Microfluidic Amperometric Biochips Based on Carbon Nanotube Arrayed Electrodes

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1. Introduction
We have fabricated label-free amperometric biosensors with microelectrodes array-modified by carbon nanotubes (CNTs). CNTs have been known to have the high ability to promote electron-transfer reactions in electrochemical measurements because of the large surface area of CNTs. Using the CNT biosensors, we have detected amino acids and prostate-specific antigen with high sensitivity by deferential pulse voltammetry (DPV) [1, 2].

In this abstract, microfluidic chips with pneumatic micro pumps were fabricated on CNT arrayed electrodes to detect electrochemically molecules. With this system, all of the measurement processes are curried out on one chip by integrated passages, pumps and sensors. Moreover, it enables to decrease amount of reagents and downsize chips.

2. Experiments
Plan and cross-sectional views of the microfluidic chip are shown in Figs. 1 and 2, respectively. This chip has two pneumatic micro pumps and these pumps consist of three layers. The optical image of the pump is shown in the inset of Fig. 1. When the air line is evacuated or pressurized, the pump can delivery a constant volume. Using two pumps, two kinds of reagents can be introduced into the chip. The CNTs for working electrodes were synthesized by thermal CVD method, as shown in Fig. 3. The optical view of the microfluidic chip is shown in Fig. 4.

3. Results and Discussion
Two kinds of reagents such as phosphate buffer solution (PBS) and K₃[Fe(CN)₆] were introduced into each line of the microfluidic chip for electrochemical detections.

First of all, PBS (50 mM) was introduced into CNT electrodes using a micro pump and was measured by DPV. No electrochemical signal was obtained in Fig. 5(a). Next, K₃[Fe(CN)₆] (10 mM) was flowed by another pump. The electrochemical signal of K₃[Fe(CN)₆] was clearly observed in Fig. 5(b). Furthermore, after PBS was introduced by the first micro pump again, the electrochemical signal of K₃[Fe(CN)₆] disappeared, as shown in Fig. 5(c). These results indicate that this chip can automatically rinse CNT electrodes by a small amount of PBS. Finally, the K₃[Fe(CN)₆] concentration dependence of electrochemical peak currents was carried out using this chip. Figure 6 shows peak currents of electrochemical signals of K₃[Fe(CN)₆] as a function of K₃[Fe(CN)₆] concentration (0.1 - 10 mM), revealing that a linear concentration dependence was clearly obtained.

4. Conclusion
In conclusion, using a combination of the amperometric biosensor with CNT electrodes and pneumatic micro pumps, we have fabricated microfluidic chips. This chip can automatically introduce reagents and electrochemically detect molecules. The microfluidic chips with CNT-arrayed electrodes are considered to be a promising candidate for development of hand-held electrochemical sensors.

Reference
Fig. 1. Plan view of microfluidic chip. The inset picture is optical image of a micro pump.

Fig. 3. SEM images of a CNT electrode.

Fig. 5. Differential pulse voltammograms after introduction of (a) PBS, (b) K₃[Fe(CN)₆] and (c) PBS.

Fig. 4. Optical image of a microfluidic chip.

Fig. 6. K₃[Fe(CN)₆] concentration dependence of peak current by differential pulse voltammograms.