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Nanostructured Pt/MnO2 Catalysts and Their Performance for Oxygen Reduction Reaction in Air Cathode Microbial Fuel Cell

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Abstract : Microbial fuel cells (MFCs) represent a promising technology for simultaneous bioelectricity generation and wastewater treatment. Catalysts are significant portions of the cost of microbial fuel cell cathodes. Many materials have been tested as aqueous cathodes, but air-cathodes are needed to avoid energy demands for water aeration. The sluggish oxygen reduction reaction (ORR) rate at air cathode necessitates efficient electrocatalyst such as carbon supported platinum catalyst (Pt/C) which is very costly. Manganese oxide (MnO2) was a representative metal oxide which has been studied as a promising alternative electrocatalyst for ORR and has been tested in air-cathode MFCs. However, the single MnO2 has poor electric conductivity and low stability. In the present work, the MnO2 catalyst has been modified by doping Pt nanoparticle. The goal of the work was to improve the performance of the MFC with minimum Pt loading. MnO2 and Pt nanoparticles were prepared by hydrothermal and sol-gel methods, respectively. Wet impregnation method was used to synthesize Pt/MnO2 catalyst. The catalysts were further used as cathode catalysts in air-cathode cubic MFCs, in which anaerobic sludge was inoculated as biocatalysts and palm oil mill effluent (POME) was used as the substrate in the anode chamber. The as-prepared Pt/MnO2 was characterized comprehensively through field emission scanning electron microscope (FESEM), X-Ray diffraction (XRD), X-ray photoelectron spectroscopy (XPS), and cyclic voltammetry (CV) where its surface morphology, crystallinity, oxidation state and electrochemical activity were examined, respectively. XPS revealed Mn (IV) oxidation state and Pt (0) nanoparticle metal, indicating the presence of MnO2 and Pt. Morphology of Pt/MnO2 observed from FESEM shows that the doping of Pt did not cause change in needle-like shape of MnO2 which provides large contacting surface area. The electrochemical active area of the Pt/MnO2 catalysts has been increased from 276 to 617 m2/g with the increase in Pt loading from 0.2 to 0.8 wt%. The CV results in O2 saturated neutral Na2SO4 solution showed that MnO2 and Pt/MnO2 catalysts could catalyze ORR with different catalytic activities. MFC with Pt/MnO2 (0.4 wt% Pt) as air cathode catalyst generates a maximum power density of 165 mW/m3, which is higher than that of MFC with MnO2 catalyst (95 mW/m3). The open circuit voltage (OCV) of the MFC operated with MnO2 cathode gradually decreased during 14 days of operation, whereas the MFC with Pt/MnO2 cathode remained almost constant throughout the operation suggesting the higher stability of the Pt/MnO2 catalyst. Therefore, Pt/MnO2 with 0.4 wt% Pt successfully demonstrated as an efficient and low cost electrocatalyst for ORR in air cathode MFC with higher electrochemical activity, stability and hence enhanced performance.

Keywords : microbial fuel cell, oxygen reduction reaction, Pt/MnO2, palm oil mill effluent, polarization curve
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