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Keio University

Thesis Abstract

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Thesis Title

One-side-electrode-type fluid-based inclination sensor combined with CMOS detection circuitry

Thesis Summary

In this study, a one-side-electrode-type fluid-based inclination sensor was realized by using micro fabrication technique. Sensing electrodes and insulator layer were fabricated on a ceramic substrate. A PDMS (Polydimethylsiloxane) or glass container was bonded on the substrate to form a sensor cavity. The cavity was half filled with an electrolyte and the movement of the electrolyte due to gravity was detected by measuring the capacitance difference between these electrodes. The capacitance difference was proportional to an inclination angle. The sensor was integrated with a low-voltage capacitance detection circuitry on the reverse side of the ceramic substrate.

In the 1st chapter, the background and the purpose of this study are described.

The 2nd chapter describes the principle and structure of the inclination sensor. The sensor was packaged with the charge-balanced capacitance-voltage (C-V) conversion circuitry because the capacitance difference was small.

The 3rd chapter describes the behavior of the electrolyte and an equivalent circuitry of the sensor. The dynamic characteristics depend on a surface tension of the electrolyte and container surface. In order to reduce the meniscus effect, a propylene carbonate and the PDMS were selected as electrolyte and container material, respectively. Referring to the partial length value (κ^{-1}) of propylene carbonate, the sensor with inner size of ϕ 4.0 mm × 1.0 mm was fabricated. The electrolyte is behaved as a conductor by an electrical double-layer principle. So that, a simple parallel-plate capacitor is formed on the electrodes.

In the 4th chapter, the design and evaluation of the detection circuitry are described. The C-V conversion circuits by using an operational amplifier configuration and an inverter amplifier configuration were studied. These detection circuits were connected with variable capacitors. The detection circuit by using inverter amplifier configuration showed a higher sensitivity than the operational amplifier configuration at V_{dd} = 1.3 V. The current consumption of the detection circuit was 38 μA at V_{dd} = 1.3 V.

In the 5th chapter, the evaluation of the sensor is described. The sensor showed a high-sensitivity about 7 mV/deg between ±60 deg at V_{dd} = 1.3 V. The response time and resolution were 0.7 s and 1.0 deg, respectively. The output voltage was not affected by vibration over 25 Hz at acceleration ±2G. The span voltage temperature characteristic was 10.9%F.S./0-50℃. In this chapter, the new bonding technique between the glass container and PDMS insulator layer was implemented by using silica coating liquid. The span voltage temperature characteristic was improved to 2%F.S./0-50℃ when the glass material was used as the container.

In the 6th chapter, conclusions and future perspectives are described.

From these proposals, it is found an idea to realize a small size, simple structure and low-voltage of fluid-based inclination sensor which sustain high frequency vibration and considerable shock.