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Short Communication

A glucose bio-battery prototype based on a GDH/(polymethylene blue) bioanode and a graphite cathode with an iodide/tri-iodide redox couple

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ABSTRACT

A glucose bio-battery prototype independent of oxygen is proposed based on a glucose dehydrogenase (GDH) bioanode and a graphite cathode with an iodide/tri-iodide redox couple. At the bioanode, a NADH electrocatalyst, poly(methylene blue) (PMB), which can be easily grown on the electrode (screen-printed carbon paste electrode, SPCE) by electrodeposition, is harnessed and engineered. We find that carboxylated multi-walled carbon nanotubes (MWCNTs) are capable of significantly increasing the deposition amount of PMB and thus enhancing the PMB's electrocatalysis of NADH oxidation and the glucose bio-battery's performance. The choice of the iodide/tri-iodide redox couple eliminates the dependence of oxygen for this bio-battery, thus enabling the bio-battery with a constant current-output feature similar to that of the solar cells. The present glucose bio-battery prototype can attain a maximum power density of 2.4 μW/cm^2 at 25 °C.

1. Introduction

Biofuel cells are an emerging class of fuel cells, which utilize microorganisms or enzymes for the direct conversion of chemical energy into electrical energy. Compared to most matured fuel cells working with hydrogen and methanol, the concept of producing electricity from glucose is gradually becoming one of the major goals. Glucose biofuel cells have shown great potential in sugar-powered portable electronics (Sakai et al., 2009), blood-powered sensors (Endo et al., 2009), and implantable devices (Heller, 2006). Glucose oxidase (GOx) and glucose dehydrogenase (GDH) are two major enzymes used in glucose biofuel cells. The reaction between glucose and GOx is oxygen-dependent. Thus, glucose sensors with GOx are subject to interference with O_2 and could result in the O_2 concentration-dependent drift (Kurtinaitienė et al., 2010). Glucose dehydrogenase, which does not utilize O_2 as an electron acceptor, has been the promising bioelectrocatalyst for O_2 insensitive biosensors and is used in the present work. For enhancing the GDH bioanode, the present work uses the poly(methylene blue) (PMB)/carboxylated MWCNTs composite in electrocatalyzing NADH oxidation. Carboxylated MWCNTs are expected to enhance NADH oxidation catalysis from the following aspects: (1) a result of increased PMB deposition; (2) an enhancement in electron-collecting efficiency; (3) an improvement of intrinsic catalytic property using functionalized MWCNTs.

In most studies on biofuel cells, the reactions at cathode are related to the reduction of oxygen involving microorganisms (Rosenbaum et al., 2011) or enzymes (Bullen et al., 2006). However, with a proper redox system, a non-enzyme electrode can be used as the cathode in a biofuel cell. From Addo et al.'s research, Prussian blue cathode was used for development of a rechargeable bio-battery (Addo et al., 2011). Besides, the introduction of catalytic agents to cathodes also showed an improved performance over cathodes without catalytic agents (Villano et al., 2010). Learning from the experience of dye-sensitized solar cells (DSSCs) (Grätzel, 2003), we employ the iodide/tri-iodide redox system, which is well characterized and leads to very good electron collection and high solar cell efficiency, as the cathode component for a glucose biofuel cell for the first time. The DSSCs, based on a TiO_2 photoanode and the iodide/tri-iodide redox couple, exhibit a constant current output while loaded. This constant-current property is highly desirable for consumer electronics. It is anticipated that the use of the same redox system in a biofuel cell would yield a constant-current output characteristics. Therefore, we formulate the catholyte by incorporating the iodide/tri-iodide redox couple in the solution, in conjunction with a graphite rod cathode.

The glucose bio-battery prototype investigated in this work is an electrochemical cell with an anodic chamber and a cathodic chamber that are separated by a Nafion® 117 proton-exchange

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