# Electropolymerization of Thiophene on Stainless Steel and using for Anticorrosion

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**Abstract:** In this research electropolymerization of Thiophene (Th) on Stainless Steel (SS) electrode has been studied by applying cyclic voltammograms in acid solutions in nitrogen gas at different reaction parameters for example concentration of monomer, concentration of perchloric acid and temperature. The electropolymerization method respects first order kinetics with respect to the concentration of monomer, the order of reaction with respect to the supporting electrolyte concentration (HClO<sub>4</sub>) was found to be 0.743. The experimentally achieved equation of kinetic was PR = KE [HClO<sub>4</sub>]<sup>0.743</sup> [monomer]<sup>1.017</sup>. A easy mechanism for the electrochemical reaction of (Th) was suggested and the apparent activation energy was define. The obtained dark films of Polythiophene (PT) were characterized by FTIR, X-ray, TEM and FESEM analysis. Traditional electrochemical methods for the obtained polymer such as cyclic voltammetry and linear sweep voltammetry methods were used to characterized, synthesis and investigate the application of the PT polymer as corrosion inhibitors for stainless steel in 3.5% NaCl.

Key words: Activation, temperature, analysis, application, concentration, parameters

# INTRODUCTION

Conducting polymers are organic substance shaving optical, magnetic, electronic and electrical properties of a metallic compounds while maintaining a fairly good mechanical properties. Unique properties found in these organic compounds which are generally contain simply of C-H and simple hetero atom such as S and N and the numerous of properties coming from it, result from exclusively from II-conjugation which is the main requirement in polymers for conduction (Uleanya *et al.*, 2013).

Anodic electrochemical oxidation is the best broadly utilized technique to prepare poly heterocycles of high-level conductivity (Bingol *et al.*, 2005). It's a good way to create smooth thin films from polymers on conductive surfaces. Homogeneous films from the conductive polymer, conductive to electricity can be obtained which can be easily peeled from the surface of the electrode. By controlling the oxidation voltage in this method, the thickness of the thin film formed on the surface of the electrode can be controlled. By changing the factors used in electrochemical polymerization different polymers can be obtained from the same monomer (Chiang *et al.*, 1977).

Electrochemical polymerization method is commonly utilized for thiophene to prepare thin conducting films with controlled thicknesses (Loewe *et al.*, 2001). Polythiophene (PT) have various popular and interesting areas of use such as light emitting diodes, corrosion protection of metals, non-linear optical devices, sensors for volatile organic materials and organic solar cells (Kumar *et al.*, 2015). Corrosion is defined as the physical or chemical change that happens to the metal or alloy by the effect of electrochemical processes. Corrosion occurs as a result of oxidative reactions the corrosion process stops when prevent sone of the reactions of oxidation or reduction. By two mechanisms conducting polymers can protect the substrate from corrosion 6 (Kashif *et al.*, 2014).

Firstly, supplies a barrier among the environment and the metal. The other provides a passivation of the metal surface as anodic or cathodic protection (Medrano-Vaca *et al.*, 2008). In literature, polythiophene film has the corrosion protection of stainless steel in 3.5% NaCl solution.

## MATERIALS AND METHODS

**Experimental part:** Thiophene, perchloric acid solution and acetonitrile as solvent all were purchased for Merck, Germany. All perchloric acid solutions were prepared by utilizing newly DI water.

**Electrodes:** The Working Electrode (WE) was a stainless steel sheet with area of 2 cm<sup>2</sup>. The auxiliary Electrode (CE) was a gold wire with the length 3 cm as the WE. A reference electrode was saturated calomel electrode. Electrochemical experiments were achieved by means of the DY2000 series multi-channel potentiostat.

## **RESULTS AND DISCUSSION**

**Electropoly merization of thiophene:** Electropoly merization of (Th) on SS electrode from solution containing 70 mM HClO<sub>4</sub>/ acetonitrile at 298 K



Fig. 1: Electropolymerization of Th at repetitive cycling of solution containing 70 mM HC<sub>1</sub>O<sub>4</sub> with scan rate 50 mVsec<sup>-1</sup> at 298 K



Fig. 2: Effect of scan rate on electropoly merization of thiophene at 298 K

was investigated in cyclic voltammetry at potential run between +200 to +2000 mV (vs. SCE) at scan rate of 50 mVs<sup>-1</sup>. The gotten voltammograms was given in Fig. 1 the electrochemical behaviors of (Th) at SS electrode had oxidation peak at 1.73 and a reductive peak at 1.16 V with a scan rate of 50 mV sec<sup>-1</sup>. The peak at 1.73 correspond to oxidation of monomer to give thiophene radical which adsorbed on SS-electrode (Gattrell and Kirk, 1993). The cathodic peak was found at 1.16 V which correspond to the reduction of the created polymer films. Figure 1 also shown that the effect of repetitive cycles on SS-electrode in solution containing 70 mM HC<sub>1</sub>O<sub>4</sub> with 6 mM monomer at 298 K. Through the results, we note that after the second cycle it gets reduced in the oxidation and the reduction peak currents. The reason for the decline in the repetitive cycling is the full surface of the electrode by the product of the polymer film which prevents diffusion of thiophene ions to the surface of the electrode and this causing a significant decrease in the anodic and cathodic peaks current. The results show that the thickness of the film independent on

oxidation and reduction reactions this is evident by the lack of change in the potential peaks (Sayyah *et al.*, 2010).

Effect of scan rate: The cyclic voltammogram of monomer solution was track at distinct scan rates. As the scan rate changes from 10-200 mV sec<sup>-1</sup> there is a shift in the anodic peak potentials. From Table 1 it is easy to conclude that as the scan rate increases the peak-to-peak separation ( $\Delta$ Ep) also changes. The ratio of the anodic peak current to the cathodic peak current is also different from unity. Hence, the electrochemical reaction of thiophene is irreversible. The current function reduces from 1.992×10<sup>-3</sup> A cm<sup>-2</sup> V<sup>-1/2</sup> s<sup>1/2</sup> to 1.603×10<sup>-3</sup> A cm<sup>-2</sup> V<sup>-1/2</sup> s<sup>1/2</sup> with rising scan rate. This indicates the presences of a chemical reaction coupled to the electron transfer (ECE mechanism) (Bard and Faulkner, 1982) (Fig. 1).

There was a perfect linear relationship between scan rate and peak current (Fig. 3 a). Ip = 0.027 v+0.002;  $R^2 = 0.9983$ .

In addition, there was a linear relationship between log Ipa and log v Fig. 3b, identical to the resulting equation: log Ipa = 0.425 log v-2.8921;  $R^2$  = 0.9647. With the value of slope 0.425 the results indicate that the diffusion of thiophene ions from bulk of solutions to the surface of the electrode is diffusion control process because the slope value is close to the theoretical value 0.5 (Hegde *et al.*, 2009). The linear relationship between peak potential and logarithm of scan rate Fig. 3c can be expressed as: Epa = 0.1153 log v+1.8879;  $R^2$  = 0.9914. This behavior is due to the nature of the electrochemical reaction in which an irreversible chemical reaction occurs in addition to the reaction of the electrode (Laviron, 1979).

According to Laviron for an irreversible process of electrode (Brown *et al.*, 1964) Epa is defined by the Eq. 1:

$$E_{p} = E^{0} + \left(\frac{2.303RT}{\alpha nF}\right) \log\left(\frac{RTK^{0}}{\alpha nF}\right) + \left(\frac{2.303RT}{\alpha nF}\right) \log \upsilon \quad (1)$$

Where:

 $(k^0)$ : The standard heterogeneous rate constant

- ( $\alpha$ ) : The transfer coefficient
- $\upsilon$  : The scan rate
- $(E^0)$ : The formal redox potential
- (n) : The number of electrons transferred

Thus, the value of ( $\alpha$ n) can be easily calculated from the slope of Epa vs. log v. In this process, the slope is 0.1153, then ( $\alpha$ n) computed to be 0.513, taking R = 8.314 JK<sup>-1</sup> moL<sup>-1</sup>, T = 298 K and F = 9648°C moL<sup>-1</sup>. According to Bard and Faulkner (1980)  $\alpha$  can be given as:



Fig. 3:(a) Dependence of redox peak current on scan rate, (b) Linear relationship between logarithm of redox peak current and logarithm of scan rate, (c) Linear relation between redox peak potential and logarithm of scan rate of ox-red of thiophene solution and (d) Linear relation between redox peak current and the square root of scan rate

Table 1: Shows the influence of scan rate on peak current and peak potential for the oxidation of thiophene with cyclic voltammogram of 6 mM thiophene in 70 mM  $HClO_4$ 

Scan rate (mVsec <sup>-1</sup> )	Ipa (µA)	Ipc (µA)	Ipa/Ipc	Ea (V)	Ec (V)	$\Delta E(V)$
10	199.4	71.88	2.774	1.689	1.199	0.490
20	234.1	46.93	4.988	1.711	1.177	0.534
50	317.2	-11.29	-29.100	1.726	1.157	0.569
100	465.5	-83.37	-5.584	1.764	1.141	0.623
200	714.8	-212.6	-3.362	1.829	1.121	0.708

$$\alpha = \frac{47.7}{\mathrm{Ep} - \mathrm{E}_{\mathrm{p}/2}} \mathrm{mV}$$
 (2)

where,  $E_{p/2}$  is the value of potential at the current is at half the peak value. From this we got  $\alpha$  value equals to 0.472. The number of transferred electron in the electro oxidation of Th was calculated to be  $1.08 \approx 1$ . The value of  $k^0$  can be determined from the intercept of the peak potential and logarithm of scan rate plot if the value of  $E^0$  is known the intercept for  $E_{pa}$  versus log  $\nu$  plot was 1.8879 and  $E^0$  was achieved to be 1.678, the  $k^0$  was calculated to be  $1320.2 \text{ sec}^{-1}$ . The value of  $E^0$  in Eq. 1 can be obtained from the intercept of anodic oxidation potential versus scan rate by extrapolating to the vertical axis at  $\nu = 0$  (Wu *et al.*, 2004).

As is shown in Fig. 3c, the linear relation between Ipa vs. v<sup>1/2</sup> indicated the diffusion-controlled Th oxidation. From Fig. 3d and c can be concluded that the electrochemical process consists of a mixture of diffusion and adsorption controlled processes, depending on the scan rate (Salimi *et al.*, 2004; 2008; Siswana *et al.*, 2006; Ye *et al.*, 2005).

**Kinetic studies:** The kinetics of electropolymerization of thiophene was investigated by utilizing solution containing different concentrations of monomer in the range 6, 8, 13, 17, 21 mM where  $HClO_4$  concentration in the range 70,85,95,105,115 mM at 298K. The CV and the relation between the logIpa vs. log [monomer] or log Ipa vs. log [HClO<sub>4</sub>] were plotted from which linear relations were obtained.

Influence of monomer concentration on the electropolymerization processes: The effect of (Th) concentrations on the cyclic voltammetry performance was studied in solution containing 70 mM HClO<sub>4</sub> at 298K scan rate of 50 mVsec<sup>-1</sup> is shown in Fig. 4a. The CV show that the anodic peak current densities (Ipa) increase with the monomer concentration increasing in the range between 6 and 21 mM. This is behavior due to the increased of electro active species availability in solution. At higher monomer concentrations (i.e., concentration >21 mM) the peak current didn't increase, this is because at higher concentration the oxidation reaction is not limited by diffusion alone. A double logarithmic plot of the (Ipa) against monomer concentrations are graphically represented in Fig. 4b, straight line with slope of 1.017



Fig. 4: Effect of monomer concentration on electropolymerization of thiophene from solutions containing 70 mM HClO<sub>4</sub> at scan rat 50 mV sec<sup>-1</sup>



Fig. 5: Effect of acid concentration on electropolymerization of thiophene from solutions containing 6 mM thiopheneat scan rat 50 mV sec<sup>-1</sup>

was obtained. Therefore, respect to monomer concentration the reaction order is a first-order reaction.

Effect of acid concentration on the polymerization process: The effect of perchloric acid concentration on the CV using 6 mM monomer at 298 K with scan rate of 50 mVsec<sup>-1</sup> is represent in Fig. 5a. Voltammograms display that the anodic peak current (Ipa) increase with the acid concentration increasing. At higher acid concentrations (>115 mM) the oxidation peak current was

began to decrease as a result of solubility and the degradation of the polymer film from the SS electrode surface.

A double logarithmic plot (Ipa) against log [acid] is graphicall y represented in Fig. 5, straight line with slope of 0.742 was obtained. Therefore, the kinetic rate laws obtained from this method can be written as: Rate =  $k_E$ [monomer]<sup>1.017</sup> [acid]<sup>0.742</sup>  $k_E$  is kinetic rate constant.

Effect of temperature on the polymerization process: The effect of solution temperature on



Fig. 6(a-c): (a) Effect of temperature on electropolymerization of thiophene from solution contain 70 mV acid and 6 mM monomer at 50 mV sec<sup>-1</sup>, (b) Arrhenius plot of the anodic oxidation of thiophene monomer and (c) Eyrring plot of the anodic oxidation of thiophene monomer



Fig. 7: (a) The infrared spectra of thiophene and (b) Polythiophene

electropolymerization voltammograms curves in the range between 288-313 K by using 6 mM monomer concentration and 70 mM acid concentration) was illustrated in Fig. 6a. From this figure, we show that an increase of the reaction temperature resulted in an increase in the anodic peaks currents. The plot of the log(Ipa) vsec. 1/T is appeared in Fig. 6b given straight line with slope value equal to -1897.7. The apparent activation energy was found to be 36.33 kJ moL<sup>-1</sup> when calculated using arrhenius equation.

The enthalpy  $\Delta H^*$  and entropy  $\Delta S^*$  of activation for the electro polymerization reaction can be calculated from

Eyring equation (Eyring, 1935) as shown in Fig. 4. This result in linear relationships with slope equal to

$$\left(-\frac{\Delta H^*}{2.303 \text{ R}}\right)$$
 and intercept equal to  $\left(\log \frac{R}{Nh} + \frac{\Delta S^*}{2.303 R}\right)$ .

From the slope and intercept values,  $\Delta H^*$  and  $\Delta S^*$  for Th are calculated to be 33.84 kJ moL<sup>-1</sup> and -197.8 J.K<sup>-1</sup> moL<sup>-1</sup>, respectively.

# Characterization of polythiophene

**Infrared spectroscopic studies:** The nano structure of polythiophene was studied by FTIR spectroscopic technique (Fig. 7). The FT-IR spectra of polythiophene



Fig. 8: Raman spectroscopy of polythiophene thin film



Fig. 9: The X-ray Diffraction (XRD) of polythiophene

and Th monomer show that the distinguishing absorption bands of polythiophene are alike to those prepared by conventional method (Genies et al., 1983; Ballav and Biswas, 2003). The peak at 3105  $cm^{-1}$  for Th might be assigned to C-H vibration of the  $\alpha$ -situation of the thiophene unit, this peak missing in PT which implied that the thiophene unit was stable through the free radical electropolymerization and also shown that the electropolymerization happened at the 2,5-positions of the ring, indicating that Th was polymerized to form PT through  $\alpha$ ,  $\alpha$ '-coupling of thiophene unit. Their IR spectra show the typical characteristic thiophene ring stretching vibration, C-C, stretching vibration of in-plane C-H, C-S and C-H out-of-plane bending vibration absorption at about 1438, 1298, 1087 and 937, 675 and 626 cm<sup>-1</sup> (Yildiz et al., 2006; Furukawa et al., 1987).

The Raman spectra of PT show two main peaks where the first prominent peak appeared within 1400-1500 cm<sup>-1</sup> corresponds to C = C stretching region which is symmetric in phase vibration of thiophene ring. The second small peak observed in the range 936-1033 cm<sup>-1</sup> corresponds to C-C stretching along with C-H wagging component. This vibrational feature confirmed that the  $\pi$ -electrons in PT are confined within each thiophene ring. The peak at about 1354 cm<sup>-1</sup> was C-C ring stretching. The peaks at 1149 cm<sup>-1</sup> and 1049 cm<sup>-1</sup> refer to the ring symmetric bending vibration and the in-plane C-H bending mode, respectively. The peaks at 483-622 cm<sup>-1</sup> was attached to the ring deformation C-S-C.

**XRD analysis of polythiophene:** The crystal structure of deposited polythiophene was examined by the XRD, Fig. 8 is shows a peaks around  $2\theta = 19.1^{\circ}$ ,  $23.5^{\circ}$ ,  $27.2^{\circ}$ ,  $30.4^{\circ}$ ,  $31.8^{\circ}$ ,  $33.4^{\circ}$ ,  $36.6^{\circ}$ ,  $41.2^{\circ}$ ,  $43.6^{\circ}$ ,  $45.6^{\circ}$ ,  $47.6^{\circ}$ ,  $52.0^{\circ}$  and  $73.4^{\circ}$ , this peaks give semi-crystalline of polymer because it has partially crystalline and partially amorphous structure. The normal crystallite size of sharp peaks is assessed by utilizing scherrer's equation prompts the crystallite size of PT about 24.34 nm.

Scanning electron microscopy and transmission electron microscopyanalysis: The FESEM and TEM images of PT thin film shows the surface morphology in Fig. 9: as shown by FESEM images in Fig. 10, the surface structure of PT showed a rod-like structure with crystalline structure size around 51 nm. TEM measurements of polythiophene Fig. 10b: it can be seen that the particle size is 51.4 nm with rod like shape The particles have good dispensability and clear mesh structure.

## Application of polythiophene as corrosion inhibitors on stainless steel in 3.5% NaCl

**Polarization measurements:** Polarization studies were performed using linear sweep voltammetry with a cell containing three-electrode a counter electrode was Pt wire, reference electrode SCE the potentiodynamic polarization curves were logged utilizing a PC which was linked to the electrochemical device. The polarization information was analyzed utilizing EC-lab electrochemical software. The inhibition efficiency (IE%) was well-defined by giving Eq. 4 (Ashassi-Sorkhabi *et al.*, 2005): J. Eng. Applied Sci., 14 (Special Issue 9): 10600-10609, 2019



Fig. 10: FESEM and (8) TEM analysis of polythiophene

Table 2: Values of peak positions  $(2 \theta)$  crystallite size, FWHM, d-spacing and intensity of polythiophene

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20	FWHM	d-spacing	Size (nm)	Intensity
19.179	0.3455	4.6240	23.56938	97
23.511	0.4395	3.7809	18.66086	135
27.215	0.3770	3.2741	21.91333	196
30.417	0.4395	2.9363	18.93253	233
310861	0.3135	2.8065	26.63513	134
33.493	0.3450	2.6733	24.30449	129
36.632	0.8475	2.4511	9.979856	84
41.216	0.3140	2.7917	27.31961	87
43.664	0.4395	2.0713	19.68103	37
45.610	0.3455	1.9297	25.21077	53
47.054	0.2200	1.9874	39.80644	47
52.077	0.3135	1.7548	28.50555	72
73.486	0.3140	1.2876	31.91136	40

$$IE\% = \frac{Icorr, un-Icrr, in}{Iocrr, un} \times 100$$
 (4)

where, the Icorr un and Icorr in are the corrosion current density without and with inhibitors, respectively. The inhibition efficiency was increase with inhibitor prepare concentration increase from (1.2-1.75) but decrease with temperature.

The Tafel plots obtained from the potentiodynamic polarization test for the corrosion of PT-coated and uncoated stainless steel in 3.5% NaCl at different prepare concentration and different prepare concentration are presented in Fig. 11. The corrosion parameters (corrosion potential, corrosion current and polarization resistance) for both PT coated and uncoated SS were determined from the Tafel extrapolation method and are presented in Table 2 and 3. Tafel plots for PT-coated SS showed a decrease in

current density (Icorr) as well as a positive shift in corrosion potential (Ecorr) with respect to the uncoated.

**Kinetic of corrosion:** Arrhenius Eq. 5 (El Ayyoubi *et al.*, 2012) was applied to study the influence of temperature on the corrosion kinetic of SS without and with polythiophene as an inhibitor to perfect the data of electrochemical response in salt media:

$$Logicorr = LogA - \frac{Ea}{2.303RT}$$
(5)

The orderly line shaped from a scheme between 1/T and logarithm of Icorr to obtain the activation Energy (Ea) from the slop, the exponential factor (A) can be obtain from the intercept, Fig. 12:

The calculation showed that the activation energy raises with rising of concentration resulting increasing layer thickness on the surface of SS as shown in Table 4.

Table 3: Corrosion kinetic parameters for mild steel in absence and presence of polythiophene at a different temperature range 293-323 K and different prepare concentration

Variables/T (C)	Ecorr (mV)	Icorr (µA)	Ba (mV)	βc (mV)	IE (%)	R
Blank						
20	-328	29.936	275.7	172.1		4.095*10 <sup>-3</sup>
30	-412	33.300	483.4	180.9		4.555*10 <sup>-3</sup>
40	-359	38.374	605.0	175.9		5.249*10 <sup>-3</sup>
50	-388	44.626	655.7	161.9		6.104*10 <sup>-3</sup>
10 ppm						
20	301	1.6880	235.2	261.4	94.36	0.5522*10-3
30	334	2.0130	240.3	248.6	93.95	0.6333*10-3
40	371	2.3000	212.5	251.9	94.01	0.7236*10-3
50	473	2.7380	92.70	316.7	93.86	0.8614*10 <sup>-3</sup>
12 ppm						
20	316	1.0760	231.7	293.3	96.41	0.3385*10 <sup>-3</sup>
30	373	1.5470	221.4	231.6	95.35	0.4867*10-3
40	404	2.5290	195.9	221.5	93.41	0.7957*10 <sup>-3</sup>
50	448	3.0460	127.8	212.4	93.17	0.9538*10 <sup>-3</sup>
14 ppm						
20	1.69	0.8260	159.7	202.5	97.24	0.2599*10 <sup>-3</sup>
30	253	1.0490	207.2	168.3	96.85	0.3300*10-3
40	372	1.9540	205.2	260.6	94.91	0.6148*10 <sup>-3</sup>
50	453	2.5530	118.1	263.6	94.28	0.8032*10-3
16 ppm						
20	237	0.8490	216.4	164.6	97.16	0.2671*10-3
30	348	1.2460	138.7	82.6	96.35	0.3826*10-3
40	403	2.1860	155.7	155.1	94.30	0.6878*10 <sup>-3</sup>
50	461	2.7810	105.7	227.3	93.77	0.8750*10-3



Fig. 11(a-d): Polarization curves of SS in 3.5% NaCl in the absence and present polythiophene thin film at (293-323 K) and at 10 ppm, (a), 12ppm, (b), 14 ppm, (c) and 16 ppm and (d)

The activation energies are lower than the threshold value of 80 KJ moL<sup>-1</sup> required for chemical adsorption. This means that adsorption is physical adsorption (Manimegalai and Manjula, 2015). Enthalpy  $\Delta$ H, the entropy  $\Delta$ S values (Table 4) are calculated by using of Arrhenius condition 6 (Awad, 2006):

$$Ln\frac{Lcorr}{T} = \frac{R}{Nh} + \frac{\Delta s}{R} - \frac{\Delta H}{RT}$$
(6)

plotted of ln Icorr /T vs. 1/T to give strength line has slope =  $-\Delta$ H/R and intercept equivalentln (R/Nh)+ $\Delta$ S/R as exposed in Fig. 12: the values of  $\Delta$ H° lower than 40 KJ moL<sup>-1</sup> which attributed the physical adsorption and the value 100 KJ mol<sup>-1</sup> indicate chemical adsorption (Avci, 2008).  $\Delta$ S shows a negative value that mean the growth of activated complex reductions while  $\Delta$ H has positive values which indicate endothermic process of

	temperature range 295-525 K				
Туре	Concentration (ppm)	Ea (KJ mole.K <sup>-1</sup> )	ΔH (KJ/mole. K)	$\Delta S(J/mole. K)$	Ea-∆Ha
Blank		7.869949	5.314059	-191.951	2.555724
	10	12.45936	9.903637	-206.611	2.555724
	12	28.50039	25.94467	-155.526	2.555724
РТ	14	31.4926	28.93688	-148.058	2.555724
	16	32.65905	30.10333	-143.490	2.555724

Table 4: The activation Energy (Ea.) and the thermodynamic parameters for the corrosion activation PT of MS of using inhibitor or not over the temperature range 293-323 K



Fig. 12: Arrhenius plots of log Icorr versus 1/T in presence and absence of PTh at different concentration, transition-state plot for stainless steel corrosion current (Icorr) in absence and presence of PT at different concentration

activation complex formation (Bhat and Alva, 2011; Valek and Martinez, 2007). Free energy can be calculated applying thermodynamic Eq. 7 (Abdallah *et al.*, 2009; Musa *et al.*, 2009). The positive value of f ree energy meaning that corrosion reaction non-spontaneous and its value increases with increasing the concentration of polythiophene:

$$\Delta G^* = \Delta H^* - T \Delta S^* \tag{7}$$

#### CONCLUSION

During the research an electropolymerization of thiophene was carried out using the cyclic voltammetry methods a thin films on stainless steel sheets. The kinetic of electropolymerization was studied and the kinetic rate equal to (Rate =  $[monomer]^{1.017}[acid]^{0.742}$ ) the effect of temperature on the electropolymerization reaction and the calculation of the thermodynamic functions of the reaction was also studied. The polymer film was characterized using FTIR, Raman, TEM, FESEM and XRD and found from XRD measurement that the polymer with a nano-crystalline structure have 24 nm. The effect of polymer on the protection of stainless steel from corrosion was also studied. The polymer has a high protection ratio about 90%.

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