radius and 10µm thickness under silicon substrate. This low-cost device should be useful for applications in public health, environmental monitoring.

Keywords- Pressure sensor, SU-8, Microelectromechanical System (MEMS).

I. INTRODUCTION

Diaphragm based pressure sensors are from the first and most commercially successful MEMS-type sensors. They have already been employed to many applications (automotive, aerospace, industrial, and medical). In addition to, Nano and micro diaphragm are fundamental building blocks for the design of some other kind mems sensor like: micro membrane capacitive biosensor, ultrasonic and tactile sensors.

Silicon based pressure microsensors is conventional in many applications (automation, robatic and so on) Due to ability in operation in a wide range of temperatures. Although In some application especially biological system there is a requirement of sensing the change in temperature at the lower range. In this cases Rather than using Si to form sensor membranes, groups have utilized polymers such as Polyimide, SU-8 and Parylene as membrane materials.

The attractions of polymeric pressure sensor come from three significant features. First polymer and silicon have Young's modulus of 5 GPa and 180 GPa, respectively, stress sensitivity is about a factor of 2 in favor of silicon. Second the silicon microfabrication typically requires surface micromachining and/or bulk micromachining (including wafer bonding) based on photolithographic processes. In this approach the device manufacturing involves a number of lithographic steps that are time consuming and expensive. Third polymers are main structure for fabrication of microfluidic and lab on a chip system so polymeric pressure microsensors can easily be incorporated in microfluidic systems.

In spite of the benefits of polymeric diaphragms, some obstacles still exist in development of them. For example Ko and coworkers have proposed sensor cavity and the sensor diaphragm were made of SU-8. Despite promising of SU-8 unfortunately SU-8 is sensitive to crack and fatigue phenomena. In addition to SU-8 process generates a lot of residual stress which can reduce the quality of sensor.

The pressure microsensor with 100µm thick poly(ethylene terephthalate) (PET) polymer is developed in; but using the thick polymer layer can decrease the sensitivity of microsensor and besides piezoresistive detector which has large thermal drifts can amplifier the temperature dependence of the polymer material.

Although SU-8 based diaphragms under 10µm thickness are used in the micromachining, the performance of them is often limited due to a lot of residual stress. Another candidate for low thickness diaphragm is parylene witch need expensive facilitates in compare with SU-8 based pressure sensors proposed in this paper.

In this paper we are interested in the development of new polymeric capacitive pressure microsensor, where the emphasis is on minimizing cost, and maximizing performance in applications with minimum temperature variation like biological application. The proposed fabrication method generates SU-8 diaphragm with minimum residual stress

In the following section the simulation and design of proposed pressure microsensor has been obtain. In section 3, the fabrication of designed microsensor has been presented. The next section is dedicated to read out method and testing the pressure microsensor. We close the paper with conclusions in section 5.

II. CONFIG.URATION AND SIMULATION

We designed and fabricated a test device, as shown in Fig.1. The test device is mainly composed of a circular diaphragm with 5 mm diameter and 10 µm thickness SU-8 chip bonds to a glass substrate with 10µm gap (Fig.. 3).

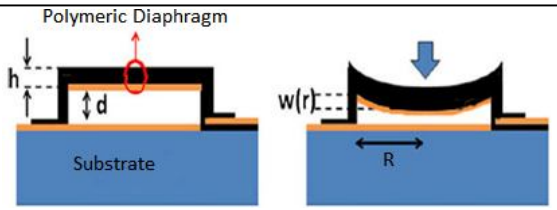


Figure 1. Schematic shape of pressure sensor

The capacitance change in pressure sensor is measured using changes in position of the diaphragm by the following equation.

$$C = \iint \frac{\varepsilon}{d - w(r,\theta)} r\,dr\,d\theta \quad (1)$$

For calculation of diaphragm deflection the diaphragm deflection is given by:

$$w(r) = \frac{p\left(R^2 - r^2\right)^2}{64\left(Eh^3/(12(1-\nu^2))\right)} \quad (2)$$

By replacing Equation (2) in Equation (1) and integration, we have the capacitance of the sensor Fig. 1 as below equation

$$C = 8\pi\varepsilon\sqrt{\frac{E\,h^3}{12\,p\,d\,(1-\nu^2)}} \times \tanh^{-1}\left[\frac{R^2}{8}\sqrt{\frac{12\,p\,d\,(1-\nu^2)}{E\,d\,h^3}}\right] \quad (3)$$

Fig. 4 shows the simulation results for proposed sensor.

III. FABRICATION

As shown in Fig.2 the fabrication process of proposed pressure sensor is consisted of three separated steps: (i) prepare stress-free SU-8 diaphragm on silicon substrate, (ii) fabricate electrode and spacer on glass substrate and (iii) bonding and sealing two separate part.

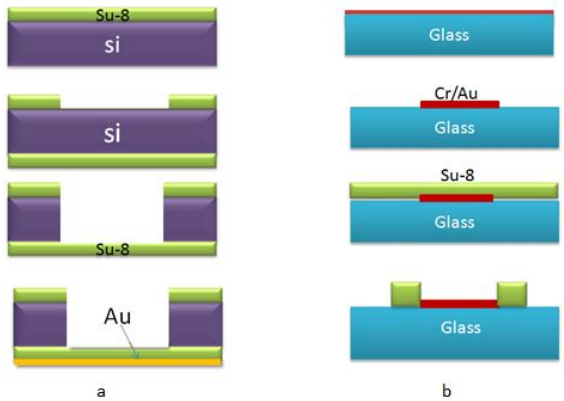


Figure 2. Fabrication process of the pressure sensor: (a) SU-8 diaphragm and (b) glass substrate fabrication

A. SU-8 diaphragm

The starting material is 4 inch silicon wafer. In the proposed method the orientation of silicon wafer is not important. The wafer is cleaned initially and coated by the SU8 2010 epoxy-based Photoresist (Microchem Co.). After spinning of SU-8 resist on the substrate at 3000 rpm speed to reach 10 micrometer thickness, it was pre-baked at 65 °C for 30min and at 95°C for 10 min on a hotplate, prior to UV exposure. UV exposure was done for 2 minutes and exposed SU-8 was post-baked for 15min at 65°C and 8 min at 95°C and cooling slowly to avoid thermal stress. To develop the pattern, we used SU-8 developer (MicroChem Corp.). Next the other side of wafer is coated with 300 nm of sputtered chromium. Then by a lithography step and a metal-assisted chemical etching of silicon (as mentioned on reference) a circular pattern with 3 cm diameter etch until the SU-8 diaphragm. Finally 30 nm layer of gold is deposited using an electron-beam evaporation process, as depicted in Fig. 3(a). This coating is used to make conductive the diaphragm.

B. Electrode on glass substrate

First a glass substrate pretreatment such as RCA cleaning process and acetone/IPA rinse, we dehydrated it 20 min at 180°C. A layer of Cr/Au of 10/50 nm thickness is deposited on the glass as the electrode. Then the second mask is transferred to the wafer through a standard photoresistive/ photolithography process and the exposed conductor areas are etched (Fig. 3b). Finally a 10 µm SU-8 as a spacer patterned around the electrode as shown in Fig.3b.

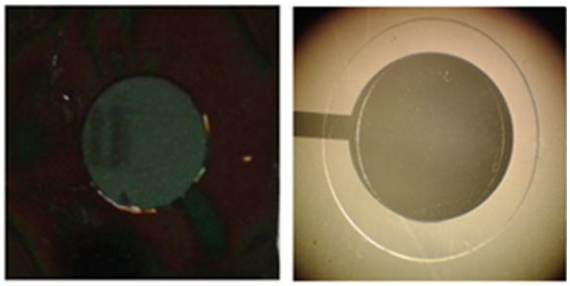


Figure 3. Picture of the pressure sensor: (a) SU-8 diaphragm and (b) glass substrate

C. Bonding and sealing electrodes

For bonding of two wafer adhesive bonding technique proposed to reference has been used. Finally the glue was utilized for sealing pressure sensor. We use isotropic conductive paste (silver paste, Namics H9807) to wire bond the chip pad and the printed circuit board (PCB). The paste is hardened in an oven at 80 °C for 2 hours or at room temperature over night.

IV. EXPERIMENTAL RESULTS AND DISCUSSIONS

The output of the sensor was characterized by using a pressure chamber and a calibrated reference sensor (sensys PSCH00). The capacitive change of sensor has been measured by digital RLC meter (LCR-745G) for capacitance measurement. The pressure applied to the sensor varies from 0.25 to 2 KPa and the corresponding capacitance of the pressure sensor is

continuously measured, as shown in Fig.4. It is found that our simulation model (solid lines) is consistent with the experimental result.

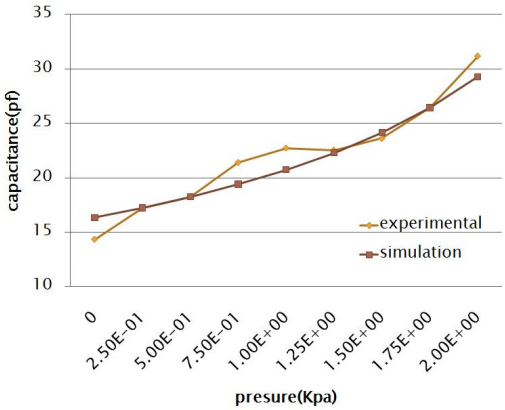


Figure 4. Variation between the pressure and the capacitance of the sensors

CONCLUSION

A novel fabrication process for a micro-polymer pressure sensor has been presented. The fabrication process has been completely simplified, and has none of the stiction problems. The rate of the metal-assisted chemical etching of silicon for release SU-8 diaphragm is so high and takes one hour to etch a silicon wafer with 450 µm thickness. Finally the micropressure sensor test and compared with the simulation results. The polymer pressure sensor can be readily made, and is low cost and reliable.

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