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Simultaneous determination of uric acid, dopamine and ascorbic acid based on poly(bromocresol green) modified glassy carbon electrode

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ABSTRACT

A glassy carbon electrode modified with poly(bromocresol green) was prepared by electropolymerization process for simultaneous determination of uric acid, dopamine and ascorbic acid. The interface morphology and structure of poly(bromocresol green) film were characterized by scanning electron microscopy and Fourier transform infrared spectroscopy. The simultaneous determination of uric acid (UA), dopamine (DA) and ascorbic acid (AA) in 0.1 M phosphate buffer solution (pH 6.0) was carried out by differential pulse voltammetric technique. Under optimum conditions, the results show that the peaks of three species were well separated. The proposed sensor exhibited linear responses to UA, DA and AA in the ranges of 0.5–200, 0.05–10 and 0.5–1000 μM, respectively. Moreover, the poly(bromocresol green) modified electrode has been successfully applied to determine UA, DA and AA in human serum samples and vitamin C tablets.

1. Introduction

Uric acid (UA) is the final oxidation product of purine metabolism and exists in biological fluids such as blood or urine [1]. The normal UA levels in human serum and urinary excretion in the range of 240–520 μM and 1.4–4.4 mM, respectively [2]. Disorders of UA are symptoms of several diseases such as gout and hyperuricemia [3,4]. Dopamine (DA) is the predominant catecholamine neurotransmitters in the mammalian brain, where it controls a variety of functions including locomotor activity, cognition, emotion, positive reinforcement, food intake, and endocrine regulation [5]. Abnormal levels of DA may cause neurological diseases such as Parkinson's and schizophrenia [6,7]. L-Ascorbic acid (AA), a soluble vitamin, is an essential nutrient for humans. It plays an important role in the prevention and treatment of some diseases such as scurvy, common cold, cancer and hepatic disease [8]. UA, DA and AA usually coexist in biological samples. Therefore, a simple, accurate, rapid and inexpensive method for their simultaneous determination is highly desirable for analytical application and diagnostic research.

At present, a series of analytical methods including capillary electrophoresis [9–11], liquid chromatography–tandem mass spectrometry [12] and fluorimetry [13–15] have been developed for determination of UA, DA and AA. These methods have attracted much attention in life sciences due to their high efficiency and small sample-size requirement. However, time-consuming sample pretreatment and high cost of instrument limit their extensive application in routine analysis.

Since UA, DA and AA are highly electrochemically active, electrochemical techniques currently appear to be suitable for their determination due to their high sensitivity, simplicity, rapidity and fast response. However, overlapping of the oxidation peaks of these three species at traditional electrodes makes it highly difficult for their simultaneous determination. To overcome this problem, various methods have been applied such as polymers [16–18], noble metal/alloy nanoparticles (NPs) [19,20], carbon-based materials [21–24] and ionic liquid [25]. Among these methods, polymer film have attracted great attentions due to their good stability, biocompatibility, homogeneity and strong adherence to electrode surface [26,27]. Since the thickness, permeation and charge transport of polymeric films can be controlled by adjusting the electrochemical parameters, polymer modified electrodes have the advantages of improving electrocatalysis, absence of surface fouling and prevention of undesirable reactions competing kinetically with the desired electrode process [28–30]. It has been demonstrated that polymer modified electrodes, especially those coated with dyes and dyestuffs show excellent stability, reproducibility and homogeneity [31–33]. Most of the redox dyes are artificial electron donors [34,35], and they are able to undergo electropolymerization to generate stable redox active layers [36].

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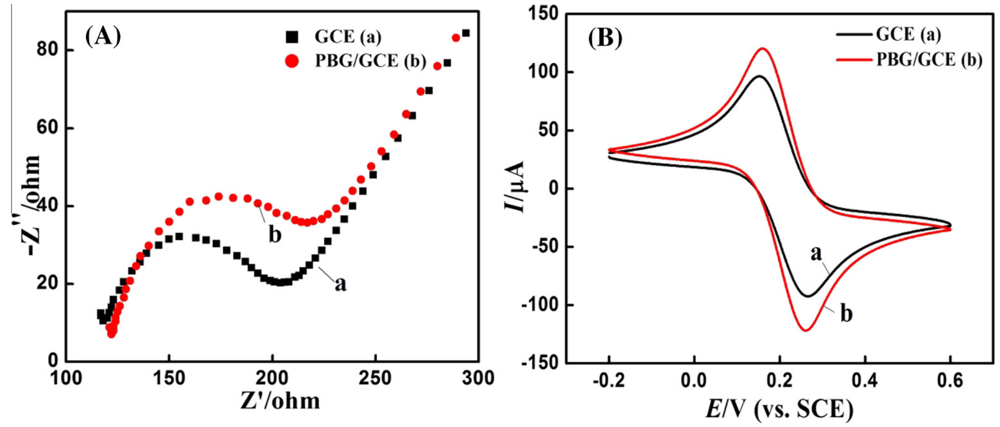

Fig. 1. Electrochemical impedance spectra (A) and cyclic voltammograms (B) of bare GCE (a) and PBG/GCE (b) in 0.1 M KCl containing 5 mM [Fe $(CN)_6]^{3-/4-}$ at the scan rate of 100 mV s^{-1}.

In this work, bromocresol green was chosen as a monomer to obtain a polymer of poly(bromocresol green) film (PBG) modified on glassy carbon electrode by electrochemical polymerization. The process was simple and fast. Besides, because of high electron density of hydroxyl (OH^-) in bromocresol green molecule, the PBG film has high concentrations of negatively charged surface-functional groups. The modified electrode showed excellent electrocatalytic properties in simultaneous determination of UA, DA and AA, making it suitable for the analytical purpose.

2. Experimental

2.1. Reagents and apparatus

DA was purchased from Aladdin Chemical Reagent Co., Ltd. (Shanghai, China). AA and UA were obtained from Sinopharm Chemical Reagent Co., Ltd. (Shanghai, China). Bromocresol green was supplied from Shanghai Chemical Reagent Factory. Phosphate buffer solutions (PBS, 0.1 M) with different pH values were prepared by mixing stock solution of 0.1 M K_2HPO_4 and 0.1 M KH_2PO_4 (Shanghai Chemical Reagent Co., Ltd., China). All chemicals were of analytical grade and used without further purification.

All electrochemical experiments were carried out on a CHI 660C electrochemical workstation (Shanghai Chenhua Co., Ltd., China) with a conventional three-electrode system consisting of a PBG modified glassy carbon electrode, a saturated calomel reference electrode and a Pt foil counter electrode. Fourier transform infrared (FTIR) spectra was carried out on a Fourier transform infrared spectrometer (AVATAR 370, America).

2.2. Preparation of PBG/GCE

Prior to modification, the GCE was polished on chamois leather with 0.05 μm α-alumina powder, thoroughly rinsed with water and sonicated in 1:1 (v/v) HNO_3, absolute alcohol and doubly distilled water in turn. Electropolymerization of bromocresol green on the GCE was carried out by 20 circles between −1.0 and 1.8 V at 100 mV/s in 0.1 M NaOH containing 1 mM bromocresol green. Then PGB/GCE was fabricated.

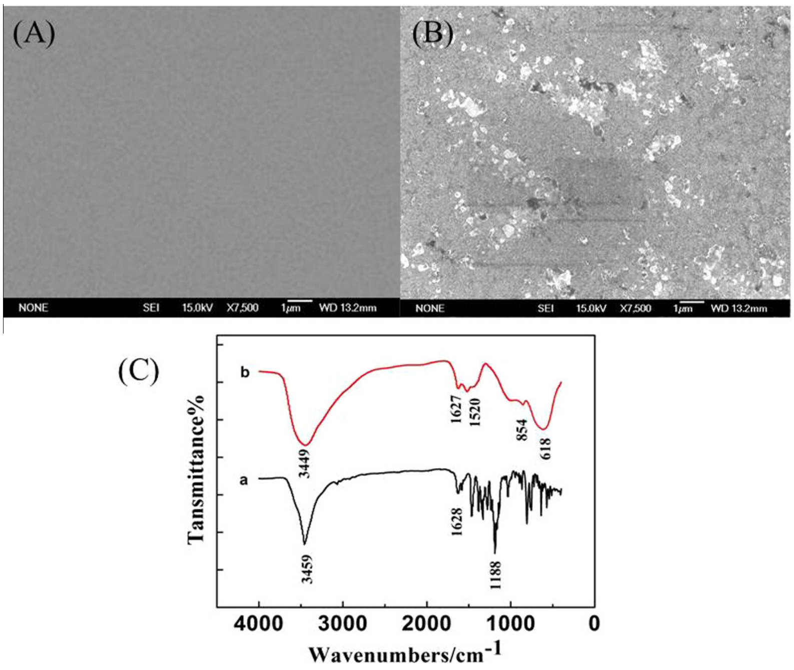

Fig. 2. Scanning electron micrograph of bare GCE (A) and PBG/GCE (B), and (C) Fourier transforms infrared spectra of bromocresol green (a) and poly(bromocresol green) film (b).