Sensors and Actuators B 177 (2013) 634–642

Contents lists available at SciVerse ScienceDirect

Sensors and Actuators B: Chemical

journal homepage: www.elsevier.com/locate/snb

Simultaneous determination of guanine and adenine in DNA based on $NiFe_2O_4$ magnetic nanoparticles decorated MWCNTs as a novel electrochemical sensor using adsorptive stripping voltammetry

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ARTICLE INFO

Article history:
Received 13 August 2012
Received in revised form 31 October 2012
Accepted 11 November 2012
Available online xxx

Keywords:
Magnetic nanoparticles decorated MWCNTs
Hydrodynamic amperometry
Guanine and adenine

ABSTRACT

An electrochemical sensor was developed for guanine and adenine detection using multiwall carbon nanotubes (MWCNTs) decorated with $NiFe_2O_4$ magnetic nanoparticles on a glassy carbon electrode. Incorporation of MWCNT/$NiFe_2O_4$ nanohybrid on the surface of the electrode significantly increases oxidation the peaks currents but reduces the peaks potential of guanine and adenine. The modified electrode was employed for detecting purine bases using linear sweep voltammetry and hydrodynamic amperometry. With hydrodynamic amperometry, the peaks current of both guanine and adenine showed linear dependence on their concentrations in the range of 3.0–45.0 μmol L^{-1} for guanine and 3.0–40.0 μmol L^{-1} for adenine. When linear sweep voltammetry was used, the peak currents exhibited linear dependence on guanine in the concentration range of 0.05–3.0 μmol L^{-1} and on adenine in the concentration range of 0.1–4.0 μmol L^{-1}. The limit of detection (S/N = 3) was found to be 0.006 and 0.01 μmol L^{-1} for guanine and adenine, respectively. Linear sweep voltammetry was also used for simultaneous determination of adenine and guanine. Finally, the proposed electrochemical sensor was employed to determine guanine and adenine in single-strand deoxyribonucleic acid (ssDNA) samples with satisfactory results.

1. Introduction

Nucleosides and their metabolic products, such as guanine and adenine, play fundamental roles in life processes [1,2]. Guanine and adenine bases are the building blocks in both DNA and RNA [3]. They have widespread effects on coronary and cerebral circulation, control of blood flow, inhibition of neurotransmitter release, and modulation of adenylatecyclase activity [4]. Their concentration levels are considered to be important indicators of cancers, AIDS, and myocardial cellular energy status [5]. Therefore, selective and sensitive detection methods are required for the analysis of these compounds. Different analytical methods such as liquid chromatography or electrophoresis combined with different detection techniques have been developed for the analysis of purine bases in nucleic acids [6–11]. Although these methods are sensitive, they are disadvantageous due to their complicated instrument and time-consuming sample pretreatment requirements.

Simplicity, rapidity, high sensitivity, and low cost are the main advantages of electrochemical techniques for the analysis of biological compounds [12]. Several electrochemical detection methods mostly based on either reduction of purine bases on a hanging mercury drop electrode [13] or oxidation of both guanine and adenine on unmodified carbon electrode [14–16] have been reported. However, the electrochemical responses of most electrodes toward oxidation of purine bases are poor with high oxidative potential. Furthermore, direct oxidation of guanine and adenine reportedly pronounces the fouling effect that results in poor reproducibility. High overpotential and/or poor reproducibility usually limit the use of bare electrodes for direct detection of purine bases in biological substances.

Modification of different electrode surfaces with various electron transfer mediators is used to improve the sensitivity and selectivity of electroanaytical methods for guanine and adenine detection. For example, Sun et al. studied the electrochemistry of adenine and guanine on a carbon ionic liquid electrode, which was useful for the simultaneous analysis of adenine and guanine from denatured DNA [17]. Abbaspour and Ghaffarinejad demonstrated that adenine sand guanine yielded a well-defined and very sensitive oxidation peak at the carbon nanotube ceramic electrode [18]. Tang et al. used multiwall carbon nanotubes incorporated with poly (new fuchsin) composite film modified glassy carbon electrode for the simultaneous determination of adenine, guanine, and thymine by cyclic voltammetry [19]. Liu et al. investigated the direct electrochemistry of guanine and adenine at a PbO_2–carbon nanotube–ionic liquid composite and developed a sensitive electrochemical technique for

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0925-4005/$ – see front matter
http://dx.doi.org/10.1016/j.snb.2012.11.028