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Electrochemical Linear Polarization Studies of Amodiaquine Drug as a Corrosion Inhibitor for Mild Steel in 0.1M HCL Solution

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Abstract
The effect of amodiaquine on corrosion of mild steel in hydrochloric acid was investigated by linear polarization resistance (LPR) electrochemical method. The results indicated that corrosion inhibition efficiency and degree of surface coverage were increased with rise in the concentration of amodiaquine. The inhibitor followed monolayer chemisorption since it obeyed the Langmuir adsorption isotherm.
Keywords: linear polarization resistance (LPR), amodiaquine drug, corrosion inhibitor, mild steel, HCl

1. Introduction

The deterioration and corrosion of metallic structures is a global scientific problem as its effect cuts across various spheres of endeavours, be it in metallurgical, chemical, materials and oil industries (Bhat & Alva 2009). Therefore, efforts towards enhancing the corrosion resistance of metals have become a continuous idea (Popoola et al. 2012). Previous reports have shown the use of drugs as efficient corrosion inhibitors (Gece 2011; Fouda et al. 2010, Ahamad et al. 2010, Shukla & Quraishi 2010).

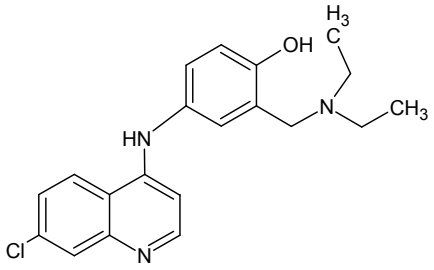
Hitherto, several methods have been employed in the monitoring and studying of corrosion processes including weight loss, gasometric, thermometric and various electrochemical techniques (Umoren et al. 2008; Khaled 2006; Umoren et al. 2009; Zhang & Hua 2009). The electrochemical technique offers an *in situ* set up that is quick, sensitive and non-destructive, whereby introduction of impurities due to handling of coupons are greatly reduced.

In contribution to the search for efficient corrosion inhibitors for metals in acidic corrodents, the authors undertake alternative focus on cheap and commercially available drugs and report in this paper, the result of the corrosion inhibition of mild steel in acidic medium by amodiaquine drug by electrochemical linear polarization technique. This investigation is part of an extensive project carried out and still going on in our laboratory to study the corrosion of metallic surfaces in various media and their inhibition by some drugs.

2. Experimental

2.1 The Inhibitor

The inhibitor used in this study was a drug with an anti-malarial and anti-inflammatory activities commonly call amodiaquine. It is chemically designated as 4-[(7-chloroquinolin-4-yl)amino]-2-[(diethylamino)methyl]phenol. The molecular formula of amodiaquine is $C_{20}H_{22}ClN_3O$ with molecular weight of 355.86g/mol. Amodiaquine has the chemical structure shown below:



Amodiaquine

The tablets of amodiaquine were obtained from a local pharmacy and were used without further purification. Appropriate concentrations of the drug were prepared by dilution.

2.2 Corrosive medium

The corrosive solution was prepared from reagent grade of HCl by dilution using doubly distilled water without further purification. The concentration of the solution ranged from 0.003M to 0.006M.

2.3 Mild steel specimen

Mild steel (98% Fe) used for this investigation was obtained and identified locally. The metal sheets were mechanically press cut into rectangular coupons of about 3cm by 3cm. The thickness of the metal was 0.1cm. In the electrochemical measurements, the working electrode was cut from the mild steel. The coupons were used without further polishing. However, they were degreased in acetone, washed with double distilled water and finally dried.

2.4 Electrochemical measurements

A conventional three-electrode system consisting of mild steel as working electrode, carbon as an auxiliary electrode, carbon as an auxiliary electrode and saturated calomel electrode (SCE) as reference electrode was used for the measurements.

3. Results and Discussions

3.1 Linear polarization resistance

In the linear polarization resistance (LPR) technique, the values of change in current as a result of applied potential obtained from electrochemical measurements are used. Useful data are obtained from the slopes extrapolated from the initial linear region of the polarization curves of the potential versus current plots (Stern 1958). After measuring the currents and potentials, a plot of the parameters measured for mild steel as the working electrode immersed in 0.1M HCl containing different concentrations of amodiaquine as inhibitor is presented in Figure 1.

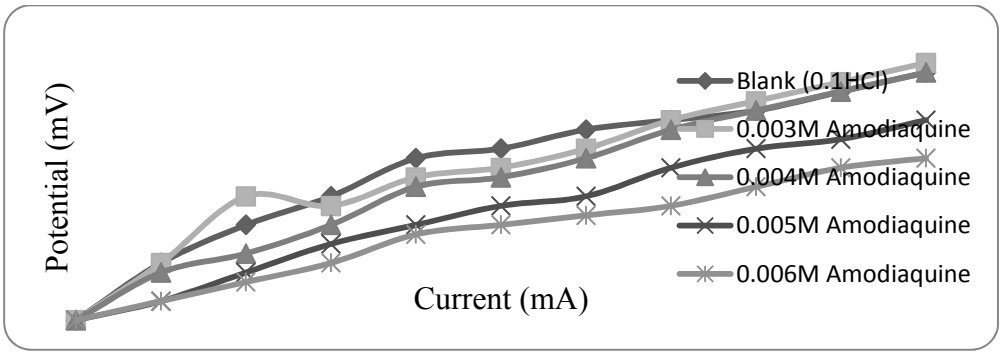


Figure 1: The variation of applied potential and current change for mild steel corrosion in 0.1M HCl in the presence and absence of different concentrations of the inhibitor.

With the help of equation 1, the polarization resistance (Rp) were computed from the slopes of the initial regions of the polarization curves according to Achary et al. 2008.

$$Rp = A \times (slope\ of\ plot\ of\ E\ versus\ I) \quad (1)$$

where A is the surface area of the electrode, E is the potential and I is the current.

The corrosion current densities (Icorr) were calculated from Equation 2 (Gerengi & Sahin 2012; Kuang et al. 2010). This was done to help give an insight about the extent of corrosion.

$$I_{corr} = \frac{B}{R_p} \quad (2)$$

where B is a proportionality constant, which equals 0.026V for a particular system (Gerengi & Sahin 2012).

The computation of Icorr gave access to the estimation of the percentage corrosion inhibition efficiency (%IE) via Equation 3 (Achary et al. 2008).

$$\%IE = \frac{I^o_{corr} - I_{corr}}{I^o_{corr}} \times 100 \quad (3)$$

where I^o_{corr} and I_{corr} are the corrosion current densities in the absence and presence of the inhibitor.

Observation of table 1 reveals that the corrosion current densities (Icorr) were higher in the free acid medium –meaning that corrosion rate was higher there. Again, it can be seen that the polarization resistance obtained for mild steel in the free acid solution as well as those containing different concentrations of the inhibitor indicate that the drug significantly increased the resistance of the metal against corrosion.

Table 1: It shows corrosion parameters obtained from polarization measurements for mild steel in 0.1M HCl in the presence and absence of different concentrations of the inhibitor at 30°C.

System/Concentration	Rp (Ωcm^2)	Icorr (mA/cm^2)	Degree of surface coverage (Θ)	%IE
Blank (0.1M HCl)	450	0.0578	-	-
0.003M Amodiaquine	545	0.0477	0.1747	39.73
0.004 M Amodiaquine	620	0.0419	0.2744	39.95
0.005 M Amodiaquine	696	0.0374	0.3536	43.60
0.006 M Amodiaquine	808	0.0322	0.4433	44.33

Polarization resistance increases as the inhibition approaches maximum when the metal apparently stops corroding (Stern 1958). The experimental data obtained for the polarization resistance (Rp) and corrosion current densities (Icorr) are consistent with the known theoretical basis for the method employed; that, corrosion current density (Icorr) has an inverse relationship with polarization resistance (Rp) (Achary et al. 2008).

The values of the corrosion inhibition efficiency shown in table 1 reveal that the polarization resistance (Rp), and in consequence the ability of the metal to resist corrosion, increased as the concentration of the inhibitor increased.

3.2 Adsorption isotherms

The available data have revealed that the action of corrosion inhibitors is due to adsorption of the inhibitor molecules on the surface of the corroding metal. The adsorption may be attributed to the nature and charge of the metallic surface, the type of the corrosive medium and the molecular structure of the inhibitor (Umoren et al. 2008; Zhang & Hua 2009).

The adsorption modes are usually confirmed from the fit of experimental data into the various adsorption isotherms. The calculated values of the degree of surface coverage (Θ) which gave access to the estimation of the adsorption mode are given in table 1 and were determined using Equation 4 (Achary et al. 2008).

$$\theta = 1 - \frac{(I_{corr})inhibited}{(I^{o}_{corr})unhibited} \qquad 4$$

where I_{corr} and I^{o}_{corr} are the corrosion current densities in the presence and absence of the inhibitor respectively.

As seen from table 1, the degree of surface coverage increased with increase in the inhibitor concentration. It may be assumed that the more molecules of the inhibitor were needed to effectively obtain a wider coverage area of the metallic surface.

It was found that the experimental data fits the Langmuir's adsorption isotherm shown in figure 2; where plots of log (Θ/(1-Θ)) versus the logarithm of the concentrations of the inhibitor produced a linear graph with correlation coefficient close to 1.00.

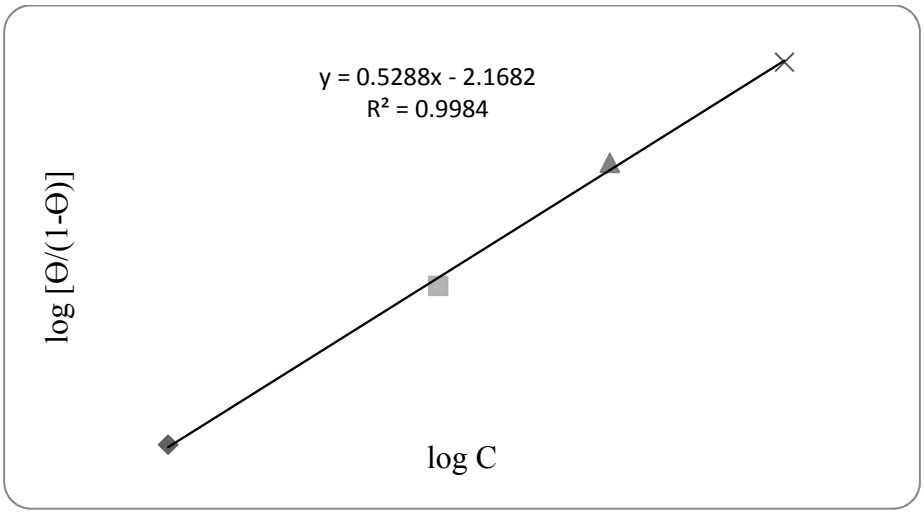


Figure 2: Langmuir's adsorption isotherm for mild steel in 0.1M HCl containing various concentrations of ciprofloxacin drug as inhibitor.

Based on the experimental data obtained, it is of assumption that mild steel corrosion in 0.1M HCl was inhibited by amodiaquine drug by adsorption unto appropriate sites of the electrode surface (Arab & Noor 1993). The Langmuir's adsorption isotherm assumes monolayer chemisorption (Saliyan & Adhikari 2009).

Conclusion

From the results of the study the following may be concluded:

1. Amodiaquine significantly acted as an inhibitor for mild steel under the investigated conditions.
2. The adsorption of amodiaquine on mild steel follows Langmuir adsorption isotherm.
3. Monolayer chemisorption most likely occurred as indicated in the Langmuir isotherm
4. The inhibiton efficiency was found to increase as the concentration modiaquine increased.
5. The inhibitory behaviour of the drug depicts the action of its molecular structure.

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