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Synthesis of Novel Organic Compound as Corrosion Inhibitor in Hydrochloric acid Medium-A Comparative Study

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ABSTRACT

A novel organic compound derivativeof Benzothiazole, BFCPA[N-Substitued-1,3-benzo-thiazol-2pheny-2-[4-(furan-2-carbonyl)piperazin-1-phenyl] acetamidehas beensynthesizied and used as inhibitor on mild steelcorrosion in 1N and 2N HCl acidic medium.Using this inhibitor the rate of orrosion and inhibitor efficiency was analysed by mass loss data and electrochemical analysis. Byincreasing concentration of the inhibitor BFCPA exhibits good corrosion inhibition effectiveness less corrosion rate shows the electron donating property.The structure of BFCPA has been confirmed using various spectral studies. Based on adsorption studies it reveals Langmuir adsorption isotherm.

Keywords: BFCPA, Corrosion inhibitor, Mass loss data and Polarization study.

INTRODUCTION

Mild steel (MS), often known as low percentage carbon steel, is a wonderful industrial material that is commonly utilized in chemical industries[1]. The use of inhibitors is one method of preventing corrosion in acidic environments[2]. Corrosion inhibitors are organic chemicals that have long been used to prevent corrosion in corrosive situations[3,4]. The organic molecule acts as an adsorbent on the mild steel surface, blocking active sites and thereby slowing the corrosion rate[5-7]. Furthermore, several organic compounds have been identified as corrosion inhibitors during the acidification process in industrial cleaning. Organic inhibitors hinder ion or more resistant ion adsorption on the metal surface[8-10]. The inhibitory efficacy of these chemicals is mostly determined by the adsorbent's composition and the structure of the adsorbent layer on surface of the metal. Nitrogen, Oxygen, Sulfur, and Phosphorus atoms are efficient organic molecule inhibitors[11,12]. The inhibition efficiency is determined by the sequence ONSP[13]. Many researchers study organic corrosion inhibitors using various manufactured organic compounds with hetero atom oxygen and sulphur atoms in the rings[14-17]. Adsorption of an organic inhibitor on a metal surface often includes water molecule replacement[18,19]. Organic inhibitors work by adsorbing on the surface of metals, blocking the active site and forming a compact barrier, lowering the corrosion rate[20-24]. We focus on innovative corrosion, organic inhibitors such as

BFCPA, which has been successfully synthesized and used as a mild steel corrosion inhibitor in 1N and 2N hydrochloric acid. The inhibitor effect was investigated using a variety of approaches, including weight loss, adsorption isotherm, potentiostatic polarization, and AC impedence assessment of mild steel.

MATERIALS AND METHODS

Mass loss method

Preparation of Specimen

Mild steel specimens with a percentage of composition were cut to an overall apparent size of 5cm in to 1cm. The elements are as follows: Fe- 99.78, Ni-0.012, Mo-0.016, Cr-0.038, Si-0.014, P-0.011, Mn-0.171, C-0.014. The steel specimens were polished using several sizes of emery papers, including 150, 320, 400, 800, 1200, and 2000, before being degreased with acetone, dried, and weighed. For electrochemical experiments such as potentiostatic polarization tests, a 1X1 cm^2 zinc electrode with stem was cut off. The electrodes were polished using grade 1, 2, 3, and 4 emery sheets and washed with acetone.

Preparation of solution

All experimental arrangments were made in twofold refined water with AR grade reagents and warmed for 15 min before deareraration of these electrolytes. Gentle steel example were submerged, after the culmination of 2 h, the coupons were eliminated from the drenched medium and washed with twofold refined water and $(CH_3)_2CO$. From the underlying weight and last weight contrast gives mass misfortune information. Weight reduction information, for example, the pace of erosion, effectiveness inhibitor, surface inclusion was determined utilizing the equation. The corrosion rate were calculated in mmpy (milli miles per year) using the relation. This method was processed at various inhibitor concentrations in different normality of hydrochloric acid medium (1N & 2N) for two hours.

Rate of corrosion (mmpy)=87.6 X W /A x T x D

W-Weight loss in mg, A–Area of specimen in cm^2, D–Density of specimen in gm/cm^3 (8.73)

T–Time for which the specimens were exposed to the corroding medium (in hours)

Inhibition efficiency I (%) = (W0 – W/W0)X100

W_0-Weight loss without inhibitors in g, W-Weight loss with inhibitors in grams

Surface coverage (θ) = W_0–W/W_0

W_0-Corrosion rate without inhibitors in g, W-Corrosion rate with inhibitors in grams

Adsorption isothermTemkin's adsorption isotherm was studied by the platting of (θ)-surface coverage versus log IC-inhibitor concentration.

The free energy change in of adsorption for various of concentrations of the inhibitors has been calculated by using the formula.

-ΔG=2.303 x RT (1.74+log (θ/1-θ)-logC) Joule/mole
ΔG=2.303 x RT (log C – log θ/1-θ – 1.74) Joule/mole

R-Gas constant-Temperature in Kelvin-Concentration of inhibitors-Surface coverage, 1.74-Conversion factor

Electrochemical measurements

The functioning terminal, the platinum cathode, and the soaked calomel anode were utilized in the potentiodynamic polarization estimations. This functioning anode was cleaned with doubly refined water, degreased with $CH_3)_2CO$, and cleaned with different emery paper grades. Each of the three cathodes were lowered in HCl corrosive arrangements of 1N and 2N both with and without BZ-I inhibitors. At an output pace of 2 mV/S, the polarization estimations were performed 200 mV away from the open circuit potential. Around 30 min after the functioning terminal was lowered in answer for lay out the consistent state potential, potentiodynamic polarization estimations were begun. Consumption current thickness, consumption potential, and anodic and cathodic Tafel slant still up in the air from the plot of E versus log I. The conditions were utilized to decide the inhibitory proficiency of these frameworks.

Inhibiton Efficency (I.E)%= (I_{Corr}-I_{corri}/I_{corr})X100
Where I_{corr} and I_{corri} consumption current in the nonappearance and presence of inhibitor.

AC Impedance study

Three anodes were utilized for the Impedance estimations. In the span of 30 min of the functioning terminal's drenching in the test arrangement, the open circuit capability of every one of the three anodes was estimated in (1N and 2NHCl) with and without inhibitors. Utilizing a CH electrochemical analyzer, examinations were directed in the recurrence scope of 10 KHz to 0.01 KHz. The low recurrence and high recurrence blocks on the Z' hub of the Nyquist plot, individually, were utilized to decide the arrangement obstruction (R_s) and complete opposition (R_t). The charge move obstruction, not entirely set in stone by the distinction among R_t and R_s values. The qualities for Cd_1 were determined utilizing the condition.

$Cd_1 = 1/2\pi\ f_{max} xRctIE\%= R_{ct}(i)-R_{ct}/R_{ct}\ x100$

Where Cd_1 is twofold layer capacitance, R_{ct} is charge move opposition fmax is recurrence at Z" esteem greatest and R_{ct} is charge move obstruction within the sight of inhibitor.

RESULT AND DISCUSSION

Structure of -BFCPA

The synthesized compound exhibited characteristic FT-IR C=O stretching frequency at 1606 cm^{-1}. The FT-IR spectrum (Fig. 2) of BFCPA showed the expected frequencies of NH, C-N and C-S at 3436 cm^{-1}, 1246 cm^{-1} and 720 cm^{-1}, respectively. In the ^{1}H-NMR spectrum (Fig. 3) of BFCPA, the proton signal at δ 12.18 ppm as broad singlet of NH identified. The eight piperazine ring protons were resonated at δ 2.62 ppm and δ 3.72 ppm as triplets. In ^{13}C-NMR spectra (Fig. 4) of BFCPA, the two characteristic C=O groups were resonated at δ 158.68 ppm and δ 169.75 ppm which confirmed the expected compound. The mass spectrum of BFCPA (Fig. 5) showed a molecular ion peak at m/z 371 (M+H)+ corresponding to molecular formula $C_{18}H_{18}N_4O_3S$.

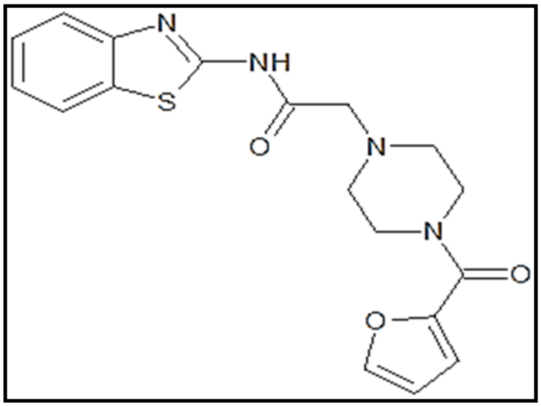

Fig. 1. Structure of BFCPA

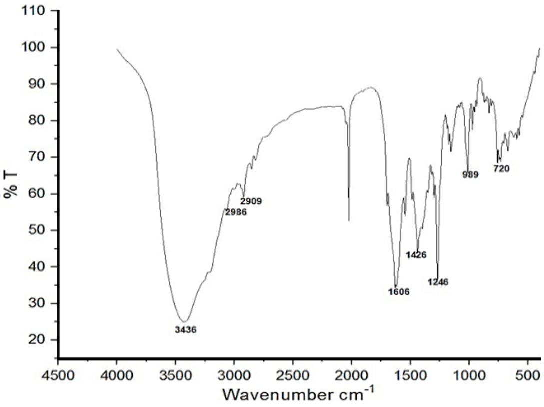

Fig. 2. FT-IR spectra of BFCPA

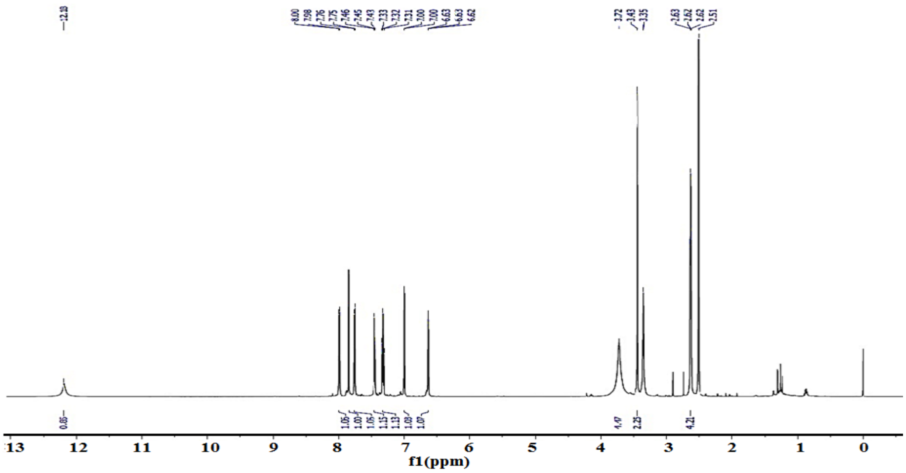

Fig. 3. ^{1}H-NMR spectra of BFCPA

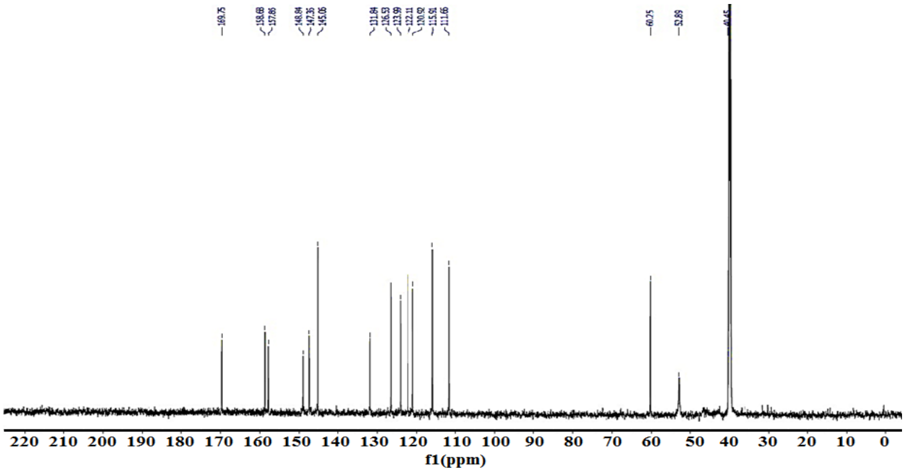

Fig. 4. ^{13}C-NMR-spectra of BFCPA

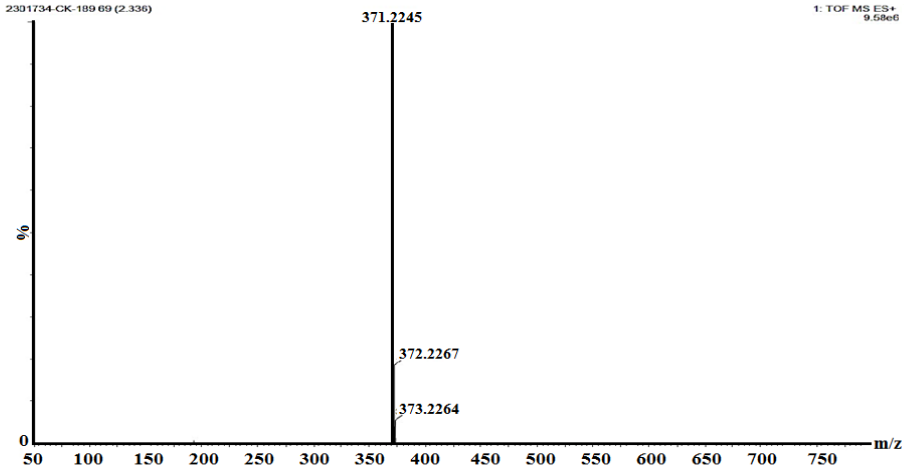

Fig. 5. Mass spectrum spectra of BFCPA

Mass Loss Studies

Behaviour of mild steel Corrosion

The corrosion behaviour of MS-mild steel in 1Normal and 2Normal Hydrochloric Acid medium with BFCPA at a room temperature concentrated by weight reduction technique and the qualities are arranged in Table 1. From the Table, it very well may be noticed that the pace of erosion (mmpy) diminished with expansion in centralization of different concentration of the inhibitor It is clear from the plot got by the plotting of erosion rate (mmpy) against centralization of inhibitor BFCPA as displayed in Fig. 6. From the Table, it is obvious from the diagram acquired by plotting of hindrance proficiency against the centralization of inhibitor BFCPAas displayed in Figure 7.

Table 1: Behaviour of mild steel Corrosionin 1N& 2N Hydrochloric Acid with BFCPA

Medium	Concentration of the InhibitorPPM	Rate of Corrosion (mmpy)	Efficiency of the Inhibitor (%)
1N HCl	Blank	19.8381	-
	10	7.1328	64.04
	20	6.4641	67.41
	40	5.4610	72.47
	60	4.1236	79.21
	80	2.8977	85.39
	100	2.1175	89.32
2N HCl	Blank	52.3593	-
	10	22.9476	56.17
	20	15.7590	69.90
	40	14.3436	72.60
	60	13.8755	73.49
	80	9.5067	81.84
	100	9.0497	82.71

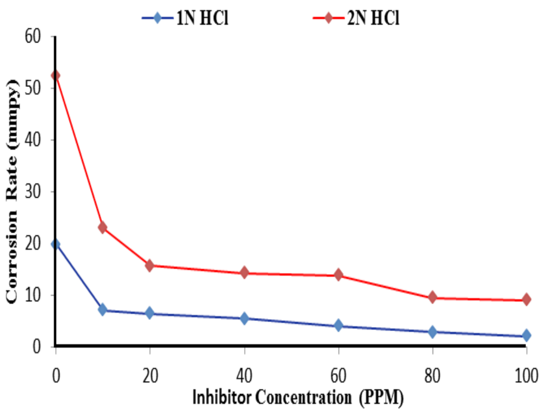

Fig. 6. Mild steel Corrosion ratein HClmediums with BFCPA for two hours

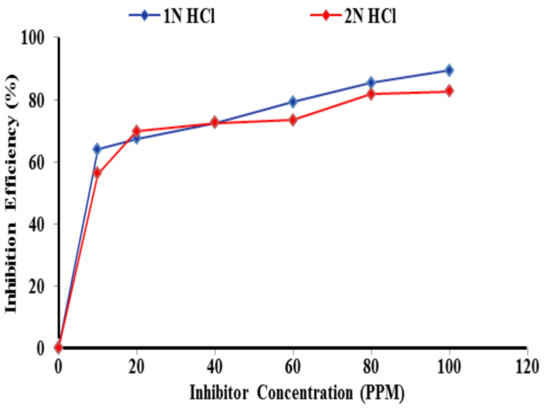

Fig. 7. Inhibition efficiency of mild steel in HCl mediums with BFCPAfor two hours

Adsorption Isotherm

The negative potential gains of the change of adsorption of free energy (ΔGads) show the unconstrained adsorption of BFCPA on delicate steel surface. Generally, potential gains of ΔGads up to -18 KJ/mole are involving with physisorption, while those around-30 KJ/mole or higher are join forces with chemisorptions. The decided ΔGads values in the Table 2, shows the adsorption arrangement of BFCPA on delicate steel in 1n and 2N HCl game plan with ideal fixation (100PPM) of BFCPA at room temperature displayed in Figure 8.

Table 2: Adsorption parameters of BFCPA on Mild Steel surface in 1N and 2N HCl at room temperature

Medium	Concentration	Surface Coverage	ΔG_{ads} Kilo Joules/mol^{-1}	Kx(10^{-2})
1NHCl	100 PPM	0.8932	-10.324	1.80
2NHCl		0.8271	-10.097	1.80

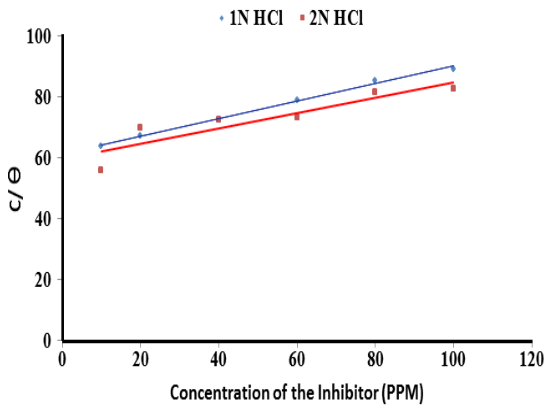

Fig. 8. Plot of C/θ Vs C BFCPA in HCl mediums at room temperature for two hours

Potentiodynamic polarization studies

Polarization behavior of test solutions of mild steel acting as both cathode and anode, as well as the electrochemical information from the research, are shown in Table 3 . The Table shows that the E_{corr} values are slightly affected in the negative direction in the presence of the inhibitor, indicating that the inhibitor prevents mild steel surface from corroding in 1N & 2N HCl by regulating both cathodic and anodic reactions by blocking negative sites . The inhibitor's action of inhibition was mixed type. With an rise in inhibitor concentration, the icorr values get dropped .The inhibition efficiencies were calculated using corrosion current density data, and it was discovered that the values followed the same general trend as those discovered using the weight loss approach. The potentiostatic polarization curve for investigations on thefMS-mild steel in HCl with and without BFCPA is shown in Figures 9(a & b).

A. C. Impedance

Impedance diagram of the related process, and Table 4 shows the air conditioner Impedance information of MSCorrosion in 1Normal and 2Normal Hydrochloric acid with different BFCPA fixations displayed in Fig. 10(a &b). The exchange opposition (R_{ct}) an incentive for MS in the uninhibited corrosive least changes after the expansion of the inhibitor with an expansion in inhibitor focus, the R_{ct} values rose. The expansions in inhibitor effectiveness support this case. In Nyquist plots the hemisperical state of the created for all preliminaries showed that the charge move process directs gentle steel consumption. As the grouping of the inhibitor expanded, the twofold layer capacitance (c_{dl}) diminished. The way that these added substances limit consumption by sticking to the metal within the sight of an inhibitor is shown by the drop in C_{dl} vales. Due to the heteroatom presence, which was found to have expanded basicity, electron thickness, and different properties, the characterisation of the delivered inhibitor BFCPA uncovered that it had an inhibitory propensity.

Table 2: Corrosion behaviour of mild steel in IN and 2NHCl. in BFCPA-Potentiostatic polarization studies

Acid Medium	Inhibitor Concentration (PPM)	Cathodic Shift βc (V dec^{-1})	Anodic Shift βa (V dec^{-1})	Corrosion Potential E_{Corr} (V)	I_{Corr} x10^{-4} (A)	Rate of Corrosion (mmpy)	Efficiency of the Inhibitor (%)
	Blank	7.156	5.89	-560	18.103	240.36	---
	10	15.373	7.945	-609	11.523	180.502	41.87
1N HCl	20	11.839	7.678	-622	7.812	60.41	45.79
	40	10.721	4.876	-591	8.348	54.692	48.36
	60	10.098	4.587	-443	9.142	42.243	55.02
	80	10.11	4.098	-388	7.724	37.891	62.85
	100	9.65	4.079	-361	4.432	22.7	81.04
	Blank	22.859	7.709	-576	29.852	206.52	---
	10	7.69	3.905	-508	17.153	80.65	42.53
2N HCl	20	12.156	5.205	-491	15.825	88.78	46.98
	40	19.991	8.24	-483	15.063	77.93	49.54
	60	10.933	3.858	-465	13.297	74.65	55.45
	80	10.135	5.127	-441	11.002	61.87	63.14
	100	18.159	8.215	-434	6.345	58.46	78.74

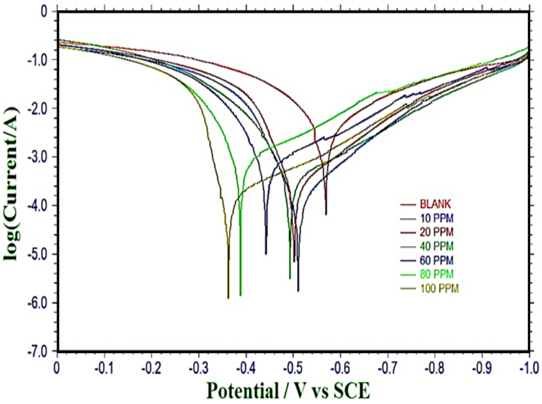

Fig. 9(a). Curves of Potentiodynamic polarization on Mild steel in 1NHCl in the absence and presence of the inhibitor

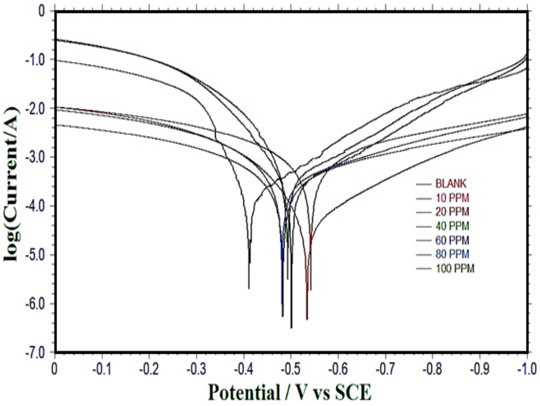

Fig. 9(b). Curves of Potentiodynamic polarization on mild steel in 2NHCl in the absence and presence of the inhibitor

Table 4: Impedance parameters inthe absence and presence of the inhibitor

Medium	Inhibitor Concentration (PPM)	Parameters Charge transfer resistance-R_{ct} (ohm cm^2)	Electrical double layer C_{dl} (μF/cm^2)	Efficiency of the Inhibitor (%)
	Blank	22.54	795.22	---
	10	26.12	638.16	43.7
1N HCl	20	36.12	545.45	56.7
	40	40.12	490.23	63.81
	60	58.25	430.75	68.28
	80	63.62	388.52	72.96
	100	159.32	247.65	81.1
	Blank	22.54	147.99	---
	10	39.12	89.04	40.34
2N HCl	20	39.87	88.91	45.46
	40	49.42	78.25	57.39
	60	56.23	70.43	69.91
	80	77.42	66.89	72.88
	100	107.12	54.24	78.95

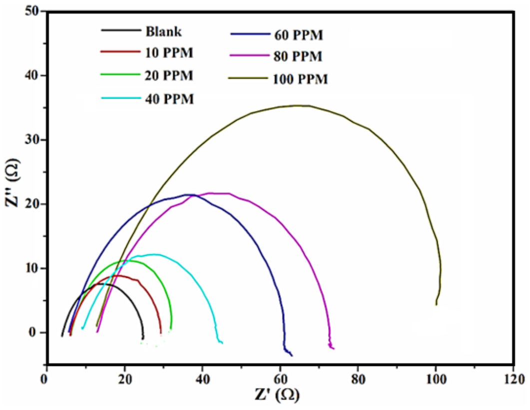

Fig.10 (a). A. C. Impedance curves immersed in 1N HCl in the absence and presence of the inhibitor

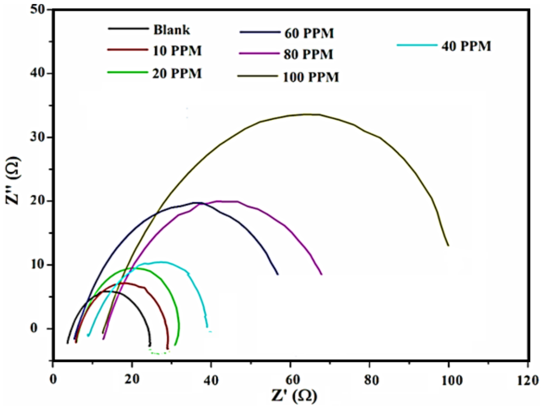

Fig. 10(b). A.C. Impedance curves immersed in 2N HCl inthe absence and presence of the inhibitor

CONCLUSION

The spectral techniques were used in this study to produce and analyze BFCPA, a new novel organic inhibitor. Due to the heteroatom oxygen's presence, which was discovered to have increased basicity, electron density, and other properties, the characterisation of the produced inhibitor BFCPA revealed that it had an inhibitory propensity. As per a concentrate on the consumption conduct of gentle steel in 1N and 2N HCl arrangements at room temperature for two hours utilizing the BFCPA by mass misfortune strategy, the manufactured inhibitor goes about as a decent erosion inhibitor.Theinhibition efficiency shows amaximum 89.32% in 1N HCl and 82.71% in 2N HCl for 2 h at room temperature at 100PPM optimum temperature, respectively. The mass loss data was reveled from the resuls obtained from electrochemical studies. Likewise in adsorption studies the inbitor shows physisorption that mean Langmuir adsorption isotherm.

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Conflict of interest

The authors declare no conflict of interests regarding the publication of this article.

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