Asian Journal of Chemistry Vol. 19, No. 4 (2007), 2574-2580

Polarization Behaviour of Stainless Steel Type 302 in HCl Solution of Benzotriazole

S.M.A. HOSSEINI*, S. EFTEKHAR and M. AMIRI
Department of Chemistry, Shahid Bahonar University of Kerman, 76169, Kerman, Iran
Fax: (98)(341)3222033; Tel: (98)(341)3222033
E-mail: s.m.a.hosseini@mail.uk.ac.ir; hosseini1957@yahoo.com

The inhibition behaviour of stainless steel type 302 in different concentrations (1×10^{-3} to 8×10^{-3} M) of benzotriazole (BTA) in 1 M HCl at various temperatures (10, 30, 50 ± 1ºC) has been studied potentiodynamically. The open circuit potential (OCP) values noted were negative before polarization but after completion of the experiment they turned positive and remained stable over long period of time indicating formation of passive and protective film on the surface of sample. It is observed that cathodic current density values increase with increasing cathodic potential (more negative). It is found that corrosion potential (E_{corr}) and passive potential (E_p) increase (toward + ve potential) with increasing benzotriazole concentrations, while corrosion current density (i_{corr}), critical current density (i_{cr}), passive current density (i_p) and corrosion rate decrease. Micrographs taken from the surface of the exposed samples in the blank solution and solution containing benzotriazole clearly reveals inhibiting role of this compound.

Key Words: Corrosion, Steel, Benzotriazole.

INTRODUCTION

Corrosion can be controlled by adding chemical substances called inhibitors into acidic media. Corrosion inhibitors may be divided into three broad classes, namely oxidizing, precipitation and adsorption[1]. In most inhibition studies the formation of donor-acceptor surface complexes between free or π-electron of an inhibitor and the vacant *d*-orbital of a metal were postulated[2-5]. Nitrogen compounds have been studied as inhibitors by several workers[6-8]. The application of acid corrosion inhibitors in the industry is widely used to prevent or minimize metal loss during contact with acids. There is a continues search for better corrosion inhibitors to meet the needs of industry because of the vast difference of the media encountered in the industry. It has been shown that organic compound containing heteroatom with high electron density such as nitrogen, sulfur and oxygen, or those containing multiple bonds, are effective acid inhibitors[9]. Of particular interest in the general field of organic inhibitors is the nature of the chemical bond at the metal surface and on explanation of the use of these substances often provide such excellent protection. In the case of benzotriazole (BTA), the protective film is of the order of molecular dimensions only. The protective action of this inhibitor has been attributed to the formation of a polymeric film of metal-BTA on the metal surface[10-12].

The aim of this work is to study the electrochemical behavior of stainless steel type 302 in absence and presence of BTA with various concentrations (1×10^{-3}-8×10^{-3} M) in HCl at different temperatures (10, 30, 50 ± 1ºC).

EXPERIMENTAL

Type 302 stainless steel is composed of 17-19 % Cr, 8-10 % Ni, 2 % Mn, 0.15 % C, 0.04 % P and 0.03 % S. The experiments were carried out at 10, 30 and 50 ± 1°C in a conventional three-electrode electrochemical cell. The working electrode was a stainless steel sheet with geometrical area of 1.2 cm^2, which before each experiment was polished with grade 400, 1200 emery paper. They were washed with distilled water and acetone. A platinum electrode and a saturated calomel electrode (SCE) were used as counter and reference electrode, respectively. The electrochemical measurements were performed by potentiostatic technique (potentiostate, CG, CV and PG system model DPSWx). The anodic and cathodic polarization curves obtained by scanning the potential of the working electrode (1 m Vs^{-1}) over the range -600 ± 200 mV. The electrochemical parameters of this investigation were obtained from the potentiodynamic polarization curves at 10, 30, 50 ± 1°C. These include the corrosion potential, corrosion current density, critical current density, passivation current density and passive potential.

RESULTS AND DISCUSSION

The effects of various concentrations of BTA in 1 M HCl on corrosion behaviour of SS_{302} at different temperatures (10, 30, 50 ± 1°C) have been examined. The potentiodynamic curves are shown in Figs. 1-3 and the corrosion parameters (E_{corr}, I_{corr}, I_{cr}, E_p, I_p, %I) are given in Tables 1-3. The open circuit potential (OCP) of SS302 in 1 M of HCl before polarization ranged from -320 to -410 mV *vs.* SCE. But after completion of polarization these values became positive (+310 to +500 mV *vs.* SCE) and remained stable over long period of time. The nobling of open circuit potential (OCP) after polarization is possibly due to the formation of passive film on the surface of sample.

It is observed from the polarization curves that the cathodic current densities increase with increasing cathodic potential (more negative). It is also found that E_{corr} shifted toward noble direction in the presence of BTA

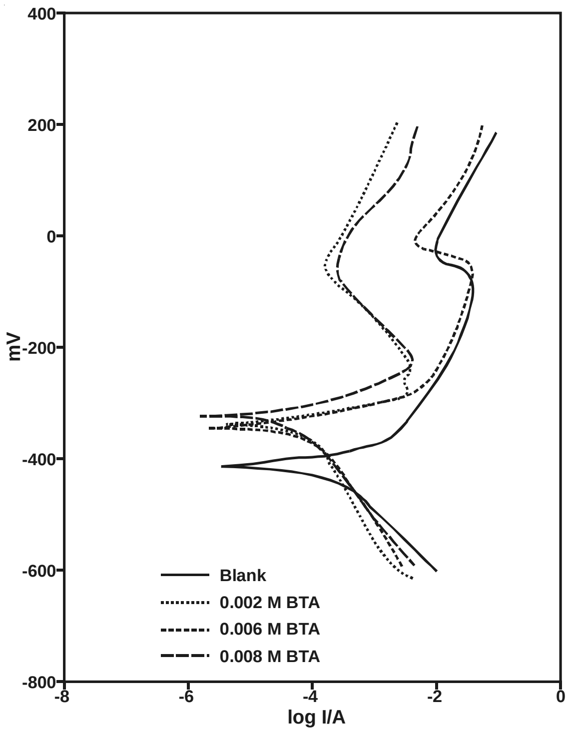

Fig. 1. Polarization curves for SS_{302} at 10 ± 1°C in HCl (1 M)

TABLE-1
EFFECT OF BENZOTRIAZOLE ON THE CORROSION PARAMETERS OF STAINLESS STEEL TYPE 302 AT 10 ± 1ºC

[BTA] (M)	Corrosion potential ($-E_{corr}$)/mV	Corrosion current (I_{corr})/μAcm^{-2}	Inhibition efficiency (I %)
Blank	409	102.56	–
2×10^{-3}	351	33.80	67
6×10^{-3}	336	32.00	69
8×10^{-3}	333	46.00	55

TABLE-2
EFFECT OF BENZOTRIAZOLE ON THE CORROSION PARAMETER BEHAVIOUR OF STAINLESS STEEL TYPE 302 AT 30 ± 1ºC

[BTA] (M)	Corrosion potential ($-E_{corr}$)/mV	Corrosion current (I_{corr})/μAcm^{-2}	Inhibition efficiency (I %)
Blank	412	109	–
10^{-3}	338	52	52
4×10^{-3}	333	43	60
8×10^{-3}	322	47	56

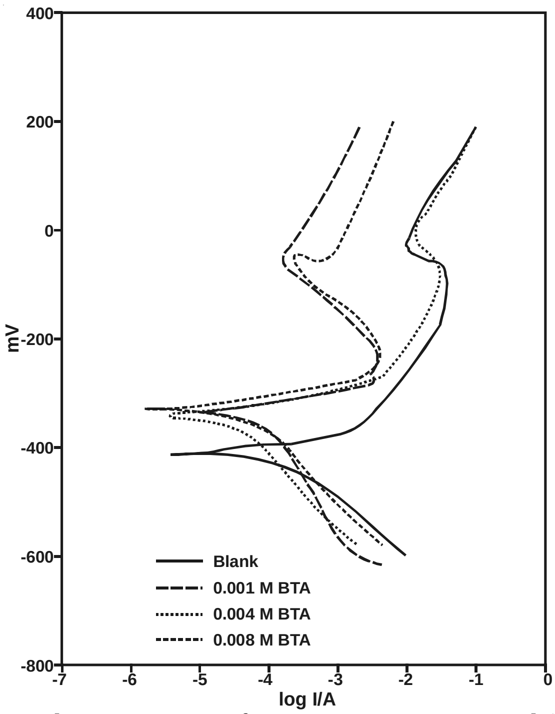

Fig. 2. Polarization curves for SS_{302} at 30 ± 1°C in HCl (1 M)

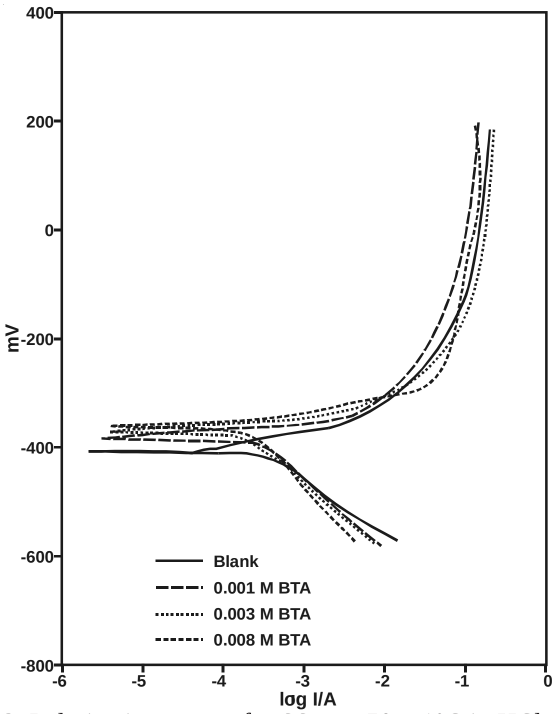

Fig. 3. Polarization curves for SS_{302} at 50 ± 1°C in HCl (1 M)

TABLE-3
EFFECT OF BENZOTRIAZOLE ON THE CORROSION PARAMETER BEHAVIOUR OF STAINLESS STEEL TYPE 302 AT 50 ±1ºC

[BTA] (M)	Corrosion potential ($-E_{corr}$)/mV	Corrosion current (I_{corr})/μAcm^{-2}	Inhibition efficiency (I %)
Blank	403	319	–
10^{-3}	308	283	11
3×10^{-3}	369	198	34
8×10^{-3}	362	215	33

and I_{corr} decreased remarkably. The maximum shift in E_{corr} was about 136 mV *vs.* SCE in the presence of 8×10^{-3} M of BTA at 50 ± 1°C. It is observed that critical current density and passive current density decreased appreciably with increasing BTA concentration, but passive range increased remarkably. Evolution of gas was observed during these experiments, as expected in acidic media, indicate that the cathodic reaction is hydrogen evolution in each case. Anodic polarization curves revealed active-passive transition behaviour for this alloy in acidic solution. The nature of cathodic and anodic polarization curves at different temperatures (Fig. 4) is similar, but temperature showed its influence on the current densities (E_{corr}, I_{corr}, E_{cr}, I_{cr}, E_p and I_p). There is an appreciable increase in current densities as the temperature is increased. The broadly similar curves at different temperatures suggest similar reactions at the surface of the electrode, but with different rates. It has been reported[13] that inhibitor used for SS_{321} in 1 M C_2H_5OH-H_2SO_4 solution reduces corrosion current, critical current and passive current density. The inhibitor also resulted shift in corrosion potential towards noble direction. In the present investigation benzotriazole affected all the corrosion parameter and shifted corrosion potential toward positive direction. Thus, it is suggested that BTA may acts as a good inhibitor in HCl medium. The corrosion reaction can be regarded as an Arrhenius-type process. The rate is given by:

$$I_{corr} = \kappa \exp(-E_a/RT)$$

where κ is the Arrehenius pre-exponential constant and E_a is the activation corrosion energy for the corrosion process.

The E_a values were determined from the slopes of these curves and are calculated to be $E_a = 26.83$ kJ mol^{-1} for blank and $E_a = 37.74$ kJ mol^{-1} in the presence of 0.008 ppm of BTA. The apparent activation energy obtained for the alloy in this media may be considered to be associated with the complex process/mechanism/resistance/dissolution that occur in this region[14].This value may be attributed to the spontaneous formation of passive film on the surface of samples.

The inhibition efficiency (I %) was given by :

$$(I\ \%) = 100\ (1 - i_{corr}/i^0_{corr})$$

where i_{corr} and i^0_{corr} denotes the corrosion current density in the presence and absence of an inhibitor, respectively[15]. It is found from the table that maximum inhibition efficiency (I %) occur in 8×10^{-3} M of BTA is about 56 %.

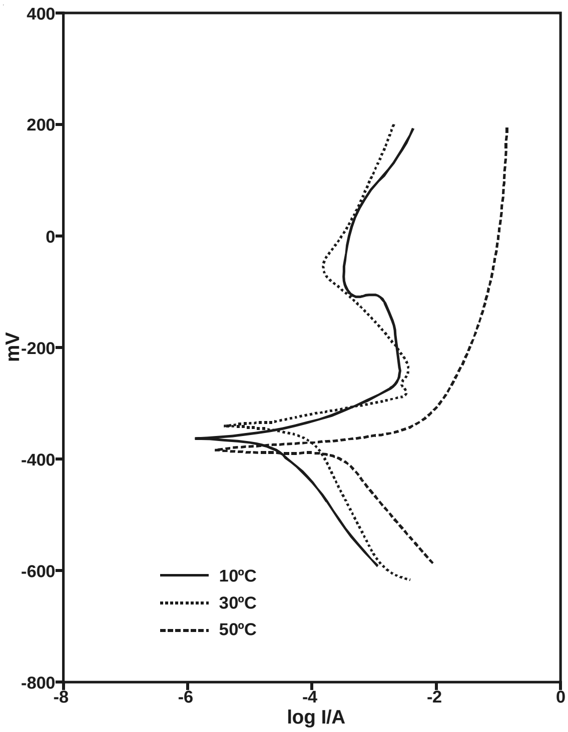

Fig. 4. Polarization curves for SS_{302} at 10, 30 and 50 ± 1°C in HCl 1 M) + BTA (0.008 M)

Conclusions

The electrochemical studies of the inhibition behaviour of SS_{302} in 1 M of hydrochloric acid solution show an interesting active-passive nature which is influenced by the concentration of benzotriazole. The addition of benzotriazole to the acid solution resulted in nobling of OCP of this alloy. Benzotriazole considered as an effective inhibitor at low concentrations between 1×10^{-3} and 8×10^{-3} M. Passive potential (E_p), corrosion potential (E_{corr}) increase with increasing benzotriazole concentrations, while critical current, corrosion current, passivation current and corrosion rate decrease.

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(*Received*: 5 January 2006; *Accepted*: 17 December 2006) AJC-5289