

Preparation of a Bio-fuel Cell Using Enzyme Immobilized Electrodes

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Electron transfer reaction is one of the key reactions for generating a biological function. Preparation of a suitable electrode/solution interface, at which electron transfer reaction of biological systems take place, is important not only for studying biological functions of the systems but also for applying biological functions to various bio-electrochemical devices including bio-sensors and bio-fuel cells [1]. Glucose sensors have been developed by using immobilized glucose oxidase (GOD) with an electron-transfer mediator onto the electrode surface, and some enzymes are known to work very well for a catalytic four-electron reduction of oxygen to water in a neutral solution. By combining a suitable glucose sensor electrode and an oxygen bio-sensing electrode, a biological glucose-air battery is prepared as a simple bio-fuel cell. Since the anode and cathode give no cross-reaction (or no cross-talk) to each other because of selective reaction at enzyme electrodes, a simple bio-fuel cell can be fabricated. In the present paper, using bio-electrochemical systems a sugar-air battery was prepared and its performance was demonstrated.

The enzyme electrodes were prepared by immobilizing both enzyme and mediator of interest on a glassy carbon (and/or carbon paper) electrode in various ways: casting a polyethylenimine solution with glutaraldehyde onto the electrode surface or forming a poly-ion complex on the electrode surface by casting poly-styrene sulfonic acid (PSS) and poly-L-lysine solutions (PLL) by turns. Cyclic voltammetry was carried out at a carbon disk electrode ($\phi = 3$ mm) mainly in a phosphate buffer solution (pH 7) at 25 °C. A platinum plate was used as a counter electrode and an Ag/AgCl (saturated KCl) was used as a reference electrode. All solutions were prepared using ultra pure water (Milli-Q 18.2 M Ω cm, Millipore system). The battery performance was measured for a cell composed of two enzyme electrodes having an active area of 1 cm² in an air-saturated 0.1 M phosphate buffer solution with 0.1 M KCl and 0.1 M glucose by changing an inserted resistance (1 – 10⁵ Ω).

At a glassy carbon electrode, on which surface both GOD and TTF (as an effective electron-transfer mediator for GOD) modified by using polyethylenimine and glutaraldehyde, stable catalytic oxidation currents of glucose were observed at potentials more positive than +0.05 V (vs. Ag/AgCl) in phosphate buffer solutions at pH 5-7. Also, in a neutral solution at TTF and GOD co-immobilized on a glassy carbon electrode by using a poly-ion complex thin film of PSS and PLL, anodic oxidation of glucose started around 0 V with the peak potential of ca. 0.15 V (vs Ag/AgCl). The peak current obtained was larger by roughly three times at the latter electrode than at the former electrode. On the other hand, bio-

electrochemical oxygen reduction took place with the aid of bilirubin oxidase (BOD), which was modified onto a glassy carbon electrode with 2,2'-azino-bis(3-ethylbenzo)thiazoline-6-sulfonic acid (ABTS as an effective mediator [2]) using a poly-ion complex of PSS and PLL, at +0.6 V (vs Ag/AgCl) in an O₂-saturated phosphate buffer solution (pH 7).

Using above-mentioned bio-electrochemical reactions for both anode and cathode, the following glucose-air battery was prepared, where carbon paper electrodes instead of glassy carbon electrodes were used to obtain larger surface area. The obtained glucose-air battery showed the open-circuit potential of ca. 0.5 V, the short-circuit current of ca. 600 μ A cm⁻² (with respect to an apparent geometrical surface area) and the maximum power of 75 μ W cm⁻² at the cell voltage of ca. 0.25 V.

REFERENCES

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