A Microfluidic System with Nonenzymatic Glucose Sensor

Segyeong Joo[*], Sejin Park[**], Hyojin Lim[**], Teak Dong Chung[**] and Hee-Chan Kim[***]

[*]Interdisciplinary Program-Biomedical Engineering Major,
Seoul National University, Korea, sgjoo@melab.snu.ac.kr
[**]Department of Chemistry, Sungshin Women's University, Korea
[***]Department of Biomedical Engineering, College of Medicine and
Institute of Biomedical Engineering, Medical Research Center, Seoul National University, Korea

ABSTRACT

In this paper, we report an amperometric-type enzymeless glucose sensor system based on nanoporous platinum (Pt) and platinum/platinum oxide (Pt/PtO) reference electrode, which are integrated with microfluidic chip. This microchip system is comprised of microfluidic transport channels and a nonenzymatic glucose sensor system with nanoporous Pt electrode. From this microfluidic chip system, rinsing and reconditioning of sensor can be possible and multiple-use sensor system can be achieved. The sensitivity of developed system was 0.28 μA/mM when tested with glucose solution diluted in PBS buffer.

Keywords: microfluidic system, nonenzymatic glucose sensor, nanoporous electrode

1 INTRODUCTION

More reliable and cost-effective measurement of glucose is obviously one of the most important challenges in the industry of biomedical analysis system [1-2]. However, biological components, mostly the enzymes immobilized, in conventional glucose sensor cause intrinsic problems such as poor preservation and short lifetime, which ultimately lead to cost increase. In this respect, glucose sensor employing no enzyme implies a breakthrough in developing a new one with better reliability and longer shelf time.

Recently our research group reported that nanoporous Pt electrodes work as an excellent glucose detector, which substantially overcomes the critical drawbacks of the previously developed enzymeless sensors [3]. This novel invention is expected through further straightforward modification to be applied to the disposable strip-type glucose sensor which is now all enzyme-based sensor. For a multiple-use sensor system, however, it requires appropriate peripheral devices that rinses and reconditions the sensor in a programmed sequence. To address this matter, we integrated porous Pt films on patterned Pt substrate and Pt/PtO as a solid state reference electrode on a microfluidic chip including such peripheral devices.

2 MICROFLUIDIC CHIP STRUCTURE AND FABRICATION

Fig. 1 shows the schematic diagram of proposed microfluidic system. Pt electrodes for electroosmotic flow (EOF) and fore electrochemical detection were deposited on the bottom glass substrate. The upper layer of poly(dimethyl siloxane) (PDMS) was cast from a silicon wafer mold that has the pattern for microchannels and reservoirs. The mold is an etched silicon wafer with reactive ion etching (RIE) system. Both of the channel width and height are 30 μm.

Fig. 2 shows the overall fabrication process. First, a 2" × 3" slide glass (Model S, Matsunami, Japan) was cleaned with piranha solution and photoresist (AZ5214E, Clariant, Switzerland) was patterned on the top of the glass. Sputtering Ti/Pt (200/2000 Å) was followed by lift-off process to yield the metal electrode pattern, on which the nanoporous Pt working electrode and a Pt/PtO reference electrode were laid in the same way as previously reported [1]. On the other hand, PDMS on the prefabricated silicon mold was underwent additional treatment with O_2 plasma to promote adhesion with the bottom slide glass. Fig. 3 shows the complete system as made.

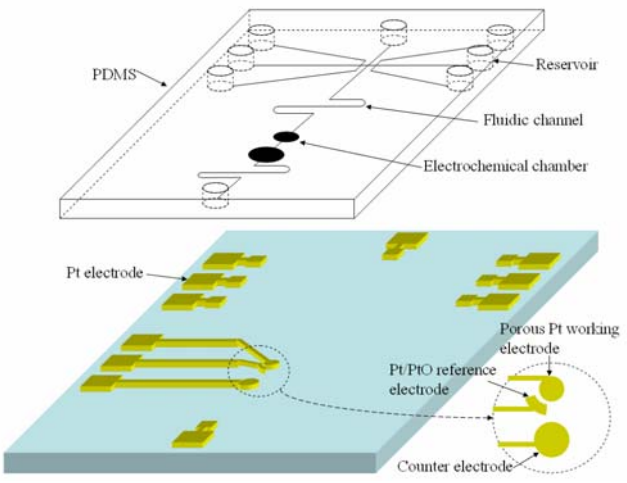

Figure 1: Schematic diagram of proposed microfluidic sysyem.

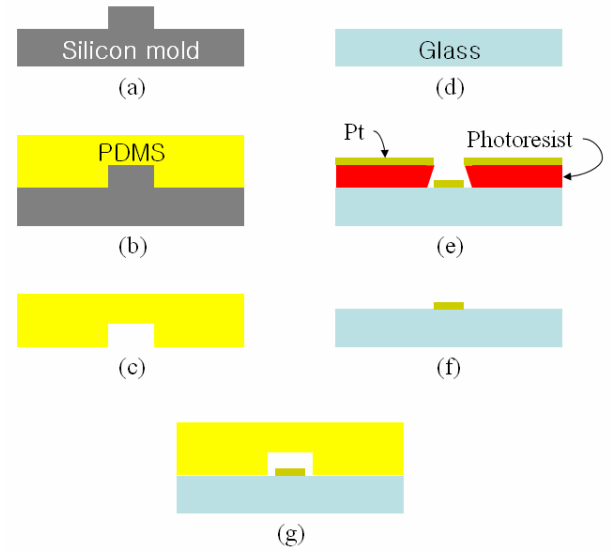

Figure 2: Fabrication process flow (a) Silicon mod (b) Curing PDMS on silicon mold (c) Peer off cured PDMS cover (d) Glass substrate (e) Pt deposited on patterned photoresist (f) Bottom glass after lift-off (g) PDMS bonded to bottom substrate.

3 RESULTS

Fig. 4 shows the result of preliminary tests of the amperometric responses from the working electrode in real-time. Each glucose solution was diluted in PBS buffer (pH 7.2) and injected to each reservoir. Then, they were electroosmotically delivered to the electrochemical reaction (sensor) chamber by applying high voltage (~2 kV) to the electrode under the corresponding reservoir. Once the electrochemical reaction chamber filled with the glucose solution, EOF was stopped and the oxidation current of glucose from the working electrode was monitored upon applying 0 V to the Pt/PtO reference electrode for 30s. Repeating this process to other glucose solutions with different concentrations provided the data of oxidation current corresponding to the glucose concentration. The sensitivity of the glucose sensor system was 0.28 μA/mM.

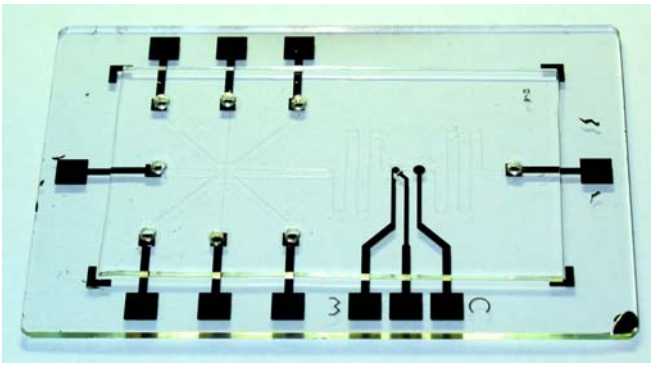

Figure 3: Fabricated microfluidic system with nanoporous Pt nonenzymatic glucose sensor.

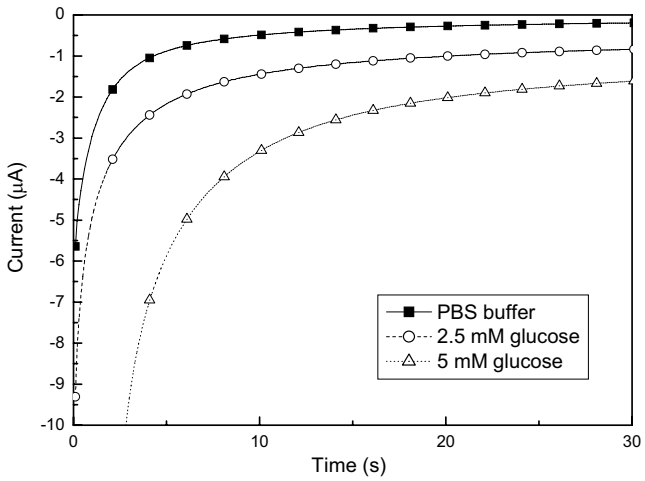

Figure 4: Real-time measurement data of oxidation current of glucose with PBS buffer, 2.5 mM glucose and 5 mM glucose solution.

4 CONCLUSION

We reported a multiple-use glucose detection system as a microfluidic system with an enzymeless glucose sensor. The developed system consists of a PDMS microchannel network and a glass substrate with Pt electrodes, nanoporous Pt working electrode and Pt/PtO reference electrode. We successfully observed the EOF transport of glucose solutions and verified the performance of the automatic glucose sensing system. We envision that this system will be a promising prototype of a portable micro glucose analysis system.

REFERENCES

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