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MEMS-Based Multi-Sensors: Fabrication and Analysis

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1. Introduction

Today, the society is developing into an exorbitant velocity. In particular, the protection of information has become increasingly important, not only for individuals, but also for companies and nations as a whole. For this reason, research regarding tamper detection is in progress, but the technology is still in its infancy.

In this paper, newly-designed multi-sensors of two types are proposed. The first-type multi-sensor is fabricated on the same chip. The multi-sensor consists of three different sensors, a piezoresistive sensor, a capacitive proximity sensor, and a photodiode sensor for system units which consist of two different sensors, a capacitive proximity sensor and a photodiode sensor for mobile applications. A piezoresistive sensor perceives external vibrations, a capacitive proximity sensor perceives capacitance changes and a photodiode sensor perceives light that has been introduced into the unit by a tamper reaction [1-2].

The second-type multi-sensor which is responsible for each function is combined with a sandwich structure.
The multi-sensor consists of three different sensors: a piezoresistive sensor, a tilt sensor, and a photodiode sensor. The piezoresistive sensor and the tilt sensor perceive external vibrations which are caused by an obstruction, respectively. The photodiode sensor perceives light that has been introduced into the unit by external tampering. However, the silicon might lose 34% of light at long wavelength range around of 1.1 μm and 54% of light at short wavelength range around of 0.4 μm. For that reason, in this study, the photodiode sensor was fabricated using porous silicon that has a sufficient area which produced more excess career rather than the use of single silicon.

The multi-sensors of two types are independently operated within the multi-sensor as a whole.

2. Fabrication

Figure 1 shows the proposed design of the multi-sensor, which is composed of five different sensors.

< First-type multi-sensor>

The fabrication process of the multi-sensor is illustrated in Figure 2. Three different types of sensors a piezoresistive sensor, a capacitive proximity sensor, and a photodiode sensor-conventional type, are fabricated on the same chip.

< Second-type multi-sensor>

Figure 3 shows the proposed design of the multi-sensor. The pressure sensor was fabricated according to the flow chart of the first-type multi-sensor.

The photo detection characteristic using porous silicon is higher than the photo detection characteristic using single silicon which was examined in a former study. For that reason, in this study, the photodiode sensor was fabricated using porous silicon that has sufficient areas which produced more excess career rather than the use of single silicon.

In order to fabricate a tilt sensor, it used a (100) silicon wafer. A silicon oxide film is deposited with a thermal furnace, after initial cleaning. The passivation layer for TMAH etching is defined by a photolithography process. The tilt sensor part is etched. It deposited a silicon oxide to use the insulator of an electrode again. The Pt / Ti (2000Å/ 300 Å) is deposited with an e-beam to use an electrode. It put the electrolyte in the silicon cavity and bonded the glass cover not to flow to the electrolyte [3].

3. Results and Discussion

Figure 4 and 5 show the fabricated multi-sensor (two types). In this study, the piezoresistor sensor was investigated with measurements taken by a mechanical force gauge, as shown in Figure 6. The resistance changes on the right axis show when the sensor added the power of 0~10N. The voltage changes on the left axis show the results of a Wheatstone's bridge circuit. According to the pressure added, the voltage and resistance increases were relatively similar.

The proximity sensor had a spiral shape. The proximity sensor was evaluated by measuring the C-V characteristics with and without a cap on top of the sensor, as shown in Figure 7. In order to measure the opening and shutting of the system and mobile units with various materials, the caps used were made of various materials. Three different caps were used, plastic, metal, and glass. In all cases, the cap size was 1 mm^2. The proximity sensor showed the largest capacitance with an open cap and different values for the various caps used. The photodiode sensor (conventional type) had a wider single sensing area for a given light. Using a halogen lamp and fluorescent lamp, the photo sensitivity of the diodes was measured and the results are shown in Figure 8. The results could confirm the difference of a lamp being on or off. As shown in Figure 9, it is the results that compared the characteristics of a photodiode sensor using porous silicon with and a photodiode sensor using single silicon. Especially, two sensors measured individually and compared in darkness with light. According to the results of the measurement, it can confirm a large change if it used a photodiode sensor using porous silicon than a photodiode sensor using single silicon.

The fabricated tilt sensor consisted of a deep cavity and an electrolytic solution, and metal electrodes. The electrolytic used the oil that was also used at the level test system. It analyzed the characteristics of the tilt sensor. The movement of the electrolytic reacted in less than 1 sec, respectively at 15, 30, and 45 angle with external tampering. The results mean the tilt sensor can react at once to external tampering. Figure 10 shows the schematic of measurement with the tilt sensor. The characteristic of a tilt sensor can be confirmed according to an angle change.

Acknowledgements

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3. Conclusions

A newly-designed multi-sensor has been fabricated onto a SOI wafer, using a TMAH etching, a doping, a LPCVD process and a MEMS technology. The various components of the multi-sensor can perceive different types of external tamper independently, resulting in more reliable responses. The multi-sensor could be applied to detect external tampers on various types of system units.

References

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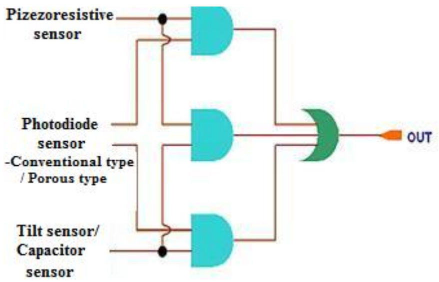

Fig. 1. The multi-sensor’s logic gate in the system unit.

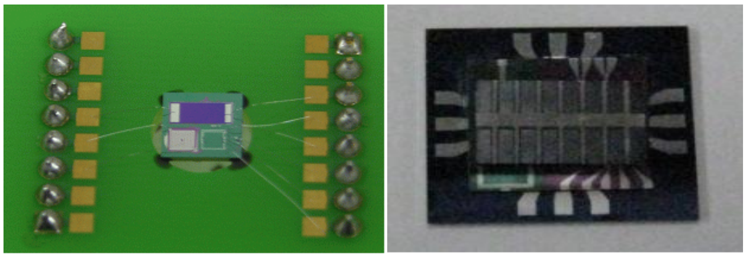

Fig. 4 and 5. The fabricated multi-sensor (two types).

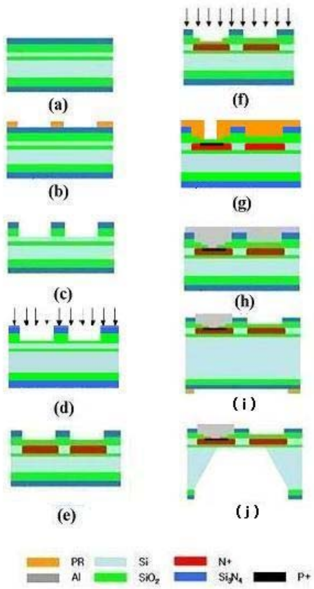

Fig. 2. The fabrication process of the multi-sensor.

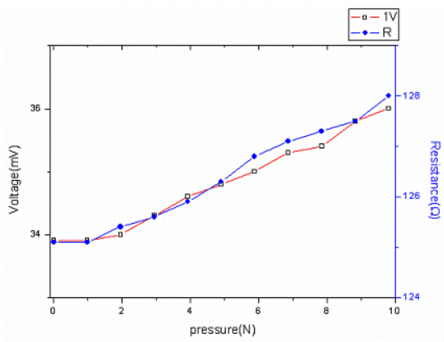

Fig. 6. The vibration characteristic of the piezoresistive sensor.

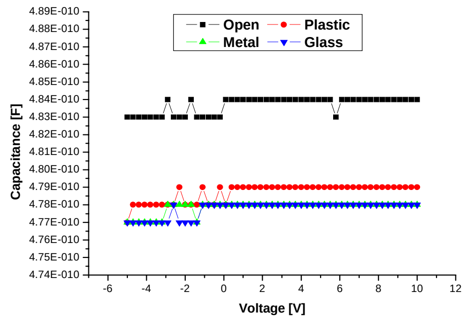

Fig. 7. The C-V characteristics of the proximity sensor.

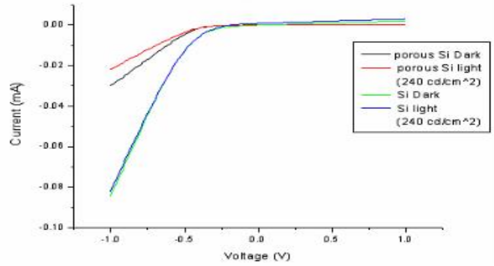

Fig. 8. The I-V characteristics of the photodiode sensor.

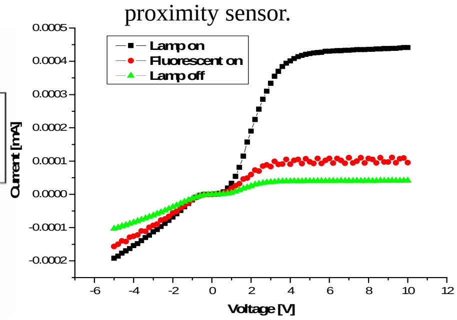

Fig. 9. The characteristics of comparison of the photodiode using porous silicon with the photodiode using single silicon.

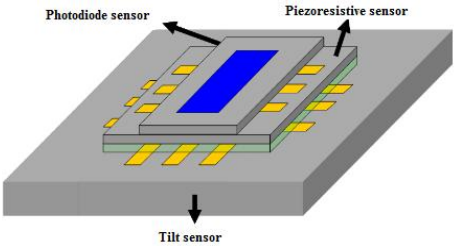

Fig. 3. The proposed design of the multi-sensor (second-type).

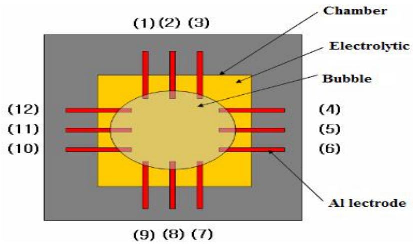

Fig. 10. The schematic of measurement with the tilt sensor.