Corrosion Protection Properties of 4-hydroxy-\(N'\)-[(1\(E\), 2\(E\))-3-phenylprop-2-en-1-ylidene] Benzohydrazide on Mild Steel in Hydrochloric Acid Medium

Preethi Kumari P\(a\), Prakash Shetty\(b\), and Suma A Rao\(a\)

\(a\)Department of Chemistry, Manipal Institute of Technology, Manipal University, Manipal, 576104 India
\(b\)Department of Printing and Media Engineering, Manipal Institute of Technology, Manipal University, Manipal, 576104 India
e-mail: prakash.shetty@manipal.edu

Received August 6, 2014

Abstract—The corrosion behaviour of mild steel immersed in 0.5 M HCl in the absence and presence of 4-hydroxy-\(N'\)-[(1\(E\), 2\(E\))-3-phenylprop-2-en-1-ylidene] benzohydrazide (HPB) was evaluated using Tafel polarization and electrochemical impedance spectroscopy techniques. The effect of inhibitor concentration and temperature on the corrosion inhibition efficiency (% IE) of HPB was studied and discussed. It is observed that the inhibition efficiency increased with increase in inhibitor concentration and also with increase in temperature for a given inhibitor concentration. The polarization study revealed that HPB acts as a mixed type of inhibitor by inhibiting both anodic and cathodic reactions. The corrosion inhibition process follows Langmuir–adsorption isotherm and takes place predominantly through chemisorption.

DOI: 10.1134/S2070205115060143

1. INTRODUCTION

Mild steel is extensively used in industrial manufacturing, particularly in the automotive and machinery segments, due to its low production costs coupled with excellent mechanical properties, moderately high strength to weight ration and overall integral reliability [1]. Acidic solutions are extensively used in acid cleaning, pickling, for the removal of rust and scale formed during forming processes. Steel surfaces deployed in service in such environments undergo considerable corrosion [2]. Significant reduction in corrosion rates has been achieved by various means including reduction of the metal impurity content, application of several surface modification techniques, thermal mechanical treatments as well as incorporation of suitable alloying elements. However, the use of corrosion inhibitors is the most practical and economical methods for corrosion protection and prevention of unexpected metal dissolution in aggressive acid media [3].

A number of hetero cyclic compounds have been reported as corrosion inhibitors for mild steel in HCl and screening of synthetic heterocyclic compounds is still being continued. All these studies reveal that heterocyclic compounds show significant inhibition efficiency due to the presence of hetero atoms such as N, O and S [4, 5]. The polar functional groups can absorb on the metal surface and block the active sites on the surface, thereby reducing the corrosion rate [6]. The adsorption of organic molecules at the metal/solution interface plays an important role in surface science and can markedly improve the corrosion-resisting properties of metals [7].

Hydrazides constitute an important class of biologically active organic compounds and their therapeutic uses. Hydrazides and their condensation products are reported to possess a wide range of biological activities including antibacterial activity, tuberculostatic properties, antifungal and many more [8, 9]. Some aromatic hydrazides and its derivatives have been reported as efficient corrosion inhibitors for mild steel [10, 11]. Keeping in view the importance of hydrazide and its derivatives as potential corrosion inhibitors, 4-hydroxy-\(N'\)-[(1\(E\), 2\(E\))-3-phenylprop-2-en-1-ylidene] benzohydrazide (HPB) have been synthesized. The results of its corrosion inhibition action on mild steel in 0.5 M HCl are reported in this paper.

2. EXPERIMENTAL

2.1. Material

Commercially available grade of mild steel with composition of (% wt) C (0.159), Si (0.157), Mn (0.496), P (0.060), S (0.062), Cr (0.047), Ni (0.06), Mo (0.029), Al (0.0043), Cu (0.116) and rest iron was employed in this study. The specimen was prepared in the form of a cylindrical rod embedded in epoxy resin, having one end of the rod with an open surface area of 0.95 cm\(^2\). Prior to the tests, the specimens were pol-
ished with different grades of emery polishing papers, respectively and finally on disc polisher using levigated alumina abrasive. The polished specimen was washed with double distilled water, cleaned with acetone, and finally dried before immersing in the medium.

2.2. Medium

Stock solution of 0.5 M hydrochloric acid was prepared by diluting AR grade hydrochloric acid with double distilled water and was standardized by potentiometric method.

2.3. Inhibitor Preparation

HPB was prepared as per the reported literature [12]. An equimolar mixture of ethanolic solution of trans-3-Phenyl-2-propenal (0.01 mol) and 4-hydroxyl benzohydrazide (0.01 mol) was refluxed on a hot water bath for about 2h. The precipitated product was filtered, dried and recrystallized from ethanol. FTIR spectra of the dried sample was recorded using spectrophotometer (Schimadzu FTIR 8400S) in the frequency range of 4000 to 400 cm\(^{-1}\) using KBr pellets. The chemical structure of the HPB molecule is given in Fig. 1.

2.4. Electrochemical Measurements

Tafel polarization and electrochemical impedance spectroscopy were performed using a Potentiostat (CH Instrument USA Model 604D series with beta software). The measurements were carried out using a conventional three electrode Pyrex glass cell with platinum foil as the counter electrode and a saturated calomel electrode as the reference electrode. The mild steel specimen was used as the working electrode. Electrochemical impedance spectroscopy (EIS), measurements were carried out on the steady open circuit potential (OCP) disturbed with amplitude of 10 mV a.c. signal at the frequency range from 100 KHz to 10 mHz. Impedance data were analysed using Nyquist plots. The charge transfer resistance, \(R_{ct}\) was extracted from the diameter of the semicircle in the Nyquist plot. In Tafel polarization measurement, a finely polished mild steel specimen was exposed to 0.5 M HCl without and with inhibitor at different temperatures (30–60°C), and allowed to establish a steady state open circuit potential. The potentiodynamic polarization studies were then carried out in the potential range of −250 mV to +250 mV at a scan rate of 0.1 mV/s with respect to OCP.

2.5. Scanning Electron Microscopy (SEM)

The surface morphology of the mild steel specimen immersed in 0.5 M hydrochloric acid solution in the presence and absence of HPB were compared by recording the electron micrographs of the specimen using scanning electron microscope of model (EVO 18–5–57 model).

3. RESULTS AND DISCUSSION

3.1. Characterization of HPB

Crystalline white solid (95%); m.p: 264–266°C, \(C_{16}H_{14}N_{2}O_{2}\). IR (KBr) [cm\(^{-1}\)]: 1612 (C=N str.), 1758 (C=O), 1558 (Ar. C=C str.), 3016 (CH str.), 3201 (NH str.), 2669 (C–H assy str), (2846 C–H sym str), 3502 (OH).

3.2. Electrochemical Impedance Spectroscopy

Electrochemical impedance spectroscopy is powerful technique to obtain information about the kinetics of interfacial mass transfer processes for mild steel corrosion in the presence of the studied inhibitor. Impedance measurements were undertaken in 0.5 M HCl without and with HPB in the range 0.1 mM to 0.8 mM and at the temperature range 30–60°C. The recorded electrochemical impedance spectroscopy spectra in inhibited and uninhibited solutions are presented in term of Nyquist plot as shown in Fig. 2.

The Nyquist plots showed one depressed capacitive loop, a single time constant for the impedance response. The observed depression of the capacitive loop, however, indicates frequency dispersion of interfacial impedance. This anomalous phenomenon is attributed to the nonhomogeneity of the electrode surface arising from the surface roughness or interfacial phenomena [13]. When such non-ideal frequency response is present, the capacitor is replaced by a constant phase element (CPE), with impedance \(Z_{CPE}\) as follows,

\[
Z = Q^{-1}(iw)^{-n},
\]  

Where \(Q\) is the proportionality coefficient, \(w\) is the angular frequency, \(i\) is the imaginary number and \(n\) is the exponent related to the phase shift. If the value of \(n = 1\), the CPE behaves like an ideal double layer capacitor [14].

The double layer capacitance is calculated using the following equation:

\[
C_{dl} = \frac{1}{2\pi f_{max} R_{ct}},
\]  

where, \(f_{max}\) is the frequency at which the imaginary component of impedance is maximum [15].

![Chemical structure of HPB.](image)