ADDRESSABLE ELECTRODE ARRAY DEVICE INCORPORATED WITH IDA ELECTRODES FOR BIOLOGICAL ANALYSES

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In the past decade, several kinds of microelectrode arrays have been applied to chemical and biological analyses. These electrochemical array devices have substantial advantages, including rapid response time and qualitative and quantitative detection. Among the various systems that are based on electrochemical detection, individually addressable electrode arrays have been used for simultaneous multi-analyte detection. In many cases, the multi-analyte detection was realized using individual addressing by connecting each electrode to a corresponding bond pad in the 1:1 mode. Therefore, the integration of a large number of electrodes is difficult because the space for bond pads on the chip border is limited.

To solve the problem, we have developed a novel device consisting of row and column electrodes [1-3]. Based on redox cycling at the crossing points of the row/column electrodes, electrochemical responses at \( n \times n \) crossing points were detected by using only \( 2^n \) bond pads. In this study, we incorporated interdigitated array (IDA) electrodes into the device to place all electrodes on a single chip and form 256 or 1024 sensor points. By using the device, we detected enzyme activity and cell topology electrochemically.

The system and the fabrication process are previously reported [1]. Briefly, the device consisted of the 32 (or 16) row electrodes and the 32 (or 16) column electrodes to form 1024 (or 256) IDA electrodes (Figs. 1, 2). The scanning process was automatically performed with the program developed by LabVIEW. Since \( n \times n \) sensors can be incorporated into the device by using only \( 2^n \) bond pads, the sensor density in our device is higher than that in the conventional device (Fig. 2).

For time-course electrochemical imaging of enzyme activity, an alkaline phosphatase (ALP) membrane was put on the sensors and the electrochemical images were acquired every 0.5 min. The detection scheme for ALP is detailed in Fig. 3. After 0.1 min of adding the \( p \)-aminophenylphosphate (\( p \)APP), the electrochemical image was unclear because of the injection flow of \( p \)APP solution (Fig. 4). After 5 min of adding the \( p \)APP, the electrochemical image followed the position of the ALP membrane in the solution (Fig. 4). The electrochemical responses increased and spread slowly because of the diffusion of the \( p \)-aminophenol (\( p \)AP) yielded from \( p \)APP by ALP (Fig. 4). These results show that time-course enzyme activity was detected spatially (Fig. 4).

For electrochemical imaging of cell topology, breast cancer cells (MCF7) were seeded on the device. After seeding the cells, ferrocenemethanol (FMA) solution was induced into the device. After cell spreading, the cells blocked the redox cycling of FMA/FMA\(^+\), and therefore, the electrochemical responses at the designated sensors were significantly deceased compared with uncoated sensors (Fig. 5). The results suggest that electrochemical imaging of cell topology can be performed.

In conclusion, a multipoint addressable electrochemical device with a high density of sensor points was proposed. The device can be used as a comprehensive, high throughput lab-on-a-chip tool for several kinds of biological analyses.
Figure 1: Scheme of local redox cycling-based electrochemical detection. The column electrodes were perpendicular to the row electrodes and these electrodes formed an interdigitated array (IDA) electrode at individual crossing points. The potentiostat was connected to these electrodes through the multiplexer and these instruments were controlled with the PC. The local redox cycling was induced at the only cross point of the row and column electrode with the appropriate voltage.

Figure 2: (A) Addressable electrode array device with IDA electrodes. (B) Sizes of a device incorporated 1024 sensors when the width of the pad is 500 μm and bond pads in the 1:1 mode are used or our system is used.

Figure 3: pAPP solution was introduced into the device. The ALP membrane was added on the device. pAPP was catalytically hydrolyzed by ALP to yield pAP, which oxidized at the anode (+0.30 V). The oxidation product, QI, is reduced back to pAP at the cathode (0.00 V) and diffused to the anode to be oxidized.

Figure 4: Time-course of electrochemical imaging of ALP membrane. (A) ALP membrane on the device. (B) Electrochemical imaging (16 × 16). (C) The diffusion of pAP.

Figure 5: (A) Scheme of the electorchemical cell imaging. (B) Electrochemical images of cell topology.

REFERENCES: