Electrodeposition of copper oxide/polypyrrole/reduced graphene oxide as a nonenzymatic glucose biosensor

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ABSTRACT

We report the synthesis and application of copper oxide/polypyrrole nanofiber/reduced graphene oxide nanocomposite (CuO/Ppy/rGO/GCE) for the detection of glucose (GLC). CuO, Ppy and rGO were synthesized via electrodeposition process. The formation of the rGO and Ppy were approved by Fourier Transform Infrared Spectroscopy (FT-IR), Energy-dispersive X-ray spectroscopy (EDX), and X-ray diffraction (XRD) confirmed the formation of copper oxide. The field emission scanning electron microscopy (FESEM) images depicted the existence of wrinkled rGO, Ppy nanofibers with diameter around 100 nm and the uniformity of the CuO particles deposited on the Ppy nanofibers. Electrochemical impedance spectroscopy (EIS) data also indicated the charge transfer of each layer decreased compared to the underneath layer. By using cyclic voltammetry (CV) and chronoamperometry under pH 7.2, the electrocatalytic activity of CuO/Ppy/rGO/GCE toward GLC was explored. The sensor presented a linear range of 0.1–100 mM (R² = 0.991) of GLC, that is higher than most of the present nonenzymatic glucose biosensors based on CuO, Ppy and rGO. The limit of detection (LOD) reaches 0.03 μM (at S/N = 3). Additionally, the sensor exhibited remarkable reproducibility, stability and selectivity properties which make CuO/Ppy/rGO/GCE a good nonenzymatic GLC sensor.

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1. Introduction

More than 220 million of people around the world are suffering from diabetes which is a highly extensive disease bringing about metabolic disorders. Testing the blood glucose (GLC) is very crucial for diabetic patients and helps to evade the clustering of blood GLC (in the range of 4.4–6.6 mM). Therefore it is of high significance to establish straightforward system with high sensitivity, selectivity and stability in order to distinguish GLC levels [1–3].

Graphite oxide was primarily recorded 150 years ago and reappeared tremendously in the studies due to the low cost and volume production of graphene-based materials. The layered structure of graphite oxide is similar to graphite’s structure but in graphite oxide, the sheet of carbon atoms is densely decorated by groups which contain oxygen, which besides increasing the interlayer distance, it makes the atomic-thick layers hydrophilic. Therefore, this resulted to the exfoliation of oxidized layers in water under moderate ultra-sonication [4–9]. It also should be mentioned that the most interesting feature of GO is being partly reduced to graphene-like sheets through the removal of the groups which contain oxygen with the recovery of a conjugated structure [7,8,10–12].

In 1977, Shirakawa et al. [13] reported electrical conductivity in a conjugated polymer and since then conducting polymers have been largely explored due to their unique electrical characteristics. Polypyrrole, among the conducting polymers is specifically advantageous for its different financial applications like chemical sensors [14,15], supercapacitors [16–19], biosensors [20,21,22,23,24], gas sensors [20] and corrosion protection [21–23] because of being environmentally stable, electrically conductive and flexible. Recently a huge attempt has been made to expand polypyrrole nanostructures which exhibit unique physical and chemical characteristics preferable to their bulky counterpart and that is due to an expanding need for conducting polymers in the field of nanoscience and technology [24–27]. Electrochemical polymerization provides a one-step procedure and offers precise control of the thickness and the structure of the resulting film [28].

Transition metal oxides, like CuO are drawing a huge attention as sensors for detection of glucose because of their good characteristics such as low cost, ease of synthesis and post synthesis