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Amperometric determination of paracetomol by a surface modified cobalt hexacyanoferrate graphite wax composite electrode

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Abstract

A stable electro active thin film of cobalt hexacyanoferrate (CoHCF) was deposited on the surface of an amine adsorbed graphite wax composite electrode using a simple method. Cyclic voltammetric experiments showed two pairs of well defined peaks for this CoHCF modified electrode which exhibited excellent electrocatalytic property for the oxidation of paracetomol at a reduced overpotential of 100 mV and over a concentration range of 3.33×10^{-6} to 1.0×10^{-3} M with a slope of 0.208 μA/μM with good sensitivity. The influence of the supporting electrolyte on peak current and peak potential were also obtained in addition with effects of common interference (e.g., ascorbic acid) on the response of the modified electrode. Various parameters that influence the electrochemical behavior of the modified electrode were optimized by varying scan rates and pH. Electrochemical impedance spectroscopy studies suggested that the electrode reaction of the CoHCF film is mainly controlled by transport of counter ion. The immobilized CoHCF maintained its redox activity showing a surface controlled electrode reaction with the electron transfer rate constant (K_s) of 0.94 s^{-1} and charge transfer coefficient of 0.42. Hydrodynamic and chronoamperometric studies were done to explore the utility of the modified electrode in dynamic systems. The results of the differential pulse voltammetry (DPV) using the modified electrode was applied for the determination of paracetomol in commercially available tablets. The results obtained reveal that the electrode under study could be used as an effective sensor for online monitoring of paracetomol.

Keywords: Cobalt hexacyanoferrate; *p*-Phenylenediamine; Paracetomol; Cyclic voltammetry; Differential pulse voltammetry

1. Introduction

There has been considerable interest in developing methods to measure compounds of medicinal and biological interest among which electrochemical technique has proven to be significantly advantageous. Paracetomol (acetaminophen or *N*-acetyl-*p*-aminophenol) is a commonly used drug in humans and veterinary sciences. The most common formulation is tablets, generally containing 500 mg paracetomol per tablet. It has the preferred alternative analgesic-antipyretic to aspirin, particularly to patients who cannot tolerate aspirin. *p*-Aminophenol, the primary hydrolytic degradation product of acetaminophen, can be present in pharmaceutical preparations as a synthetic intermediate or as a degradation product of acetaminophen [1] which can cause serious nephrotoxocity and tetragenic effects. The utility of paracetomol is so popular that it becomes necessary to find a suitable technique to measure it quantitatively since overusage of this particular drug could lead to some serious side effects which could some time prove to be irreversible. Side effect to the paracetomol (overusage) includes: liver disorders, skin rashes and inflammation of the pancreas. Therefore, development of a simple, economical and accurate analytical method for the determination of paracetomol would be useful for many commercial applications and also to investigate the stability of paracetomol in pharmaceutical preparations for quality control. Spectrophotometry [2,3], liquid chromatography [4,5], capillary electrophoresis (CE) [6–8], enzyme based assay methods [9], flow injection analysis [10], and electrochemistry [11] have been effectively used for the determination of paracetomol in body fluids and pharmaceutical preparation. Though these methods have been proven to be effective methods of analysis, they usually involve steps like preconcentration and take a long time to perform.

With the growing realization of the challenges in the determination of compounds of chemical and biological interest, there

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is tremendous demand to develop high performance immobilized catalytic surfaces that are reliable, efficient, and stable to long time operation under a variety of operating conditions and the possibility for miniaturization and also for on-line applications. Chemically modified electrodes which are of recent interest as chemical sensors have attracted immense attention because of their sensitivity and selectivity in analysis of compounds of trace level concentrations. The slow electron transfer kinetics at the bare/unmodified electrode surface is substantially changed on modifying the bare electrode which in turn speeds up the electron transfer kinetics of the reaction at the surface and enables the reaction to occur at a faster rate and also at an appreciable reduced over voltage. Recently there has been renewed interest in the preparation and characterization of metal hexacyanoferrates as electro active material [12,13] among which cobalt hexacyanoferrate is an important member of mixed-valence transition metal hexacyanoferrates as it has proven to have excellent properties in electro catalysis and electrochromicity [14,15], capacity to store counter cations [16,17] and ion exchange selectivity [18,19]. CoHCF exhibits well defined and reproducible electrochemical responses because both the oxidized and reduced CoHCF structures seem to be fairly open and permit transport of alkali metal cations providing charge balance during redox reactions. CoHCF films can be easily fabricated on various surfaces [20]. All of the above traits make it an obvious candidate for electroanalytical applications such as electron transfer mediator, electrochromic devices and ion selective devices since they show good electrocatalytic activity toward a variety of substrates including ascorbic acid, nitrite, hydrazine, NADH and hydroxylamine [20–25].

In this paper, we report the fabrication, electrochemical characterization, and electrocatalytic application of a CoHCF surface modified graphite wax composite electrode prepared from an amine adsorbed graphite which stands as the base. Our present effort was to modify a graphite paraffin wax composite electrode with Cobalt hexacyanoferrate using an amine adsorbed graphite powder and to study its electrocatalytic activity towards the electrochemical oxidation of paracetomol. In our previous report [26], the same electrode was characterized and used effectively for the amperometric determination of butylated hydroxy anisole (BHA). In short, the modification was achieved by initially adsorbing *p*-phenylenediamine onto graphite powder which was then made into a graphite paraffin wax composite electrode, Co^{2+} ions which possess high affinity for the nitrogen of amine was coordinated to the adsorbed amine. The coordinated transition metal was then derivatised to its stable hexacyanoferrate form by cycling in potassium ferrocyanide solution of suitable concentration to form a thin layer of CoHCF on the electrode surface. The CoHCF modified electrode exhibited excellent electrocatalytic activity towards the oxidation of paracetomol. Despite other methods of electrode modification [27–31] the sensor reported here was simple and reliable and found to be a very sensitive for electrochemical determination of paracetomol. The developed method was applied to determine paracetomol in commercial tablet samples too.

2. Experimental

2.1. Apparatus

FTIR spectra were recorded using a Perkin Elmer RX 1 Spectrometer. Electrochemical measurements were done using a Electrochemical workstation CH Instruments (660B) controlled by an IBM personal computer with standard three-electrode configuration. Impedance experiments were done using an Autolab PG stat 302 electrochemical workstation. All experiments were done in a three-armed cell of volume 100 ml. The surface modified CoHCF graphite wax composite electrode acted as the working electrode, a platinum electrode served as the counter electrode with standard calomel electrode as the reference.

2.2. Chemicals and reagents

Paracetomol was purchased from Himedia Laboratories (P) Ltd, Mumbai, India and Graphite powder was from Aldrich Chemicals, USA. All other reagents and solvents were of analytical grade. All aqueous solutions were made from doubly distilled water. Paracetomol tablets were purchased from a local drug store. Studies on effect of pH were carried out using 0.1 M HCl and 0.1 M NaOH solutions. *p*-Phenylenediamine solution (10 mM) and cobalt solution (0.01 M) were prepared by dissolving appropriate quantity in dry DMF and ethanol, respectively. 0.1 M KNO_3 was used as the background electrolyte. All measurements were done after carefully degassing the solutions with pure nitrogen for 10–15 min.

2.3. Tablet sample preparation

Five tablets (500 mg paracetomol per tablet) were finely pulverized and dispersed in a 20 mL of 0.5 M acetic acid in a 100 mL standard flask. The flask was shaken vigorously using a cyclomixer for about 10 min until most of the sample got dissolved and the mixture was centrifuged to obtain a clear solution which was filtered through a Whatmann 41 filter paper and finally diluted to the required concentration. The supernatant was adjusted to the pH of the experiment.

3. Electrode preparation

As reported in our previous work [26], the electrode fabrication can be summarized to four steps: (i) physical adsorption of *p*-phenylenediamine (PPD) onto graphite powder, (ii) preparation of a graphite paraffin wax composite electrode using the amine adsorbed graphite powder, (iii) coordination of Co^{2+} ions to the adsorbed amine and (iv) derivatization of the coordinated metal ion to its hexacyanoferrate forming a thin and stable layer of CoHCF on the electrode surface.

Physical adsorption of PPD on graphite powder was achieved following reported procedures with slight modifications [31,32]. A wax composite electrode was made using the above diamine-functionalized graphite optimizing the amine functionalized graphite powder:paraffin wax ratio to 3.4:1. Metal ions have