Experimental approach of Sulfamethoxazole as a corrosion Inhibitor for Carbon Steel in 1M HCl

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Abstract. The inhibition effect of the *Sulfamethoxazole* as corrosion inhibitor for carbon steel in 1M HCl has been investigated at 303K temperature. Corrosion rate was analysed by using weight loss and electrochemical methods. The inhibitive action may be attributed to adsorption of inhibitor molecule on the active sites of mild steel. Polarization results indicates that the inhibitor act as mixed-type inhibitor. Electrochemical impedance spectroscopy was used to investigate the mechanism of corrosion inhibition.

Keywords: Inhibitor, EIS, SEM

1. Introduction

Carbon steel is an important category of material due to their wide range of industrial and structural applications. It is used in many industries due to its excellent mechanical properties. These are used in petroleum industries, storage tanks and reaction vessels. Acids are used for pickling, descaling, acid cleaning and other applications. Due to their high corrosive nature acids may cause damage to the system components. Various methods are used to reduce the corrosion rates in acids; among the different method use of inhibitor is commonly used. The use of inhibitors is one of the best methods of protecting metals against corrosion [1].

In present study focused on the study of inhibition effect of Sulfamethoxazole on corrosion of carbon steel in 1M HCl solution at different concentrations by weight loss, Tafel polarization, and electrochemical impedance spectroscopy measurements.

2. Material and methods

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2.1 Carbon steel

Corrosion studies were performed on mild steel strips with compositions 0.04% C, 0.35% Mn, 0.022% P, 0.036% S and the rest being Fe (99.55%) were used for all the experiments. Mild steel Strips of dimensions of 5 cm x 1 cm x 0.1 cm were abraded with emery papers from grade no.80 up to 1200, washed thoroughly with double distilled water, degreased with acetone and dried at room temperature were used for weight loss measurements. For electrochemical measurements same carbon steel strips were used, with an exposed area of 1 cm2 (rest is covered with Araldite resin).The corrosive media 1M HCl solutions were prepared by using AR grade HCl and distilled water.

2.2 Inhibitor

Sulfamethoxazole is a antibiotic drug molecule. It was dissolved in 1 cm^3 of ethanol, and then added into HCl corrosive media those were used for all the measurements. The IUPAC name of Sulfamethoxazole is 4-Amino-N-(5-methylisoxazol-3-yl) benzene sulfonamide. The molecular structure of inhibitor is as shown in Figure 1. Due to the presence of these electro-active elements in its structure is expected to act as a good inhibitor for corrosion of carbon steel in acid media. The range of concentrations of this inhibitor was used as in concentration ranges from 10 ppm to 50 ppm.

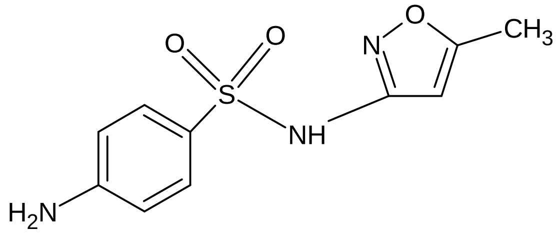

Figure 1. Molecular structure of Sulfamethoxazole.

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2.3 Weight loss measurement

Weight loss measurements were performed by immersing steel plates in a glass beaker containing 50 cm^3 of corrosive media (1M HCl) with different concentrations of inhibitor. After an immersion time of 24 hours, a steel plate was taken out and washed well with plenty of tap water followed by distilled water, dried and weighed accurately using digital balance. All experiments were carried out in static and aerated condition.

2.4. Electrochemical Measurements

The electrochemical measurements were carried out at the CHI608D electrochemical work station (manufactured by CH Instruments, Austin, USA) at 303 K. The cell consists of three electrodes namely, the working electrode (steel), counter electrode (platinum) and reference electrode (Ag/AgCl electrode). Before each electrochemical measurement, the working electrode was allowed to stand for 30 min in the test solution to establish steady state open circuit potential (OCP). In Tafel measurements, potential-current curves were recorded at a scan rate of 0.001 V s^{-1} in the potential range obtained by adding -0.2 and +0.2 V to the open circuit potential (OCP) value [2]. The corrosion parameters such as corrosion potential (E_{corr}), corrosion current density (i_{corr}) cathodicTafel slope (β_c) and anodic Tafel slope (β_a) were calculated from the software installed in the instrument. Impedance measurements were carried out using an AC signal with amplitude of 5 mV at OCP in the frequency range from 100 kHz to 10 mHz. The impedance data were fitted to the most appropriate equivalent circuit by using Z-Simp Win 3.21 software. The impedance parameters were obtained from Nyquist plots [3].

3. Results and Discussion

3.1 Weight loss method

The weight loss method of monitoring corrosion rate and inhibition efficiency is useful because of its good reliability [4]. Triplicate experiments were conducted and reproducibility of results obtained for both corrosion rate and percentage inhibition efficiency values. **Table 1** gives values of the inhibition efficiency (η_w) and corrosion rate (ρ) with different concentrations of Sulfamethoxazole for carbon steel in 1M HCl solution at 303 K temperature. The inhibition efficiency was calculated as follows

$$\eta_w = \frac{W^o - W}{W^o} \times 100 \qquad (1)$$

Where, W° and W are weight loss of carbon steel in the absence and presence of inhibitor. The rate of corrosion ρ (g cm^{-2} h^{-1}) was calculated from following equation.

$$\rho = \frac{W^o - W}{ST} \times 100 \qquad (2)$$

Here, *S* is the surface area of the steel strips and *T* is the immersion time in hours.

From the Table 1, the rate of carbon steel corrosion significantly decreased upon the addition of Sulfamethoxazole. The inhibition efficiency increased with increase in the concentration of the inhibitor and 50 ppm of inhibitor shows maximum inhibition efficiency about 82.14 %.

Table 1.
Corrosion parameters obtained from weight loss measurement.

Corrosive medium of Sulfamethoxazole(ppm)	**Corrosin Rate (gm/cm^2 hr)**	**Inhibition Efficiency(η_w) (%)**
Blank	0.028	-
10	0.016	42.50
20	0.013	53.57
30	0.008	71.42
40	0.006	78.57
50	0.005	82.14

3.2 Electrochemical Tafel Polarization measurement

Tafel polarization method is a best tool to calculate the corrosion kinetic parameters. In this measurement, the relationship of current against potential for the corrosion of carbon steel in absence and presence of various concentrations of inhibitor in 1M HCl solution were discussed. The Tafel plots were recorded by varying potential by ±0.1 V from the corrosion potential (E_{corr}) with a scan rate of 1mV/s by using electrochemical analyzer. The obtained Tafel plots are as shown in Figure 2. The electrochemical corrosion kinetic parameters such as corrosion potential (E_{corr}), corrosion current density (i_{corr}), corrosion rate, cathodic Tafel slope (β_c), anodic Tafel slope (β_a) and inhibition efficiency (η_p) are reported in Table 2.

The inhibition efficiency (η_p) was calculated from following relation,

$$\eta_P = \frac{i^0_{corr} - i_{corr}}{i_{corr}} \times 100 \quad (3)$$

Where, i^o_{corr} and i_{corr} are corrosion current density in the absence and presence of inhibitor, respectively.

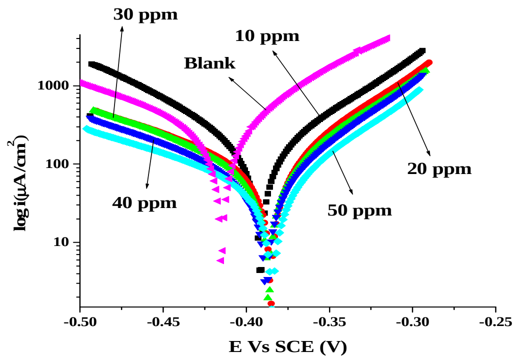

Figure 2. Tafel polarization plot

Investigation of Table 2, results obtained from the Tafel polarization measurement indicate inhibition efficiency (η_p) increased with increase the inhibitor concentrations. This behaviour shows because of the inhibitor adsorbing on the surface of carbon steel [5]. In the Tafel plots there is a reduction of both anodic and cathodic currents in the presence Sulfamethoxazole with different concentrations with respect to the blank solution. Which indicates that the addition of inhibitor, which slowdown the both anodic reaction (metal dissolution) as well as cathodic reaction (hydrogen evolution). The cathodic tafel slope (β_c) value of Sulfamethoxazole influence the kinetics of the hydrogen evolution reaction [6,7].

This is an indication of an increase in the energy barrier for proton discharge, leads to lesser hydrogen evolution. Almost same value anodic tafel slope (β_a) value for Sulfamethoxazole indicates that Sulfamethoxazole was first adsorbed onto the metal surface which blocking the reaction sites of the metal surface without affecting the anodic reaction [8]. In the present study there was a small change in corrosion potential (E_{corr}) value of 30 mV with respect to the blank solution, which shows that the Sulfamethoxazole acts as a mixed type inhibitor.

Table 2

Electrochemical Tafel polarization parameters.

Temp (K)	**Inhibitor conc^n (ppm)**	**Corrosion potential E_{corr} (V)**	**Corrosion current density i_{corr} (μA / cm^2)**	**Corrosion rate ν_{corr} (mpy)**	**Cathodic slope (βc) mV/dec**	**Anodic slope βa mV/dec**	**Inhibition efficiency η_p %**
303	Blank	-0.415	0.228	0.369	0.121	0.075	-
	10	-0.389	0.130	0.211	0.084	0.074	42.77
	20	-0.388	0.050	0.121	0.121	0.068	77.75
	30	-0.387	0.040	0.105	0.111	0.070	80.77
	40	-0.386	0.034	0.082	0.117	0.064	84.98
	50	-0.383	0.029	0.070	0.135	0.067	87.12

3.3 Electrochemical Impedance Spectroscopy (EIS) measurement

The impedance spectra (Nyquist plots) of carbon steel in 1M HCl containing various concentrations of sulfamethoxazole at 303K temperature is as shown in Figure 3. The experimental results of Electrochemical Impedance spectroscopic (EIS) measurements obtained for the corrosion of mild steel in 1M HCl in the absence and presence of various concentration of Sulfamethoxazole is given in Table 3. Measured impedance data were analyzed by fitting in to an equivalent circuit as shown in Figure 4. Table 2 Consists of Polarization resistances (Rp), double layer capacitance (Cdl) and inhibition efficiency (η) can be calculated by the fallowing equation.

$$\eta_Z = \frac{R_P(inhibitor) - R_P}{R_P(inhibitor)} \times 100 \quad (4)$$

Where R_P *(inhibitor)* and *Rp* are the charge transfer resistance in the presence and absence of inhibitor respectively.

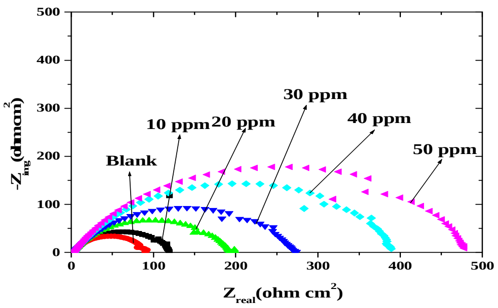

Figure 3: Nyquist plot

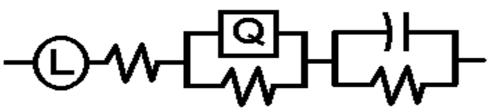

Figure 4 : Electrical Equivalent circuit model

Table 3
EIS Parameters

Temp K	Inhibitor con^n ppm	R_p Ωcm^2	C_{dl} $\mu F\ cm^{-2}$	η_z %	Surface coverage θ
303	Blank	88.30	1057	-	-
	10	119.01	859	25.80	0.25
	20	193.21	509	54.29	0.54
	30	270.61	462	67.37	0.67
	40	394.89	162	77.63	0.77
	50	484.68	141	81.78	0.81

The electrochemical impedance spectra (Figure 3) of carbon steel consist of semicircles. In general the diameter of the semicircles represents polarization resistance (Rp) value, which increases with increasing in Sulfamethoxazole concentration. This behaviour attributed due to the charge transfer process from the inhibitor molecule to the charged mild steel surface. Hence increasing Rp values, increases the inhibition efficiency of the mild steel by the inhibitor, we found inhibition efficiency up to 82 % at 333 K temperature as a maximum value.

From Table 3, the C_{dl} values are decreased with increase in inhibitor concentration due to the either decrease in dielectric constant or increase in the thickness of electric double layer due to the adsorption of *Sulfamethoxazole* at the metal/solution interface.

Conclusions

- Sulfamethoxazole acts as an efficient corrosion inhibitor for corrosion of mild steel in 1M HCl solution. Inhibition efficiency increases with increase in concentration of the inhibitor up to 88 % at 50 ppm concentration.
- Tafel polarization measurement concludes that, inhibitor acts as mixed type of inhibitor.
- The electrochemical impedance spectroscopy measurement concluded that the decrease of electrical double layer with increase in concentration of inhibitor suggested that the Sulfamethoxazole shows inhibitory action due to the adsorption process and also increase of Rp and Inhibition efficiency shows that Sulfamethoxazole is an excellent inhibitor.

Acknowledgements

The authors are grateful to Srinivas school of Engineering for providing the basic lab facilities to carry out the research work. PBM thank full to the principal and management of Jain Institute of Technology, Davanagere for their support.

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