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Characterization of carbon nanotubes decorated with $NiFe_2O_4$ magnetic nanoparticles as a novel electrochemical sensor: Application for highly selective determination of sotalol using voltammetry

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ABSTRACT

A magnetic nano-composite of multiwall carbon nanotube, decorated with $NiFe_2O_4$ nanoparticles, was synthesized with citrate sol–gel method. The multiwall carbon nanotubes decorated with $NiFe_2O_4$ nanoparticles ($NiFe_2O_4$–MWCNTs) were characterized with different methods such as Fourier transform infrared spectroscopy (FT-IR), transmission electron microscopy (TEM), atomic force microscopy (AFM), vibrating sample magnetometer (VSM), cyclic voltammetry (CV), and electrochemical impedance spectroscopy (EIS). The new nano-composite acts as a suitable electrocatalyst for the oxidation of sotalol at a potential of 500 mV at the surface of the modified electrode. Linear sweep voltammetry exhibited two wide linear dynamic ranges of 0.5–1000 μmol L^{-1} sotalol with a detection limit of 0.09 μmol L^{-1}. The modified electrode was used as a novel electrochemical sensor for the determination of sotalol in real samples such as pharmaceutical, patient and safe human urine.

1. Introduction

Nanoparticles of a variety of shapes, sizes and compositions are changing nowadays the bioanalytical measurement [1]. Preparation and investigation of novel nano materials are important in material science. Carbon nanotubes (CNTs) are one of the best candidates for the preparation of the electrocatalytic-based nano-composite materials. Since their discovery by Iijima [2], CNTs have attracted considerable attention due to their fascinating physical, chemical, mechanical, and electrical properties [3–9]. The nanostructures with large specific surface area could provide an important and feasible platform for catalysis [10], separation [11], sensing [12–16] and fuel cells [17]. Modification of the surface of CNTs with metals, metal oxides, complex metal oxides and polymers [18–23] can improve disparity of CNTs in solvents [24] or impart new optical, electrical, magnetic properties of CNTs [25–28]. Decoration of CNTs by spinel ferrite nanoparticles with chemical formula MFe_2O_4 (M = Mn, Co, Ni, Mg, or Zn), which are very important magnetic materials, can improve optical, magnetic and electrochemical properties of CNTs [29–31]. The magnetic CNTs have applications as magnetic data storage [32], microwave absorbing materials [33,34] and magnetic composites for drug delivery [35].

Electrochemical methods of analysis have become one of the important methods in environmental monitoring, medicine and biotechnology, and industrial process control [36]. The chemically modified electrodes are very interesting tools for the analysis of many substances at trace level, using sensitive electroanalytical techniques. An important point in chemically modified electrode utilization in speciation work is to choose the most convenient modifier for each analyte, because the sensitivity and selectivity of the electroanalytical response depend on the characteristics of the modifier.

Sotalol, N-{4-[1-hydroxy-2-(propan-2-ylamino)ethyl] phenyl}methane sulfonamide, is a chiral β-adrenoceptor antagonist marketed in racemic form for the treatment of hypertension, angina pectoris and cardiac arrhythmia [37,38]. To date, numerous methods have been proposed for the analysis of sotalol using different analytical techniques such as liquid extraction material [39,40], fluorescence [41], high performance liquid chromatographic–electrospray ionization mass spectrometric [42], high performance liquid chromatography–UV detection [43–50], and voltammetry [37,51]. The subtle electronic behavior of nanotubes shows that they are able to mediate electron transfer reactions of electroactive species in solution when they are used as a material to modify electrodes.

This work describes the synthesis and study of a magnetic nanocomposite of MWCNTs decorated with spinel ferrite $NiFe_2O_4$, using citrate sol–gel method. The multiwall carbon nanotubes decorated $NiFe_2O_4$ nanoparticles ($NiFe_2O_4$–MWCNTs) was characterized with different methods such as Fourier transform infrared spectroscopy (FT-IR), transmission electron microscopy (TEM), atomic force microscopy (AFM), vibrating sample magnetometer (VSM), cyclic voltammetry (CV), and electrochemical impedance spectroscopy (EIS). The results of the study confirm strong adsorptive ability, huge specific area and subtle electronic properties of the nanoparticles. The suitability of $NiFe_2O_4$–MWCNTas a mediator in electrochemical method was checked

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