Corrosion Inhibitive Nature Of 2-Propyl Pentanoic Acid Doped Poly N-Methyl Aniline Coating on Stainless Steel

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***Abstract**: A new polymer was synthesized using N-methyl aniline and 2-Propyl pentatonic acid on 304- stainless steel by electrochemically. An adherent polymer film was obtained by cyclic voltammetry method. The PANi-2PPA coated polymer was investigated against corrosion inhibitive nature in 0.5 M sulphuric acid solutions by Potentiodynamic polarization technique and electrochemical impedance spectroscopy. Corrosion current, corrosion current density, anode and cathode tafel slopes, charge transfer resistance, double layer capacitance parameters were observed in the electrochemical corrosion investigation methods. The maximum inhibition efficiency was achieved by potentiodyanamic polarization method.*

Keywords: Potentiodynamic, Electrochemical, Cyclic Voltammeter, Inhibition, PNMA-2PPA

1.Introduction

The most studied conducting polymers have been synthesized in two routes in the recent years in which either chemically synthesized conducting polymers or electrochemically synthesized conducting polymers. Among various chemically synthesized conducting polymers having good solubility in common organic solvents and it has well environmentally stable. Chemical oxidative polymerization has a great deal of attention in those applications [1-17]. Because electrical behaviour reversibly can be controlled by charge transfer doping and by protonation [18]. Even electrochemically synthesis conducting polymer takes place directly on the metal surface it is expected to have better adherence than the chemically synthesized one. The success of the electrochemical polymerization reaction needs the choice of the solvent which should have high dielectric constant, low viscosity, and low freezing point, therefore each metal needs some specifications which may be related to the nature of the metal. Most of the electrochemical reactions are carried out non-aqueous media. Two types of mechanisms related to conducting polymer coatings passivization and barrier effect. Firstly Passivization of the metal shifts towards more positive values and modifying the oxygen reduction reaction, therefore metallic surface protected by the passivization mechanism [19-22]. Barrier effects mean the synthesized polymers protected on the metal surfaces and avoids the contact of corrosive medium. [23-25]. The aim of the work is poly N-methyl aniline doped with 2- Propyl pentanoic acid using cyclic voltammetry on 304 stainless steel and to investigate against corrosion protective nature in 0.5 molars sulphuric acid medium.

2. Reagents and Chemicals

2.1 Electrochemical synthesis on stainless steel

The monomer and other chemicals were purchased from Aldrich chemicals analytical grade and 2-Propyl pentanoic were used without further purification. To synthesis of the polymer by electrochemically en electrochemical instruments were used. It has three electrodes set up in which platinum foil served as a counter electrode, silver electrode served as a reference electrode and Teflon coated cylindrical rod served as a working electrode. All the electrodes were mirror-polished before to polymerization to get a smooth surface and degreased with ethanol. Then the electrodeposition was performed by cyclic potential sweeping method at the scan rate of 50mV/s using potentio galvanostat PARSTAT-2273 electrochemical instrument..

2.2 Electrochemical measurements

PARSTAT-2273 an advanced electrochemical instrument was used to measure impedance measurements with the same three-electrode set up in a 0.5 M H_2SO_4 solution. The power suit software version 3.21 was used to data from the instrument. The electrochemical data obtained frequency range was 10-10.2Hz From the impedance measurements we can observe charge transfer resistance (R_{ct}) and double layer capacitance (C_{dl}) values. From these values, we can calculate inhibition efficiencies using the following equations.

$$IE\% = \left(\frac{R'_{ct} - R_{ct}}{R'_{ct}}\right) x\ 100$$

Rct- Charge transfer resistance values in uninhibited solution.

R'ct- Charge transfer resistance values in inhibited solution.

2.3 Polarisation measurements

Using the same electrochemical setup we can measure polarisation measurements for polymer-coated and on coated polymer stainless steel electrodes. The potential was swept at the rate of 1.66mvs^{-1}. From corrosion current density (I_{corr}) values we can calculate Inhibition efficiencies (IE%) using the following equation,

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

Icorr- corrosion current density obtained in the absence of inhibitor.

I'corr- corrosion current density obtained in the presence of inhibitor.

3. Results and Discussion

3.1 Cyclic Voltammetry

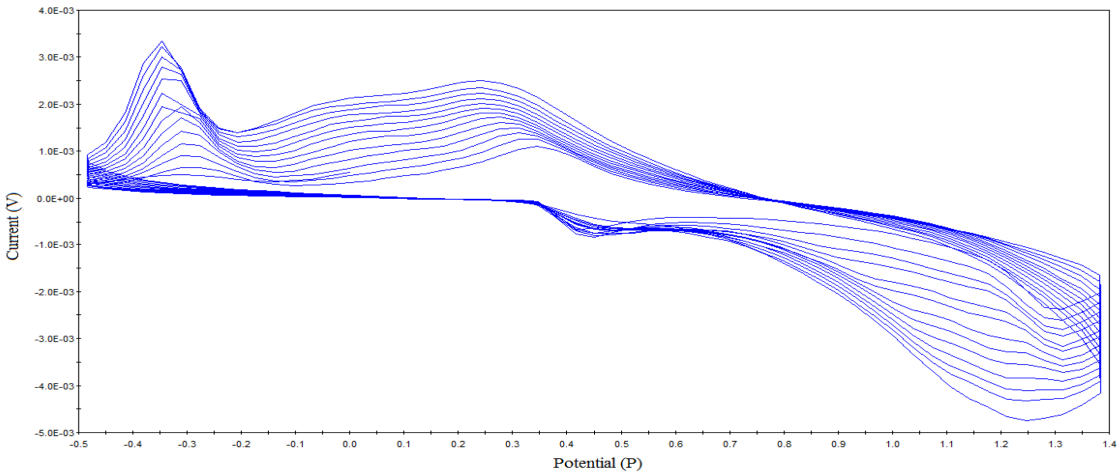

Figure 1. cyclic voltammogram for 2PPA solution containing 0.15M N-methyl aniline.

The electrochemical synthesis of PNMA-2PPA polymer explains Figure 1**.** The cyclic voltammogram of 2-propyl pentatonic acid solution containing 0.15M N-methyl aniline monomer using 304-stainless steel used as a working electrode at the scan rate of 50mV/s. An increasing number of cycles on the stainless steel surface confirm the formation polymer due to the oxidation and reduction taking place simultaneously. The potential scanned range was -0.5 V to +1.4 V. The monomer oxidation process was observed at +0.7 V corresponds to the reduction process and reduction potential was observed at -0.3 V corresponds to the oxidation process.

3.2 Electrochemical Impedance Measurements

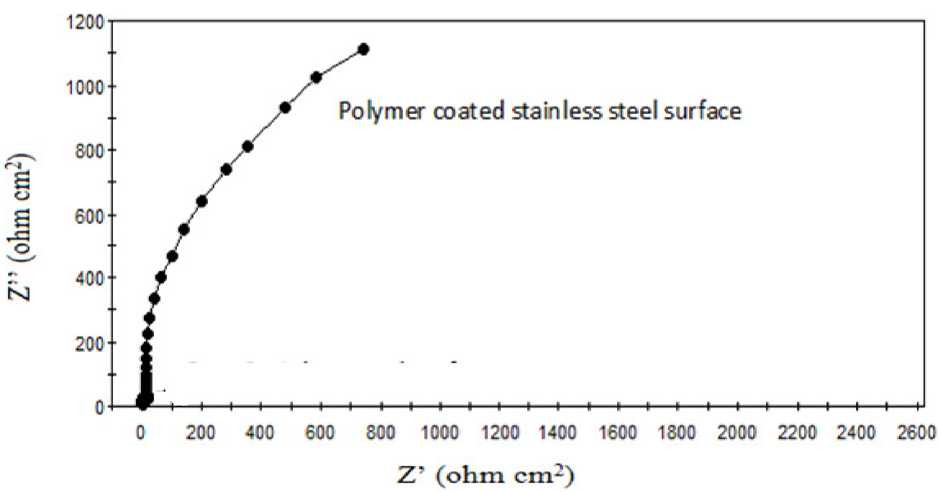

Figure 2. The electrochemical impedance spectra of doped PNMA-2PPA coated stainless steel electrode in a 0.5M H_2SO_4 solution.

From the electrochemical impedance spectra, we observed two semicircles for PNMA-2PPA polymer-coated and uncoated 304-stainless steel immersed in a 0.5 M H_2SO_4 solution. The Nyquist plot of the bare stainless steel electrode in 0.5 M H_2SO_4 fits well with the simple –R(CR)- (Randles circuit) model.

Table 1. Corrosion parameters of PNMA-2PPA polymer

Inhibitor (ppm)	Rct ohm cm^2	C_{dl} ($\mu F\ cm^{-2}$)	Inhibition Efficiency (%)
0.5M H_2SO_4 (Blank)	155	1.3052×10^{-3}	-
100	4128	8.0×10^{-10}	96.25

The electrochemical spectra parameters were listed in Table 1, The PNMA-2PPA coated stainless steel Charge transfer resistance (4128 ohm cm^2) very high when compared to a bare stainless steel surface(155 ohm cm^2). Simultaneously double-layer capacitance (C_{dl}) value decreased from $1.3052\times10^{-3}\ \mu F\ cm^{-2}$ to $8\times10^{-10}\ \mu F\ cm^{-2}$ for the PNMA-2PPA coated stainless steel electrode in 0.5 M H_2SO_4 solution.

3.3 Polarization studies.

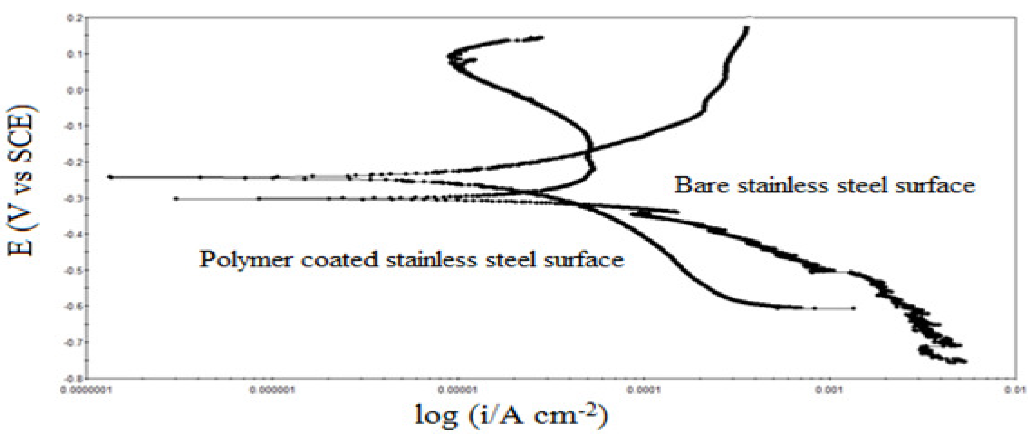

Figure 3. Tafel curves of (a) bare (b) PNMA-2PPA coated stainless steel, in 0.5M H_2SO_4 solution.

Fig.3 shows the potentiodynamic polarization curve for bare and PNMA-2PPA polymer-coated stainless steel surface. Here corrosion current decreased about two orders for polymer-coated stainless steel surface when compared to the bare stainless steel surface.

Table 3**.** Corrosion inhibition efficiencies evaluated by Tafel polarization method Inhibitor system: PNMA-2PPA

Inhibitor (ppm)	$-E_{corr}$ (mV)	β_a (mV)	β_c (mV)	i_{corr} ($mA\ cm^{-2}$)	Inhibition Efficiency (%)
0.5M H_2SO_4	303	36	79	31.48×10^3	-

(Blank)					
100	350	67	99	0.1634×10^3	99.48

The potentiodynamic polarization parameters like corrosion current (E_{corr}), corrosion current density(I_{corr}), anodic Tafel slope (β_a), cathodic Tafel slope (β_c) and the percentage of inhibition efficiency listed in Table 2. Corrosion current density decreased for polymer-coated stainless steel surface 31.48 $\times$ mA $cm^{-2} \times 10^3$ to 0.1634 $\times$ mA $cm^{-2} \times 10^3$ simultaneously corrosion potential towards move more positive potential. Anodic and cathodic Tafel slopes changed concerning corrosion potential. Here displacement of corrosion potential 47 mV, hence the polymer treated as a mixed-type inhibitor. Therefore the polymer-coated stainless steel surface does not alter the reaction mechanism because the polymer samples deposited on the active center of the stainless steel surface thereby reduce the availability area of corrosion.

Conclusions

1. PNMA-2PPA polymer synthesis was achieved successfully on the stainless steel electrode surface.
2. Cyclic Voltammogram results were confirmed by the polymerization process.
3. Electrochemical and Impedance studies were confirmed the polymer molecules deposited on the active center of the stainless steel.
4. The maximum inhibition efficiency was observed in the potentiodyanamic polarization method and the inhibition efficiency was 99.48 %.
5. The inhibitor type was mixed type of inhibitor.

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