Int. J. Electrochem. Sci., 11 **(2016)** 2263 - 2268

International Journal of
ELECTROCHEMICAL
SCIENCE
www.electrochemsci.org

Note

Fabrication of Flexible Micro pH Sensor for use in Proton Exchange Membrane Fuel Cell

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Received: 15 December 2015 / *Accepted:* 12 January 2016 / *Published:* 1 February 2016

Proton exchange membrane fuel cell (PEMFC) performance and the life of internal components are affected by the acidic environment. When the operating temperature of fuel cell and the relative humidity is too high, the working efficiency of the fuel cell will decrease, and shorten the life of internal component. PH sensors are brittle, bulky and expensive, so the sensor cannot be embedded inside the fuel cell. Therefore, this work applied the micro-electro-mechanical systems (MEMS) technology to develop flexible micro pH sensors. The advantages of flexible micro pH sensors include their flexibility, against acidic environment and ability to be placed anywhere in a fuel cell.

Keywords: Flexible micro pH sensor; MEMS; PEMFC.

1. INTRODUCTION

The abuse of fossil energy results in global warming and drastic climate change. In recent years, developing green energy becomes a new trend. The acid environment in the fuel cell can shorten the life of elements in the low temperature fuel cell and influence the fuel cell operating performance. The gradual degradation of the fuel cell performance with time is extensively covered in the literature [1]. Therefore, it is required to use microsensors to monitor the internal parameters of low temperature fuel cell instantly, and to correct the abnormal data to normal range [2]. The increment of pH value can improve its anti-corrosion behavior [3]. At present, the pH sensors on the market have large size and long response time, difficult to be used for diagnosing the physical quantities in the low temperature fuel cell. Therefore, this study plans to develop a flexible micro pH sensor to measure the pH value of the fluid in the fuel cell, so that the developers can implement real-time diagnosis and modification process. In order to be embedded in the low temperature fuel cell, the substrate of micro pH sensor must be flexible and corrosion resistant, so the selection of material is very important. The MEMS technology is used to develop the flexible micro pH sensor on the polyimide (PI) flexible substrate, the thickness is 50μm. The PI polymer is characterized by high temperature resistance, compression resistance, high flexibility and good durability.

2. EXPERIMENT

This experiment is divided into three parts: (1) preparation of sensing material hydrogel; (2) production of flexible micro pH sensor and (3) correction of micro pH sensor.

2.1 Preparation of sensing material hydrogel

The sensing material is made by mixing conductive polymer and solvent with the adhesion layer made of resin. The conductive polymer is made of PPY and polyaniline powder mixed uniformly with butyl glycol ether solvent. The polyaniline is highly sensitive to acid, enhancing the sensitivity of sensor to pH value. The PPY increases the overall resistance of sensor and enhances the stability of sensor, so that the sensor can work normally in different conditions and similar correction curves can be obtained.

The adhesion layer is made of PVB resin. The PVB resin is dissolved in butyl glycol ether solvent in proportion, heated to form PVB glue. The uniformly mixed conductive polymer is mixed with the PVB glue, stirred uniformly for 30 minutes to complete the preparation of hydrogel, as shown in figure 1.

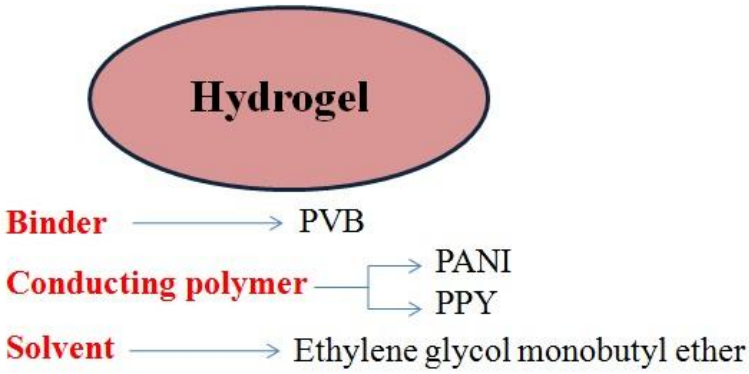

Figure 1. Schematic diagram of preparation of hydrogel.

2.2 Introduction to flexible micro pH sensor

2.2.1 Types of pH sensor

In order to develop the flexible micro sensor which can measure pH value, the optimal microsensor must be selected from potential pH sensor and conductance pH sensor. The potential pH sensor deduces the pH value from the potential difference between measuring electrode and reference electrode, the measurement is stable in different fluids, but the process is complex and it is too large to be embedded in the low temperature fuel cell [4]. The conductance pH sensor uses interdigital electrode, coated with dielectric to measure the conductance, this method reduces the sensor area greatly and has higher accuracy, and the specific fluid measuring range is wide. Therefore, this study uses the advantageous conductance pH sensor [5-7].

2.2.2 Sensing principle of pH sensor

The conducting polymers PPY and polyaniline in the sensing material hydrogel can react with the hydrogen ions in the fluid, and then the electrical conductivity of hydrogel is changed. The proportions of PPY and polyaniline are prepared in this study, so that the micro pH sensor has better correction curve in a fixed pH range [8].

2.2.3 Production of flexible micro pH sensor

Figure 2 shows the process of flexible micro pH sensor, based on MEMS technology, the process steps are described below.

(1) The selected PI foil substrate is immersed in acetone and methanol, vibrated by ultrasonic cleaner to wash out the surface oil and fat and fine dust, so that the process has the best metal and photoresist adhesion.

(2) The Cr is evaporated as the adhesion layer between Au and PI substrate, enhancing the adhesiveness between Au and PI, and Au is deposited as sensing material.

(3,4) The interdigital sensing patterns are defined by lithography and wet etching processes.

(5) The hydrogel is coated on interdigital electrode to complete the definition of sensing layer. Figure 3 shows the optical micrograph of flexible micro pH sensor.

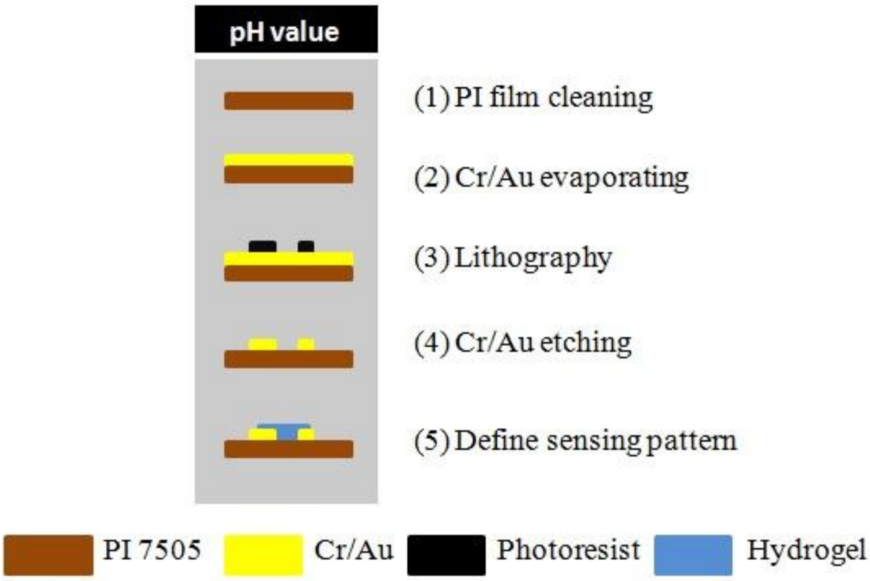

Figure 2. Process of flexible micro pH sensor.

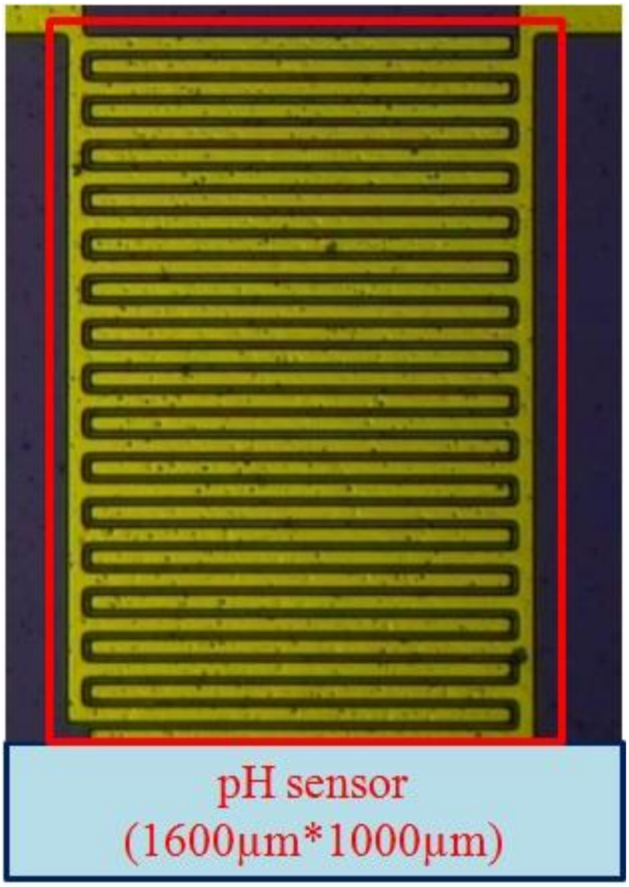

Figure 3. Optical micrograph of flexible micro pH sensor.

2.3 Correction of micro pH sensor

Figure 4 is the schematic diagram of correction of flexible micro pH sensor. As the fluid in the low temperature fuel cell is acidic, the standard solution of pH 7 is the first titer, and the standard solution of pH 6 to pH 4 is measurement liquid. The correction method is that the flexible micro pH sensor is immersed in the first titer, and the conductivity is measured by LCR meter. Afterwards, the sensor is immersed in the standard solution of pH 6 to pH 4 and the conductivity is measured, so as to obtain the pH value and conductivity correction chart, as shown in Figure 5.

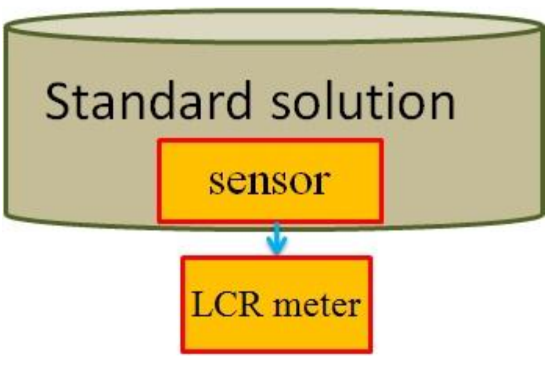

Figure 4. Schematic diagram of correction of flexible micro pH sensor.

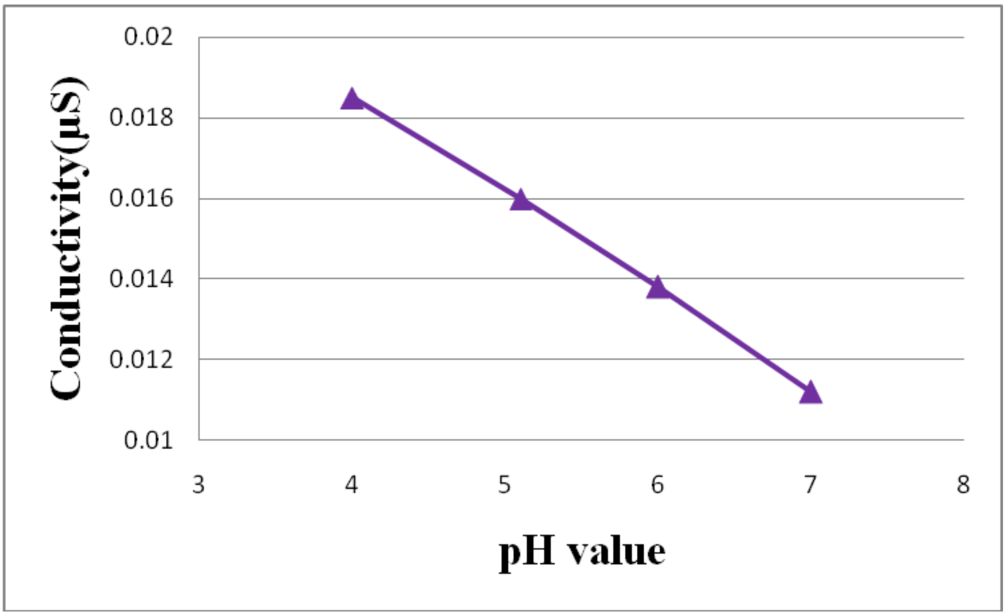

Figure 5. Correction curve of flexible micro pH sensor.

3. RESULTS AND DISCUSSION

The hydrogel sensing material in appropriate proportion is prepared in this study, which is flexible and acid resistant, and it is sensitive to pH with destruction resistance. We can increase or decrease the signal when measuring by adjusting the percentage of PPY and polyaniline. The micro pH sensor is made on the PI foil by using MEMS technology, so that the micro pH sensor is sensitive and nonfragile, and it can be embedded in the low temperature fuel cell. The pH value of fluid in low temperature fuel cell is about 4 to 6, so we put flexible micro pH sensor in acidic and neutral environment to do the correction. Figure 5 shows the correction curve of flexible micro pH sensor. The experimental results show that the pH value is almost linearly related to the electrical conductivity. The advantages of flexible micro pH sensors include their flexibility, against acidic environment and ability to be placed anywhere in a fuel cell.

4. CONCLUSIONS

This study used MEMS technology to develop a flexible micro pH sensor on PI foil successfully. This micro pH sensor is characterized by real-time measurement, compactness, acid corrosion resistance, being free of brittleness, rapid response and optional position. The old pH sensor only measures the parameters of external gas inlet/outlet of low temperature fuel cell, the flexible micro pH sensor can be embedded in the low temperature fuel cell for local measurement in the future, so that the internal microscopic diagnosis information can be fed back to the user accurately for operation management, and the internal reaction information when the low temperature fuel cell is in operation can be known completely, so as to improve the performance and life of low temperature fuel cell.

ACKNOWLEDGEMENTS
This work was accomplished with much needed support and the authors would like to thank for the financial support by Ministry of Science and Technology of R.O.C. through the grant MOST 104-2815-C-155-017-E,102-2221-E-155-033-MY3, 103-2622-E-155-006-CC2, 104-2622-E-155-007-CC2, 104-2623-E-155-004-ET, 104-2622-E-155-004 and 105-ET-E-155-002-ET. In addition, we would like to thank the YZU Fuel Cell Center and NENS Common Lab, for providing access to their research facilities.

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