ABSTRACT

A microbial fuel cell (MFC) is a bifunctional bio-electrochemical device having promising characteristics as efficient wastewater treatment and one-step electricity conversion ability. Under ideal situation, a MFC can generate 1.1 V between two reverse polar electrodes, but in practical conditions, the voltage severely declines due to huge energy demand during redox reactions. Among different electrochemical reactions occurring in MFCs, the energy loss to carry out oxygen reduction reaction (ORR) in MFC has major contribution to decline the voltage output. Hence, a suitable low-cost electrochemical catalyst is required to enhance the ORR in order to increase the current production from MFC. In addition, growth of microorganisms, fungus and deposition of salts on cathode have also been identified as critical issues, which can lethally decline the performance of MFCs by deteriorating the cathode quickly. Thus, the present study was aimed to develop different low-cost oxide, alloy catalyst and cathode materials to improve the ORR for onsite use of MFC. MnO_2 was synthesized using chemical co-precipitation method and tested in MFC as cathode catalyst. Maximum power density of 1.66 $W.m^{-3}$ with a coulombic efficiency of 9% from MFC using MnO_2 was found to be 3-time higher than control MFCs. The power density could be enhanced to 6.6 $W.m^{-3}$ by using V_2O_5/Vulcan XC composite as catalyst in cathode. Upon mixing graphene as highly conductive support with V_2O_5, the power density significantly enhanced to 8.8 $W.m^{-3}$, demonstrating graphene as excellent electrode material. Low-cost $Cu_{5.6}Sn$ alloy was prepared using thermal nucleation method and used as ORR catalyst in MFC. Excellent d-band sharing characteristics of Cu-Sn alloy could assist MFC to produce an enhanced power density of 9.5 $W.m^{-3}$ with an excellent coulombic efficiency of 36%. Although, the power density and coulombic efficiency could be enhanced successively, but the performance of MFCs were found to inconsistent due to development biofouling of biofouling composed with aerobic, facultative bacteria and Fungi on ORR interface. Thus, Ag-based single metal (Ag^O) and bimetal alloy (Ag_3Pt) was synthesized to obtain consistent performance from MFCs. A 10% loading of Ag^O was found to be sufficient to eradicate the biofouling from cathode and could maintain an excellent power density of 9.8 $W.m^{-3}$ with a coulombic efficiency of 29.3%. These performance values could further enhanced substantially to 1 $W.m^{-2}$ and 60%, respectively by using Ag_3Pt catalyst as cathode. Finally, a sediment MFC was installed in an aquaculture pond cultured with Nile tilapia Fish for onsite demonstration of this technology. Under continuous feeding, the Fish survival rate was noted to be 100% with an excellent specific growth rate of 1.55. In addition, the obtained power could be used to successfully operate a wireless temperature sensor. The wastewater treatment in the form of chemical oxygen demand removal efficiency in all the cases was found to be more than 80%, which can be considered as good treatment efficiency.

Keywords: Catalyst; Fish market; Microbial fuel cell; Power density; Synthesis; Wastewater treatment