Enhanced oxygen reduction reaction in air-cathode microbial fuel cells using flower-like Co$_3$O$_4$ as an efficient cathode catalyst

Ravinder Kumar, Lakhveer Singh*, A.W. Zularisam
Faculty of Engineering Technology, Universiti Malaysia Pahang, 26300 Kuantan, Malaysia

Abstract

In this study, the potential of mesoporous flower-like Co$_3$O$_4$ is investigated for the application of oxygen reduction reaction (ORR) in aqueous air-cathode microbial fuel cell (MFC). The flower-like Co$_3$O$_4$ was prepared by a hydrothermal route. The X-ray photoelectron spectroscopy results suggested that flower-like Co$_3$O$_4$ contained positively charged ions i.e., Co$^{2+}$/Co$^{3+}$ on its surface that probably acted as ORR active sites. The electrochemical tests demonstrated that flower-like Co$_3$O$_4$ enhanced the electrocatalytic activity of the cathode significantly as the onset potentials obtained in cyclic voltammetry and linear sweep voltammetry were more positive than the bare cathode. Besides, Tafel plots showed that Co$_3$O$_4$ increased the electron transfer kinetics and achieved an exchange current density of 2.46 A/m$^2$, which was ~30% higher than bare cathode. Subsequently, this improved ORR activity increased the power output in the MFC and a maximum power density of 248 mW/m$^2$ was achieved, which was 6.3 times higher than the bare cathode. The higher ORR activity and improved electric output in the MFC could be attributed to the excellent electrocatalytic activity of Co$^{2+}$/Co$^{3+}$ and mesoporous nature of flower-like Co$_3$O$_4$ that exposed extra active sites for oxygen molecules on the cathode surface.

Introduction

Microbial fuel cell (MFC) technology, foreseen as the most revolutionary technology in future for wastewater treatment and bioenergy production is facing critical challenges for its commercialization [1,2]. For example, high cost of electrode materials and Nafion membrane, low electric output, need of an efficient cathode catalyst etc. are of serious concerns and need to be addressed as soon as possible to launch this technology at the pilot-scale. Moreover, a choice of electron acceptor in the cathode is another barrier to overcome. Nevertheless, oxygen has been the favourite option for electron acceptor because of its free availability and high potential and therefore, air-cathode MFCs have been widely used for bioelectricity generation and other applications [3–5]. However, a highly active electrocatalyst is required for oxygen reduction reaction (ORR) to ameliorate the sluggish reaction kinetics [6]. Commonly, platinum is used as ORR catalyst in MFCs, which is extremely expensive and makes the MFC technology uneconomic, hence, a competitive alternative of platinum is essential to scale-up the technology.

Different types non-platinum cathode catalysts in combination with materials of high surface area such as activated