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Adsorption and inhibitive properties of aminobiphenyl and its Schiff base on mild steel corrosion in 0.5 M HCl medium

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Abstract

Electrochemical measurements were performed to investigate the effectiveness and adsorption behaviour of aminobiphenyl (Aph) and 2-(3-hydroxybenzylideneamino)biphenyl (Aph-S), as corrosion inhibitors for mild steel (MS) in 0.5 M HCl solution. Potentiodynamic polarization, linear polarization resistance (LP) and electrochemical impedance spectroscopy (EIS) techniques were applied to study the metal corrosion behaviour in the absence and presence of different concentrations of Aph and Aph-S. In order to gain more information about adsorption mechanism the AC impedance technique was used to evaluate the potential of zero charge (PZC) from polarization resistance (R_p) versus voltage (E) plot. Potentiodynamic polarization measurements showed that Aph act as cathodic type inhibitor where as Aph-S act mixed type. The inhibition efficiency (IE%) increases with increasing concentration of compounds and reached 92.6% for Aph and 97.2% for Aph-S at 5×10^{-3} M. Double layer capacitance (C_{dl}) and polarization resistance (R_p) values are derived from Nyquist plots obtained from AC impedance studies. The experimental data fit Langmuir isotherm for both Aph and Aph-S, and from the adsorption isotherm some thermodynamic data for the adsorption processes are calculated and discussed. The effect of exposure time on the corrosion behaviour of mild steel in the absence and presence of inhibitor over 168 h was also studied.

Keywords: Corrosion inhibitor; Mild steel; Schiff bases; PZC; Adsorption

1. Introduction

The study of the mechanism of corrosion inhibitors action has a great importance both for the formulation of new inhibitors and for the correct use of these inhibitors under different conditions. In many industrial operations, like pickling and acid cleaning, the choice of optimum working temperature and process duration is of particular importance. The inhibitors used have to be chemically stable and to provide high protective effect under the conditions discussed. If an inhibiting effect (IE) of 50% is adequate for water-supply systems, an effect higher than 87% is required for pickling [1]. Aqueous solutions of acids are among the most corrosive media. Therefore, investigating and exploring corrosion inhibitor for steel corrosion in acid solutions is important not only for its academic meaning but also for its application [2]. The extent and mode of adsorption depends on definite physico-chemical properties of the organic molecule, such as functional groups, aromaticity and π orbital character of the donating electrons, steric effects and electron density of the donor atom and the electronic structure of the molecule. The adsorption extent also depends on the nature of the metal surface and the electrolyte [3].

Inhibitors of corrosion in acid solution can interact with metals and affect the corrosion reaction in a number of ways, some of which may occur at the same time. It is often not possible to assign a single general mechanism of action to an inhibitor because the mechanism may change with experimental conditions. Thus, mechanism of inhibition of an inhibitor may vary with factors such as concentration, pH, nature of the anion of the acid, and the nature of the metal. The mechanism of action of inhibitors with the same functional group may additionally vary with factors such as the effect of the molecular structure on the electron density of the functional group and the size of the aromatic and aliphatic portions of the molecule [4,5].The main target of several research papers related with Schiff bases [6–9] and N, O, S contained organic compounds [10–13] has

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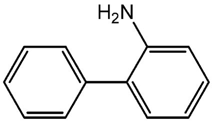
been to use of these compounds as inhibitors in preventing corrosion of metals and alloys. Recently, use of new synthesized Schiff bases getting increasingly important in investigations of corrosion inhibitors. In present work, the Schiff base (Aph-S) has been newly synthesized and has not been studied yet, for corrosion prevention.

The aim of this study, is to gain some insight into the effect of adding extra phenyl group on inhibition efficiency of studied amine (Aph) and describe the adsorption mechanisms both amine and Schiff base's by finding their PZC values.

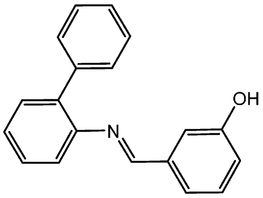
2. Experimental

2.1. Inhibitors

The Schiff base compound was synthesized by a condensation reaction of amine with salicylaldehyde in ethanolic media. The structure of amine, aminobiphenyl (Aph), and synthesized Schiff base, 2-(3-hydroxybenzylideneamino)biphenyl (Aph-S) were shown below:



Aminobiphenyl (Aph)



2-(3-hydroxybenzylideneamino)biphenyl (Aph-S)

2.2. Preparation of electrodes

The working electrode was prepared from a cylindrical mild steel (MS) rods having following chemical composition: C 0.7%, Mn 0.4%, Cu 0.12%, Si 0.05%, P 0.025%, S 0.025%, Sn 0.01%, Ni 0.009% and remainder iron. Samples were insulated with polyester resin such that the area exposed to solution was 0.24 cm^2. The surface preparation of the specimens was carried out using different grade emery papers up to 1200, degreased in acetone, washed with bi-distilled water.

2.3. Polarization measurements

A three-electrode cell assembly consisting of a mild steel rod embedded as working electrode (WE), a platinum sheet as counter electrode (CE) and Ag/AgCl electrode as reference (RE) were used for electrochemical measurements. Prior to measurements, the working electrode was kept in 0.5 M HCl solution containing various concentrations of Aph and Aph-S for 2 h. The temperature of the electrolyte was maintained at $25 \pm 1\,^{\circ}C$.

The polarization curves were recorded by using computer controlled CHI660B electrochemical analyzer. The potential increased with a scan rate of 2 mV/s. The experiments were carried out separately for anodic and cathodic directions. Cathodic and anodic curves were recorded from E_{ocp} to −0.8 V and E_{ocp} to −0.2 V, respectively. After each measurement, the working electrode was taken out from the cell and pretreated again for next measurement. All measurements were carried out open to the atmosphere without any stirring. Corrosion current I_{cor} were calculated using the Stearn–Geary relationship (I_{cor}).

2.4. Linear polarization measurements (LP)

In order to determine the polarization resistance, R_p the potential of the working electrode was polarized ±10 mV from open circuit potential at a scan rate of 1 mV/s. The polarization resistance was calculated from the slope of the potential versus current plots.

2.5. Impedance measurements (EIS)

Electrochemical impedance measurements were carried out at open circuit potential in the frequency range of 10^5–10^{-2} Hz, after 2 h of immersion time, by amplitude of 5 mV. All electrochemical experiments were recorded using an CHI 660B electrochemical analyzer with 64721A serial number coupled to a computer.

3. Results and discussion

3.1. Potentiodynamic measurements

The potentiodynamic anodic and cathodic polarization behaviour of mild steel in 0.5 M HCl with the addition of different concentrations of Aph were recorded and the results were shown in Figs. 1 and 2, respectively. Corrosion current of mild steel decreases with the increasing the concentration of Aph. From the figures it can be seen that; the cathodic reaction is remarkably affected by the inhibitor, whereas the anodic one

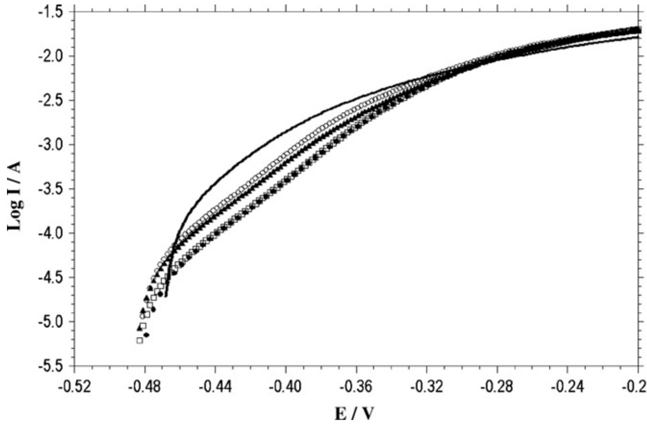


Fig. 1. Anodic polarization curves of MS obtained in 0.5 M HCl (–), 5×10^{-3} M (●), 1×10^{-3} M (□), 5×10^{-4} M (▲) and 1×10^{-4} M (○) Aph containing solutions.