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Sodium dodecyl sulfate modified carbon nanotubes paste electrode as a novel sensor for the simultaneous determination of dopamine, ascorbic acid, and uric acid

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ABSTRACT

A novel modified multiwall carbon nanotubes paste electrode with sodium dodecyl sulfate as a surfactant (SDS) has been fabricated through an electrochemical oxidation procedure and was used to electrochemically detect dopamine (DA), ascorbic acid (AA), uric acid (UA), and their mixture by cyclic voltammetry (CV) and differential voltammetry (DPV) methods. Several factors affecting the electrocatalytic activity of the hybrid material, such as the effect of pH, of the scan rate and of the concentration were studied. The bare carbon nanotubes paste electrode (BCNTPE) and SDS-modified carbon nanotubes paste electrode (SDSMCNTPE) were characterized using Field Emission Scanning Electron Microscopy (FESEM) and Energy-Dispersive X-ray spectroscopy (EDX). Using the CV procedure, a linear analytical curve was observed in the 1×10^{-6}–2.8×10^{-5} M range with a detection limit at 3.3×10^{-7} M in pH 6.5, 0.2 M phosphate buffer solutions (PBS).

1. Introduction

Electrochemical detection of analytes is a very elegant method in analytical chemistry [1]. The interest in developing electrochemical-sensing devices for use in environmental monitoring, clinical assays, and etc. Electrochemical sensors satisfy many of the requirements for such tasks, particularly owing to their inherent specificity, rapid response, sensitivity, and simplicity of preparation for the determination of organic molecules, including drugs and related molecules in pharmaceutical dosage forms and biological fluids [2,3].

Dopamine (DA) is an important neurotransmitter molecule of catecholamines and its deficiency leads to brain disorders, such as Parkinson's disease and schizophrenia [4–6]. Thus, detecting and determining the concentrations of dopamine and their metabolites in the presence of interfering species is an important goal in electrochemical analysis. Much attention has been paid to the design and development of novel materials coated on electrode surfaces with improved molecular recognition capabilities [7,8]. Different types of electrode materials are tailored to identify and measure the neurotransmitter molecules [9–13]. Measurements at bare carbon electrodes are complicated due to the coexistence of high concentrations of ascorbic acid (AA) and other related species, which are oxidized in the same potential region [11]. Uric acid (UA) also attenuates the detection of neuromolecules, such as dopamine (DA).

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Several types of electrode modifications are reported in the literature to detect dopamine by electrochemical methods, such as surface coating [9], carbon paste electrodes [13], self-assembled monolayers [14]. The electroanalytical techniques have been excellently applied to the determination of various electroactive species [15–20]. However, each type of modification has its own advantages and limitations. Carbon electrodes, especially paste electrodes, are widely used in electrochemical investigations [21–25].

Electrochemical sensors based on carbon nanotubes (CNTs) represent a new and interesting alternative for quantification of different analytes. Carbon nanotubes can be used to promote electron transfer reactions when used as electrode material in electrochemical devices [26], electrocatalysis and electroanalysis processes due to their significant mechanical strength, high electrical conductivity, high surface area, good chemical stability, as well as relative chemical inertness in most electrolyte solutions and a wide operation potential window [27]. The electronics properties of these nanomaterials have been exploited as means of promoting the electron transfer reaction for a wide range of molecules and biological species, including carbohydrates [28], hydrogen peroxide [29], glucose [30], norepinephrine [31], aminophenol [32], morin [33], cytochrome *c* [34], promethazine [35], thiols [36], methyldopa [37], epinephrine [1], and nicotinamide adenine dinucleotide [38].

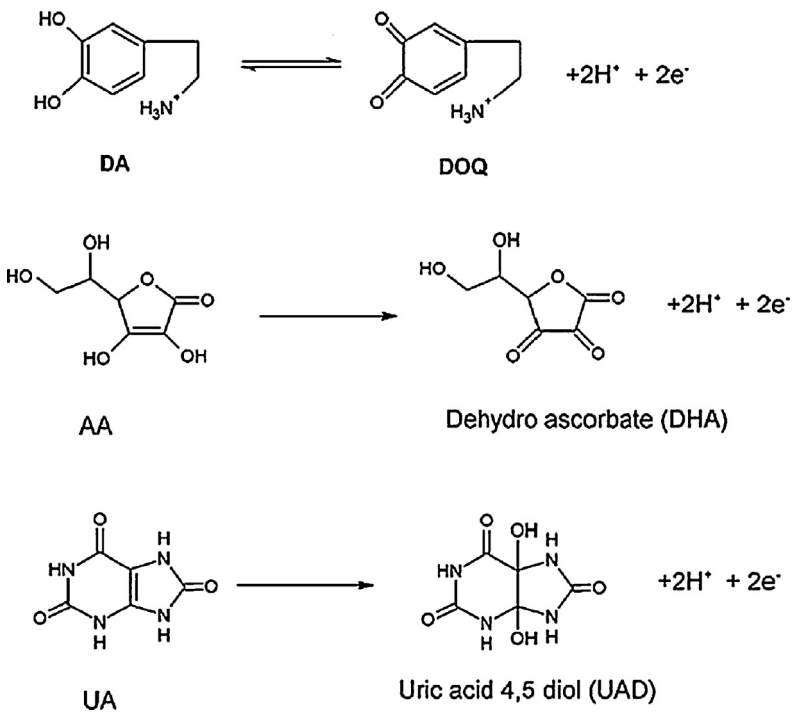
Surfactants are a kind of amphiphilic molecule with a polar head on one side and a long hydrophobic tail on the other one. The applications of surfactants in electrochemistry and electroanalytical chemistry have been widely reported [39]. Many of the studies of modified electrodes were undertaken simply because electrochemists were curious about how new species attached to electrode surfaces behave compared to these species in solution [40]. Some less soluble surfactants were employed in the immobilization of macromolecules or other functional materials. Wu et al. [41] developed a stable carbon nanotube (CNT)-modified electrode based on the immobilization of CNT in the film of insoluble dihexadecyl phosphate (DHP) on a glassy carbon electrode. This electrode exhibited an electrocatalytic activity towards biomolecules and has been used as a sensor for the determination of these species [42,43]. We described initially the preparation and suitability of a SDSMCNTPE as a new electrocatalyst in the electrocatalysis and determination of dopamine, ascorbic acid, and uric acid in an aqueous buffer solution.

In this study, we fabricated carbon nanotube paste electrodes modified by SDS surfactant. DA, AA, and UA are important neurotransmitters in the mammalian central nervous system. They were selected as analytical molecules for electrochemical detection. These SDSMCNTPEs allow better sensitivity and selectivity for the determination of DA in the presence of AA and UA and proved better than unmodified electrodes. Thus, the fabrication of the SDSMCNTPE has been considered in detail. This SDSMCNTPE was used for the determination of DA, AA, UA and mechanisms also studied (see Scheme 1).

2. Experimental

2.1. Reagents

SDS, DA, AA, UA, and silicone oil were obtained from Sigma–Aldrich, Malaysia. SDS was prepared as a 25×10^{-3} M



Scheme 1. Oxidation reactions of dopamine, ascorbic acid and uric acid.