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Mini Review

Carbon Nanomaterials for Modification of Parameters of Bioelectrochemical Devices Electrodes

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Abstract

In the modification of microbial biofuel cells (MFC) and enzyme biosensors, multi-walled carbon nanotubes (MWCNTs) and thermally expanded graphite (TEG) were used. It is shown that the modification of MFC MWCNTs leads to an increase in the power density due to a decrease in the internal resistance of the anode. TEG modification of alcohol oxidase and glucose oxidase biosensors based on screen-printed electrodes also reduces the internal resistance of the work electrode and increases the sensitivity, which can be effectively used in real devices.

Keywords: MWCNTs; Thermally Expanded Graphite; Biofuel Cell; Biosensor

Introduction

The interaction of various nanomaterials (NM) with microorganisms (MO) and enzymes in biosensors and biofuel cells has been widely studied recently. The range of studied NMs is quite wide. The largest number of publications is devoted to such carbon materials as single and multi-walled nanotubes, which lead to a decrease in the charge transfer resistance of the electrode due to an increase in conductivity. A graphene-like material — thermally expanded graphite (TEG) —was developed with high electrical conductivity, large specific surface area, chemical stability, and biocompatibility [1]. To assess the effects of NMs, changes in bioelectrocatalytic characteristics are widely used, which are the main parameters of the electrodes (anodes / work electrodes) in biosensors or microbial biofuel cells - MFC. In the presented material, the effects of the influence of NMs on MFC and enzyme biosensors are considered. Bacteria of the genus *Gluconobacter* were considered as a model biomaterial during the creation of MFC. Alcohol oxidase (AO) and glucose oxidase (GO) enzymes were used as a biologically sensitive element of biosensors.

Carbon nanotubes

Simultaneous immobilization of *G. oxydans* bacterial cells and nanotubes in a chitosan on the surface of a bioanode led to an increase in MFC power density and a decrease in internal resistance compared to MFC based on spectral graphite electrodes [2]. As a practical application of MFC, electric energy was accumulated using a converter and a 6800 μF capacitor charged from an initial voltage of 0.4 to 3.2 V. The stored energy was used for long-term supply of a biosensor electrode, as well as for short-term power supply of a Bluetooth transmitter with three sensors, a miniature electric motor and LED [3].

Thermally expanded graphite

Due to the layered fibrous structure, TEG is easily pressed and molded into electrodes, and also has a high specific surface area reaching 2000 m^2 g^{-1} [1]. Electrodes from TEG allow the use of membrane fractions (MF) of Gluconobacter microbial cells as an alternative biocatalyst [4]. In fact, MFs are parts of the cell membrane and contain various cellular membrane structures, including membrane PQQ-dependent dehydrogenases. The authors of [4] showed for the first time that the electrooxidation of ethanol on a bioanode containing MFs immobilized on TEG can proceed by two mechanisms — the direct electron transfer mechanism and the mediator transfer mechanism.

The screen printed electrodes (SPE) were modified by TEG and AO or GO. The study of chronoamperometric and cyclic current-voltage characteristics showed that the TEG modification of the SPE leads to an increase in the values of the recorded currents. The sensitivity of AO- and GO-TEG biosensors was 7 times higher than the sensitivity of biosensors without applying TEG and was 2.43 μA mM^{-1} for AO-TEG biosensors and 3.89 μA mM^{-1} for GO-TEG biosensors.

An analysis of the literature data on the creation of MFC with new characteristics suggests that one of the trends is the development of small planar and volume MFC. Such systems will require, respectively, small electrodes - the anode and cathode. Graphene-like materials have properties that ensure their use in the design of small-sized MFC. Thus, they have a high surface/volume ratio, have high electrical conductivity, high strength, and biocompatibility. The use of the NM - MO complex expands the range of capabilities and allows the development of efficient new generation devices.

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