Towards the Sensors Implementation and Integration Using the CMOS MEMS Platform

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Abstract -This study presents a novel double-side CMOS post-process to monolithically integrate various capacitance type CMOS MEMS sensors on a single chip. As a result, the monolithic integration of (1) accelerometers in three different axes, (2) pressure sensors, and (3) Pt temperature sensor, are demonstrated. The measurement results of the pressure sensors show the sensitivity is 2.7mV/kPa. The 3-axes accelerometer has the sensitivity of 0.54mV/G in X-axis, 0.32mV/G in Y-axis, and 0.19mV/G in Z-axis. The sensitivity of temperature senor is 1.74mV/ºC. In summary, this study demonstrates a SoC approach for sensors integration based on standard CMOS process.

Keyword: CMOS post-process, pressure sensor, accelerometer, sensors integration.

1. INTRODUCTION

The CMOS MEMS process has the advantage of monolithic integration of the IC and micro mechanical components. In addition, the mature CMOS fabrication processes are available in many IC foundries. Thus, the CMOS-based micro fabrication technology provides a promising approach to implement MEMS sensors. Presently, various CMOS-based MEMS sensors have been reported, for instance, the inertial sensors [1], chemical gas sensors [2], microphones [3], and pressure sensors [4].

Although there are many available micro sensors implemented using the CMOS MEMS processes [5], it is difficult to monolithically integrate these CMOS MEMS sensors since they have different post-processes. It would be useful to establish a generic post-process platform to simultaneously implement various CMOS MEMS sensors, so as to further realize the monolithic integration of sensors.

2. CONCEPT OF SENSORS DESIGN

Fig.1 shows the design of the monolithic CMOS-MEMS chip containing inertia, pressure, and temperature sensors. Fig.1a shows the 3-axis accelerometer consisting of one proof-mass, two supporting frames, three sets of springs and gap-closing sensing electrodes. These three sets of springs are designed only flexible in one axis. A novel out-of-plane (Z-axis) serpentine spring is designed, thus its out-of-plane stiffness is two orders smaller than its in-plane stiffness. The coupling of sensing signals between Z-axis and the in-plane axes is significantly suppressed. Fig.1b shows the design of capacitive pressure sensor. The pressure sensor consists of deformable sensing electrodes embedded in a diaphragm and stationary sensing electrodes embedded in a suspended structure. The pressure difference on both sides of the diaphragm will lead to the deformation of the membrane, so as to change the gap and the capacitance between the sensing electrodes. Fig.1c shows the thermal-resist type temperature sensor. In this study, the Pt film will be deposited and patterned as the thermal-resist type temperature sensor at the post-CMOS process. Thus, the temperature change will be detected by the variation of the Pt resistance.

3. CMOS MEMS DOUBLE-SIDE POST PROCESSING

Fig.2 shows the process flow to integrate sensors. The chip was firstly fabricated using the TSMC 0.35μm 2P4M CMOS process (Fig.2a). Figs.2b-g illustrate the presented low-temperature CMOS post-process. In Fig.2b, the 1500 A platinum layer was deposited onto the standard CMOS layer by E-gun, and then the shape of Pt thermal sensor was patterned by lift-off. In Fig.2c, the backside silicon substrate was etched by DRIE to expose the dielectric and metal layers. In Fig.2d, the liquid spin-on-glass was dispensed to protect Pt layer during the following metal wet etching. After that, the metal and tungsten-via layers were etched by the H_2SO_4 and H_2O_2 solutions from both sides of the substrate to partially release the MEMS structures and also to define the out-of-plane sensing gaps for sensors, as in Fig.2e. In Fig.2f, the RIE anisotropic etching was then employed to remove the passivation and dielectric films from the front-side of substrate. The top metal layer (M-4) acted as the etching mask to define the planar shape of sensors. Thus, the movable components of the 3-axis accelerometer were fully released from substrate. In Fig.2g, the substrate was further sealed by Pyrex 7740 glass at backside for pressure sensor.

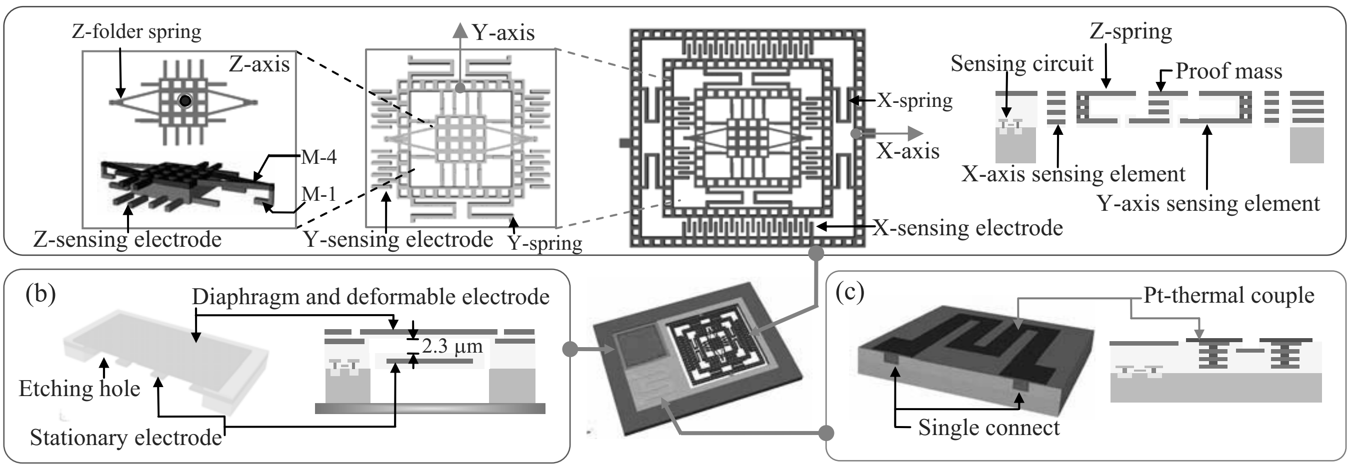

Fig.1 Design concept of the integrated chip, (a) tri-axis accelerometer, (b) capacitive pressure sensor, and (c) Pt temperature sensor.

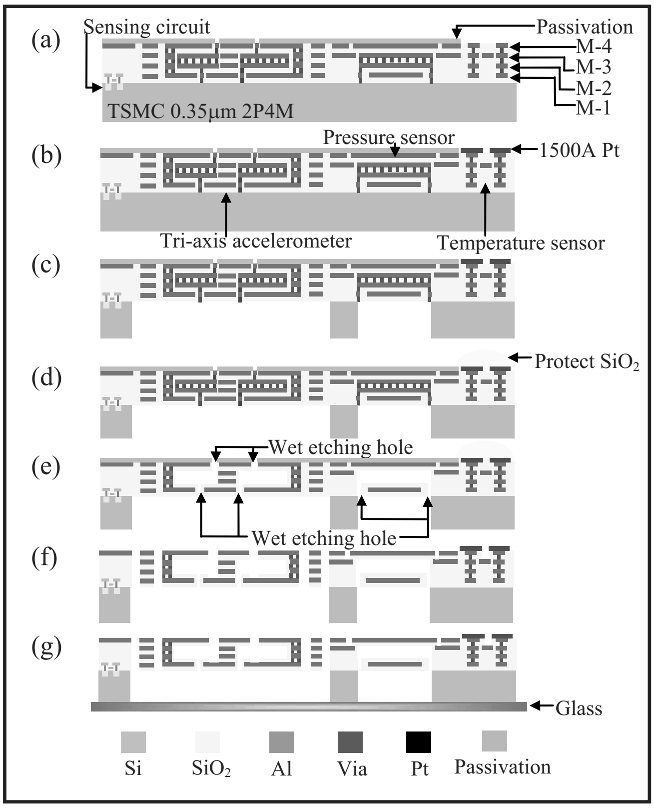

Fig.2 Fabrication process steps for Sensors integration on a single chip

4. RESULTS

Fig.3 shows a typical fabricated CMOS-MEMS sensors integrated device (2.5mm × 2.5mm), contains tri-axis accelerometer, pressure and temperature sensor. The device after sealing with glass and wire bonding is shown in Fig.4. Fig.5 shows the experiment setup and the related measurement results. The sensitivity of the tri-axis accelerometer in Fig.5a is 0.54mV/G (X-axis), 0.32mV/G (Y-axis), and 0.19mV/G (Z-axis), respectively. Fig.5b-c shows the characterization of pressure and temperature sensors. The sensitivities of pressure and temperature sensors are 2.7mV/KPa and 1.74mV/ °C, respectively. Other detail specifications of sensors are summarized in Table1. The measurement results demonstrate the feasibility of the presented CMOS-MEMS device.

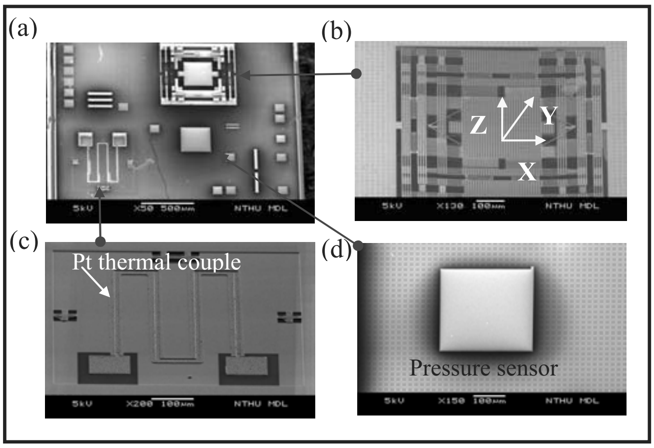

Fig.3 The SEM micrographs of, (a) the full chip, (b) tri-axis accelerometer, (c) Pt temperature sensor, and (d) pressure sensor.

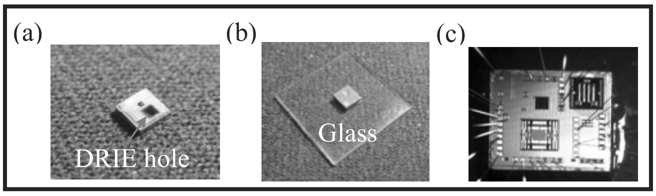

Fig.4 The fabricated chip, (a) after backside DRIE Si etching, (b) bonding with Pyrex glass, and (c) wire bonding and packaged on ceramic housing.

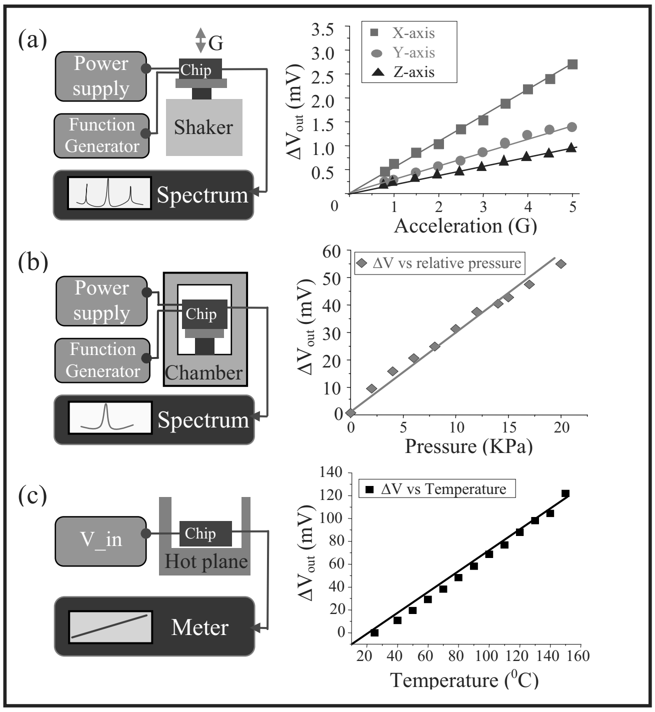

Fig.5 Measurement setups and typical characterization results of the different sensors, (a) tri-axis accelerometer, (b) pressure sensor, and (c) temperature sensor.

5. CONCLUSION

This study successfully demonstrates novel monolithic different sensors using the CMOS MEMS processes. This CMOS-MEMS device consists of the capacitive-type tri-axis accelerometer, the capacitive-type pressure sensor, and the thermal-resist type Pt temperature sensor, on a single chip. In addition, the signal processing ICs are also integrated in the same chip.

Table 1 Specifications of the presented integration sensor.

	G-sensor	*P-sensor*	*T-sensor*
Sensitivity	0.54 / 0.32 /0.19 X/Y/Z (mV/G)	2.7 mV/KPa	1.74 mV/°C
Non-linearity	< 5%	4.58 %	4.29 %
Sensing range	0.8~5 G	0~20 KPa	25~150 °C

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