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Renewable non-enzymatic copper-based surfaces for the detection of glucose, fructose, sucrose, and galactose

Abstract

This study aims to circumvent the environmental and logistical drawbacks of disposable electrode strips by developing Cu-based sugar sensors that can be renewed for use. In this work, Cu-based sugar sensors were prepared through the electrodeposition of CuAg or lactate-templated Cu onto a carbon paste electrode (CPE) followed by electrochemical oxidation in a sodium hydroxide solution. Users can perform this process themselves by using a pre-programmed power supply and following the provided instructions. Important synthesis parameters were initially screened using experiments with a 2^k factorial design to identify the most crucial factors that affect the performance of the sugar sensor. Optimization was conducted using a central composite design when necessary. An optimal lactate-templated Cu oxide-based sugar sensor with an average sensitivity of 523 μA cm^2 mM^{-1} and an optimal CuAg oxide-based sugar sensor with a sensitivity of 191 μA cm^2 mM^{-1} are obtained. Cyclic voltammetry (CV) analysis revealed that the oxidation rate of glucose on CuAg and lactate-templated Cu oxide-based sugar sensors is limited by surface kinetics. Electrochemical impedance spectroscopy (EIS) revealed that increasing glucose concentration in the electrolyte causes a decrease in charge transfer resistance (R_{ct}). A higher glucose level results in better electron transfer and therefore a higher proportional current. Field emission scanning electron microscopy (FESEM) revealed that both CuAg and lactate-templated Cu oxide-based sugar sensors produced under optimized conditions also have better active material coverage and more uniquely shaped nanostructures. Energy-dispersive X-ray spectroscopy (EDX) analysis revealed that both the optimal CuAg oxide-based sugar sensor and the lactate-templated Cu oxide-based sugar sensor have a higher oxygen-to-copper ratio, which could positively influence their catalytic properties. The current density of both sensor types was found to decline over a period of 10 days. The CuAg oxide-based sugar sensor suffered an average drop of 27.10 % in current density and lactate-templated Cu oxide suffered an average drop of 31.4 % in current density. Additionally, when subjected to a constant potential of 0.5 V in a 6.04 mM glucose solution for 12 hours, both sensors displayed a significant decline in current density, 40.3 % for the CuAg oxide-based sugar sensor and 45.0 % for the lactate-templated Cu oxide -based sugar sensor. However, the sugar sensors can be renewed easily after each use, circumventing the issue of electrode stability.

Keywords

Copper oxide; Copper-based; Non-enzymatic; Sugar sensor