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Electro-oxidation study of promethazine hydrochloride at the surface of modified gold electrode using molecular self assembly of a novel bis-thio Schiff base from ethanol media

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ABSTRACT

In this study, a new Schiff base of bis-N-(2-mercaptophenyl) salicylaldimine (MPSI) has been immobilized on a bare gold electrode as a novel self assembled monolayer (SAM) sensor for determination of promethazine hydrochloride (PMZ). Cyclic voltammetry and electrochemical impedance spectroscopy are used to study the properties of monolayer of Schiff's base on a gold electrode (MPSI-Au SAM electrode) using the $[Fe(CN)_6]^{3-/4-}$ probe. Also, the characterization of the MPSI-Au electrode was performed by scanning electron (SEM) and atomic force microscopy (AFM). The electrochemical behavior of PMZ on the MPSI-Au SAM electrode was studied by several voltammetry methods in phosphate buffer solution as supporting electrolyte. The modified electrode showed good selectivity in the presence of interference of ascorbic and uric acid. A calibration curve was obtained for PMZ in a linear range of 1.0–240.0 μmol L^{-1}. The detection limit for promethazine hydrochloride was found to be 24.6 nmol L^{-1}. The results indicated that the MPSI-Au SAM electrode could be employed for the determination of promethazine hydrochloride in urine and plasma samples.

1. Introduction

The interest in developing sensing devices for use in environmental monitoring, clinical assays or process control is a rapidly growing field of research. Electrochemical sensors satisfy many of the requirements for such tasks, particularly owing to their simplicity of preparation, high selectivity and sensitivity, and fast response. The utility of sensors based on solid (bare) electrodes is often hampered by their low selectivity arising from high over potentials [1]. In particular, complexity of real biological systems may result in overlapping voltammetric signals. Moreover, the limited number of electrode materials makes only a restricted number of analytes suitable for electrochemical detection with high sensitivity and selectivity. Therefore, efforts have been made to modify the electrode surfaces for the purpose of lowering the over potential, improving the mass transfer velocity for effective enrichment of the desired substance and/or restraining the effect of interferences [2–6].

Self-assembly procedure as a precise modification of the surface structure in nanometer-scale [7] is recently employed in surface protection [8,9], fabrication of sensors [10,11] and biosensors [12,13]. It has been revealed that by changing the charge state of electrodes, one can control the electrochemical properties of the surface as insulation behavior and inhibition from fouling effects of the redox active molecules [14,15].

Promethazine hydrochloride (PMZ) is a prominent compound in the large group of phenothiazine derivatives widely used for its antihistaminic, sedative, antipsychotic, analgesic and anticholinergic properties [16,17]. However, adverse effects caused by PMZ in humans have also attracted enormous attention, such as cardiac, reproductive alterations, endocrinal, occasional hypotension and so on [18]. Therefore, its determination in commercial formulations is extremely important. Up to now, many analytical techniques have been reported for the determination of PMZ, such as chemiluminescence [19], high performance liquid chromatography [20,21], capillary zone electrophoresis [22], titrimetric procedures [23], spectrophotometry allied to flow-injection analysis [24–26] and spectrofluorimetry [27]. However, most of these methods are complicated, time consuming and also require expensive instrumentation. Recently, electroanalytical techniques have been employed to determine PMZ, since they are simple, cost little, and require relatively short analysis times [28,29].

Electrochemical techniques have proved to be excellent alternatives to determine pharmaceutical compounds, since they are simple, cost little and require relatively short analysis times, without the need for derivatizations or time-consuming extraction steps [30]. Moreover, these techniques are less sensitive than other analytical techniques to the effects of excipient substances in commercial formulations. As for evaluation of the electrochemical behavior and quantification of PMZ by

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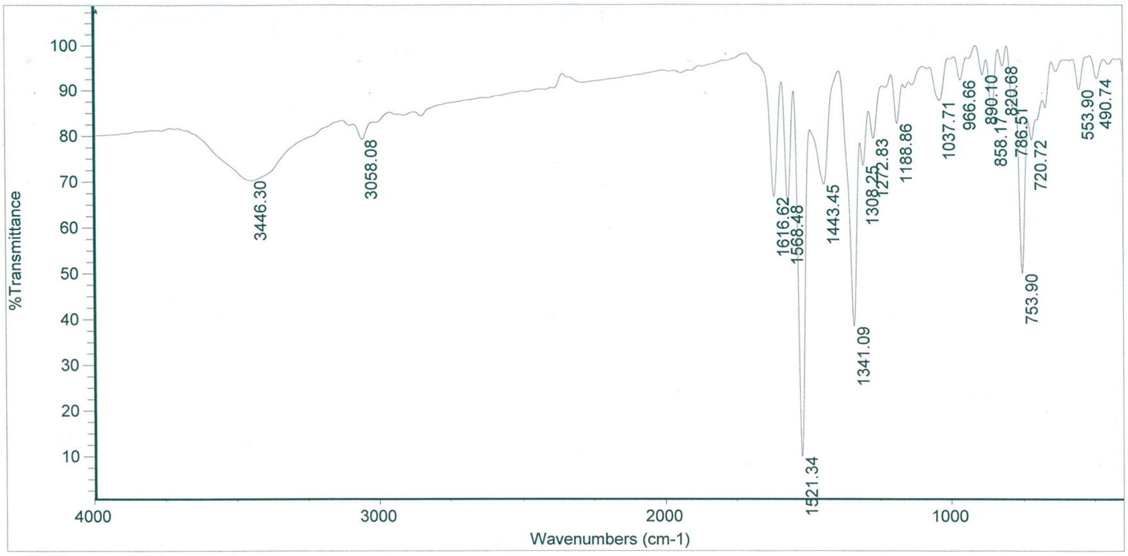


Scheme 1. The FT-IR spectrum of synthesized MPSI Schiff base.

electroanalytical techniques, several electrodic surfaces such as highly boron doped diamond electrode [31], glassy carbon electrode [32], molecularly imprinted polymer carbon paste electrode [33] and gold electrode [34] have already been used as working electrodes. Nanomaterials, owing the nanometer size and specific physicochemical characteristics, will offer special opportunities for electrochemistry.

In the present work, an MPSI-Au SAM electrode as a new nanostructure was fabricated and applied for PMZ sensing. Scanning electron microscope (SEM), atomic force microscopy (AFM), cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) methods were used for the characterization of monolayer of Schiff base at the surface of gold electrode. Also, differential pulse voltammetry (DPV) was used to measure of PMZ in real sample.

2. Experimental

2.1. Chemicals and apparatus

PMZ, AA, UA and other chemicals were of pure grade and purchased from Merck. The gold electrode (Au, 99.99%, 0.0314 cm^2) was purchased from Azar Electrode Co., Urmia, I. R. Iran. The voltammetric and EIS measurements were carried out using an Autolab Potentiostat/Galvanostat PGSTAT30 (Eco Chemie, Utrecht, The Netherlands) controlled by General Purpose Electrochemical Systems (GPES) and Frequency Response Analyser (FRA) 4.9 software and adopted by a conventional three-electrode system. The working electrode was MPSI-Au SAM electrode and the auxiliary and reference electrodes were a Metrohm platinum rod and Ag/AgCl/KCl (3.0 M) electrodes, respectively. All experiments were done at room temperature (25 °C). A Metrohm 691 pH/ion meter was also used for adjusting pH of buffers.

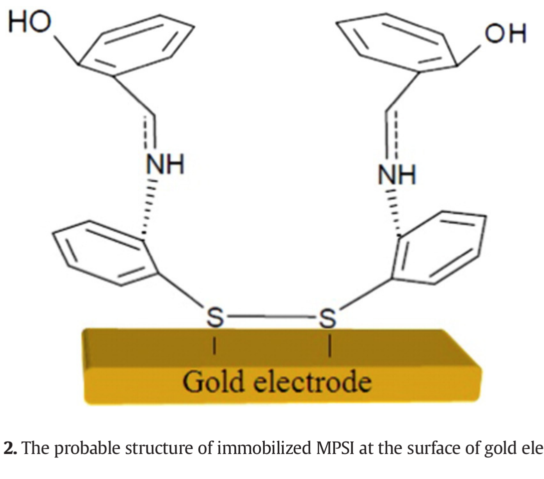
A scanning electron microscope (TESCAN, Czech Republic) and an atomic force microscope (NT-MDT. noncontact) were used to study of the surface of gold electrodes. Also, a Fourier transformation infrared (FT-IR) Magna 550 Nicolet spectrophotometer was used to characterize of synthesized Schiff base using a KBr pellets in a range of 400–4000 cm^{-1}.

2.2. Synthesis of bis-N-(2-mercaptophenyl) salicylaldimine (MPSI)

The aromatic Schiff base was prepared according to the literature through a well-known procedure [35] as follows: Bis (2-aminophenyl) disulfide (2.00 g, 8.05 mmol) was mixed with 50 mL distilled methanol which was stirred using a magnetic stirrer. Then, salicylaldehyde (1.97 g, 16.10 mmol), dissolved in 10 mL of distilled methanol was added drop by drop using a dropping funnel to the above solution. The mixture was refluxed for 6 h and the yellow precipitate which appeared was filtered off and recrystallized from chloroform/methanol (94% yields). M.p: 169 °C. Anal. Calc. for MPSI: C = 68.40; H = 4.42; N = 6.14. Found: C = 68.17; H = 4.33; N = 6.25%. Main IR (KBr, cm^{-1}), $\nu_{C{=}N}$ (cm^{-1}): 1616. ^{1}H NMR (400 MHz) chemical shift (δ ppm), 14.80 (s, 2H, O–H), 9.08 (s, 2H, CH=N), 6.55–7.67 (m, 16H, H-aromatic). Also, to confirm synthesized MPSI, the FT-IR study of MPSI was investigated which its spectrum is shown in Scheme 1.

2.3. Preparation of MPSI-Au SAM electrode

Firstly, the gold electrode was immersed in Piranha solution (1:3, v/v; 30% H_2O_2 and concentrated H_2SO_4 for 3.0 min and rinsed thoroughly with double-distilled water. Then, the gold electrode was carefully polished with 0.5 μm and 0.05 μm Alumina powder on micro cloth pads and rinsed with ethanol between each step (an ultrasonic bath is required); then rinsed with water and sonicated in water/chloroform/water each step 5 min, to remove physically adsorbed particles and contaminants. Then the cleanliness of the electrode surface was cleaned electrochemically by cycling the electrode potential between 0.000 and +1.500 V vs. a reference electrode, with a 100 mV s^{-1} scan rate in 0.5 mol L^{-1} H_2SO_4 and 0.000 until −1.400 V with a 100 mV s^{-1}



Scheme 2. The probable structure of immobilized MPSI at the surface of gold electrode.