Biosensors and Bioelectronics 50 (2013) 373–381

Contents lists available at SciVerse ScienceDirect

Biosensors and Bioelectronics

journal homepage: www.elsevier.com/locate/bios

Biotic and abiotic characterization of bioanodes formed on oxidized carbon electrodes as a basis to predict their performance

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ARTICLE INFO

Article history:
Received 26 March 2013
Received in revised form
14 June 2013
Accepted 24 June 2013
Available online 4 July 2013

Keywords:
Bioanode
Carbon based electrodes
Oxidation treatments
Electroactive biofilm
Electrode characterization

ABSTRACT

Bioelectrochemical systems (BESs) are based on the catalytic activity of biofilm on electrodes, or the so-called bioelectrodes, to produce electricity and other valuable products. In order to increase bioanode performance, diverse electrode materials and modification methods have been implemented; however, the factors directly affecting performance are yet unclear. In this work carbon cloth electrodes were modified by thermal, chemical, and electrochemical oxidation to enhance oxygenated surface groups, to modify the electrode texture, and consequently the electron transfer rate and biofilm adhesion. The oxidized electrodes were physically, chemically, and electrochemically characterized, then bioanodes were formed at +0.1 V vs. Ag/AgCl using domestic wastewater amended with acetate. The bioanode performance was evaluated according to the current and charge generated. The efficacy of the treatments were in the order Thermal > Electrochemical > Untreated > Chemical oxidation. The maximum current observed with untreated electrode was 0.152 ± 0.026 mA (380 ± 92 mA m^{-2}), and it was increased by 78% and 28% with thermal and electrochemical oxidized electrodes, respectively. Moreover, the volatile solids correlated significantly with the maximum current obtained, and the electrode texture was revealed as a critical factor for increasing the bioanode performance.

1. Introduction

In the last decade interest in BESs has increased. BESs are based on the catalytic activity of biofilm adhered to electrodes to convert the chemical energy present in organic matter into electrical energy. The applications of BESs comprise microbial fuel cells (MFCs), microbial electrolysis cells (MECs), and more recently, MFC-based biosensors (Su et al., 2011). BESs are dependent on multiple factors, one of which is the biofilm formation on different electrode surfaces. Electrode materials and their modifications have been broadly studied (Zhou et al., 2011), as well as the electron transfer mechanisms between the microbial cells and the electrodes (Torres et al., 2010). Carbon materials are the most widely used electrodes due to their chemical stability, conductivity, biocompatibility, and relatively low cost; they traditionally include carbon, graphite, activated carbon, glassy carbon, and nanotubes, in different structures such as plate, foil, rod, brush, paper, felt, cloth, mesh, or particles. To increase BESs performance, different modifications focus on changing the pore texture, increasing the surface area, and modifying the surface chemistry. Some modifications of carbon electrodes are summarized in Table 1. Among the methods that have been explored are covering with metals or polymers, heat treatments under specific atmospheres and electrochemical and chemical oxidation using acid soaks.

Recently carbon electrodes have been modified with electrochemically active species like RuO_2 and graphene (Liu et al., 2012;

Abbreviations: ANCOVA, Analysis of covariance; ANOVA, Analysis of variance; BES, Bioelectrochemical system(s); C, Capacitance; %CE, Coulombic efficiency; CO, Chemically oxidized electrode; CODs, Soluble chemical oxygen demand; CPE, Constant phase element; CV, Cyclic voltammetry; %CV, Coefficient of variation; EAA, Electrochemically active area; EO, Electrochemically oxidized electrode; ΔEp, Potential peak separation; I, Current; Ip, Current peak; M, Diffusion element; MEC, Microbial electrolysis cell(s); MFC, Microbial fuel cell(s); OCP, Open circuit potential; PEIS, Potentiostatic electrochemical impedance spectroscopy; PZC, Point of zero charge; Q, Constant phase element; R, Resistance; R_{CT}, Charge transfer resistance; Ro, Ohmic resistance; SSA, Specific surface area; TO, Thermal oxidized electrode; UE, Untreated electrode; VS, Volatile solids; W, Warburg's diffusion element

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http://dx.doi.org/10.1016/j.bios.2013.06.051