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Investigation on Ethylenediaminetetra-Acetic Acid as Corrosion Inhibitor for Mild Steel in 1.0M Hydrochloric Acid

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Abstract

The influence of ethylenediaminetetra-acetic acid (EDTA) on the corrosion of mild steel in 1.0 M hydrochloric acid solution was investigated by means of potentiodynamic polarization and electrochemical impedance spectroscopy (EIS). The efficiency of EDTA was compared with thiourea. Primary results obtained revealed that EDTA performed as good corrosion inhibitor for mild steel in 1.0 M hydrochloric acid media comparing with thiourea. Polarization curves show that the behavior of EDTA and thiourea are mixed-type inhibitors. EIS shows that the control step for corrosion process is a charge transfer mechanism.

Keywords: Corrosion inhibitor, Ethylenediaminetetra-acetic acid, Thiourea, Mild steel, Electrochemical measurement

1. Introduction

Mild steel is widely used as a constitutional material in many industries due to its good mechanical properties and low cost. The corrosion of mild steel is of fundamental academic and industrial concern that has received a considerable amount of attention. Acid pickling baths are employed to remove undesirable scale from the surface of the metals. Once the scale is removed, the acid is then free for further attack on the metal surface. The use of inhibitor is one of the most practical methods for protection against corrosion, especially in acidic media.

A survey of literature reveals that the applicability of organic compounds as corrosion inhibitors for mild steel in acidic media has been recognized for a long time. Compounds studied as inhibitors include triazole derivatives (Bentiss et al 1999a , Bentiss et al 1999b), bipyrazolic derivatives (Touhami et al 2000), surfactants (Algaber et al 2004, Branzoi et al 2000) aromatic hydrazides (Quraishi et al 2001) , organic dyes (Oguzie et al 2004a, Oguzie et al 2005b) , Poly

(4-vinylpyridine) (Larabi et al 2004) and thiosemicarbazide-type organic compounds (Benali 2006). These compounds can adsorb on the mild steel surface and block the active sites decreasing the corrosion rate.

This paper describes the affect of ethylenediaminetetra-Acetic acid (EDTA), $C_{10}H_{16}N_2O_8Na_2$, on corrosion inhibition of mild steel in 1.0M hydrochloric acid solutions comparing with thiourea. Figure 1 shows the molecular structure of used inhibitors.

2. Experimental

Commercially mild steel metal was used. Sample was mechanically polished using SiC paper in successive grades from 200 to 1500 and was rinsed with methanol. The acid solutions were made from RA grade HCl. Appropriate concentration of acid was prepared by using distilled water. The measurements were carried out in a three electrodes electrochemical cell with a graphite counter electrode and saturated calomel electrode (SCE) as reference. Potentiodynamic polarization curves were obtained starting from *Ecorr* with the potential scan rate of 125 μV/s. EIS measurement was carried out on steady state open circuit potential (OCP) disturbed with amplitude of 10 mV A.C. sine wave at frequencies between 0.01 Hz and 100 KHz. Measurements were performed at room temperature using Potentiostat/Galvanostat/ZRA (Gamery instrument, Ref600 model, USA)

3. Results and Discussion

3.1 Polarization measurements

The effect of the concentration of EDTA and thiourea are shown in Figure 2 which presents the anodic and cathodic Tafel curves of mild steel in 1 M HCl. Values of anodic *βa* and cathodic *βc* Tafel constant and corrosion current density are listed in Table 1 and 2. These values were calculated from the intersection of the anodic and cathodic Tafel lines of the polarization curve at *Ecorr*. The inhibition efficiencies are calculated by the following expression:

$$IE\% = \frac{i_{unhibit} - i_{inhibit}}{i_{unhibit}} \times 100 \quad (1)$$

where $i_{unhibit}$ and $i_{inhibit}$ are respectively, the corrosion current density without and with EDTA or thiourea in 1.0 M HCl solution.

The anodic and cathodic Tafel lines for mild steel in presence of EDTA or thiourea were almost parallel upon increasing inhibitor concentrations. This suggests that the inhibitor act by simple blocking the mild steel surface (Manahan, 1996). In the other words, the inhibitor decreasing the exposed surface area for corrosion as well as it doesn't affect the mechanism of mild steel dissolution or hydrogen evolution reaction. Only when the change in *Ecorr* value is no less than 85 mV, a compound can be recognized as an anodic or a cathodic type inhibitor (Ashassi-Sorkhabi et al 2004). The largest displacement of the corrosion potentials (E) were about 8 mV and 11 mV in presence of EDTA and thiourea, respectively. Therefore, EDTA and thiourea are acts as corrosion mixed-type inhibitors. Also the inhibition efficiencies increase with increasing inhibitors concentration as shown in Table 1 and 2.

3.2 EIS measurements

The results of EIS were figured by Nyquist plots, Figure 3. Double layer capacitance values (*Cdl*) and polarization resistance values (*Rp*) were obtained from impedance as described by Moretti (2004). The fitted values of *Rp* and *Cdl* are listed in Table 1 and 2. The inhibition efficiencies IE% is calculated by polarization resistance (*Rp*) as follows:

$$IE\% = \frac{Rp_{inhibit} - Rp_{unhibit}}{Rp_{inhibit}} \times 100 \quad (2)$$

The *Rp* values increase with the increase in concentration of either EDTA or thiourea, indicating an insulated adsorption layer formation; the decrease in *Cdl* values suggested a decrease in local dielectric constant between the metal and electrolyte induced by the adsorption of EDTA or thiourea (Khaled and Hackerman 2003).

4. Conclusion

EDTA showed good inhibition performance comparing with thiourea. Polarization curves indicated that the EDTA and thiourea behave mainly as mixed-type inhibitors. EIS showed that the charge transfer controls the corrosion process in the uninhibited and inhibited solutions either for EDTA or thiourea.

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Table 1. Polarization parameters and EIS parameters for mild steel in 1.0 M HCl with different concentrations of EDTA

Technique	Parameters	Inhibitor concentration (mg/l)					
		Blank	10	20	40	80	160
Polarization parameters	Ecorr (mV)	493	497	500	499	503	495
	Icorr ($\mu A/cm^2$)	615	452	356	334	289	192
	βa (mV/decade)	0.12	0.16	0.11	0.1	0.1	0.1
	βc (mV/decade)	0.14	0.17	0.13	0.13	0.13	0.12
	IE%	0	26.50	42.11	45.69	53.01	68.78
EIS parameters	Rp (ohm. cm^2)	36.5	48.06	49.23	54.15	55.02	68
	Cdl ($\mu F/cm^2$)	173.9	137.6	127.7	113.1	111.9	89.5
	IE%	0	24.05	25.86	32.59	33.66	46.32

Table 2. Polarization parameters and EIS parameters for mild steel in 1.0 M HCl with different concentrations of thiourea

Technique	Parameters	Inhibitor concentration (mg/l)					
		Blank	10	20	40	80	160
Polarization parameters	Ecorr (mV)	493	510	512	507	514	513
	Icorr (μA/cm^2)	615	504	431	371	298	234
	βa (mV/decade)	0.12	0.11	0.10	0.11	0.10	0.12
	βc (mV/decade)	0.14	0.13	0.13	0.13	0.12	0.13
	IE%	0.00	18.05	29.92	39.67	51.54	61.95
EIS parameters	Rp (ohm. cm^2)	36.5	68.27	73.64	84.64	86.59	95.55
	Cdl (μF/cm^2)	173.9	147.4	135,2	127.2	114.5	85.4
	IE%	0	46.53	50.43	56.87	57.84	61.8

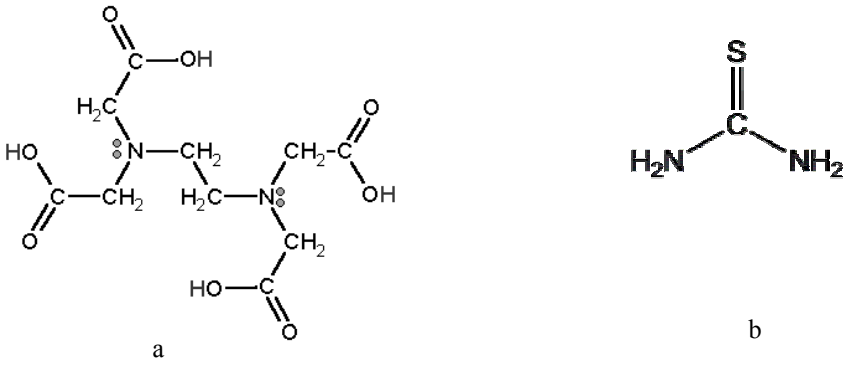
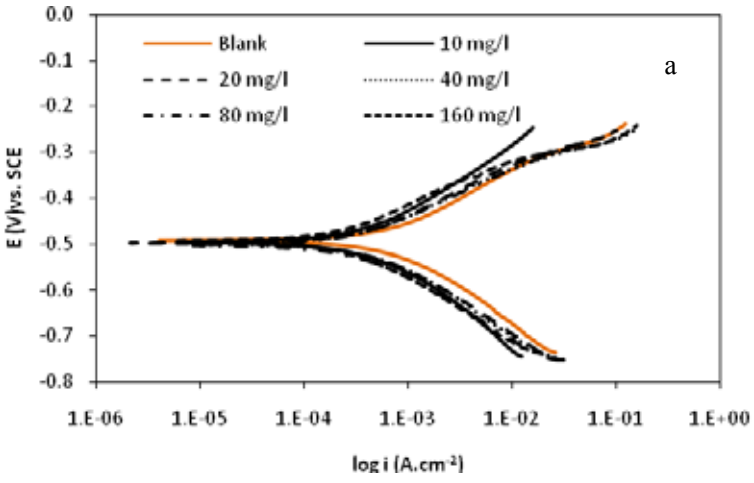


Figure 1. Molecular structures for EDTA (a) and thiourea (b)



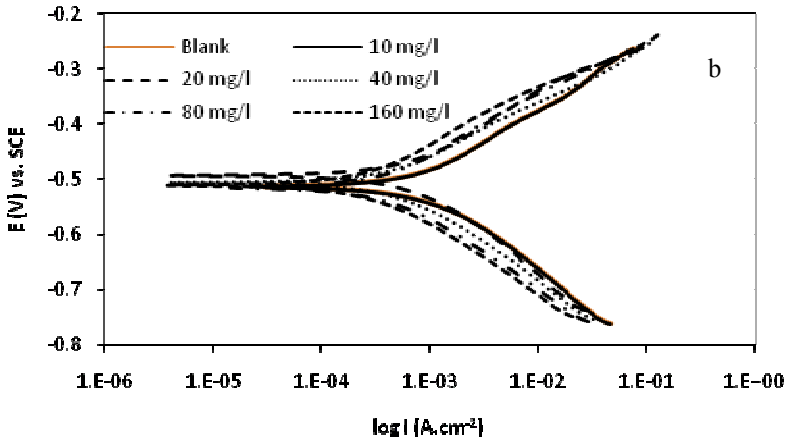


Figure 2. Polarization curves for mild steel in 1.0 M HCl with different concentrations of EDTA (a) and thiourea (b)

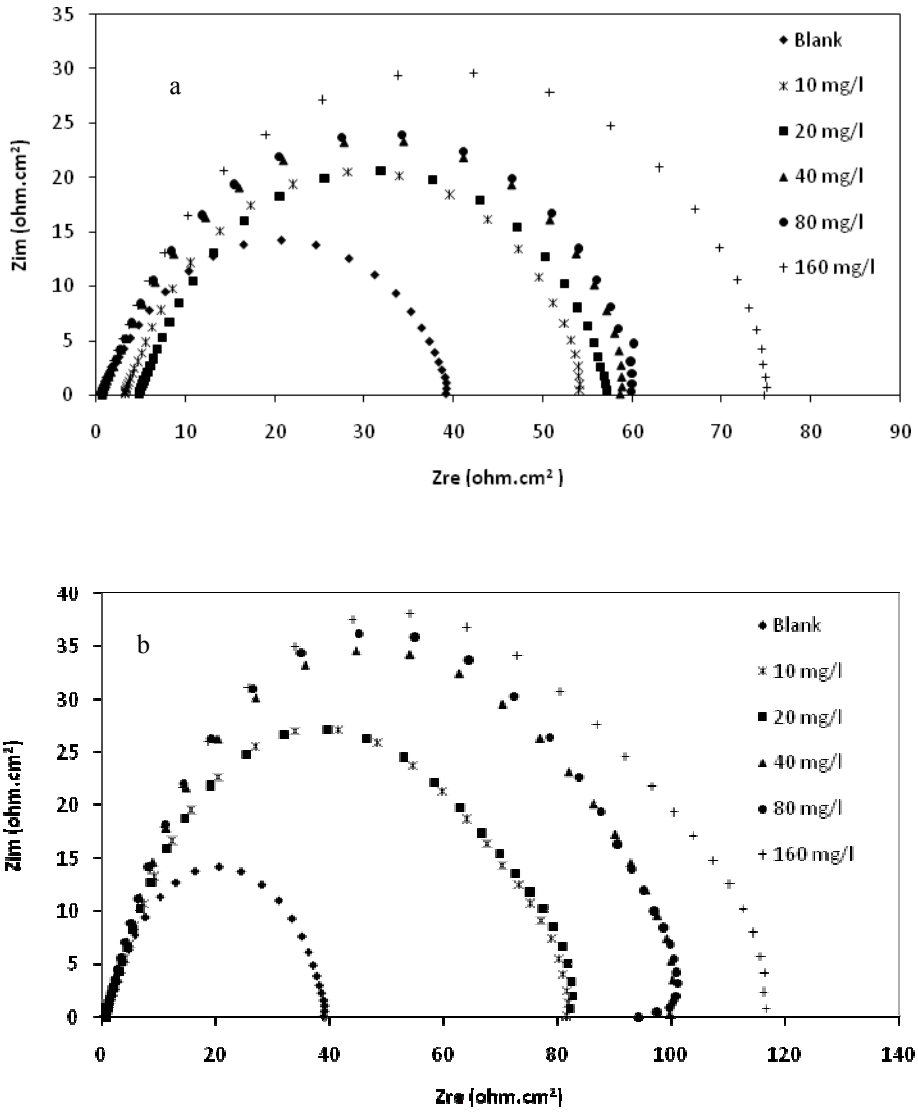


Figure 3. Nyquist plots for mild steel in 1.0M HCl with different concentrations of EDTA (a) and thiourea(b)