CHAPTER - VI

INHIBITION EFFICIENCY OF SELECTED POLYESTERS UNDER VARIOUS ACIDIC ENVIRONMENTS – A COMPARISON

6.1 INTRODUCTION

Owing to the unique properties of mild steel such as low cost, facile fabrication and strength, industrial dependence on mild steel has tremendously increased. When such mild steel experiences industrial exercises like pickling, cleaning of boilers or descaling, base metal dissolution arises which cannot be eliminated at any cause[1]. These process are mainly done to remove the impurities present on the metal surface. Though HF-HNO_3 mixture has the capability of removing scale and dust, its toxic environmental footprints like emission of nitrate effluents has paved the way for the usage of low cost mineral acids like H_2SO_4, HCl or H_3PO_4 for a long time rather than organic acids. H_2SO_4 commonly termed as universal chemical, has potential usage in diverse sectors like manufacturing of fertilisers, pharmaceuticals, gasolines, batteries, bleaching, steel manufacturing, refineries, electrolysis, sulphonation and regeneration of ion exchange resins. It is a very important commodity chemical, from which an industrial strength can be determined. Besides, its importance in metal industries for pickling process is endless due to its low cost.

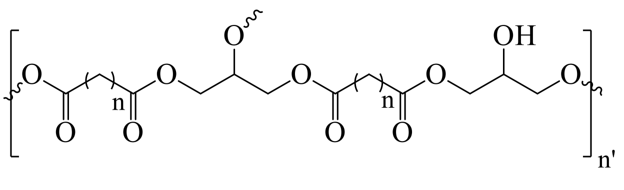
HCl is a strong inorganic acid with a repository of industrial applications like pickling, oil and gas processing, chemical and petrochemical sectors[2-4] before subjecting to the process such as extrusion, rolling, galvanizing etc., Though H_2SO_4 and HCl are strong acids, HCl is considered as a predominant one since its pickling rate is faster compared to H_2SO_4. Phosphoric acid (H_3PO_4) has gained important application in manufacture of fertilizers[5]. Its peculiar property of removing rust at a faster rate makes its role significant in cleaning expensive and precise items which hinders re-rusting process for a long period[6]. On the other hand, large scale industrial sectors utilises H_3PO_4 for chemical/electrolytic polishing, etching, passivating and phosphating the surface of the metal[7]. Though H_3PO_4 is a medium-strong acid, its affinity towards iron materials are high which has made researchers to think of a material that can minimise this affinity. Practically metals that exist in stable oxidised form has the tendency of reacting with the atmosphere to form metal oxides which is generally termed as rust. Eliminating this metal loss is too tedious whereas minimising this loss can be done effectively by using various strategies. In this regard, necessary measurements were taken to choose a low cost method which is obviously an application of inhibitor, where the resulting compound fulfils the capability of getting oxidised, covering large surface, eco-friendly and safe handling which in turn minimises the metal dissolution[8].

As an attempt, lot of research has been carried out to synthesise the inhibitors adopting various methodologies either to end with organic or inorganic compounds[9-12]. Various organic moieties synthesised were used as effective corrosion inhibitors for mild steel by **Hmimou *et al.*,**[13], **Al-Senani**[14], **Zaferani *et al.*,**[15], **Desai *et al.*,**[16], **Aziz *et al.*,**[17] **Divakara Shetty *et al.*,**[18] **Abdel Hameed *et al.*,**[19]. However cost, hazard nature and tedious synthetic procedures has minimised its usage in taking up the role of corrosion inhibitors. As a remedy, an alternate source of inhibitors were focussed which were of macromolecular size, possessing high molecular weight with a facile eco-friendly synthesis termed as polymers. As iron products decide the economy of industrial sectors, minimising its severity has to be stressed which has triggered us to evaluate the effect of linear polyesters PGAZ, PGSE and cardo polyesters MPOD, MPOU on mild steel protection. Compared to H_2SO_4 and HCl, only a less effort has been contributed towards the study of metal protection under the influence of phosphoric acid. Owing to this, present chapter has been designed to compare the efficiencies under 0.5 M H_2SO_4, 1 M HCl and 0.3 M H_3PO_4.

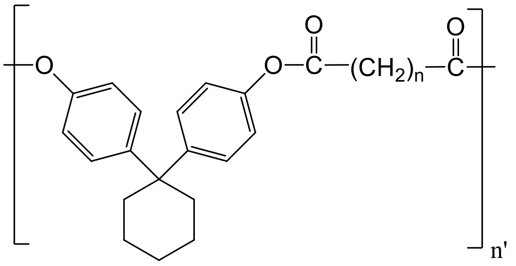
6.2 EXPERIMENTAL METHODS

6.2.1 Inhibitors

The inhibitors PGAZ, PGSE, MPOD and MPOU with maximum inhibiton efficiencies whose synthetic procedure are dealt in chapter II were chosen for the present discussion. The structure of the selected inhibitors are represented below.



n = 7, Poly (glycerol azealate) (PGAZ)
n = 8, Poly (glycerol sebaccate) (PGSE)



n = 7, 4-(1-(4-methoxyphenyl) cyclohexyl) phenyl 9-oxodecanoate (MPOD)
n = 8, 4-(1-(4-methoxyphenyl) cyclohexyl) phenyl 10-oxoundecanoate (MPOU)

6.2.2 Materials

Mild steel couponsof desired dimensions were preferred for the present study. Various solutions of 0.5 M H_2SO_4 1 M HCl and 0.3 M H_3PO_4 were prepared by diluting analytical grade of respective acids with distille water.

6.2.3 Evaluation of metal protecting ability

To compare the inhibition efficiences of the selected inhibitors towards 0.5 M H_2SO_4, 1 M HCl and 0.3 M H_3PO_4, methodologes described in the earlier chapters were followed which could be outlined as shown.

Non- Electrochemical method – Mass loss method

Metal : Mild steel
Major composition : Fe (99.32%)
Duration : 3 hrs
Electrolyte : 0.5 M H_2SO_4, 1 M HCl and 0.3 M H_3PO_4

Electrochemical methods

Working electrode : Mild steel rod with an exposed area of 0.785 cm^2
Counter electrode : Platinum electrode
Reference electrode : Calomel electrode
Software : Ivium compactstat

Impedance measurements

- Frequency range : 10 KHZ to 0.01 HZ
- Amplitude : 10 mV

Polarisation measurements

- Potential range : -200 to +200 mV
- Scan rate : 1 MV/sec

6.3 RESULTS AND DISCUSSION

6.3.1 Evaluation of metal protecting ability

6.3.1.1 Mass loss method

To analyse the fundamental response of an inhibitor in protecting the metal surface under aggressive medium, mass loss method can be adopted where the loss in mass of the specimens can be evaluated by immersing the mild steel specimens of standard dimensions in 100 ml test solution of 0.5 M H_2SO_4 / 1 M HCl / 0.3 M H_3PO_4 medium. From the data shown in **Tables 6.1-6.3**, it is observed that on increasing the concentration (10, 50, 100, 500, 000 ppm) of the inhibitors, a favourable increase in the surface coverage[20] on the mild steel surface was noticed thereby minimising the metal surface getting exposed to the acid medium. Comparing the weight loss data, at any concentration of the inhibitor, the inhibition efficiency was found to be in the order of HCl > H_2SO_4 > H_3PO_4 which could be attributed mainly based on the extent of adsorption of the inhibitor on the mild steel surface[21]. Out of the four inhibitors studied, the highest inhibition efficiency at optimised concentration of 1000 ppm obtained for MPOU and MPOD could be reasoned due to its + inductive effect of $–CH_2-$ moieties along with the bulky structure and aromaticity that can involve π-electron cloud to interact with the metal surface thereby creating a better surface covering ability than the linear polyesters PGAZ and PGSE where aromaticity is not observed.

6.3.1.2 Electrochemical impedance spectroscopy (EIS)

From the Nyquist plots shown in **Figs. 6.1-6.3**, the response of the added polymers PGAZ, PGSE, MPOD and MPOU in 0.5 M H_2SO_4 / 1 M HCl / 0.3 M H_3PO_4 test medium can be clearly understood. In the case of uninhibited medium (blank) of all the three acids, the diameter of the semicircle was obviously less which insisted the lesser resistance to the metal dissolution in acidic media ie., the metal has undergone pronounced corrosion. On addition of selected concentrations (10, 100, 1000 ppm) of the inhibitor to the medium, successive increase in the diameter of the semicircle was observed with increased charge transfer resistance (R_{ct}) as listed in **Tables 6.4-6.6**. The increase in R_{ct} also suggested the formation of a protective barrier on the metal specimens thereby hindering the flow of ions into the medium[22]. On the other hand the double layer capacitance decreased with increase in the concentration of the inhibitors, which can be reasoned due to the replacement of already adsorbed water molecules on the metal surface by the added inhibitors where maximum replacement was favoured by MPOU resulting in higher inhibition efficiency of 93.24% in HCl medium. However the depression noticed in the semicircles might be due to the inhomogeneity of the metal surface or dispersion in frequency[23]. As suggested by most of the researchers, the obtained data were fitted within Randle's equivalent circuit which consisted of solution resistance (R_s), charge transfer resistance (R_{ct}) and double-layer capacitance (C_{dl}). In the present discussion, R_{ct} and C_{dl} referred to the resistance and double layer capacitance of polymer-solution interface. Moreover corrosion inhibition process was found to be high in inhibited medium than the uninhibited ones which could be due to the addition of the inhibitors favouring a protective film on the metal surface thereby protecting the metal surface from getting exposed to the acidic medium[22] or by decreasing surface heterogeneity due to the adsorption of inhibitors on the active sites[24].

6.3.1.3 Potentiodynamic polarisation technique

The influence of the inhibitor on the cathodic and anodic reactions were studied with the aid of potentiodynamic polarisation studies. The resulting polarisation parameters such as Tafel slopes (b_a and b_c), corrosion current (I_{corr}) and corrosion potential (E_{corr}) corresponding to 0.5 M H_2SO_4 / 1 M HCl / 0.3 M H_3PO_4 are listed in **Tables 6.7-6.9**. Close observation of the data revealed that the I_{corr} values of uninhibited acidic medium decreased successively on addition of inhibitors revealing reduced corrosion process where a metal getting exposed to the acid medium is considerably reduced[25]. Minimum changes observed in the Tafel slopes does not change the metal dissolution mechanism. From **Figs. 6.4-6.6**, it can be seen that the addition of inhibitors PGAZ, PGSE, MPOD and MPOU affected both the cathodic and anodic curves. Observation of Tafel slopes did not show much variation implying that the added inhibitor has acted by simply blocking the surface and inducing inactivation towards corrosion[26]. Moreover the addition of inhibitor in the medium gets adsorbed in the metal/solution interface[27] thereby reducing the polarisation of the metal specimen ie., reducing the conversion of metal into metal ions. In addition the displacement in E_{corr} value[28] observed was 45.1 mV, 38.7 mV and 39.1 mV under the influence of 0.5 M H_2SO_4 / 1 M HCl / 0.3 M H_3PO_4 which was less than 85mV thereby suggesting mixed type of inhibition favouring the reduction of both anodic metal dissolution and cathodic hydrogen evolution.

6.3.1.4 Comparision of inhibition efficiency

Evaluation of the inhibition efficiency rendered by the inhibitors PGAZ, PGSE, MPOD and MPOU under various acidic environment like H_2SO_4, HCl and H_3PO_4 has been made by weight loss, AC impedance and potentiodynamic polarisation techniques. All the measurements done revealed increased metal protecting ability on increasing the concentration of the inhibitors. Comparison of data presented in **Table 6.10**, showed increased inhibition efficiency for 1 M HCl test solution compared to 0.5 M H_2SO_4 and 0.3 M H_3PO_4 which could be reasoned due to the fact that Cl^- have a stronger tendency to get adsorbed and has greater electrostatic influence on the inhibitor adsorption than SO_4^{2-} and PO_4^{3-} ions[29,30]. Thus the mode of inhibition lies in the order of HCl > H_2SO_4 > H_3PO_4 which indicates the acid anions as well as degree of protonation mainly influenced metal dissolution process[31,32]. This is additionally evident from the increased surface coverage of 0.9686 (1 M HCl) than 0.9298 (0.5 M H_2SO_4) and 0.8107 (0.3 M H_3PO_4) at 1000 ppm concentration of MPOU. As well the obtained C_{dl}

values around 24.8 μF/cm^2 for HCl, 66.7 μF/cm^2 for sulphuric acid and 69.81 μF/cm^2 for phosphoric acid also supported the same. When a mild steel specimen is immersed in a test solution of 1 M HCl / 0.5 M H_2SO_4 / 0.3 M H_3PO_4, comparatively Cl^- ions being smaller in size and its lesser degree of hydration enables it to get strongly adsorbed first on the mild steel surface creating excess negative charge[33,34] than SO_4^{2-} and PO_4^{3-} ions which possess lower degree of hydration rendering weaker mode of adsorption. From the results obtained, it can be suggested that the added inhibitor could either replace already adsorbed Cl^- ions or it could favour a synergistic mode of inhibition where the inhibitor gets adsorbed on Fe-Cl surface[35]. The increased inhibition favoured under HCl medium can be reasoned due to the joint adsorption where the chloride ion has worked along with the inhibitor. It is a general mechanism that the mild steel immersed in acidic medium gets positively charged which creates an electrostatic repulsion between the protonated inhibitor molecules. Thus in the present study, among the existing anions Cl^-, SO_4^{2-} and PO_4^{3-} ions Cl^- possess the capability of adsorbing more cations[36] than SO_4^{2-} and PO_4^{3-} ions favouring the inhibition efficiency in the order of HCl > H_2SO_4 > H_3PO_4. Also major factors like functional groups and molecular structure[37] also contributes towards the inhibition phenomena where a single polymeric molecule has the capability of displacing more water molecules than organic compounds[38]. The present discussion also revealed the same favouring higher inhibition efficiency for MPOU due to aromaticity, bulky structure and electron donating ability of oxygen atoms[39,40] than PGSE of lower inhibition efficiency because of the absence of the aromatic electron cloud.

6.4 CONCLUSIONS

From the above comparison studies, the following conclusions were drawn.

(ix) Mass loss method favoured highest inhibition efficiency of 96.86 % for MPOU in HCl medium.

(x) Efficiencies obtained from AC impedance and polarisation measurements were in good agreement with each other.

(xi) The comparison study revealed the inhibition of mild steel specimens in the order of 1 M HCl > 0.5 M H_2SO_4 > 0.3 M H_3PO_4.

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Table 6.1 Inhibition efficiencies of various concentrations of the polyesters for corrosion of mild steel in 0.5 M H_2SO_4 by weight loss measurement at 303 K

Name of the Inhibitor	Conc. (ppm)	Weight loss (g)	Inhibition Efficiency (%)	Surface Coverage (θ)	Corrosion rate (g cm^{-2} hr^{-1})
BLANK		0.2015	-	-	19.97
PGAZ	10	0.0976	51.59	0.5159	9.67
	50	0.0934	53.66	0.5366	9.25
	100	0.0929	53.88	0.5388	9.21
	500	0.0756	62.49	0.6249	7.49
	1000	0.0645	67.97	0.6797	6.40
PGSE	10	0.0956	52.55	0.5255	9.48
	50	0.0923	54.18	0.5418	9.15
	100	0.0919	54.38	0.5438	9.11
	500	0.0723	64.14	0.6414	7.16
	1000	0.0451	77.63	0.7763	4.47
MPOD	10	0.0698	65.36	0.6536	6.92
	50	0.0610	69.71	0.6971	6.05
	100	0.0559	72.24	0.7224	5.54
	500	0.0329	83.69	0.8369	3.26
	1000	0.0164	91.85	0.9185	1.63
MPOU	10	0.0624	69.04	0.6904	6.18
	50	0.0536	73.4	0.734	5.31
	100	0.0480	76.19	0.7619	4.75
	500	0.0201	90.01	0.9001	1.99
	1000	0.0141	92.98	0.9298	0.76

Table 6.2 Inhibition efficiencies of various concentrations of the polyesters for corrosion of mild steel in 1 M HCl by weight loss measurement at 303 K

Name of the Inhibitor	Conc. (ppm)	Weight loss (g)	Inhibition Efficiency (%)	Surface Coverage (θ)	Corrosion rate (g cm^{-2} hr^{-1})
Blank	-	0.2216	-	-	21.96
PGAZ	10	0.0877	60.41	0.6041	8.69
	50	0.0816	63.18	0.6318	8.09
	100	0.0704	68.22	0.6822	6.98
	500	0.0592	73.29	0.7329	5.87
	1000	0.0510	76.98	0.7698	5.06
PGSE	10	0.0704	68.23	0.6823	6.98
	50	0.0683	69.19	0.6919	6.77
	100	0.0612	72.38	0.7238	6.07
	500	0.0460	79.25	0.7925	4.56
	1000	0.0332	85.03	0.8503	3.29
MPOD	10	0.0529	76.14	0.7614	5.24
	50	0.0407	81.65	0.8165	4.03
	100	0.0337	84.81	0.8481	3.34
	500	0.0238	89.24	0.8924	2.36
	1000	0.0172	92.22	0.9222	1.71
MPOU	10	0.0447	79.85	0.7985	4.43
	50	0.0358	83.86	0.8386	3.54
	100	0.0285	87.13	0.8713	2.83
	500	0.0163	92.64	0.9264	1.62
	1000	0.0070	96.86	0.9686	0.69

Table 6.3 Inhibition efficiencies of various concentrations of the polyesters for corrosion of mild steel in 0.3 M H_3PO_4 by weight loss measurement at 303 K

Name of the Inhibitor	Conc. (ppm)	Weight loss (g)	Inhibition Efficiency (%)	Surface Coverage (θ)	Corrosion rate (g cm^{-2} hr^{-1})
Blank	-	0.2138	-	-	21.19
PGAZ	10	0.1201	43.81	0.4381	11.91
	50	0.1193	44.21	0.4421	11.82
	100	0.1178	44.9	0.449	11.67
	500	0.1110	48.06	0.4806	11.01
	1000	0.1013	52.61	0.5261	10.04
PGSE	10	0.1169	45.32	0.4532	11.59
	50	0.1129	47.18	0.4718	11.19
	100	0.1077	49.63	0.4963	10.67
	500	0.0935	56.25	0.5625	9.27
	1000	0.0833	61.04	0.6104	8.26
MPOD	10	0.0966	54.84	0.5484	9.57
	50	0.0817	61.8	0.618	8.09
	100	0.0787	63.21	0.6321	7.80
	500	0.0657	69.25	0.6925	6.52
	1000	0.0506	76.33	0.7633	5.02
MPOU	10	0.0852	60.15	0.6015	8.44
	50	0.0764	64.25	0.6425	7.57
	100	0.0654	69.43	0.6943	6.48
	500	0.0528	75.32	0.7532	5.23
	1000	0.0405	81.07	0.8107	4.01

Table 6.4 AC-impedance parameters for corrosion of mild steel for selected concentrations of the polyesters in 0.5 M H_2SO_4

Name of the inhibitor	Conc. (ppm)	R_{ct} (ohm cm^2)	C_{dl} (μF/cm^2)	Inhibition efficiency (%)
BLANK	-	15.8	21.5	-
PGAZ	10	30.1	18.7	47.51
	100	35.2	18.4	55.11
	1000	43.6	14.9	63.76
PGSE	10	30.9	19.8	48.87
	100	37.3	18.5	57.64
	1000	48.5	16.8	67.42
MPOD	10	32.91	29.5	51.99
	100	46.14	18.3	65.76
	1000	88.76	16.7	82.20
MPOU	10	35.67	36.1	55.71
	100	49.95	23.1	68.37
	1000	101.86	19.2	84.49

Table 6.5 AC-impedance parameters for corrosion of mild steel for selected concentrations of the polyesters in 1 M HCl

Name of the inhibitor	Conc. (ppm)	R_{ct} (ohm cm^2)	C_{dl} (μF/cm^2)	Inhibition efficiency (%)
Blank	-	17.8	24.8	-
PGAZ	10	43.15	41.1	58.74
	100	48.95	38.3	63.63
	1000	72.82	35.3	75.55
PGSE	10	48.89	32.4	63.59
	100	51.67	30.1	65.55
	1000	95.63	29.6	81.38
MPOD	10	63.25	30.08	71.85
	100	96.01	26.84	81.46
	1000	180.01	23.20	90.11
MPOU	10	108.15	26.4	83.54
	100	149.13	23.3	88.06
	1000	263.18	23.9	93.24

Table 6.6 AC-impedance parameters for corrosion of mild steel for selected concentrations of the polyesters in 0.3 M H_3PO_4

Name of the inhibitor	Conc. (ppm)	R_{ct} (ohm cm^2)	C_{dl} ($\mu F/cm^2$)	Inhibition efficiency (%)
Blank	-	14.87	69.81	-
PGAZ	10	25.24	46.9	41.08
	100	26.32	43.5	43.50
	1000	29.98	42.1	50.40
PGSE	10	26.51	36.7	43.91
	100	26.89	35.8	44.70
	1000	34.25	29.8	56.58
MPOD	10	30.01	30.6	50.44
	100	39.22	29.7	62.08
	1000	48.94	24.1	69.61
MPOU	10	33.81	29.8	56.01
	100	40.13	26.5	62.94
	1000	53.82	22.1	72.37

Table 6.7 Potentiodynamic polarisation parameters for corrosion of mild steel with selected concentration of the polyesters in 0.5 M H_2SO_4

Name of the inhibitor	Conc. (ppm)	Tafel slopes (mV/dec)		$-E_{corr}$ (mV) vs SCE	I_{corr} (μA/cm^2)	Inhibition efficiency (%)
		b_a	b_c			
BLANK	-	63	153	476.9	896.52	
PGAZ	10	53	139	487.4	468.56	47.74
	100	57	127	493.2	435.69	51.40
	1000	68	118	522	410.25	54.24
PGSE	10	63	136	498.8	440.28	50.89
	100	62	126	492.5	415.28	53.68
	1000	69	111	517.4	342.23	61.83
MPOD	10	64	165	473.1	364.88	59.30
	100	59	161	466.9	305.27	65.95
	1000	57	163	475.8	129.73	85.53
MPOU	10	54	164	476.3	360.31	59.81
	100	52	159	475.7	295.49	67.04
	1000	50	167	474.7	159.04	82.26

Table 6.8 Potentiodynamic polarisation parameters for corrosion of mild steel with selected concentration of the polyesters in 1 M HCl

Name of the inhibitor	Conc. (ppm)	Tafel slopes (mV/dec)		$-E_{corr}$ (mV) vs SCE	I_{corr} (μA/cm^2)	Inhibition efficiency (%)
		b_a	b_c			
Blank	-	57	163	536.7	660.69	-
PGAZ	10	67	157	561.5	351.42	46.81
	100	64	143	549.4	322.94	51.12
	1000	59	137	531.1	288.52	56.33
PGSE	10	63	117	551.9	335.56	49.21
	100	59	127	552	295.06	55.34
	1000	61	126	536.7	233.02	64.73
MPOD	10	62	131	548.1	304.37	53.93
	100	57	125	575.1	255.55	61.32
	1000	57	125	575.4	172.57	73.88
MPOU	10	57	163	536.3	279.93	57.63
	100	58	153	543.5	237.18	64.10
	1000	60	138	557.1	102.27	84.52

Table 6.9 Potentiodynamic polarisation parameters for corrosion of mild steel with selected concentration of the polyesters in 0.3 M H_3PO_4

Name of the inhibitor	Conc. (ppm)	Tafel slopes (mV/dec)		$-E_{corr}$ (mV) vs SCE	I_{corr} (μA/cm^2)	Inhibition efficiency (%)
		b_a	b_c			
Blank	-	79	155	597.5	598.27	-
PGAZ	10	87	148	605.4	360.09	39.81
	100	82	142	593.4	350.46	41.42
	1000	73	147	582.3	331.32	44.62
PGSE	10	78	154	599.1	340.95	43.01
	100	79	149	591.2	338.56	43.41
	1000	79	156	587.7	297.22	50.32
MPOD	10	85	151	609.3	324.14	45.82
	100	83	144	625.7	292.01	51.19
	1000	71	168	636.6	252.17	57.85
MPOU	10	77	156	605.1	304.45	49.11
	100	79	147	608.1	267.78	55.24
	1000	74	158	627.4	210.17	64.87

Table 6.10 Comparison of inhibition efficiencies in 0.5 M H_2SO_4, 1 M HCl and 0.3 M H_3PO_4 by weight loss, AC impedance and polarisation measurements

Techniques used	Acid medium	Conc. (ppm)	Name of the inhibitor			
			PGAZ	PGSE	MPOD	MPOU
Weight loss	0.5 M H_2SO_4	10	51.59	52.55	65.36	69.04
		50	53.66	54.18	69.71	73.4
		100	53.88	54.38	72.24	76.19
		500	62.49	64.14	83.69	90.01
		1000	67.97	77.63	91.85	92.98
	1 M HCl	10	60.41	68.23	76.14	79.85
		50	63.18	69.19	81.65	83.86
		100	68.22	72.38	84.81	87.13
		500	73.29	79.25	89.24	92.64
		1000	76.98	85.03	92.22	96.86
	0.3 M H_3PO_4	10	43.81	45.32	54.84	60.15
		50	44.21	47.18	61.8	64.25
		100	44.9	49.63	63.21	69.43
		500	48.06	56.25	69.25	75.32
		1000	52.61	61.04	76.33	81.07
AC impedance	0.5 M H_2SO_4	10	47.51	48.87	51.99	55.71
		100	55.11	57.64	65.76	68.37
		1000	63.76	67.42	82.20	84.49
	1 M HCl	10	58.74	63.59	71.85	74.98
		100	63.63	65.55	81.46	85.18
		1000	75.55	81.38	90.11	93.46
	0.3 M H_3PO_4	10	41.08	43.91	50.44	56.01
		100	43.50	44.70	62.08	62.94
		1000	50.40	56.58	69.61	72.37
Potentiodynamic polarisation	0.5 M H_2SO_4	10	47.74	50.89	59.30	59.81
		100	51.40	53.68	65.95	67.04
		1000	54.24	61.83	85.53	82.26
	1 M HCl	10	46.81	49.21	53.93	57.63
		100	51.12	55.34	61.32	64.10
		1000	56.33	64.73	73.88	84.52
	0.3 M H_3PO_4	10	39.81	43.01	45.82	49.11
		100	41.42	43.41	51.19	55.24
		1000	44.62	50.32	57.85	64.87

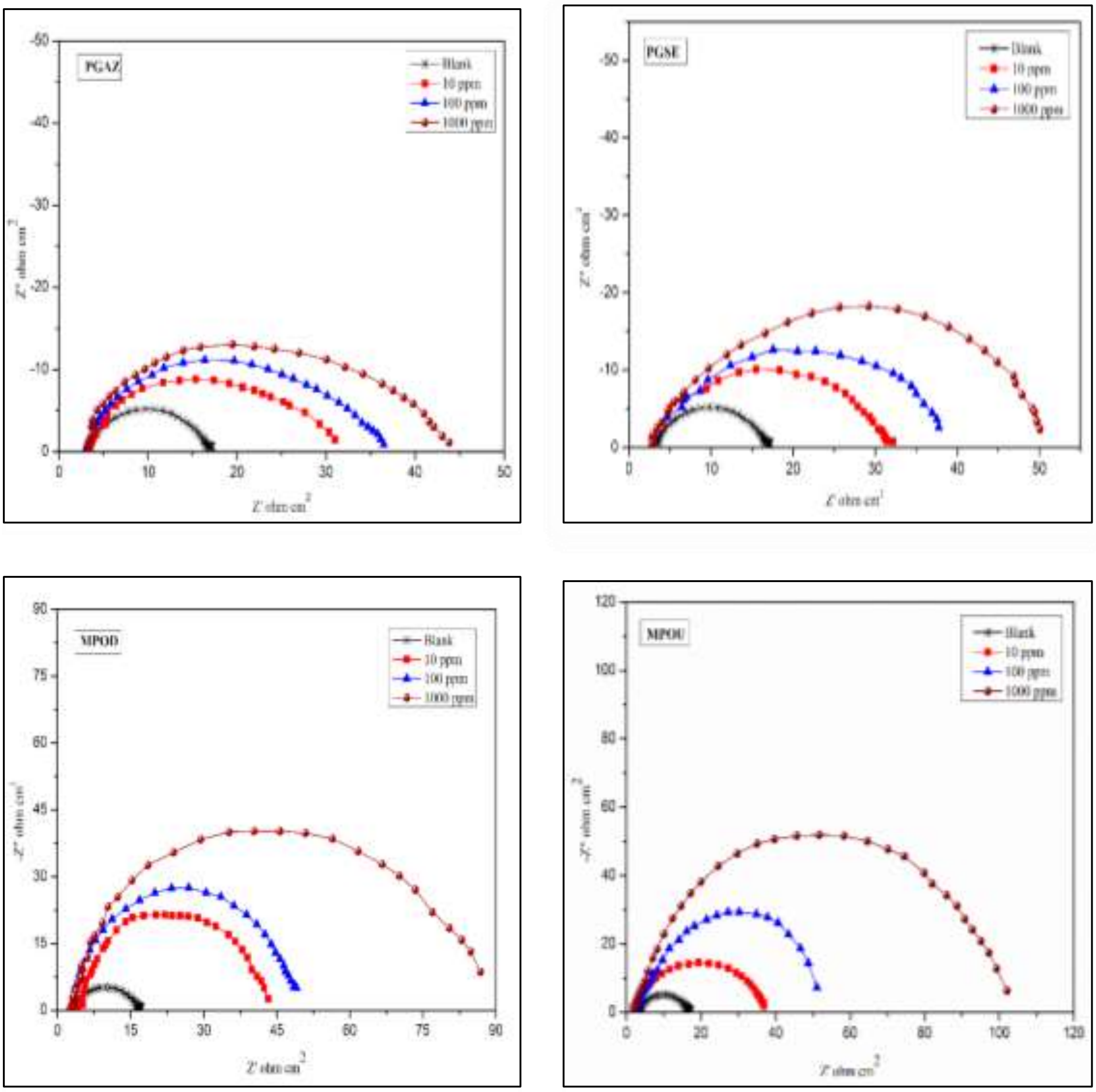

Fig. 6.1 Nyquist plot for mild steel in 0.5 M H_2SO_4 for selected concentrations of the polyesters

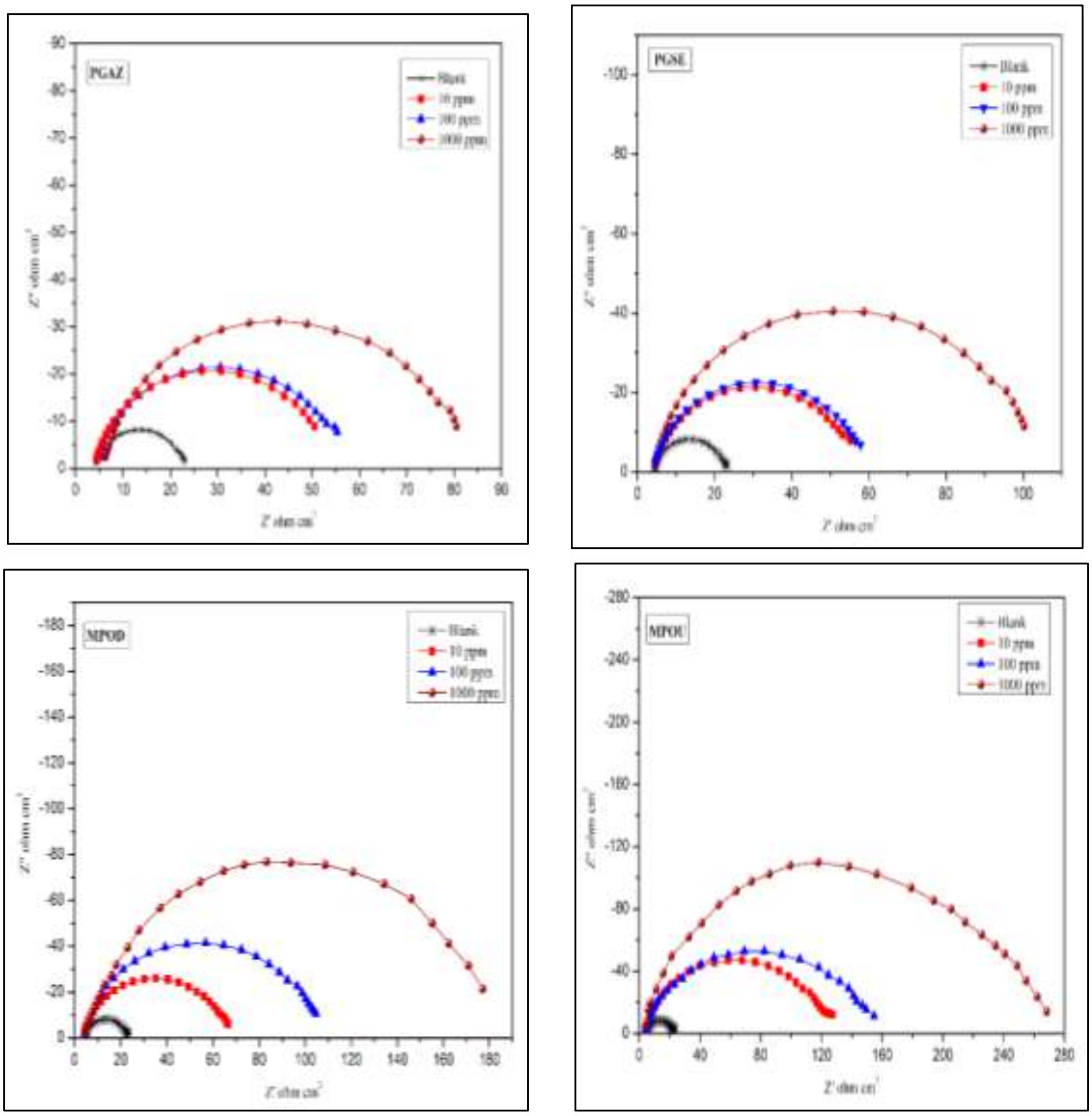

Fig. 6.2 Nyquist plot for mild steel in 1M HCl for selected concentrations of the polyesters

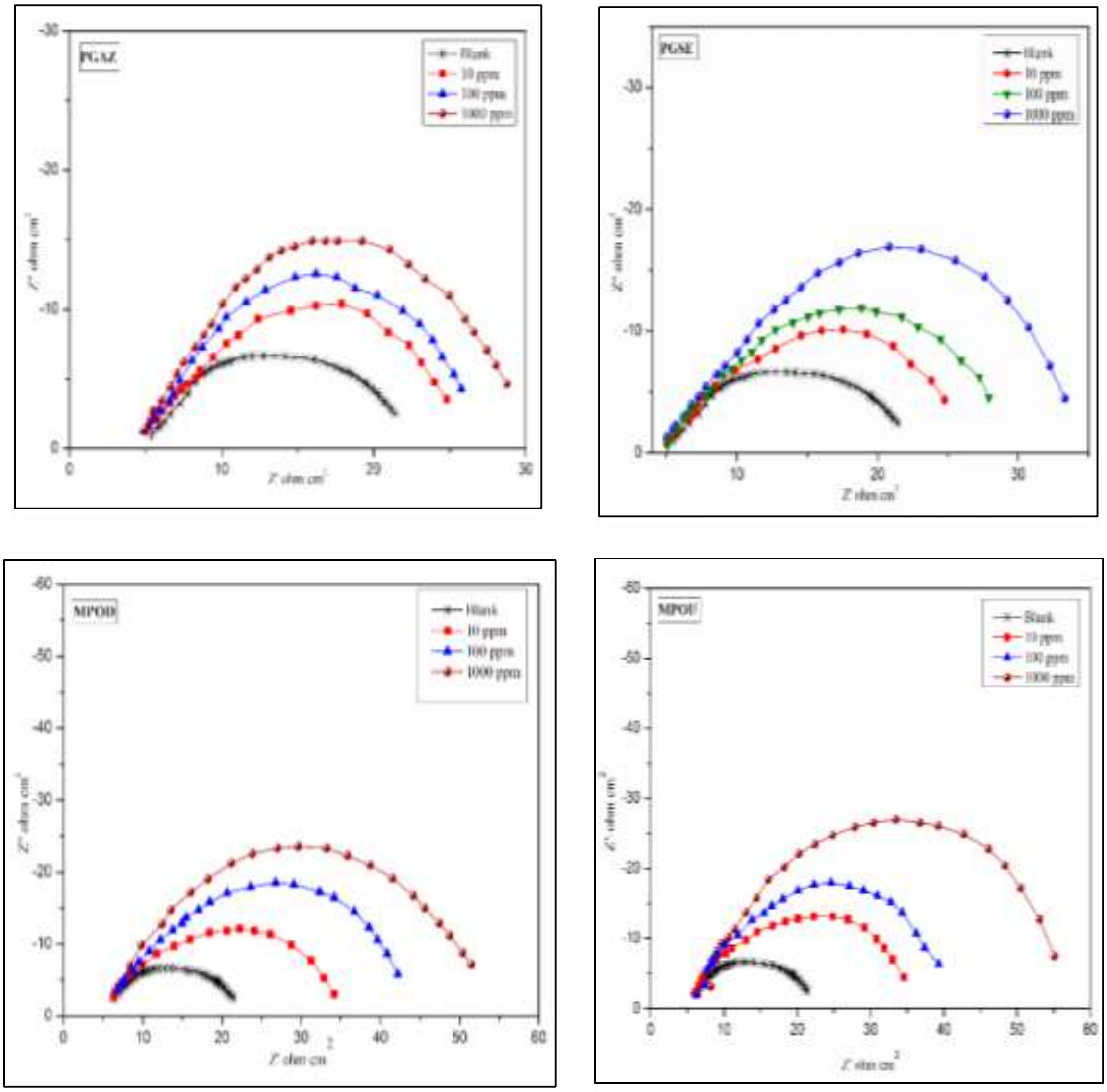

Fig. 6.3 Nyquist plot for mild steel in 0.3 M H_3PO_4 for selected concentrations of the polyesters

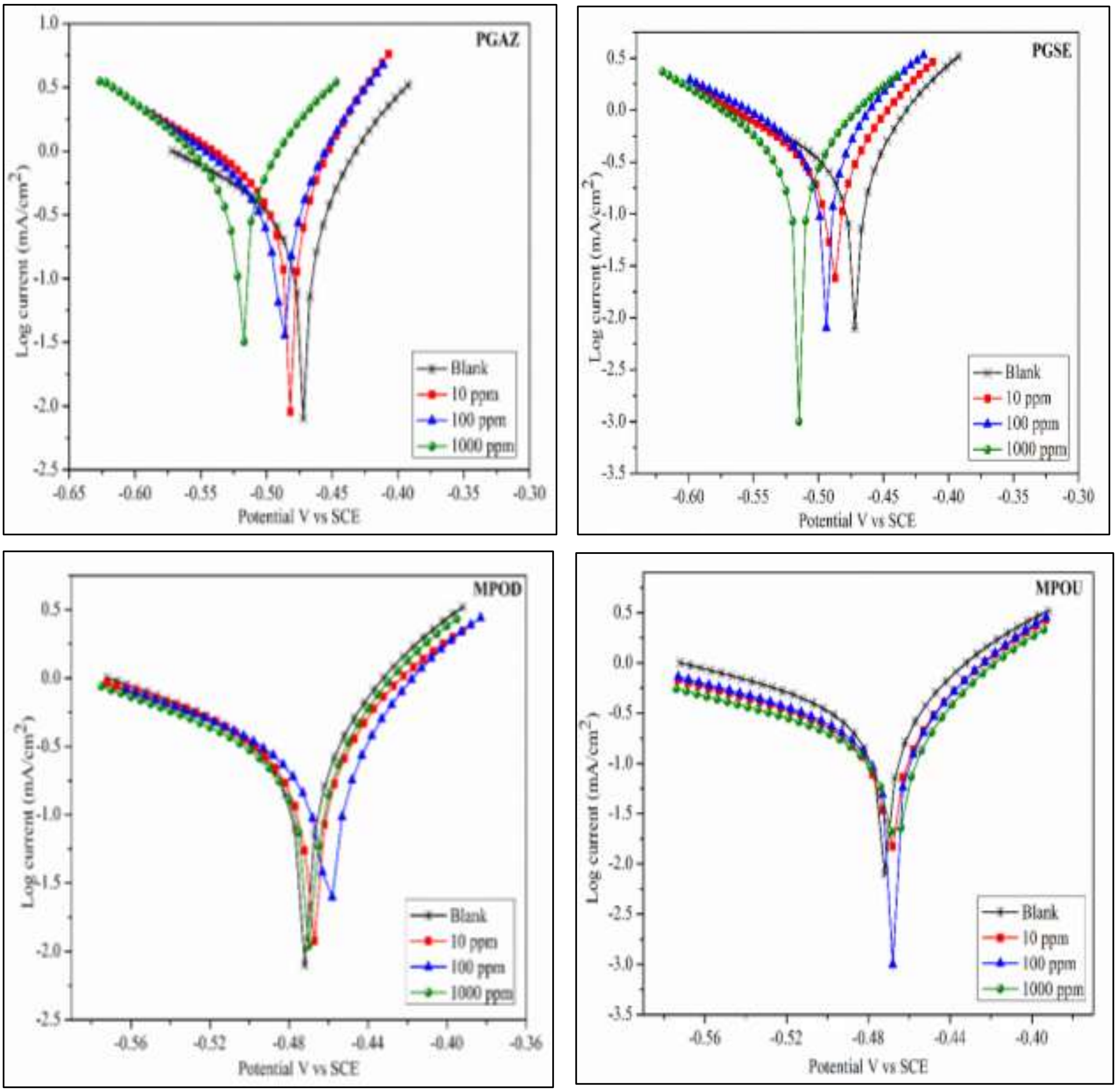

Fig. 6.4 Polarization curves for mild steel in 0.5 M H_2SO_4 for selected concentrations of the polyesters

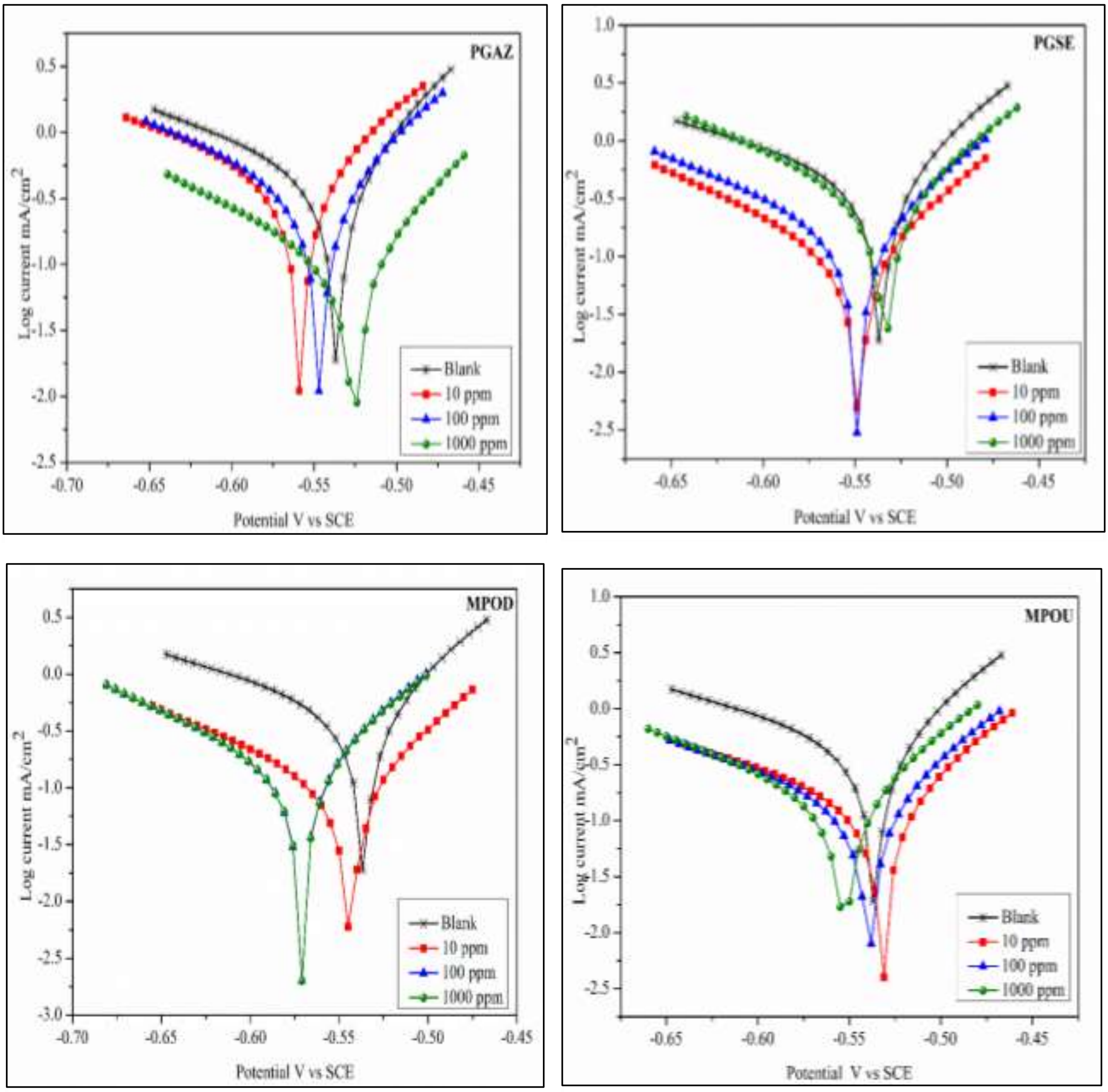

Fig. 6.5 Polarization curves for mild steel in 1M HCl for selected concentrations of the polyesters

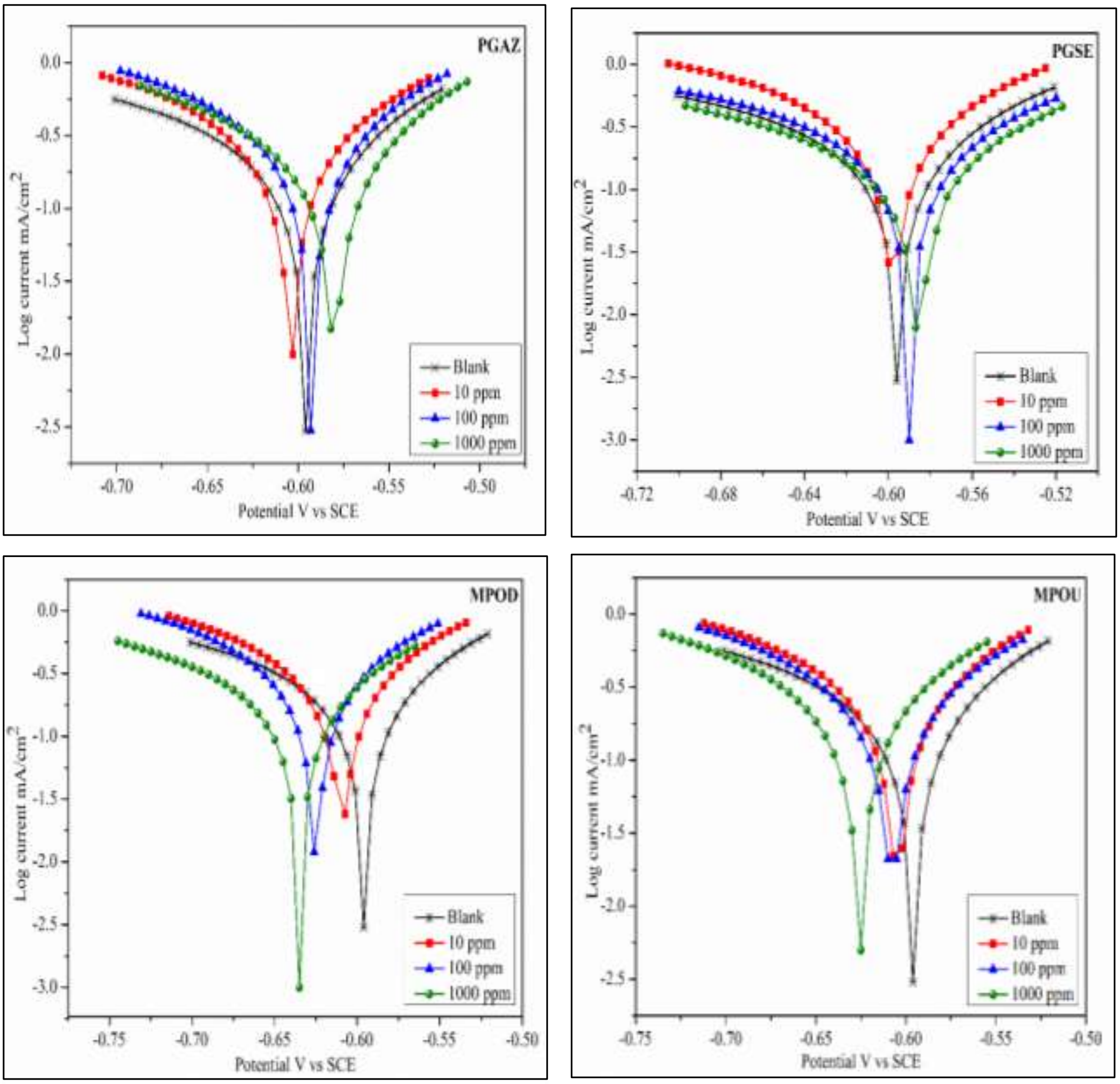

Fig. 6.6 Polarization curves for mild steel in 0.3 M H_3PO_4 for selected concentrations of the polyesters