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Determination Of Inhibition Efficiency Of Corrosion Inhibitor Based On Polymethyl Methacrylate

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Abstract

In this article, the inhibition efficiency of the corrosion inhibitor obtained on the basis of monoethanolamine, methyl methacrylate and phosphoric acid was studied by electrochemical methods, Electrochemical impedance spectroscopy (EIS) measurements and potentiodynamic polarization measurements.

Keywords: Monoethanolamine, methyl methacrylate, phosphoric acid, electrochemical methods, Electrochemical impedance spectroscopy.

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1. Introduction

Corrosion is a reversible process, which converts pure metal to different chemical compounds [1]. Nowadays, corrosion is turning into a major issue in many industries, building materials, infrastructure, tools, ships, trains, vehicles, machines, and appliances [2]. Carbon steel experiences extensive corrosion during the cleansing process with acids. The NACE 2016 reported that across the world about 2.5 trillion U.S. dollars economic fall due to corrosion and Every year 10% of metal is lost due to corrosion which severely affects the country's economy [3]. Corrosion is not only responsible for an economic loss but also related with safety issues because it decreases theshelf life of steel [4]. It has already been recognized as a major issue for the entire world, soresearchers are trying to protect the corrosion process in various ways [5]. Mostly inhibitor is typically used to protect metal from corrosion and environmental friendly inhibitors have wide application in corrosion fields and it is generally added in the metal as a low concentration [6]. We believe this study is a small initiative to find a suitable corrosion inhibitor which can able to protect materials form corrosion process. According to this study, a corrosion inhibitor were prepared based on poly (methyl methacrylate-maleic anhydride) P(MMA-MAH) s accompanied with different percentage of methyl methacrylate and maleic anhydride and the inhibitory potentiality of this inhibitor has checked on simple carbon steel in a 0.5 M HCl [7-10].

2. Materials

To synthesize this composite corrosion inhibitor, monoethanolamine and methyl methacrylate monomers (purified by driving in inert nitrogen atmosphere) and phosphoric acid, such as 1 M HCl for aggressive environments, were used. Steel composition: Fe 97.755-97.215%, C 0.17-0.24%, Si 0.17-0.37, Mn 0.35-0.65%, Ni 0.3%, S 0.04 %, P 0.035 %, Cr 0.25 %, Cu 0.3 %, As 0.08 %. 2×2.5 cm2 samples of steel with this composition were taken, the surface was cleaned with sandpapers, washed several times in acetone and dried.

3. Methods

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Experimental part

Electrochemical studies

Electrochemical impedance spectroscopy (EIS) measurements are a valuable method for characterizing various electrochemical systems and understanding the function of electrolytic processes such as batteries and the behavior of molecules during corrosion. Figure 1 shows the Nyquist plots of St20 at different concentrations for the corrosion study.

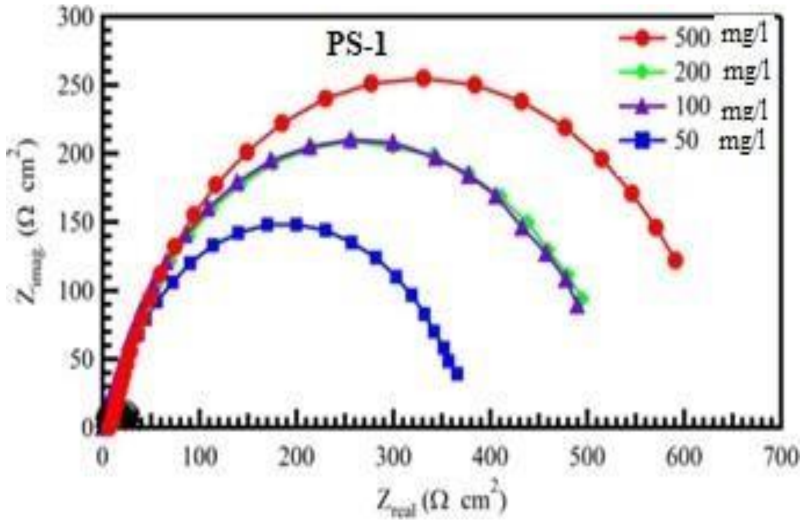

Figure 1. Nyquist plots of St20 steel in solutions in 1.0 M HCl without and in the presence of different concentrations of the MMF-1 inhibitor at 298 K

Table 1. Electrochemical impedance spectroscopy parameters of St20 in different concentrations of MMF-1 compounds and in 1.0 M HCl solutions without inhibitor at 298 K.

Inhibitor	**Inhibitor Concentration**	**E_a, kJ/mol**	**ΔH* kJ/mol**	**ΔS* kJ/mol·K**
	mg/l			
Vithout an inhibitor	0,00	-54,38	-53,69	-12,37
MMF-1	50	-97,56	-94,52	-121,64
	100	-106,67	-101,79	-144,68
	200	-125,31	-122,36	-203,56
	500	-144,89	-137,65	-262,17

The curved rings showed that the corrosion of St20 steel and the formation of surface barriers were mainly controlled by the electron transfer process. The equivalent circuit model shows in Figure 1. and was used to compare the experimental data on the impedance of St20 steel in the presence of inhibitors in 1 M HCl. According to model, the solution resistance Rs, charge transfer resistance, Rct and the double layer capacitance

(Cdl) on the metal surface were determined. Table 2 clearly explains that when additives were added to the 1M HCl solution then resistance to charge transfer, Rct and values for ST20 increased as a result the charge transfer pathways were hindered.

Inhibition efficiency, IE(EIS) and θ were calculated using the following formula (1 and 2):

$$E_{EIS} = \theta \times 100 = [\frac{R_{ct(inh)} - R_{ct(ninh)}}{R_{ct(inh)}}] \times 100 \qquad (1)$$

Here: Rct(inh) and Rct(ninh) were the resistance to charge transfer in the presence and absence of inhibitor respectively.

$$C\mathrm{dl} = (Y0R_{ct}^{1-n})^{\frac{1}{n}} \qquad (2)$$

where n was the constant phase element (CPE) indicator and Y0 was also the CPE constant. n value between 0 and 1was represented a deviation from ideal behavior. When the inhibitor was applied then the value of Cdl decreased which indicated the decreased of the local dielectric constant and also increased the thickness of the electrical double layer due to forming a protective layer on the metal surface.

Electrochemical frequency modulation (EFM) is an electrochemical method for calculating corrosion rates without prior knowledge of Tafel constants. Electrochemical requency modulation (EFM) has attracted the attention of corrosion researchers as a promising technique withhigh sensitivity due to the measurement of corrosion parameters at harmonics and intermodulations of input frequencies, as well as high accuracy due to the inherent calculation of causality factors. The ability of this method is to estimate corrosion rates, Tafel parameters, and causal factors in a single data set. Table 3 shows the corrosion parameters for protection efficiency, corrosion current density, Tafel constant, causal factors (CF-2) and (CF-3) for different concentrations in 1M HCl at 298 K.

Table 2. EFM parameters of CT20 in 1.0 M HCl in the absence and presence of different concentrations of compounds MMF-1 at 298 K

Inhibitor	**C**	**I_{corr}**	**βa**	**βc**	**K**	**CF**	**CF**	**θ**	**% IE**
	mg/l	(uA)	(mV dec^{-1})	(mV dec^{-1})	mm·y	**(2)**	**(3)**		**(EFM)**
Without an inhibitor	–	1071	72,53	94,36	459,87	2,12	3,24	0,92	92,31
MMF-1	50	82,64	52,41	61,25	39,62	1,63	1,95	0,93	93,42
	100	74,22	47,62	49,54	32,44	1,49	2,46	0,94	94,33
	200	60,56	29,54	33,17	26,53	1,15	2,97	0,95	95,15
	500	49,67	15,75	21,48	23,69	1,08	3,12	0,96	96,48

The equation can be used to calculate surface coverage and absorption efficiency %IE(EFM):

$$\%IE(EFM) = \theta \times 100 = (1 - \frac{i_{corr(inhibitors)}}{i_{corr(blank)}}) \times 100(3)$$

where $i_{corr\ (inhibitors)}$ and $i_{corr\ (blank)}$ are corrosion current density.

According to Table 3 results, the Icorr values has decreased with increasing inhibitor concentration, indicating that, when IE(EFM)) increases then these inhibitors can able to prevent corrosion by absorbing ST20 on the surface and forming physical and chemical bonds. As a result the corrosion coefficient decreased and created a protective barrier.

As per the EFM theory, the values of the causal factors (CF-2 and CF-3) were very close to their theoretical values (according to equation 2 and 3), indicating that the Tafel slopes and the corrosion current density were correct[.

Table 3. Corrosion parameters obtained from potentiodynamic polarization measurements of St2 steel in 1.0 M HCl at different concentrations of MMF-1 inhibitor at 298 K

Inhibitor	**C, mg/l**	**βa (mV dec^{-1})**	**βc (mV dec^{-1})**	**I_{corr}, (uA)**	**Ecorr vs.SCE**	**K (mpy)**	**Chi Squared**	**θ**	**IE**
Vithout an inhibitor	–	315	187	4076	-342	1822	87,62	–	–
MMF-1	50	214	238	409	-406	175,6	72,36	0,91	91,13
	100	237	223	316	-418	138,4	68,45	0,92	92,37
	200	221	289	253	-422	116,3	79,64	0,93	93,46
	500	235	302	218	-428	104,5	84,73	0,94	94,72

The polarization curves of St20 in 1 M HCl solution at 298 K with different inhibitor concentrations were determined using Equation 4.

$$\%IE\ (PDP) = \theta \times 100 = \left(1 - \frac{i_{corr(inhibition)}}{i_{corr(free)}}\right) \times 100 \qquad (4)$$

Graphs (Figure 6) of the logarithm of the current density were used to draw the polarization curve. The results of corrosion properties, including corrosion potential (Ecorr), corrosion current density (Icorr), anode and cathode Tafel slopes (If we plotted potential, E on the vertical axis and log i horizontally the gradients would be equal to ba and bc.) and inhibition efficiency percent, %IE (PDP) are included in the table-3. It has revealed that with the increase in the concentration of inhibitors in the anode and cathode reactions process, the inhibition efficiency has.

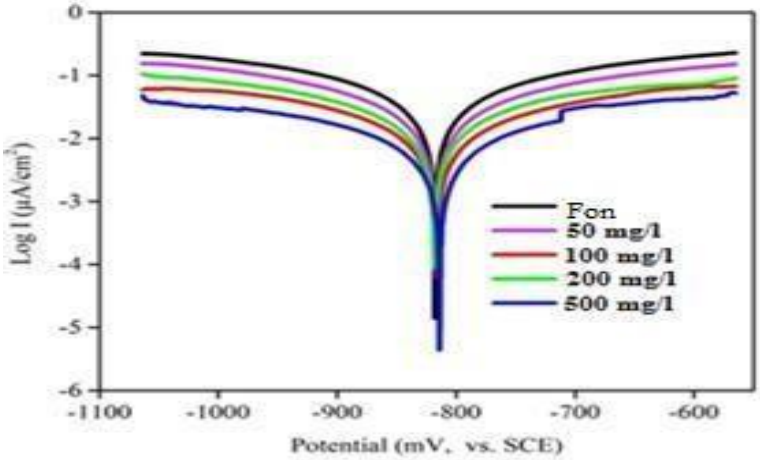

Figure 6. Tafel plot of CT20 at different inhibitor concentrations in 1.0 M HCl solution at 298 K.

Increased significantly. This protective barrier was formed by unsaturated bonds to the heteroatom and inhibitors on the surface of carbon steel. Depending on the type of reaction that often occurs in an acidic solution, the inhibitor can be an anode, cathode, or mixture. The cathodic process in which hydrogen gas evolution is observed and the dissolution of metals and the release ofelectrons are also happened at anodic process[17-22]. The plausible explanation is that the hydrogen evolution and electrochemical results usually confirm the potential ability of metal dissolution process. In addition that by controlling the charge transfer charge, hydrogen gas developed in the cathodic reaction is successfully used as a variable to separate the contribution of hydrogen gas and hydroxyl ions to the cathodic delamination of the organic coating / inhibitor film.

4. Conclusion

The MMF-1 corrosion inhibitor based on methyl methacrylate, monoethanolamine, and phosphoric acid was obtained with a yield of 87% and its structure was firmly established by spectroscopic techniques. Thermal and electrochemical properties have been studied as well. The main target of this works is to establish a newly corrosion inhibitor in terms of efficiency against corrosion process. The final postulations are made by authors which are listed below: The noteworthy observation was that the obtained composite corrosion inhibitor has been established as 94.72% Inhibitor efficiency (IE) based on electrochemical analysis method. MMF-1 corrosion inhibitor can easily use it commercially as a corrosion inhibitor based on its efficiency. However, the authors have suggested that further testing of the inhibitor's efficiency should be done prior to establish as a corrosion inhibitor.

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