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Fabrication of glucose fuel cell using carbon nanowalls

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Implantable medical devices become increasingly prevalent in the diagnosis and treatment of human disease. New implantable power sources as alternatives to lithium batteries, which can harvest energy from the human body, have attracted a lot of attention, and are studied and developed actively all over the world. One solution is to extract energy from physiologically available biological fuel substrates such as glucose. Glucose fuel cells (GFC) are particularly interesting because of the abundance of oxygen and glucose in body tissue and the possibility to generate a stable high continuous power output through the coupling of the glucose oxidation and oxygen reduction reactions.

Figure 1 shows a schematic illustration of the structure of non-enzymatic GFC including the chemical reactions where glucose is not completely oxidized owing to insufficient catalytic ability [1]. Glucose is oxidized at the surface of platinum (Pt) nanoparticles (NPs) on the anode, and proton (H^+) is produced. The electrodes are separated by an ionomer layer as proton conducting membrane. Oxygen is reduced to water at the surface of of nanocarbon cathode. The efficiency of GFC critically depends on the catalytic ability of Pt to oxidize glucose at the anode. For improving catalytic ability, it is effective to increase the Pt surface area on anode. In this study, carbon nanowall (CNW) film was used as a supporting material of Pt-NPs to form anode electrode of GFC. Preliminary experiment was carried out to investigate the possibility of Pt-NP-decorated CNWs (Pt-NP/CNWs) as the anode of GFC.

The structure of GFC fabricated in this study is shown in Fig. 2. The prototype GFC was developed using the following procedure. (1) Patterned Ti contact layer was formed on the SiO_2 substrate. (2) CNWs were grown on the anode Ti contact area by inductively coupled plasma enhanced chemical vapor deposition employing $CH_4/H_2/Ar$ mixture [2]. (3) The CNW surface was decorated with Pt-NPs by the reduction of H_2PtCl_6 to form anode electrode. (4) Anode area (Pt-NP/CNWs) was coated with ionomer to form proton exchange membrane. After that, (5) the entire area was covered with cathode comprising carbon black (CB) embedded in ionomer. Fabricated GFC was immersed in a phosphate buffer saline (PBS) solution containing 10 mM glucose, and electrochemical measurement was conducted.

Figure 3 shows power generation characteristics of prototype GFC. Resistance was attached between anode and cathode, and the current and voltage were measured. As a result of preliminary experiment, the open circuit voltage and peak power of the fabricated GFC were 0.8 V and 37 μW, respectively. The output characteristics of GFC were not stable due to the insufficient supply of glucose through cathode electrode. Improvement of the structure of cathode electrode and ionomer layer is needed for the penetration of glucose.

References
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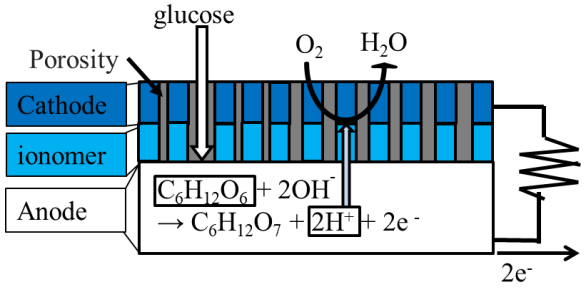

Fig. 1 Schematic illustration of glucose fuel cell

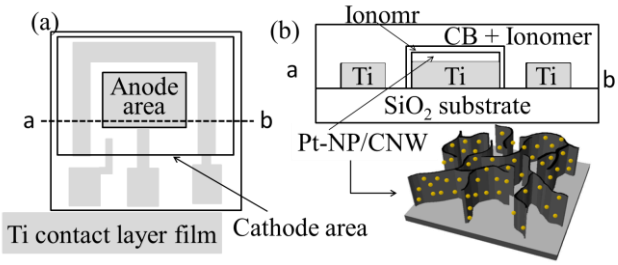

Fig. 2 (a) Top view and (b) cross-sectional view of glucose fuel cell fabricated in this study

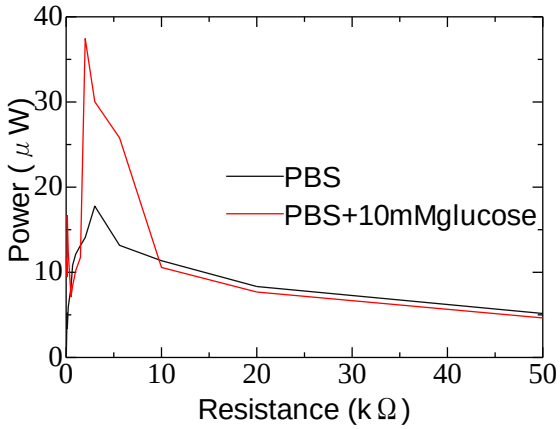

Fig. 3 Measured output resistance-power characteristics