



Corrosion inhibition of mild steel using Novel Bis Schiff's Bases as corrosion inhibitors: Electrochemical and Surface measurement



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ABSTRACT

Purpose: The aim of the present investigation is to evaluate the corrosion inhibiting properties of four novel synthesized compounds namely $N^1,N^{1'}-(1,4\text{-phenylene})bis(N^4\text{-(4-nitrobenzylidene)benzene-1,4-diamine})$ SB-I, $N^1,N^{1'}-(1,4\text{-phenylene})bis(N^4\text{-(4-methylbenzylidene)benzene-1,4-diamine})$ SB-II, $N^1,N^{1'}-(1,4\text{-phenylene})bis(N^4\text{-(4-methoxybenzylidene)benzene-1,4-diamine})$ SB-III, $N^1,N^{1'}-(1,4\text{-phenylene})bis(N^4\text{-(4-methoxybenzylidene)benzene-1,4-diamine})$ SB-IV for mild steel in 1 M HCl. Corrosion inhibitors find wide application in industries during pickling of steel, descaling and oil well acidization. Inhibitors have attracted great attention due to cost effectiveness and simplicity of the methods. **Method:** Different experimental techniques such as weight loss, open circuit potential (OCP), electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization were used to evaluate the corrosion inhibition performance of SBs for mild steel in acid solution. After the corrosion experiments, the surface morphology of metal surface in the absence and presence of SBs were studied by scanning electron microscopy (SEM) and Atomic force microscopy (AFM). **Findings:** The corrosion inhibition efficiency of SBs for mild steel are 71.42% (SB-I), 89.52% (SB-II), 92.85% (SB-III), 96.19% (SB-IV). Tafel polarization revealed that all the SBs behaved as mixed-type inhibitor but predominantly of cathodic type. The inhibition actions of these Schiff base molecules blocked the electrode surface by means of adsorption of the inhibitor molecule on metal surface, obeying the Langmuir adsorption isotherm. SEM/AFM studies of the metal surfaces confirm the protection of metal surface in presence of inhibitor as compared to the damaged surface in blank acid solution.

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1. Introduction

Corrosion is defined as degradation of metals as a result of chemical reaction with the surrounding environment. Corrosion causes heavy economic losses. In the United States, the economic losses reported in 1998 were \$276 billion per year which is now exceeds to \$1 trillion dollars a year. Mild steel is widely used metal in industries because

of its high strength, ease of fabrication and cost-effectiveness [1]. However it suffers from corrosion during acid cleaning, pickling, and descaling. Hydrochloric acid solution is used to enhance oil recovery during acidization [2–4]. The damage by corrosion generates not only high cost for renovation, replacement of various equipments, but in addition these constitute a public risk. Thus it is necessary to develop some effective corrosion inhibitors. The emphasis on the selection of corrosion inhibitor is based on the electron rich functional groups along with π -electrons inside their frameworks [5–8]. Earlier various organic compounds have been reported as corrosion inhibitors such as

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Tao et al. [9], Bentiss et al. [10] have reported triazoles inhibition efficiency 96% for DTP at 1.0×10^{-3} M and 97% for DHT at 4×10^{-4} M. Verma et al. [11], Zarrouk et al. [12] reported that pyrrole derivatives like PPC-I, PPC-II, PPC-III shows 94.38%, 96.99%, 98.69% at 50 mg/l and MPPD, PPD shows 97.5%, 94.4% at 1 Mm. Bouklah et al. [13] found that one of pyridine derivative P₁ gives 82% inhibition while pyridine P₂ itself gives only 17% at 5×10^{-3} M. Ouchrif et al. [14] have reported that HMPP (pyrazole) shows 88% inhibition at 10^{-3} M. The inhibition by indole derivative reported by Avci [15] gives 93% at 1×10^{-2} M. Schiff bases are also reported as effective corrosion inhibitors for metals giving inhibition efficiency (80–97%) in the concentration range of 300–3420 mg L⁻¹ [16–24].

The increasing popularity of Schiff bases in the corrosion field is due to their low cost starting materials, easy to synthesize, highly pure, low toxicity and eco-friendly in nature [25,26]. These facts motivate us toward the selection of four Schiff bases namely N¹,N^{1'}-(1,4-phenylene)bis(N⁴-(4-nitrobenzylidene)benzene-1,4-diamine) SB-I, N¹,N^{1'}-(1,4-phenylene)bis(N⁴-(4-methylbenzylidene)benzene-1,4-diamine) SB-II, N¹,N^{1'}-(1,4-phenylene)bis(N⁴-(4-methoxybenzylidene)benzene-1,4-diamine) SB-III, N¹,N^{1'}-(1,4-phenylene)bis(N⁴-(4-methoxybenzylidene)benzene-1,4-diamine) SB-IV as corrosion inhibitor for MS in 1 M HCl. The choices of these molecules are also based on their structural considerations. The four Schiff base derivatives different from each other due to the attached substituent's such as -CH₃, -OCH₃ and -NO₂ consists five benzene rings and delocalized π -electrons.

The aim of this study is to investigate the corrosion inhibition effect of SBs along with the substituent attached such as -CH₃, -OCH₃ and -NO₂ groups on MS in 1 M HCl by using weight loss, electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization techniques. The surface morphology is studied by SEM-EDX/AFM methods. Survey and literature reveals that these Schiff bases have not been reported as corrosion inhibitors.

2. Experimental

2.1. Materials and solutions

The MS coupons used for weight loss study having following composition (wt.%): C 0.17%; Mn 0.46%; Si 0.026%; Cr 0.050%; P 0.012%; Cu 0.135%; Al 0.023%; Ni 0.05%; and balance Fe. The MS coupons were mechanically cut into 2.5 cm $\times$ 2 cm $\times$ 0.025 cm dimensions for weight loss studies and 8 cm $\times$ 1 cm $\times$ 0.025 cm dimensions for electrochemical study with an exposed area of 1 cm² and rest of being covered by epoxy resin were used as working electrode. These coupons were abraded with emery papers (600–1200) of fine grades and washed. The test solution of 1 M HCl was prepared by diluting analytical grade 37% HCl with double distilled water.

2.2. Inhibitors

The SBs were synthesized according to the reported method [27] and crude products were recrystallized with methanol. The scheme of the synthesis is shown in

Scheme 1. The molecular structures of SBs are given in Table 1.

2.3. Weight loss measurements

Weight loss experiments were performed as reported earlier publications [28–30]. The abraded MS coupons were tested in absence and presence of various concentrations of SBs (100–250 mg L⁻¹) for 3 h of immersion time at 308 K.

2.4. Electrochemical measurements

The electrochemical experiments were performed by using Potentiostat/Galvanostat G300-45050 (Gamry Instruments Inc., USA). Echem Analyst 5.0 software package was used for data fitting. The electrochemical cell consist of working electrode with an exposed area of 1 cm², platinum electrode as an auxiliary electrode, and saturated calomel electrode (SCE) as reference electrode. All the experiments were performed after immersion of MS for 30 min in 1 M HCl in the absence and presence of SBs. Prior to polarization and EIS experiment the electrode was allowed to attain steady state potential i.e. OCP, was recorded as a function of time for 200 s without applying external potential or current. After this time, a steady-state OCP of the working electrode corresponding to the reference electrode was obtained. The EIS measurements were performed in a frequency range from 100 kHz to 0.01 Hz, with amplitude of 10 mV AC signal. Tafel curves were obtained by changing the electrode potential automatically from -0.25 V to +0.25 V versus open corrosion potential at a scan rate of 1.0 mV s⁻¹.

2.5. Surface characterization

2.5.1. Scanning electron microscopy (SEM-EDX)

Surface analyses of the MS coupons were studied by SEM model FEI Quanta 200F microscope at 500 $\times$ magnification. The changes in the metals surface were observed after 3 h of immersion time in the absence and presence of SB-IV at 250 mg L⁻¹.

2.5.2. Atomic force microscopy (AFM)

In addition to the surface analysis, AFM technique is also used which gives information about average surface roughness. The average surface roughness of uninhibited and inhibited MS surface was studied by Bruker Dimension Icon SPM with tapping mode in Air, RTESPA probe; $k = 40$ N/m and $f_0 = 302$ kHz, at 10 μ m.

3. Results and discussion

3.1. Weight loss measurements

3.1.1. Effect of inhibitor concentration

The variations in the corrosion inhibition efficiency for MS with changing the concentration (100–250 mg L⁻¹) of SBs in 1 M HCl are shown in Fig. 1 and the observed corrosion parameters such as corrosion rate (C_r), inhibition

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