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Multi-analyte Electrochemical Sensor Based on Graphene Oxide and Gold Nanoparticles Electrode

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Summary:

This paper presents the preliminary results concerning a novel multianalyte sensor platform, developed through laser scribing. Featuring two different working electrodes and one counter and reference electrode, the platform was preliminary used for uric acid detection. Modification of one working electrode with co-electrodeposited reduced graphene oxide and gold nanoparticles enables highly sensitive detection using square-wave voltammetry. This platform holds promising applications for multi-analyte rapid and accurate detection in diverse biomedical backgrounds.

Keywords: Electrochemical sensor, nanomaterials, electrochemistry, multiplex sensor, multi-analyte.

Introduction

In healthcare, there is a rising demand for a device that quickly and accurately identifies and measures metabolites in body fluids for rapid disease diagnosis and monitoring. Uric acid (UA), is found in serum and urine as it is excreted by the kidneys and plays a crucial role in various human physiological processes [1]. Elevated levels of UA can be related to various disease conditions, such as gout [2] or cardiovascular diseases [3]. Therefore, monitoring of UA levels is necessary due to its potential impact on health. Hence, numerous detection technologies have been developed. Among them, electrochemical methods enable rapid, simple, and accurate analysis with reduced sample volumes. The UA electrochemical detection depends on the electrocatalytic ability of the electrode to directly oxidize UA [4]. Nanomaterials, with their exceptional properties such as high surface area and catalytic activity [5], are well-suited for improving the performance of UA sensors in terms of sensitivity, selectivity, and low limit of detection. Indeed, reduced graphene oxide (rGO) was widely used as electrode substrates for sensitive detection of UA [6]. The performance can be further improved, by introducing nanoparticles (NPs) of noble metals, such as gold [7] or platinum [8]. In this study, an Indium Tin Oxide Polyethylene terephthalate (ITO-PET) substrate was used to create a multi-analyte sensor platform. A CO_2 laser was employed to create two working electrodes, the reference electrode, and the counter electrode on the same ITO-PET sheet. One working electrode was modified with co-electrodeposited rGO and AuNPs.

Experimental

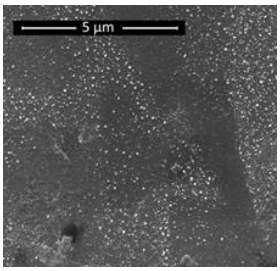

Fig. 1 rGO/AuNPs/ITO-PET electrode SEM image.

An ITO-PET sheet served as the substrate for the sensor platform. The design comprises two working electrodes (E1 and E2), a reference electrode (R), and a counter electrode (C). To achieve the formation of these four electrically insulated electrodes, the thin layer of ITO covering the PET was removed using a CO_2 laser (with a nominal power of 50 W) imposing a laser power of 1.75 W and speed of 50 mm s^{-1}.

GO and AuNPs were co-deposited on E1 electrode according to the method described in our previous work [9]. Briefly, the deposition was conducted at -0.8 V vs SCE for 200 s in acetate buffer solution (ABS) containing 0.25 mM of

$HAuCl_4$ and 0.5 mg mL^{-1} of GO. A platinum mesh was used as a counter electrode. Afterwards, the R electrode was covered with an Ag/AgCl conductive paste.

UA detection measurements were conducted in a 3D-printed cell with a volume of 3 mL. Square wave voltammetry (SWV) was performed in the range potential from -0.5 to 0.4 V vs Ag/AgCl, with a pulse of 0.025 V for 0.02 s and a step height of 1 mV.

Results

As described in our previous work [9], the potentiostatically co-deposition method ensured a uniform coating of rGO decorated with AuNPs of about 25 nm, clearly visible in the SEM image of Fig. 1.

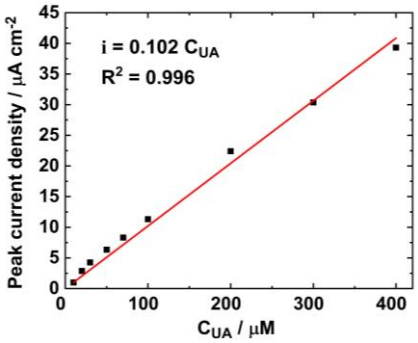

Fig. 2 Calibration line obtained with rGO/AuNPs ITOPET sensor.

The sensor calibration was performed in a Phosphate Buffer (PB, pH 7.4) varying the concentration of UA from 10 to 500 µM. The SWV voltammogram exhibited an oxidation peak at 0.15 V within the potential range of -0.5 to 0.4 V vs Ag/AgCl. This peak intensity increased with higher UA concentration. A linear range between 10 to 400 µM was observed, the calibration line is reported in Fig. 2. A satisfactory sensitivity of 0.102 µA μM^{-1} cm^{-2} was achieved. The proposed sensor performances were comparable to other studies utilizing rGO/NPs-based electrodes [10].

These preliminary satisfactory results demonstrate the feasibility of utilizing the proposed laser-scribed ITO-PET device as a sensor platform integrating internal reference and counter electrodes. This simple method allows for various designs, including those with single or multiple electrodes. According to the proposed design, the other electrode E2 could be properly modified for the detection of another analyte. Thus, further investigation would be necessary to assess the multiplex-sensor performance and its behavior in real samples.

Acknowledgments

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