A MEMS-BASED TILT SENSOR USING AIR MEDIUM

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Abstract: The proposed tilt sensor using air medium with a micro-heater and surrounded temperature sensors covers measurement range of ±90 degree with superior linearity and symmetric sensitivity. The structure and fabrication sequence of the proposed sensor are quite simple; micro-heater and temperature sensors can be simultaneously formed because they are composed of the same material.

Key words: MEMS, Convective tilt sensor, Heater, Temperature sensor

1. INTRODUCTION

Inclination sensing is quickly becoming a need for many vehicle driving systems. The development of a low-power and low-cost general-purpose sensor is broadened the inclinometer's scope of applications beyond automobile industry to include computer peripherals, car alarms, cameras, airline control of airplanes, train[1][2]. For these applications, electrolytic tilt sensor is wildly used in the industrial manufactures. Because these sensors are electrolyte based, they can sustain large shocks and high external pressure. Nevertheless, electrolyte-based tilt sensors significantly take some drawbacks; electrolytic sensing element needs inserted electrodes, which have to be in galvanic contact with the electrolyte. This causes an expensive fabrication cost, inferior durability, electrode corrosion and so on.

Therefore in this paper, a MEMS-based tilt sensor using air medium is proposed. The air sealed in an encapsulated space is heated by an integrated Pt heater and the temperature distribution of the air is detected by the Pt sensors formed around the heater, when the device encounters a tilting motion. The tilt sensor proposed in this paper has an extended measurement range (±90 degree) in comparison with previously-reported MEMS-based electrolytic tilt sensor and it shows stable performance even after long driving time[3]. Moreover, the sensor is suitable for mass production with low cost due to its simple structure and easy fabrication process.

2. EXPERIMENTAL

2.1 Fabrication

The proposed tilt sensor consists of independently processed and finally bonded top and bottom wafers; bottom wafer contains a micro-heater part to heat the air medium and temperature sensor part to detect a change of temperature distribution, and top wafer provides an air cavity.

Figure 1 shows the schematic structure and fabrication sequence of the proposed tilt sensor. Both components, heater and sensors, are formed with Pt (2200Å) / Ti (200Å) on a thin SiO_2 membrane. Pt is the material used both as temperature sensors and heater due to its superior characteristics, high and linear temperature coefficient of resistance (TCR) in wide temperature range[4]. So in this experiment Pt is used as sensors and a heater and made thorough one process.

Prepared sensing wafer is encapsulated with oxidized secondary capping wafer. The top capping wafer is etched by deep reactive ion etching (D-RIE) to form a cavity and thermally oxidized for minimizing environmental influences on the device operation. The back side of the bottom sensing wafer is then etched using tetra methyl ammonium hydroxide (TMAH). Finally top and bottom wafer are completed by epoxy bonding. Top wafer is designed and made smaller than bottom wafer to reserve the space for bonding pads.

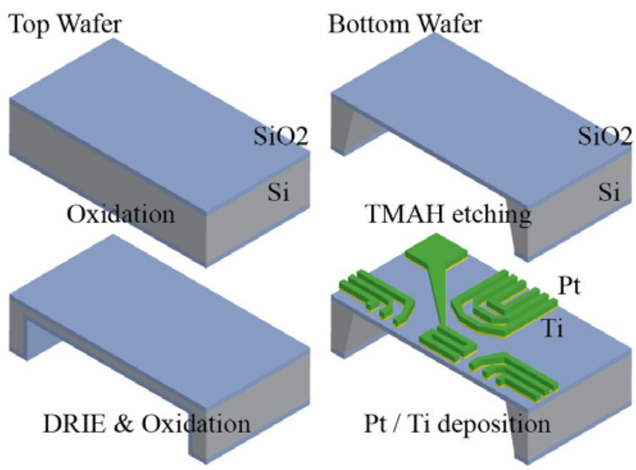

Fig. 1: Schematic structure and fabrication sequence of proposed tilt sensor.

Figure 2 shows the photos of fabricated MEMS-based tilt sensor using air medium. The proposed sensor consists of a meandered central micro-heater and four temperature sensors for two-axis inclination detection. The micro-heater and temperature sensors are formed on a thin film membrane for thermal isolation and sealed with air in a hermetic micro-chamber. In order to find an optimized distance between the heater and sensors for a given structure and material, temperature sensors are prepared on each side with three different distances from the central heater.

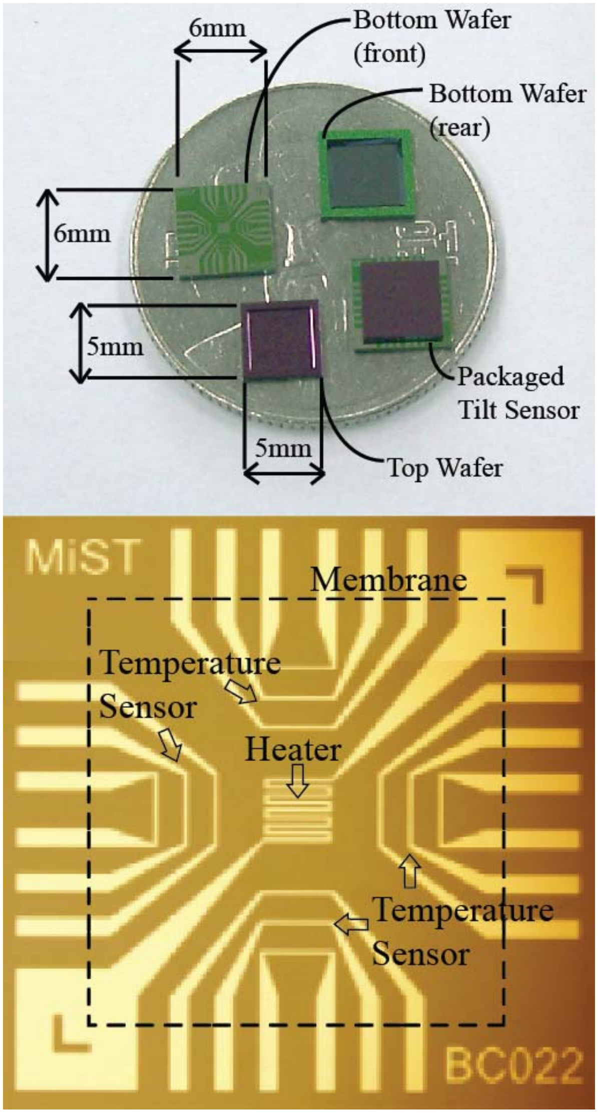

Fig. 2: Fabricated MEMS-based tilt sensor.

2.2 Functional Mechanism

Figure 3 shows the functional mechanism of proposed convective tilt sensor. Without an inclination, the micro-heater creates a symmetric temperature profile in the micro-chamber. When the device is tilted the temperature sensors measure the asymmetric temperature profile caused by the effect of inclination on free convection in the surrounding air medium.

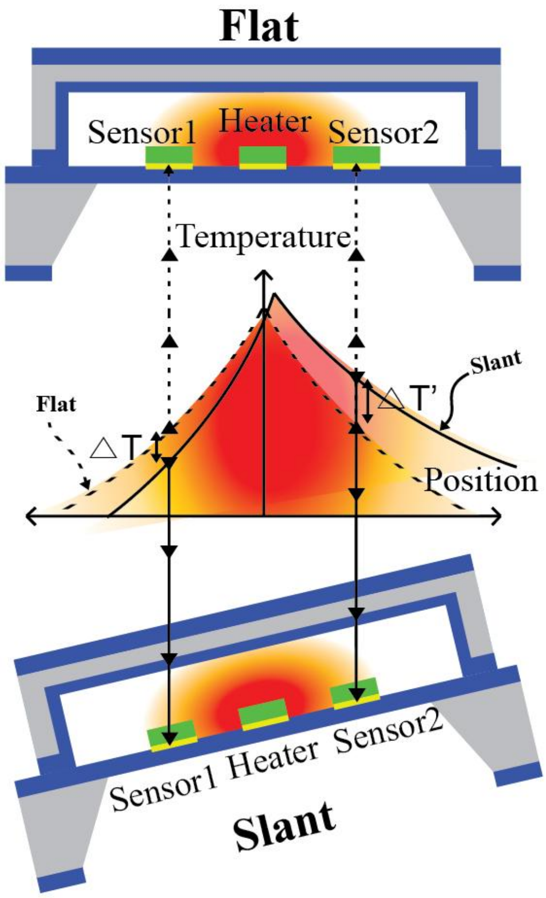

Fig. 3: Functional mechanism of MEMS-based tilt sensor using air medium.

2.3 Measurement

For the measurement, electric currents of 30mA and 10mA are flowed into the micro-heater and temperature sensors, respectively. Figure 4 shows the schematic measurement set-up for the proposed tilt sensor. In this experiment, a counter clockwise rotation is defined as the positive angle.

The measurement results revealed that the tilt sensor shows a different sensitivity depending on the position of the temperature sensor. As can be seen in Fig. 5, closest temperature sensor to the micro-heater shows most sensitive and linear result.

Figure 6 and 7 show the output characteristics of the fabricated tilt sensor as a function of tilt angle for one and two-axis measurements, respectively. Temperature changes on sensor 1 and sensor 2 caused by an inclination can be measured by monitoring either the temperature difference between sensor 1 and 2 or the temperature change on each sensor. By compositing the outputs of the sensors, it is possible to detect the angle range of ±90 degrees on two axes. Figure 7 shows the output characteristics of the fabricated tilt sensor, which consists of four temperature sensors formed around the micro-heater.

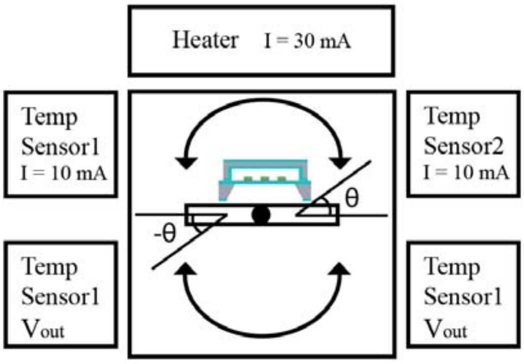

Fig. 4: Measurement set-up.

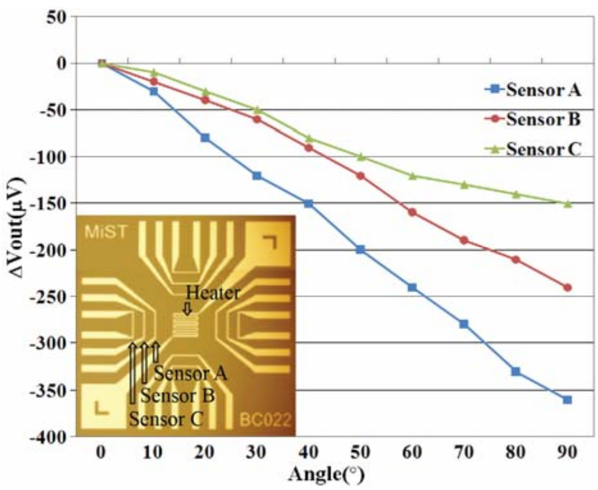

Fig. 5: Output voltage as a function of temperature sensor position.

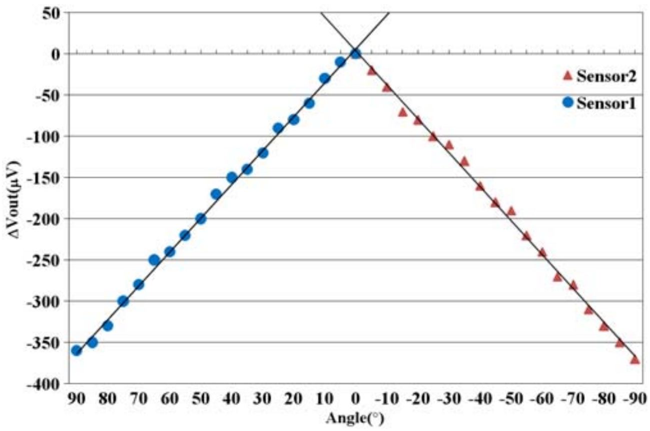

Fig. 6: One-axis output voltage as a function of tilt angle.

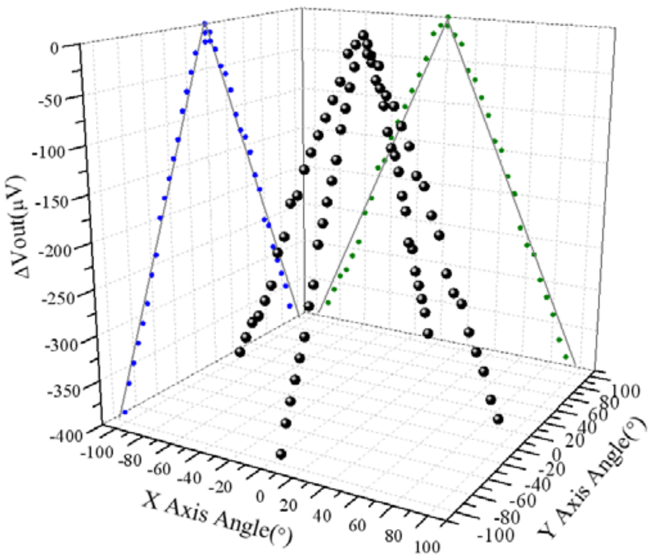

Fig. 7: Two-axis output voltage as a function of tilt angle.

3. CONCLUSION

The proposed tilt sensor using air medium with a micro-heater and surrounded temperature sensors covers measurement range of ±90 degree on two axes with superior linearity and symmetric sensitivity. The structure and fabrication sequence of the proposed sensor are quite simple; micro-heater and temperature sensors can be simultaneously formed because they are composed of the same material. The mass production of the proposed tilt sensor is feasible with low cost and the performance of the sensor can be further improved by replacing the gas medium with lighter one. Moreover, this device has a potential to be applied to two-axis accelerometer as it is without changing its structure.

Even though the proposed sensor may show a fluctuated output depending on the variation of the environmental temperature, it can be improved by adding an additional compensation circuit.

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