Development of pH Sensor Module with Wireless Transmission Function

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***Abstract*— In our previous work, we developed a solid-state pH sensor for real time pH measurement. In this work, we discuss the use of this sensor for extension applications in the health monitoring field. The pH sensor system needs to be super compact in size and have a bio-friendly interface in order to provide a good user experience. In this paper, we introduce a smaller transistor and a new sensing material for realizing an optimized sensor structure and measurement system. The measured results show that the antimony-based pH sensor has a reasonable responsivity for pH real-time monitoring.**

Keywords - pH; field effect transistor; health condition; calibration; wireless transmission.

I. INTRODUCTION

Recently, Micro-Electro-Mechanical Systems (MEMS) technology has undergone many advances, such as super compact size, high sensitivity and high uniformity of working functions. Based on the MEMS technique, we developed a solid-state pH sensor that has already been used in some application fields, not only in chemical engineering, but also in industry and agricultural science [1] [2].

In this study, we would like extend the given sensor for applications in the health monitoring field. Figure 1 shows the schematic view of our proposed pH sensor measurement system. The typical electrodes were fabricated using the MEMS technique for realizing high dimensional and high performance homogeneity. The sensor system combines the measurement and transmission boards (see insert images). The electrodes connect the gate terminal of a Metal-Oxide-Semiconductor Field-Effect Transistor (MOSFET). The specific FET is loaded on the measurement board and used to measure the pH value of target solutions. The transmission board has a wireless or a Bluetooth module to transmit the tested date to the user terminal devices (smart phone or PC), respectively. Figure 1 also shows the potential application fields of the given pH sensor: (1) the compact sensing system unit could be set in a nappy or a diaper, for real-time monitoring the health condition of children or old people; (2) the compact sensor could be packaged with a bio-friendly surface; (3) the ultra-small low-power wireless sensor node may also be implanted into animal body to measure the urine condition of pets.

The rest of the paper is structured as follows. In Section 2, we are going to describe the fabrication method of sensor electrodes and system. In Section 3, some preliminary measurement results will be presented. In Section 4, we will present a discussion and conclusion on this work.

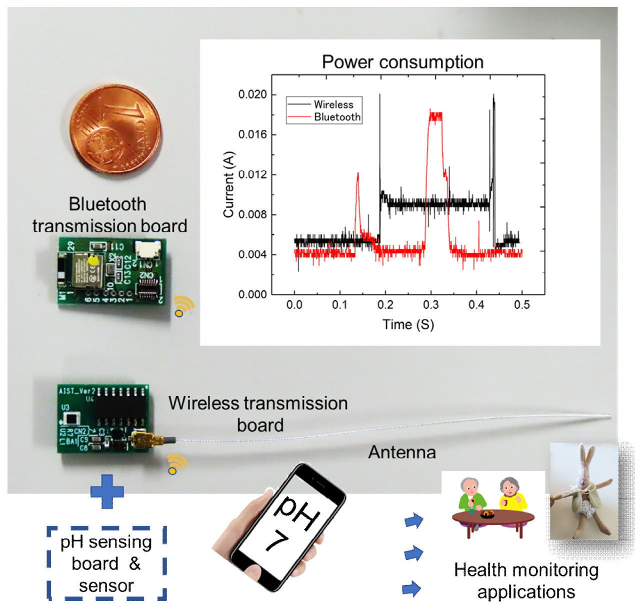

Figure 1. Smartphone based wireless pH sensor system and its potential applications.

II. SENSOR FABRICATION AND SPECIFICATION

In our previous works, we already comprehensively presented the fabrication processes of Indium Tin Oxide (ITO) -based pH sensor electrode [1]. Silicon wafers with 200-µm-thick SiO_2 for passivation layers were used to fabricate the MEMS devices in this work. After under-metal and sensing layers generation, photolithography and metal etching methods were used to generate the sensing electrode and the bottom electrode layers with high precision. Then, to pattern the sensing area and protect it with a long life time, a fluoropolymer thin film coating was fabricated on the sensor electrode. Finally, O_2 plasma was used to remove the photoresist and other residuals. On the other hand, in this work, the comparison sensor with the following specification of thick film antimony for the working electrode was used: the sensing area has a 4-mm diameter circular window.

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III. Preliminary Measurement Results

A. Metal-oxide-semiconductor field-effect transistor measurement

To provide a good user experience, the pH sensor system components should also be improved, because a small sensor node can minimize the discomfort of the users. The components on boards should be optimized with the size as small as possible. After the measurement board can be shrunk to a very compact size, the sensor system will also have a tiny size. In the new sensor system, an n-channel MOS transistor (with very low price, lower than 20 Japanese yen) was used on the sensing board for testing the pH value of solutions.

The performance of the small MOS transistor was measured. The output current of the transistor has a range from 0.875 V to 0.890 V, correspondingly to the measured pH value from 7 to 4. The responsivity of the new sensor has a reasonable value of 5 mV/pH.

B. Performance comparison of different sensing electrodes and different transmission systems

We did a performance comparison of different sensing electrodes. Figure 2 shows the digital output of the pH sensor with different sensing materials versus the measured pH values. As the results show, the ITO- and antimony-based pH sensors have similar output/pH values (the relative error between the two sensors does not exceed 5% in average). Both sensors can keep a linear output proportional to the changes in the pH value. The very small different slope between the fitting curves showed that the antimony-based pH sensor has a relatively higher sensitivity (see Figure 2 fitting curves). However, the antimony-based pH sensor also suffers from a larger deviation error comparison with ITO-based pH sensor. On the other hand, some researchers prefer the antimony-based pH sensors to apply on bio-sensing technology, for a better biocompatibility [3]. We can understand the merits and demerits of sensing materials, reasonably. After correct calibration, the sensor node can be used in field measurements to prove its stability and reliability. We also tested the power consumption of wireless and Bluetooth transmission systems; we found that they have similar power consumption at the mW level, but Bluetooth has an inner antenna, which causes the Bluetooth-based pH sensor system to be very compact in size, with larger application potentials.

IV. Discussion and Conclusion

We developed a solid-state pH sensor for real time pH monitoring. In this work, we extend its applications into the health monitoring field. In order to realize the solid-state pH sensor with super compact size and bio-friendly interface to provide a good user experience, a small transistor and a new sensing material are introduced for fabricating the sensor structure and measurement system, respectively. As the results show, the antimony-based pH sensor has a reasonable responsivity for pH real-time monitoring. Super compact solid pH sensors can provide mass data of target solutions and water to help companies realize an Internet of Things management system.

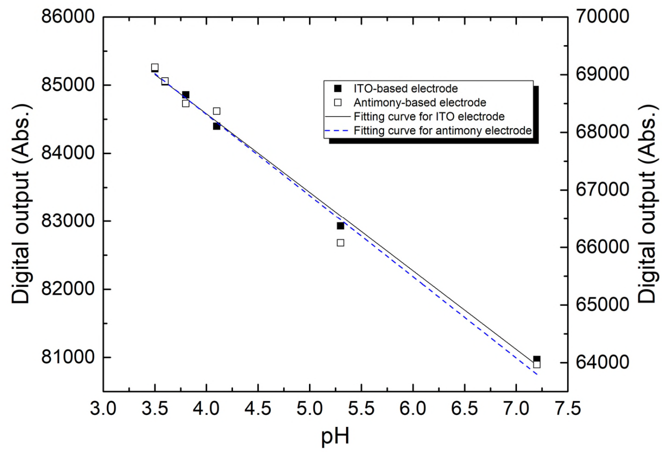

Figure 2. The output voltage of the pH sensor with different sensing electrodes against the measured pH values.

Acknowledgment

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