Anti-corrosion and Adsorption behavior of Brompheniramine Maleate on Mild Steel in Hydrochloric acid

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Abstract:
Organic compounds are widely used as inhibitors in that series brompheniramine maleate was taken as the inhibitor here. The anti-corrosion activity and adsorption ability of various concentration of brompheniramine maleate on mild steel in 0.5 M hydrochloric acid analysed by weight loss, electrochemical impedance spectroscopy and tafel polarization. It was observed that the Inhibition efficiency of the inhibitor increases with increase in concentration of inhibitor. Inhibition efficiency increases due to the formation of protective film on mild steel, the protective film formation on mild steel were analysed by Scanning electron microscope (SEM).

Keywords: Mild steel, Brompheniramine maleate, Potentiodynamic polarization, SEM, Electrochemical impedance spectroscopy

1. INTRODUCTION

The degradation of a metal by the action of air, moisture or acids is called corrosion. In modern industry carbon is the most prominent additive to a ferrous material but alloying elements of all sorts are common, In fact alloying elements are common even in piping products still considered to be Mild steel, mild steel pipes are widely used in many Industries due to its strength, easy of workability and low cost, but the surfaces of the mild steel were damaged in acid medium[1-2], To avoid this kind of issue various techniques such as anodic protection, cathodic protection and inhibitors are used. Organic inhibitor plays an important role in corrosion inhibition due to their adsorbed layer formation on the surface of Mild steel [3-6]. The aim of this study is to analyse the adsorption and inhibition efficiency of brompheniramine maleate in 0.5 M hydrochloric acid. The weight loss method, electrochemical impedance spectroscopy, potentiodynamic polarization and scanning electron microscopy confirms the shielding layer formation and increase the inhibition efficiency as the concentration of inhibitor increases

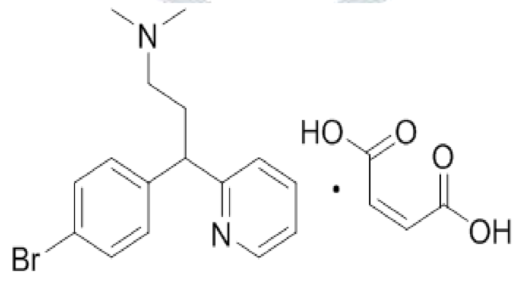

Figure 1. Structure of Brompheniramine maleate

2. EXPERIMENTAL

2.1. Material preparation

In the current study the mild steel with the composition of C - 0.10%, P - 0.06%, Mn - 0.40%, S - 0.026% and the rest of iron used, the size of the specimen was 1 x 4 x 0.2 cm^3 and it is abraded using 200-600 emery sheets. Mild steel was washed with double distilled water followed by acetone. Inhibitor used in this study is brompheniramine maleate it was bought from Sigma Aldrich, To prepare Brompheniramine maleate solution, one gram of Brompheniramine maleate dissolved and made up to 100 ml using 0.5 M hydrochloric acid in SMF, hydrochloric acid is prepared using double distilled water, Various concentration of inhibitors such as 100, 200, 300, 400 and 500 ppm were used to study the inhibition efficiency and shielding layer formation on mild steel

2.2. Weight loss method

In this method, the polished and weighed mild steel specimen were dipped in 0.5 M HCl with and without various concentration of brompheniramine maleate taken in aerated 100 ml beaker for 1 hr. All the test are conducted at room temperature after 1 hr., the specimens were taken out dried and weighed accurately, corrosion rate is calculated by the given formula

$$\text{CR (mg.dm}^{-2}\text{.hr}^{-1}) = W = \frac{M1 - M2}{SP}$$

Where, M_1- specimen mass before corrosion, M_2 - specimen mass after corrosion, S - total surface area of specimen exposure, P - the period of immersion in hour. The inhibition efficiency calculated by the formula given below

$$\text{IE (\%)} = \frac{(W_0 - W_i)}{W_0} \times 100$$

Where, W_i - corrosion rate in the absence of brompheniramine maleate, W_o - corrosion rate in the presence of brompheniramine maleate

2.3. Potentiodynamic polarization studies

Electrochemical analysis includes two essential techniques namely electrochemical impedance spectroscopy and tafel polarization which were used to study corrosion. Electrochemical impedance Spectroscopy studied by utilising cell assembly with three electrodes, Platinum wire used as a counter electrode, mild steel with the exposed surface area of 1 cm^2 acted as the working electrode, and saturated calomel electrode acted as reference electrode. Stable value of OCP must be obtained before the electrochemical measurements for that the working electrode must be immersed in 0.5 M HCl without brompheniramine maleate and then the OCP recorded for 30 minutes after that the measurement were carried out with brompheniramine maleate, electrochemical impedance measurement were studied by Princeton Applied Research analyzer in the frequency range from 1Hz to 1000000 Hz with 0.01 volt amplitude AC signal, as the result nyquist plots were obtained. In this research, the mild steel of 1 cm^2 surface area was open to the corrosion medium. The examinations were carried out in 0.5 M hydrochloric acid with many concentration of inhibitor at room temperature.

2.4. Characterization of surface morphology

The surface morphology of the metal surface were studied from scanning electron microscopy of TESCAN Vega 3 model, the surface morphology of bare mild steel, mild steel in the corrosion medium with and without the presence of brompheniramine maleate was analyzed.

3. RESULT AND DISCUSSION

3.1. Weight Loss Measurement

In this method the mild steel was exposed in the presence and absence of brompheniramine maleate in 0.5 M HCl in the duration of one hour throughout the process room temperature was maintained and the values were given in table 1. In the weight loss method it was detected that, once the concentration of inhibitor increases, IE (%) too increases, the extreme inhibition efficiency 73.69 % was attained in 500 ppm of Brompheniramine maleate in corrosion medium later the dipping period of 1hr. Figure 2(a) shows the graph drawn among inhibitor concentration and inhibition efficiency evidently displays that the extreme inhibition efficiency is reached at 500 ppm concentration of inhibitor, extra addition (600 and 700 ppm) of inhibitor concentration at no time creates any notable variation in the inhibition efficiency. The cause may be, the surface of the mild steel is totally adsorbed by the dynamic sites of the inhibitor, and there is no blank surface for adsorption of extra addition of inhibitor concentration. In Figure 2(b), the graph drawn among inhibitor concentration and corrosion rate, it evidently shows that rate of corrosion decreases from 106.82 $mgdm^{-2}day^{-1}$ to 28.41 $mgdm^{-2}day^{-1}$, when increase the concentration of inhibitor from 100 ppm to 500 ppm. The inhibitor inhibit the corrosion may be due to the π bond and heteroatoms like oxygen, nitrogen which is existing in the Brompheniramine maleate, which creates an inhibitor molecule to adsorbed on the metal surface and forms the shielding layer [7] which is water insoluble, so that corrosion is prevented.

Table 1. Corrosion rate and inhibition efficiency found from weight loss method for mild steel dipped in 0.5 M hydrochloric acid in the absence and presence of many concentrations of Brompheniramine maleate

Conc. of PM (ppm)	Weight loss ($mg.dm^{-2}$)	CR ($mg.dm^{-2}.day^{-1}$)	Surface coverage (θ)	IE (%)
Blank	10.67	106.82	-	-

100	5.90	59.01	0.4458	44.58
200	4.93	49.33	0.5358	53.58
300	4.14	41.48	0.6154	61.54
400	3.42	34.23	0.6798	67.98
500	2.84	28.41	0.7369	73.69

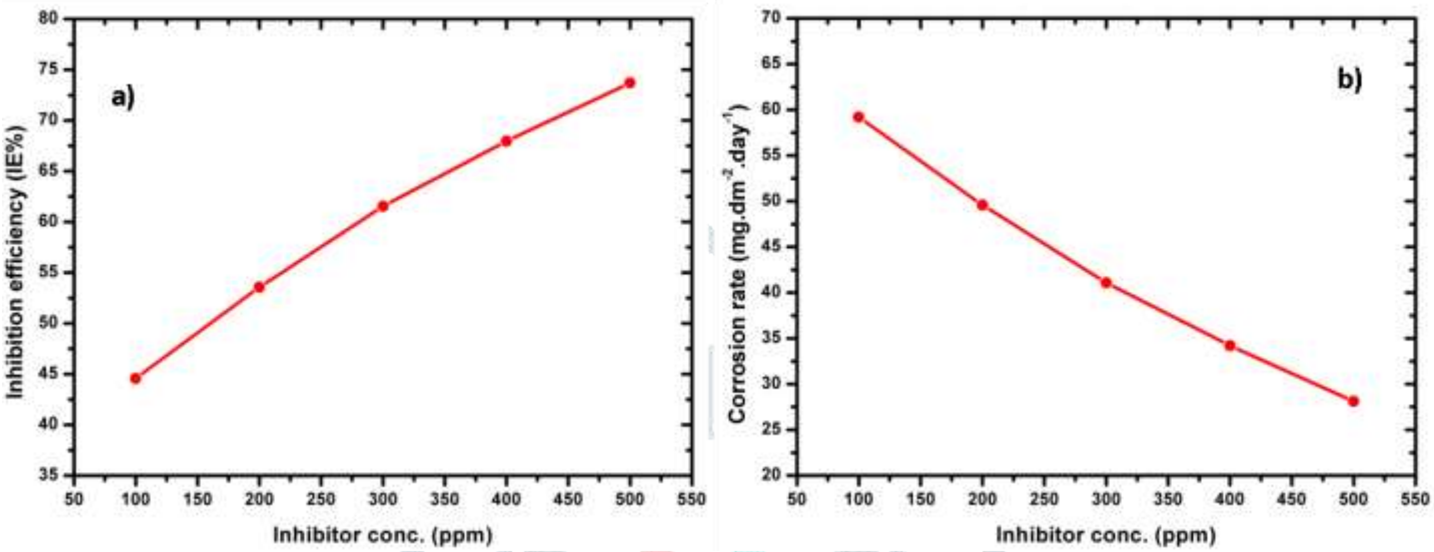

Figure 2. Weight loss curves of various concentrations of Brompheniramine maleate in 0.5 M hydrochloric acid: (a) variation of IE (%) with different concentration of Brompheniramine maleate and (b) variation of corrosion rate with different concentration of Brompheniramine maleate

3.2. Potentiodynamic polarization

Tafel polarisation plot of mild steel in 0.5 M HCl with and without different concentrations of brompheniramine maleate at room temperature is shown in figure 3. It shows both anodic and cathodic arc, the electrochemical data obtained from this plot is cathodic slope (βc), anodic slope (βa), corrosion current (I_{corr}), surface coverage area (θ), corrosion potential (E_{corr}) and inhibition efficiency were listed in Table 2, Inhibition efficiency in one hundredth were calculated by means of the following formulation[8].

$$IE\% = \left(\frac{I°corr - Icorr}{I°corr}\right) \times 100$$

Where I_{corr} and $I°_{corr}$ are the corrosion current density values in the presence and absence Brompheniramine maleate respectively, while increasing the inhibitor concentration of Brompheniramine maleate from 100 to 500 ppm in the 0.5 M hydrochloric acid solution, the corrosion current density values reduced (see Figure 3 and Table 2) at same time corrosion current density increased to a maximum value for 500 ppm of Brompheniramine maleate. The I_{corr} value of blank 480.502µA/cm^{-2} is reduced and reached the minimum value of 119.356 µA/cm^{-2} for 500 ppm of Brompheniramine maleate, it shows both anodic dissolution of mild steel and cathodic reduction reactions were reduced by the addition of Brompheniramine maleate due to the development of shielding layer, In this study the percentage inhibition efficiency increases with increase in the inhibitor concentration of Brompheniramine maleate which is also established well with weight loss method, All the above shows that addition of Brompheniramine maleate prevent the corrosion by the formation of shielding layer on the surface of mild steel. Inhibitor can be classified into two types, such as cathodic and anodic inhibitors. If E_{corr} value displacement towards anode or cathode is greater than 85 mV/SCE, with reference to the blank the indicator is anodic or cathodic, if not then the inhibitor taken for this study was considered as a mixed inhibitor[9-12], In Brompheniramine maleate E_{corr} difference between blank and inhibitor is 30.839 mV/SCE (-453.609 mv/SCE to -484.448mV/SCE). It is less than 85 mV/SCE, it shows that Brompheniramine maleate is a mixed type of inhibitor in 0.5 M hydrochloric acid corrosion medium.

Table 2. Potentiodynamic polarization data for mild steel in 0.5 M hydrochloric acid in the presence and absence of Brompheniramine maleate

Inhibitor concentration (ppm)	Blank I_{corr} (μAcm^{-2})	Inhibitor I_{corr} (μAcm^{-2})	E_{corr} (mV)/SCE	β_a (mV dec^{-1})	β_c (mV dec^{-1})	Surface coverage (θ)	IE_{PDP} (%)	IE_{WL} (%)
Blank	480.502	-	-453.609	70.877	211.373	-	-	-
100	480.502	233.203	-454.289	82.578	187.728	0.5146	51.46	44.58
200	480.502	215.038	-472.844	73.732	141.852	0.5524	55.24	53.58
300	480.502	211.389	-479.163	69.637	123.733	0.5600	56.00	61.54
400	480.502	139.463	-484.941	118.281	122.003	0.7097	70.97	67.98
500	480.502	119.356	-484.448	87.296	109.998	0.7516	75.16	73.69

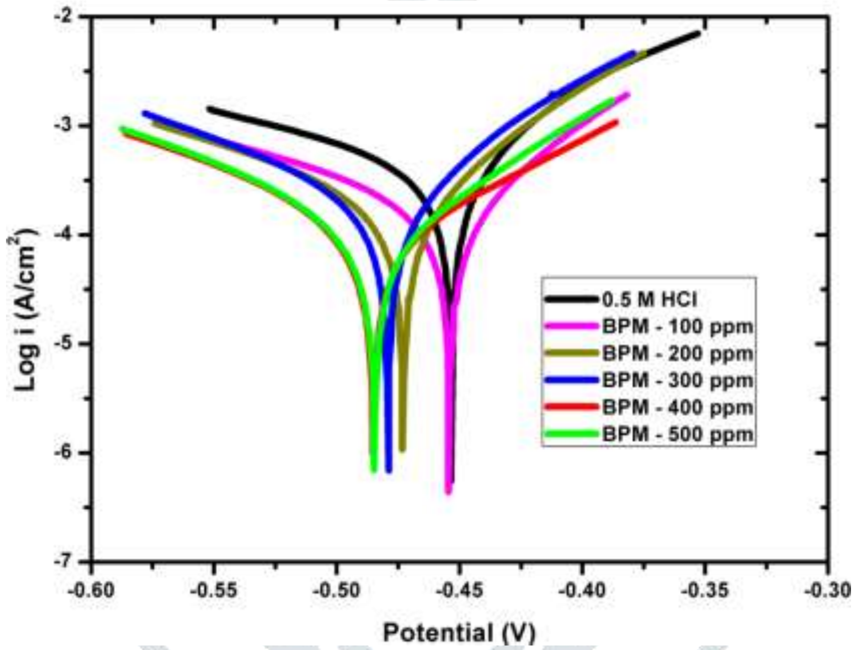

Figure 3. Potentiodynamic polarization curves for mild steel in 0.5 M hydrochloric acid in the presence and absence of Brompheniramine maleate.

3.3. Electrochemical impedance spectroscopy

Inhibition efficiency of mild steel in 0.5 M HCl at room temperature with and without various concentration of brompheniramine maleate is analyzed by electrochemical impedance Spectroscopy measurement. Nyquist diagram of mild steel corrosion in 0.5 M HCl with different concentration of brompheniramine maleate are given in figure 4, it provides the value of charge transfer resistance (R_{ct}) and double layer capacitance (C_{dl}) which is specified in the table 3. very simple electrical equivalent circuit[13-14] were used to explain the nature of Impedance, charge transfer resistance (R_{ct}), double layer capacitance (C_{dl}), and the resistor (R_s) and it is exposed in Figure. 5.

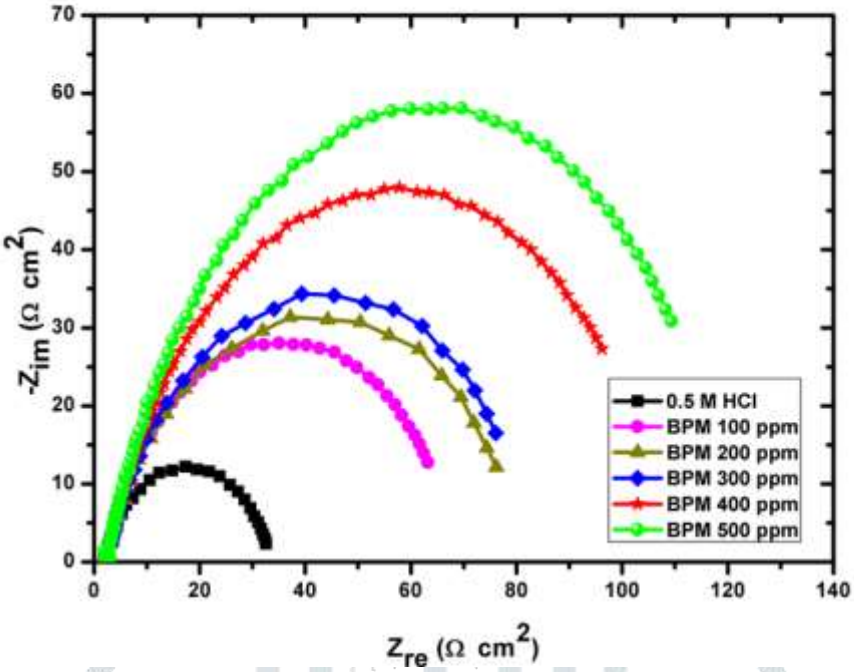

Figure 4. Nyquist graph for mild steel in 0.5 M hydrochloric acid in the presence and absence of Brompheniramine maleate

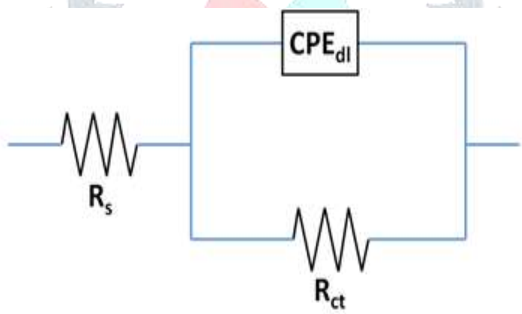

Figure 5. Equivalent electrical circuit used to fit the impedance spectra acquired for mild steel in 0.5 M hydrochloric acid in the presence and absence of Brompheniramine maleate

R_{ct} is the charge transfer resistance, R_s is the solution resistance and CPE_{dl} is the constant phase equivalent of double layer was exposed in the equivalent electrical circuit. From the nyquist plot, as soon as the inhibitor concentration of Brompheniramine maleate increases, the semicircle diameter (R_{ct}) increases. It indicates that, there is a creation of shielding layer on the mild steel surface. when the concentration of Brompheniramine maleate increases, charge transfer resistance increases and the double layer capacitance decreases this is due to the creation of shielding layer on the mild steel by the adsorption of Brompheniramine maleate and reduce dissolution reaction which extra reduce the corrosion of mild steel [15], the degrease in the C_{dl} value is due to the increase in the thickness of the electrical double layer by the adsorption of Brompheniramine maleate on mild steel. The IE (%) was calculated from R_{ct} values through the following equation.

$$IE\% = \left(\frac{R_{ct(i)} - R_{ct(b)}}{R_{ct(i)}} \times 100\right)$$

Where $R_{ct(b)}$ and $R_{ct(i)}$ are the uninhibited and inhibited charge transfer resistance correspondingly. From the table 3, the increase in the value of IE (%) with respect to the increase in the inhibitor concentration is due to the increase in the charge transfer resistance and corresponding decreases in the double layer capacitance value. Double layer capacitance (C_{dl}) is related to the thickness of the adsorbed shielding layer (d) by the equation [16-19],

$$C_{dl} = (\varepsilon\varepsilon_o A)/d$$

Where, ε - dielectric constant of the medium, ε_o - free space permittivity and A -surface area of the electrode. The decrease in the double layer capacitance value indicate that, there is an increase in the thickness of the double layer due to the strong adsorption of Brompheniramine maleate which prevent the mild steel dissolution in 0.5 M hydrochloric acid.

Table 3. Potentiodynamic polarization data for mild steel immersed in 0.5 M hydrochloric acid in the presence and absence of Brompheniramine maleate

Inhibitor concentration (ppm)	$R_{ct\ (blank)}$ ($\Omega\ cm^2$)	$R_{ct\ (i)}$ ($\Omega\ cm^2$)	Y_{max}	C_{dl} ($\mu F\ cm^{-2}$)	IE (%)	θ(imp)
100	30.391	64.662	32.33	7.6168E-05	53.00	0.5300
200	30.391	70.935	35.46	6.3292E-05	57.15	0.5715
300	30.391	80.107	40.05	4.9628E-05	62.06	0.6206
400	30.391	104.28	52.14	2.9287E-05	70.85	0.7085
500	30.391	117.64	58.82	2.3012E-05	74.16	0.7416

3.4. Surface analysis

Scanning electron microscopy (SEM) images are given in Figure 5. Figure 5(a) indicates that the uniform surface of mild steel earlier immersion of corrosion medium, Figure 5(b) indicates that the uneven surface of mild steel due to the pits observed after the immersion of 0.5 M hydrochloric acid for 1hr, but Figure 5(c) indicates that there is smooth surface of metal, when it was taken from 0.5 M hydrochloric acid with Brompheniramine maleate, This is due to the adsorption of Brompheniramine maleate on the surface of the mild steel.

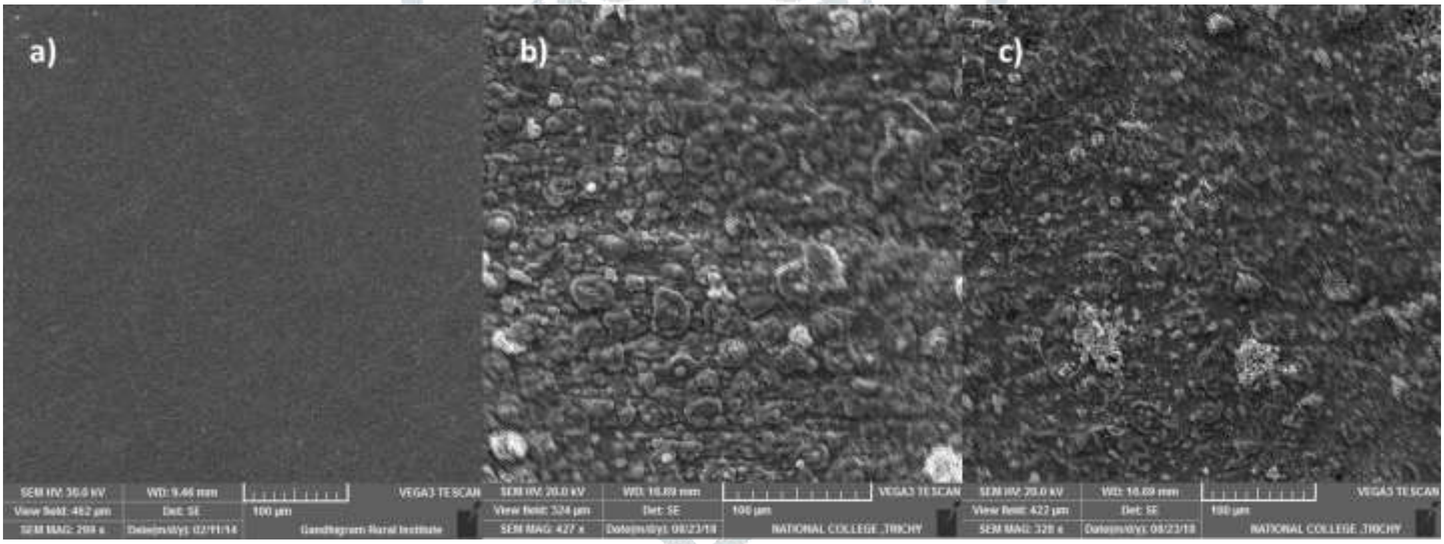

Figure 5. SEM images of mild steel: a) polished mild steel, b) mild steel immersed in 0.5 M hydrochloric acid and c) mild steel immersed in 0.5 M hydrochloric acid in presence of Brompheniramine maleate.

4. CONCLUSION

1. Brompheniramine maleate act as a good corrosion inhibitor for mild steel in 0.5 M hydrochloric acid corrosion medium, its maximum Inhibition efficiency is 73.69 % from weight class method.
2. Potentiodynamic polarization studies indicate that Brompheniramine maleate act as a mixed type of inhibitor.
3. Electrochemical impedance studies indicates that, when the concentration of Brompheniramine maleate increases, the thickness of electrical double layer also increases due to the adsorption of Brompheniramine maleate on the surface of the mild steel
4. The creation of shielding layer on the surface of the mild steel was confirmed by the smooth surface of SEM images

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