Journal of Alloys and Compounds 456 (2008) 372–378

Journal of
ALLOYS
AND COMPOUNDS

www.elsevier.com/locate/jallcom

Environmentally safe corrosion inhibition of Pb in aqueous solutions

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Received 21 November 2006; received in revised form 4 February 2007; accepted 10 February 2007
Available online 20 February 2007

Abstract

The corrosion and corrosion inhibition of lead in aqueous solutions with different pHs (2, 7 and 12) were investigated. The corrosion rate was calculated in the absence and presence of the corrosion inhibitor using polarization and impedance techniques. Amino acids have been used as environmentally safe corrosion inhibitors. The inhibition efficiency of the different amino acids at a concentration of 0.025 M was calculated. Corrosion inhibition efficiency up to 87% was recorded with glutamic acid in neutral solutions. The experimental impedance data were fitted to theoretical values according to an equivalent circuit model to explain the behavior of the metal under different conditions. The corrosion inhibition process was found to depend on the adsorption of the amino acid molecules on the metal surface; and the adsorption free energy in each case was calculated. The free energy of adsorption of glutamic acid on Pb was found to be equal to −2.9 kJ/mol, which reveals that the inhibitor is physically adsorbed on the metal surface. The results are obeying Langmuir adsorption isotherm.

Keywords: Pb; EIS; Polarization; pH; Passivation; Amino acids

1. Introduction

Lead is frequently used in chemical plants and laboratories for fume ducts, hoods, bench tops and floors [1]. Lead is also used in buildings for roofing, gutters and downspout [2]. The most important application of lead is its widespread usage in acid storage batteries [3]. For these reasons, the corrosion inhibition of lead by different organic compounds has been studied in considerable details [4–8]. Pyrazol derivatives were found to inhibit the lead corrosion in acidic chloride solutions, and the inhibition of the corrosion process was explained to be due to the stabilization of $PbCl_2$ which is formed as a barrier layer on the metal surface protecting it from continuous corrosion [9,10].

Generally, very little work has been performed on the use of amines as inhibitors for the corrosion of lead in aggressive acidic media [11]. Amino acids were reported as good corrosion inhibitors for many metals in various aggressive media [12–16]. They were tested as corrosion inhibitors for lead in 0.24 M $HClO_4$ using potentiodynamic measurements [17]. The results have shown that methionine (MET) is the best inhibitor and its corrosion inhibition efficiency reached a value of 95% at 10^{-3} M (MET). The inhibitor was found to be adsorbed on the lead surface according to Temkin isotherm model, and the corrosion inhibition efficiency (η%) was found to be independent of temperature in the range of 30–60 °C.

The objective of the present work is to study the effect of different amino acids on the corrosion of lead in aqueous solutions of different pH (2.7 and 12). In this respect, different amino acids have been used. It is aimed at the specification of the best inhibitor and the optimum conditions for the corrosion inhibition process.

2. Experimental details

The working electrodes were made from spectroscopically pure lead 99.99% (Alderich-Chemie). The electrode consists of massive rods, mounted into glass tubes by two-component epoxy resin leaving a surface area of 0.385 cm^2 to contact the solution. The cell was a three-electrode all-glass cell with a platinum counter electrode and saturated calomel reference electrode. Before each experiment, the working electrode was polished mechanically using successive grades of emery papers up to 2000 grit, rubbed with a smooth polishing cloth,

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0925-8388/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.jallcom.2007.02.087

then washed with triple distilled water and transferred quickly to the electrochemical cell. The measurements were carried out in aqueous solutions of pH 2, 7 and 12, the solutions were prepared from analytical grade reagents and triple distilled water. The buffer solutions were prepared according to the following compositions:

pH	Composition
2	62.5 ml (0.2 M) boric acid + 62.5 ml (0.05 M) borax + 62.5 ml (0.4 M) H_3PO_4 and complete into 250 ml
7	127.8 ml (0.1 M) $COOKC_6H_4COOH$ + 122.2 ml (0.1 M) HCl and complete to 250 ml
12	100 ml (0.2 M) KH_2PO_4 + 163.7 ml (0.2 M) NaOH

The electrochemical impedance investigations and polarization measurements were performed using the voltalab 10 PGZ 100 "All-in-one" potentiostat/Galvanostat system. The potentials were measured against and referred to the saturated calomel electrode (SCE). All potentiodynamic polarization measurements were carried out using a scan rate of 10 mV/s. The amino acids used in these investigations include:

1. Aliphatic amino acids: glycine, alanine and valine;
2. Sulfur containing amino acids: cysteine;
3. Acidic amino acids: glutamic acid;
4. Basic amino acids: histidine.

The corrosion current densities were measured in each case and the corrosion inhibition efficiency, η, was calculated from the values of the corrosion current densities of the metal before and after the addition of the amino acids to the corrosive medium.

3. Results and discussion

3.1. Open-circuit potential measurements

The open-circuit potentials of Pb in the absence and presence of amino acids at constant concentration of (0.025 M) were traced over 60 min from the electrode immersion in the aqueous solutions of pH 2, 7 and 12. The results are presented in Fig. 1a–c. The steady state potential is reached within the first 20 min of the electrode immersion in the test solution. In the presence of amino acids in acidic solution, the steady state potential did not show any remarkable change (cf. Fig. 1a). In the case of neutral solutions, the steady state potential gets more negative in the presence of amino acid (cf. Fig. 1b). The presence of the amino acid, especially glutamic acid in basic solutions has shifted the steady state potential towards more positive values (cf. Fig. 1c). The direction of potential shift depends on the type of the amino acid and the metal surface. The potential shift can be attributed to the adsorption of the amino acids molecules on the active sites and/or the deposition of corrosion products on the electrode surface.

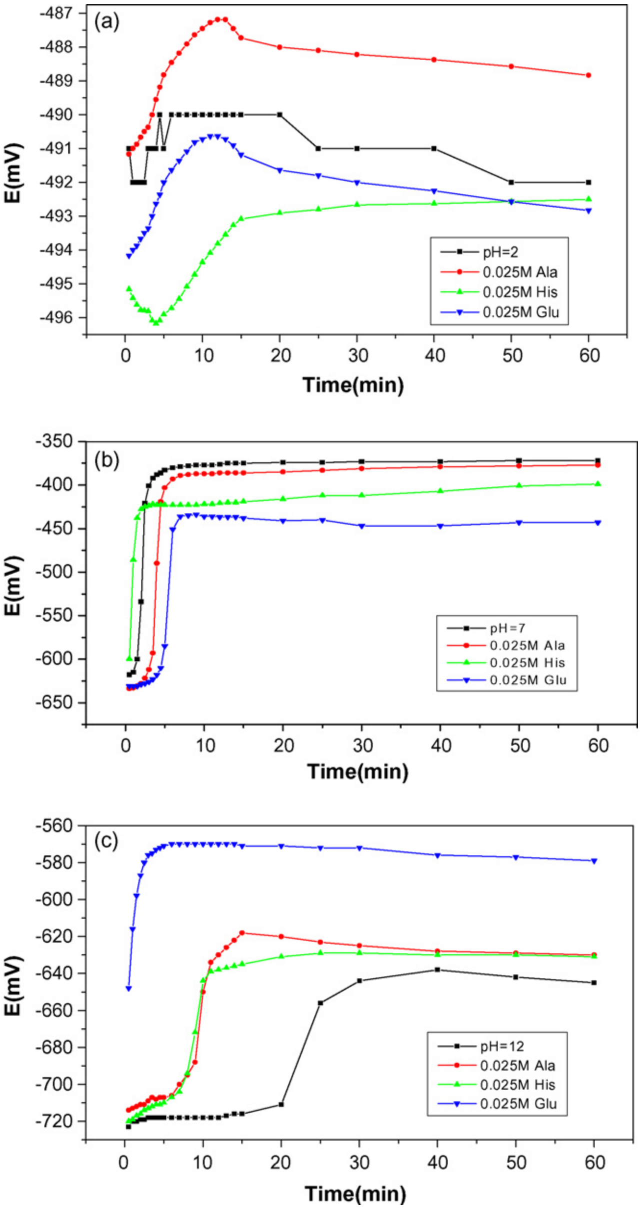

Fig. 1. Variation of the open-circuit potential with time for Pb electrode after 60 min of the electrode immersion in aqueous solutions at different pHs with different amino acids at 25 °C: (a) pH 2, (b) pH 7 and (c) pH 12.

3.2. Potentiodynamic polarization measurements

3.2.1. Behavior of Pb electrode in inhibitor-free aqueous solutions

The electrochemical behavior of lead was investigated under polarization conditions, the linear polarization and Tafel extrapolation techniques were used. Unless otherwise stated the polarization experiments were carried out at a scan rate of 10 mV/s. Fig. 2a presents the potentiodynamic polarization curves of the lead electrode after holding the metal at the open-circuit potential for 60 min in naturally aerated solutions of pH 2, 7 and 12. The effect of the solution pH on the corrosion current density is presented in Fig. 2b. It is clear that the measured current density in neutral solutions is less than the values obtained in basic and acidic solutions. In acidic solutions, the calculated value of i_{corr} reached 60.7 μA/cm^2, which is more than three times that obtained in basic solutions (15.9 μA/cm^2) and about 12 times that measured in neutral solutions (4.69 μA/cm^2). The corrosion of the metal in aqueous solutions is represented by the overall two-electron transfer reaction:

$$Pb = Pb^{2+} + 2e^- \quad (1)$$