Design of Measurement Interface and System for Ion Sensors

Jung-Chuan Chou, and Chang-Chi Lee

Abstract—A measurement system was successfully fabricated to detect ion concentrations (hydrogen and chlorine) in this study. PIC18F4520, the microcontroller was used as the control unit in the measurement system. The measurement system was practically used to sense the H^+ and Cl^- in different examples, and the pH and pCl values were exhibited on real-time LCD display promptly. In the study, the measurement method is used to judge whether the response voltage is stable. The change quantity is smaller than 0.01%, that the present response voltage compares with next response voltage for H^+ measurement, and the above condition is established only 6 sec. Besides, the change quantity is smaller than 0.01%, that the present response voltage compares with next response voltage for Cl^- measurement, and the above condition is established only 5 sec. Furthermore, the average error quantities would also be considered, and they are 0.05 and 0.07 for measurements of pH and pCl values, respectively.

Keywords—Chlorine ion sensor, hydrogen ion sensor, microcontroller, response voltage.

I. INTRODUCTION

THE extended gate field effect transistor (EGFET), was proposed by Spiegel et al. in 1983 [1]. In this study, the EGFET is improved to become separative extended gate field effect transistor (SEGFET), which such a sensor has many advantages such as simple, low cost, disposable, etc. Unfortunately, it is scanty the convenient system was designed to collect the signal of SEGFET. For this reason, we designed the measurement system as the readout device of ion sensors.

The hydrogen ion is the basic measurement sensor [2-5], any ion sensor even enzyme sensor can be developed from hydrogen ion sensor. Hence, the development of hydrogen ion sensor is very important for biosensor field. Another significant ion, chlorine ion is excellent oxidant, because it is always used as disinfectant and cleanser. Moreover, whether chlorine ion in human body is excess or scantiness, the body will be discomfortable, such as excessive perspiration, addison's diseasey, respiratory acidosis, acute renal failure, diabetes

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mellitus, etc. Therefore, detective technique of chlorine ion will be expected for people.

Microcontroller has been widely studied in industry, such as automatic controllability, electronic products, artificial neural network (ANN) model, etc [6-12]. The microcontroller usually has operation unit, control, memory, input/output (I/O) on single chip. In recent years, the many ion measurement systems are developed to use microcontroller [13-18]. Hence, the microcontroller, PIC18F4520, was used as the control unit in the measurement system of ion sensor in this study. Because this microcontroller has excellent abilities such as the compatibility with RS232, USB, wireless and operation of mathematics, etc, so it was chosen in this research for ion measurement system.

II. EXPERIMENTAL

In this study, the chlorine ion and hydrogen ion sensor were fabricated by SEGFET, whose fabricating process as mention from previous studies [19, 20].

A. Materials

The PIC18F4520 and MPLAB ICD2 in-circuit debugging were obtained from Microchip Technology Incorporated (USA). Among them, MPLAB ICD2 was used to debug program codes for simulation of target microcontroller, and it can be used to write program. In addition, the developing software (MPLAB IDE v8.10 and MPLAB C Compiler for PIC18 MCUs) was downloaded from official website of Microchip Technology Incorporated.

B. System

Fig. 1 shows the block diagram of measurement system, the sensing structure was composed of chlorine ion sensor, hydrogen ion sensor and Ag/AgCl reference electrode. When the sensors were immersed in test solution by user, the response voltages were obtained from chlorine ion and hydrogen ion sensors, respectively. Afterwards, the response voltages could be read to readout circuit system that was composed of readout circuit, and instrument amplifier, AD620, whose gain is 5.94. Then readout voltage could be sent to analog/digital (A/D) converter of microcontroller, and the signals will be changed to pH and pCl values, respectively. Finally, the pH and pCl values can be displayed on LCD.
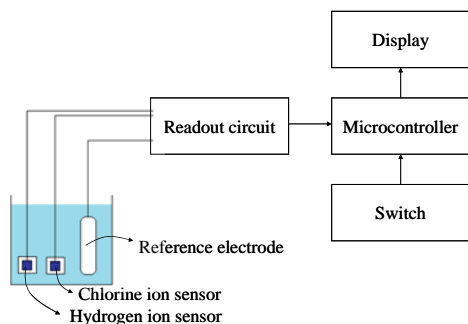
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Fig. 1 Block diagram of measurement system

C. Software

The program was set as follows: First, setting LCD, ADC, interrupt. Moreover, the thirty-two data were obtained from A/D converter, and the data will be averaged. Then the response voltages of definition will be obtained by pH1, pH7, pH11, pCl0 and pCl4, respectively. And the pH and pCl values were calculated from above parameters. Finally, digital code was obtained from A/D converter, and the pH values were calculated from voltages of measurement and were displayed on LCD.

III. RESULTS AND DISCUSSION

A. Method of calculation for pH and pCl

The response voltages will be obtained by pH1, pH7, pH11, pCl0 and pCl4, respectively. The concentration of test solution will be calculated by above definitive values, that the equations (1), (2) and (3) are shown as follows:

From pH1 to pH7:

$$variable\ quantity(V/pH) = \Delta_{pH1 \to pH7} = \left| \frac{V_{pH1} - V_{pH7}}{pH1 - pH7} \right| \tag{1}$$

From pH7 to pH11:

$$variable\ quantity(V/pH) = \Delta_{pH7 \to pH11} = \left| \frac{V_{pH7} - V_{pH11}}{pH7 - pH11} \right| \tag{2}$$

From pCl0 to pCl4:

$$variable\ quantity(V/pCl) = \Delta_{pCl0 \to pCl4} = \left| \frac{V_{pCl0} - V_{pCl4}}{pCl0 - pCl4} \right| \tag{3}$$

The sensor will be adjusted by definitive value. In addition, the pH and pCl values can be calculated from above variable quantity as following:

If $V_{out} > V_{pH7}$:

$$pH\ value = 7 - \frac{V_{test\ solution} - V_{pH7}}{\Delta_{pH1 \to pH7}} \tag{4}$$

If $V_{out} < V_{pH7}$:

$$pH\ value = 7 + \frac{V_{pH7} - V_{test\ solution}}{\Delta_{pH7 \to pH11}} \tag{5}$$

And

$$pCl\ value = \frac{V_{pCl0} - V_{test\ solution}}{\Delta_{pCl0 \to pCl4}} \tag{6}$$

B. Hydrogen ion measurement

The measurement system automatically judges stable response voltage for detecting hydrogen ion. In Fig. 2, the hydrogen ion sensor hasn't immersed in pH solution before 20 sec (under ground), afterwards, the present response voltage compares with next response voltage as following: 21 to 22 sec is 0.08%, 22 to 23 sec is 0.05%, 23 to 24 sec is 0.03%, 24 to 25 sec is 0.02%, 25 to 26 sec is 0.005%, 26 to 27 sec is 0.002%, 27 to 28 sec is 0.002%, 28 to 29 sec is 0.003%, 29 to 30 sec is 0.001%, respectively. The change quantity of response voltage is decreased to 0.01% at 5 sec as above data, so the measurement system can confirmedly obtain response voltage at 5 sec. Besides, the hydrogen ion sensor is immersed in different pH solutions, the results are shown in Table I. The error quantities are between 0.03 and 0.08, and the average error quantity is 0.06, which has confirmed that the measurement system improves the accuracy comparing with previous research [20].
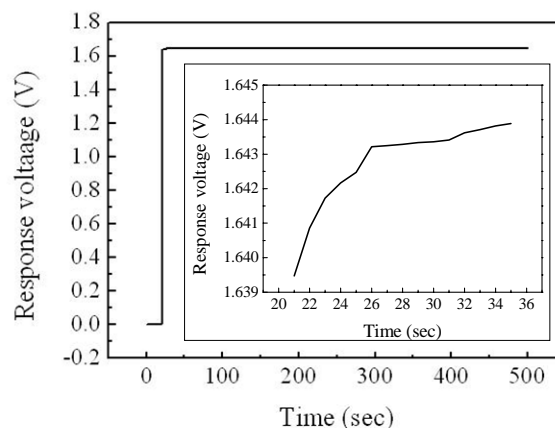

Fig. 2 Hydrogen ion sensor is measured from 0 to 500 sec in pH7 solution

TABLE I
HYDROGEN ION SENSOR IS MEASURED IN DIFFERENT pH SOLUTIONS

Standard solution(pH)	1	3	5	7	9	11
The first measurement(pH)	1.02	2.93	5.08	7.02	9.08	11.09
The second measurement(pH)	1.01	2.95	5.10	7.06	9.10	11.05
The third measurement(pH)	1.03	2.91	5.09	7.04	9.10	11.06
The fourth measurement(pH)	1.05	2.98	5.04	7.06	9.04	11.04
The fifth measurement(pH)	1.05	3.03	5.07	7.01	9.09	11.11
Average(pH)	1.03	2.96	5.08	7.04	9.08	11.07
Average error quantity (pH)	0.06					

C. Chlorine Ion Measurement

The measurement system automatically judges stable

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response voltage for detecting chlorine ion. In Fig. 3, the chlorine ion sensor hasn't immersed under pCl solution before 20 sec (under ground), afterwards, the present response voltage compares with next response voltage as following: 21 to 22 sec is 1.12%, 22 to 23 sec is 0.05%, 23 to 24 sec is 0.06%, 24 to 25 sec is 0.03%, 25 to 26 sec is 0.02%, 26 to 27 sec is 0.006%, 27 to 28 sec is 0.008%, 28 to 29 sec is 0.005%, 29 to 30 sec is 0.004%, respectively. The change quantity of response voltage is decreased to 0.01% at 6 sec as above data, so the measurement system can confirmedly obtain response voltage at 6 sec. Besides, the chlorine ion sensor is immersed in different pCl solutions, the results are shown in Table II. The error quantities are between 0.03 and 0.07, and the average error quantity is 0.05, which confirm that the chlorine ion measurement system is excellent.
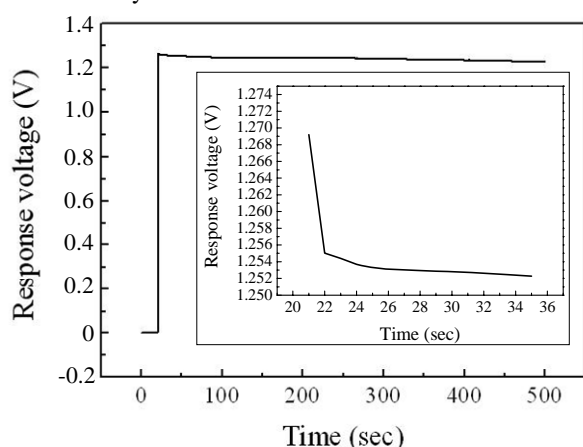

Fig. 3 Chlorine ion sensor is measured from 0 to 500 sec in pCl3 solution

TABLE II
CHLORINE ION SENSOR IS MEASURED IN DIFFERENT PCL SOLUTIONS

Standard solution(pCl)	0	1	2	3	4
The first measurement(pCl)	0.04	0.91	1.92	3.16	4.04
The second measurement(pCl)	0.00	1.08	2.00	3.14	4.00
The third measurement(pCl)	0.08	1.08	1.95	3.02	4.08
The fourth measurement(pCl)	0.03	1.02	2.02	3.08	4.01
The fifth measurement(pCl)	0.02	1.04	1.97	3.02	4.05
Average(pCl)	0.03	1.03	1.93	3.08	4.04
Average error quantity (pCl)	0.05				

IV. CONCLUSION

In this study, a measurement system for ion detection is finished, and the change quantity of response voltage is decreased to 0.01% at 5 sec for hydrogen ion measurement. Moreover, the change quantity of response voltage is decreased to 0.01% at 6 sec for chlorine ion measurement. In addition, when the pH and pCl are measured in different pH and pCl concentrations, the average error quantities are 0.06 and 0.05,

respectively. Therefore, the measurement system is excellent for ion measurement. Besides, the pH and pCl values were successfully displayed on LCD immediately.

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