Hierarchical $CoFe_2O_4$/ $NiMoO_4$-doped carbon electrodes for high bioanode performance in microbial fuel cells

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KEYWORDS
Microbial fuel cell; $CoFe_2O_4/NiMoO_4$ nanocomposite; Carbon felt; Electron transfer; electric conductivity; electrical power.

SHORT SUMMARY
The world around us is changing very rapidly and the demand for energy is increasing, which made it necessary to resort to renewable energy sources to protect the environment from pollution. Microbial fuel cells are one of the most important sources of energy. Three-dimensional electrodes (carbon felt) were examined and developed with nanoparticles ($CoFe_2O_4$),($CoFe_2O_4/NiMoO_4$), and a high-capacity electrode was produced, which produced a power density that is 70% higher than that of carbon felt, in addition to its high surface area and improved electrode performance in MFC.

EXTENDED ABSTRACT

Microbial fuel cells (MFCs) are one of the recently developed electrochemical-based technologies for renewable energy production from wastewater. The hallmark of MFCs is the ability of electrochemically active biofilm that colonize the anode surface to catalyze different electrochemical reactions and directly produce electric current [1]. Despite the advantages of MFCs over other commercial technologies for renewable energy production from wastewater, relatively low performance, in terms of electric current and electron recovery, limits the technology commercialization. The anode materials and their spatial orientation play a key role in the extracellular electron transfer (EET) and MFCs performance, since they act as a habitat for electrochemically active biofilm, and, therefore, influences the anode electron transfer resistance [2]. In this study, the performance of carbon felt anode in MFCs outfitted with hierarchical CoFe2O4/ NiMoO4 nanocomposite was evaluated. The main goal was to examine whether or not CoFe2O4/ NiMoO4 nanowire arrays nanocomposite could improve the EET and the biofilm structure, resulting in higher MFC performance. The performance of MFCs equipped with $CoFe_2O_4/NiMoO_4$ nanocomposite was examined and compared to MFCs outfitted with $CoFe_2O_4$ as well as an unmodified carbon felt bioanode (control MFC). We monitored electricity production, electrochemical performance, and biocompatibility of MFCs with modified anodes compared to control anode.

The MFCs were run for 4 consecutive batch cycles, and the cell work involving nanoparticles was shown to improve. We observed that the startup period for the MFCs equipped with $CoFe_2O_4/NiMoO_4$ bioanodes was much shorter compared to the control bioanode, most likely due to the faster adhesion of(ARB biofilm on $CoFe_2O_4/NiMoO_4$ anodes (data not shown). Among the 3 tested bioanodes, the $CoFe_2O_4/NiMoO_4$-modified bioanode exhibited the highest maximum voltage (i.e., 260 mV), which is ~1.4-fold higher than the control bioanode (119 mV), indicating better affinity of $CoFe_2O_4/NiMoO_4$-modified anodes for bacterial adhesion. Although carbon felt has been commonly used as an anode in MFCs due to its relatively low cost and large surface area, its surface is hydrophobic, resulting in low bacterial adhesion and the formation of dispersing biofilm structure [3]. In fact, we observed that the anode surface modification with $CoFe_2O_4/NiMoO_4$ nanocomposite greatly improved the microbial adhesion of the electrode surface and facilitated the electron transfer between the bacteria and the electrode surface. As a result, the $CoFe_2O_4/NiMoO_4$ bioanode generated a projected maximum current density of ~ 6.5 A m^{-2}, which is 1.4- and 0.9-fold higher than that of the bare carbon felt anode and $CoFe_2O_4$-modified carbon felt, respectively. Our results showed that $CoFe_2O_4/NiMoO_4$ doping could significantly enhance the biocompatibility of carbon-felt electrodes and microbial adhesion capability, resulting in higher current density generation. Consistent with the increase in the generated electricity, we observed that chemical oxygen demand (COD) of the substrate was significantly reduced by surface modification, with approximately 70–85%.

Similarly, $CoFe_2O4/NiMoO_4$-modified bioanode exhibited the highest power density (i.e., ~ 1000 mW), which is 1.25-2.5-fold higher than the other three MFCs (Figure 1). Figure 2 shows the basic identical trend of polarization curves for MFCs with different bioanodes. Consistent with our previous results, $CoFe_2O_4/NiMoO_4$-modified bioanode exhibited superior performance and higher open circuit potential. Our results revealed that the $CoFe_2O_4/NiMoO_4$-modified anode showed good mechanical and electrical properties, excellent microbial adhesion; it represented a high-performance, low-cost electrode material that is easy to fabricate and scale-up.

Tables and Figures

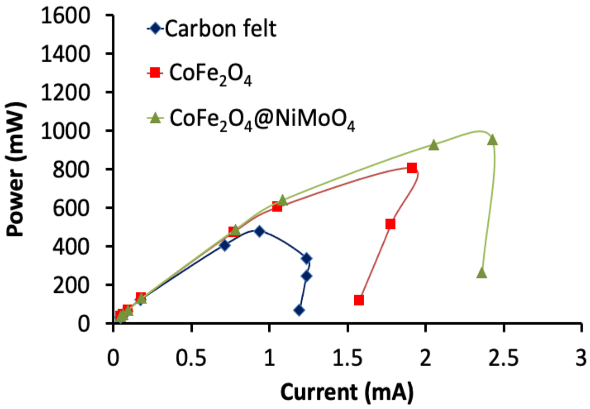

Figure 1. Power density curves of the MFCs with different anodes.

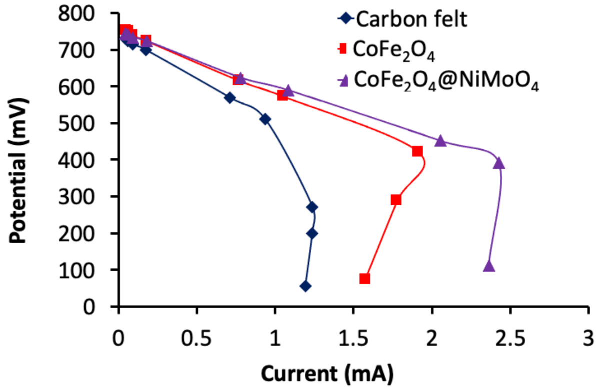

Figure 2. Polarization curves of the MFCs with different anodes.

Acknowledgements

We appreciate the financial support from the Science, Technology, and Innovation Funding Authority (STIFA), Egypt (Grant no.: 30901).

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