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Corrosion Studies of Mild Steel (MS) in 3 M HCl Solution in the Presence of Expired Perindopril Drug: Mitigation of MS Corrosion by Green Corrosion Inhibitor

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Abstract

This original article emphasizes the mitigation of MS corrosion in 3 M HCl solution by expired perindopril drug. The weight loss (mass loss) and electrochemical (Tafel plot and impedance plots) techniques were employed for the MS corrosion inhibition studies. Weight loss technique results show that, MS corrosion in 3 M HCl solution can be prevented with the inhibitor concentration (expired perindopril drug concentration) and solution temperature dependent mode. The Tafel plot results show that, the expired perindopril drug acts as mixed type corrosion inhibitor for MS in 3 M HCl solution. The Nyquist plots in the absence and presence of the corrosion inhibitor confirms the adsorption of expired perindopril drug molecules on the MS surface in the 3 M HCl solution. The scanning electron microscopy (SEM) topography further supports the results of weight loss, Tafel plots and impedance spectroscopy results.

Keywords: Expired drug, Weight loss, Tafel plot, Impedance, scanning electron microscopy.

Introduction

The material (including) protection is a global issue and the mild steel (MS) corrosion is major problem faced by almost all chemical, pharmaceutical, and engineering and petroleum industries. Corrosion is spontaneous destruction of MS which results in the huge damage of the metal under consideration. This also results in the atmosphere pollution. Control of MS corrosion is economic, aesthetic, technical and academic interest. MS metals are widely used in several industries because of their noble properties (Charitha & Padmalatha Rao, 2018; Eddy et al., 2009; Bahrami, et al., 2010). During several industrial operations such as chemical and electrochemical etching, acid cleaning and pickling process the MS metal contacts with HCl solution. The presence of HCl on the MS surface accelerates the MS corrosion process. Among the various existing corrosion prevention methods, use of corrosion inhibitors is the industrial recommended and time tested method (De Souza & Spinelli, 2009; Lebrini et al., 2005; Gunasekaran & Chauhan, 2004). Many organic species were reported as MS corrosion inhibitors in various corrosive environments. But, many synthetic organic corrosion inhibitors are expensive and toxic in nature Kamal & Sethuraman, 2012; Ostovari et al., 2009; Narasimha Raghavendra & Jathi Ishwara Bhat, 2018; Narasimha Raghavendra & Jathi Ishwara Bhat, 2017). Nowadays, hazard free and safe environment are of universal concern. Hence, there is urge to explore the safe corrosion inhibitors to control the MS corrosion. Therefore, now corrosion research focused on the use of expired medicinal products as nontoxic corrosion inhibitors for different industrial important metals in various corrosive environments. In this regard, selected expired perindopril drug (contains electron rich elements) and

studied corrosion inhibition property on the MS corrosion in 3 M HCl solution by employing the weight loss (mass loss), electrochemical Tafel plot and impedance studies. The surface studies (to observe topography variation) in the absence and presence of expired perindopril drug were carried out by scanning electron microscopy (SEM) technique.

Materials and methods

The weight loss, Tafel plot, impedance and SEM studies was performed on the MS metal whose composition is mentioned in the **Table 1**.

Table 1. The chemical composition of MS

Element	Si	S	P	C	Mn	Fe
Wt %	0.1	0.05	0.04	0.18	0.6	Remainder (99.03%)

Before exposing MS metal in the 3 M HCl solution, it is polished with different grades of emery papers. 3 M HCl solution was prepared by diluting known volume of HCl solution in double distilled water. The expired perindopril drug was collected and four concentrations namely 1 mg, 2 mg, 3 mg and 4 mg was prepared for MS corrosion studies.

Weight loss technique

The MS metal pieces submerged in 100 ml of 3 M HCl solution without and with expired perindopril drug of four different concentrations namely 1 mg, 2 mg, 3 mg and 4 mg at 333 K with immersion period of 3, 6,9, 12 and 15 hours immersion period. The weight loss technique was carried out for three times and average values are reported.

The protection efficiency of the corrosion inhibitor can be calculated as per the below equation

$$\text{Protection efficiency (\%)} = \frac{(W_1 - W_2)}{W_1} \times 100$$

Where, W_1= Weight loss of MS in free 3 M HCl solution and W_2=Weight loss of MS in protected 3 M HCl solution.

Electrochemical studies

Electrochemical measurement (both Tafel plot and impedance spectroscopy) of MS corrosion in the 3 M HCl solution without and with expired perindopril drug of four concentrations was carried out with CHI660C workstation. The MS metal (working electrode) submerged in the 3 M HCl solution consisting two electrodes (platinum=auxiliary electrode and calomel as standard electrode). The electrochemical studies were carried out with scan rate of 1 mVs^{-1} in the potential range of −250mV to +250mV.

The corrosion current density obtained from the Tafel studies was used in the calculation of protection efficiency of the inhibitor,

$$\text{Protection efficiency} = [\,1 - \frac{i'_{corr}}{i_{corr}}\,] \times 100$$

Where, i'_{corr} = corrosion current density value in the presence of corrosion inhibitor and i_{corr} = corrosion current density value in the absence of the corrosion inhibitor.

The charge transfer resistance values obtained from the Nyquist plots are used in the calculation of the protection efficiency of the corrosion inhibitor

$$\text{Protection efficiency} = \frac{R_{ct(inh)} - R_{ct}}{R_{ct(inh)}} \times 100$$

where, R_{ct} = Charge transfer resistance value in the absence of the corrosion inhibitor and $R_{ct\,(inh)}$ = charge transfer resistance value in the presence of corrosion inhibitor.

Scanning electron microscopy (SEM) technique

The adsorption of expired perindopril drug on the MS in 3 M HCl solution with immersion period of 3 hour was confirmed by scanning electron microscopy (SEM) technique.

Results and discussion

Weight loss technique

The effect of immersion time on the protection efficiency of expired perindopril drug on the corrosion of MS in the 3 M HCl solution at 333 K was studied and results are presented in the **Table 2. Table 2** presents the values of protection efficiency for the MS in the 3 M HCl solution at different immersion time. The protection efficiency increases rapidly with inhibitor concentration and decreases with rise in the contact time from 3 hour to 15 hours. The protection efficiency increases with increase in the inhibitor concentration which is due to the formation of thick film on the MS surface in 3 M HCl solution. The maximum protection efficiency obtained at 4 mg of expired perindopril drug which is due to the formation of stable protective layer on the MS surface in 3 M HCl solution. The decrease in the protection efficiency with increase in the contact time can be explained by physical attraction process. The decrease in the protection efficiency with increase in the contact time from 3 hour to 15 hours is due to instability of protective film at longer contact period. Generally formation protective film needs some time to attain its stability in the 3 M HCl solution. For longer immersion period, the attack of corrosive ions from 3 M HCl is increases which negatively effects on the protective film on the MS surface. Finally, protective film loses its stability and hence free MS surface exposed to 3 M HCl solution. The physical attraction process results from the electrostatic forces between the expired perindopril drug molecules and MS surface in 3 M HCl solution. They are fast process, but it can be eliminated from the MS surface. The rise in the contact time from 3 hour to 15 hours usually facilitates the desorption process. The increase in the desorption process weakness the stability of the protective layer and accelerates the transport kinetics hence low protection efficiency values observed at higher immersion period.

Tafel plot studies

The potentiodynamic polarization plots for MS in 3 M HCl solution without and with expired perindopril drug of four different concentrations at 333 K are given in the **Figure 1.** The various Tafel parameters obtained from the potentiodynamic polarization curves are tabulated in the **Table 3.** From the **Table 3,** it is observed that, the corrosion current density values reduced with increase in the expired perindopril drug amounts. The decrease in the corrosion current density values with increase in the expired perindopril drug amounts is an indication of corrosion inhibition property of expired perindopril drug on MS in 3 M HCl solution. The increase in the protection efficiency is may due to the adsorption of expired perindopril drug on MS surface in 3 M HCl solution. The adsorption process is responsible for the decreasing the corrosion current density values. Further, there is no significant variation in the corrosion potential, cathodic and anodic Tafel slope values. Hence, expired perindopril drug can be classified into mixed type corrosion inhibitor.

Table 2 Weight loss results

Concentration (mg)	Immersion period	Protection efficiency (in percentage)
Blank	3	
1		80.000
2		84.5
3		90.000
4		95.000
Blank	6	
1		77.142
2		79.714
3		82.000
4		85.425
Blank	9	
1		67.213
2		72.131
3		75.409
4		80.327
Blank	12	
1		66.666
2		70.000
3		72.222
4		77.777
Blank	15	
1		54.545
2		58.181
3		60.909
4		63.636

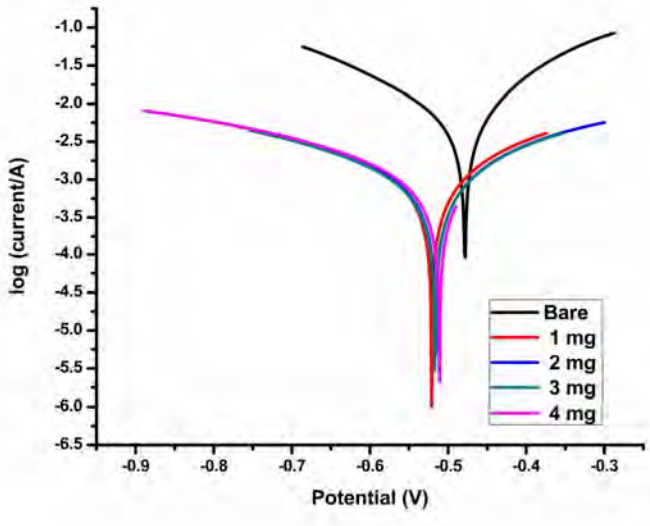

Figure 1 Tafel plots without and with inhibitor

Table 3 Tafel plot results

Concentration (mg)	Corrosion potential (mV)	Cathoidc Tafel slope (V/dec)	Anodic Tafel slope (V/dec)	Corrosion current (A)	Protection efficiency
Blank	-478	5.792	7.183	0.006398	
1	-521	4.624	5.573	0.0009349	85.387
2	-516	4.784	5.549	0.0008404	86.817
3	-517	4.785	5.638	0.0008052	87.414
4	-511	4.733	2.703	0.0004788	93.748

AC impedance spectroscopy studies

Figure 2 shows the Nyquist plots obtained for the MS corrosion inhibition at 333 K. The results obtained from the Nyquist plots are shown in the **Table 4.** It is observed that, the shape of the Nyquist plots is not changed in protected and unprotected systems, showing that there is no change in the MS corrosion in 3 M HCl solution due to the addition of expired perindopril drug of 1 mg, 2 mg, 3 mg and 4 mg concentrations. The increase in the depressed semicircle with increase in the inhibitor concentration is an indication of MS corrosion inhibition property of expired perindopril drug on the MS in 3 M HCl solution. The value of chare transfer resistance values are high in protected systems compared to unprotected system. The results of Nyquist plots fully support the potentiodynamic polarization and weight loss results.

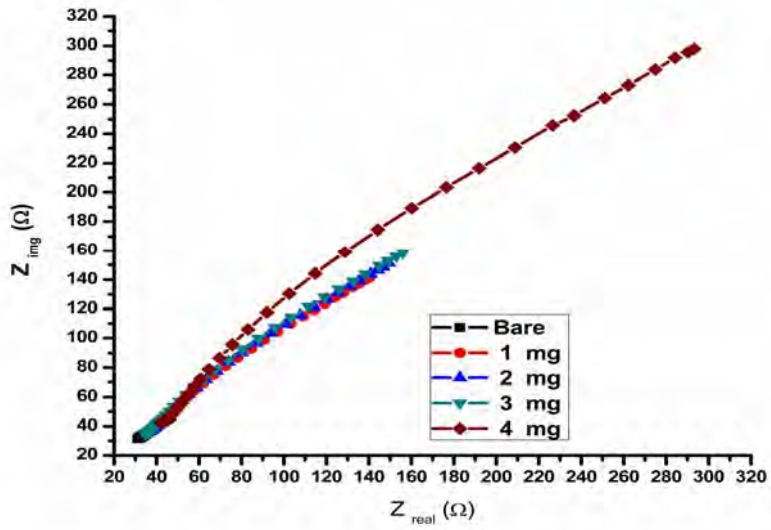

Figure 2 Impedance plots in unprotected and protected systems

Table 4 AC Impedance studies

Concentration (mg)	Charge transfer resistance (Ω)	Protection efficiency (%)
Blank	37.8	
1	145.3	73.984
2	150.7	74.917
3	169.2	77.659
4	299.6	87.383

Scanning electron microscopy (SEM) studies

The SEM topography of MS in the 3 M HCl solution without and with 4 mg of expired perindopril drug is shown in the **Figure 3.** The SEM topography of MS in unprotected system is rough with many cracks, whereas the SEM topography of MS in protected system is smooth which is due to adsorption of expired perindopril drug molecules on the MS surface in 3 M HCl solution. The smooth topography of MS in protected system is an indication of corrosion inhibition property of expired perindopril drug on MS surface in 3 M HCl solution.

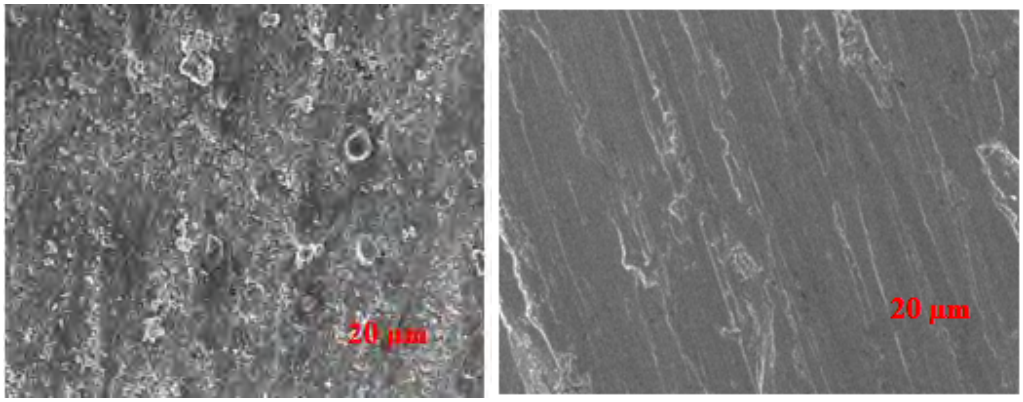

Figure 3 SEM images without and with inhibitor

Conclusion

This research article aimed towards exploration of sustainable corrosion inhibitor.

Based upon the weight loss, Tafel plot, impedance and scanning electron microscopy results, the following conclusions can be drawn:

a) Expired perindopril drug is an nontoxic corrosion inhibitor for the MS corrosion control in 3 M HCl system.

b) Expired perindopril drug act as mixed type corrosion inhibitor for the MS corrosion in 3 M HCl solution.

c) The remarkable MS surface smoothness was achieved by addition of Expired perindopril drug was confirmed by SEM analysis.

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