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Evolution of the corrosion process of AA 2024-T3 in an alkaline NaCl solution with sodium dodecylbenzenesulfonate and lanthanum chloride inhibitors

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ABSTRACT

The evolution of the corrosion process of AA 2024-T3 in 0.58 g L^{-1} NaCl solution (pH 10) with sodium dodecylbenzenesulfonate (SDBS) and lanthanum chloride inhibitors was studied with electrochemical and surface analysis methods. With the addition of the compounded $LaCl_3$ and SDBS inhibitors, in the early stage the polarization behavior of AA 2024-T3 changed from active corrosion to passivation, and both the general corrosion and pitting corrosion were inhibited. However, with the immersion time extended, the passive behavior gradually disappeared and pitting happened at the Cu-rich phases. After 24 h immersion, the compounded inhibitors still showed good inhibition for general corrosion, but the polarization curve again presented the characteristic similar to active polarization. The compounded inhibitors also inhibited the pitting corrosion to some extent. The acting mechanism of the inhibitors SDBS and La_3Cl on the corrosion process of AA 2024-T3 in the test solution was discussed.

1. Introduction

2024-T3 aluminum alloy is widely used in industries due to its high specific strength [1,2]. But in environments containing chloride ions aluminum alloys may experience corrosion damages such as pitting and intergranular corrosion [3,4]. In aqueous systems, inhibitors are frequently used to control corrosion. Among various inhibitors, the application of chromates is one of the most effective techniques for aluminum alloy [5]. However, chromates have been eliminated gradually in recent years for their toxicity [6]. It is imperative to find non-poisonous and high effective inhibitors to substitute chromates. Rare earth compounds are one of the potential selections [7]. It was reported [8] that rare earth salts provide good protection for aluminum alloys. The studies on the inhibition effects of 14 types of rare earth metallic ions on aluminum alloys in neutral NaCl solutions proved that the rare earth salts are cathodically deposited inhibitors [9] and they can inhibit the corrosion rate by forming rare earth oxides or hydroxides films on the surface and impeding the reduction reaction of oxygen [10]. On the other hand, many organic inhibitors show good inhibition effects to corrosion of metals by forming protective films on the surface through physical or chemical adsorption [11], such as sodium dodecylbenzenesulfonate (SDBS) and sodium salicylate. Many authors studied the inhibitive effects of the compounds of rare earth salts with organic inhibitors, in order to further increase the inhibition efficiency of the rare earth inhibitors and decrease the expenses. Forsyth et al. [12] found that cerium chloride and sodium salicylate show a synergistic inhibition effect for mild steel in neutral NaCl solution. Catubig et al. [2] studied the inhibition effects of thioglycollate acid rare earth salts, which was prepared by compounding sodium thioglycollate with cerium chloride or praseodymium chloride respectively, for AA 2024-T3 in 0.1 M NaCl solution. Mu et al. [13] reported that in sulfuric acid solution lanthanum chloride and SDBS show remarkable synergistic inhibition effect for zinc.

However, there were few studies about the inhibition of rare earth salts and SDBS on corrosion of aluminum alloys in basic NaCl environments. Also, there were short of studies on the inhibition effects of inhibitors on pitting corrosion which are possible for aluminum alloys in NaCl solutions. In this paper, the inhibition effects of compounded $LaCl_3$ and SDBS inhibitors on AA 2024-T3 in 0.01 mol L^{-1} NaCl (pH 10) are studied, and the inhibiting mechanism is discussed.

2. Experimental methods

The tested material was 2024-T3 aluminum alloy (AA 2024-T3), with the chemical compositions shown in Table 1.

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Table 1
The nominal compositions of AA 2024-T3 (wt%).

Element	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Percent (wt. %)	0.5	0.5	3.8–4.9	0.3–0.9	1.2–1.8	0.1	0.25	0.15	Bal

The aluminum alloy material was cut into 13 mm × 13 mm × 10 mm samples. Then the samples were sealed by epoxy resin, abraded with 240#, 600# and 1000# abrasive papers in turn, rinsed with deionized water and degreased with alcohol and acetone. The final exposed area was 4 mm × 4 mm, and the edges around the exposed area were sealed again to avoid crevice corrosion. The samples were placed in dryer before electrochemical tests.

The inhibitors used include $LaCl_3$ (reagent grade, The Chemical Reagent Company, Beijing) and sodium dodecylbenzenesulfonate ($C_{12}H_{25}C_6H_4SO_3Na$, SDBS, Chemical grade, Fuchen Chemical Reagent Plant, Tianjin). The basic solution was 0.01 mol L^{-1} (0.58 g L^{-1}) NaCl solution. When the inhibitor $LaCl_3$ was added in the solution, the chloride ions in $LaCl_3$ was included in the total chloride concentration. The final pH of the solution was adjusted to pH 10 by adding NaOH after the addition of inhibitors. The pH meter used was a PHS-3C type (Shanghai Precise Instruments Co.). All the other chemicals used were reagent grade. The solution was prepared with deionized water without deaeration, and all the experiments were carried out at room temperature.

The potentiodynamic polarization tests were carried out using a CS350 electrochemical work station (COST Co., Wuhan). A typical three electrode system was used for the polarization tests. The system was composed of a saturated calomel electrode (SCE) as reference electrode, a platinum sheet as counter electrode, and the aluminum alloy sample as working electrode. Before the polarization test, the working electrode was immersed in the solution for 30 min meanwhile the open circuit potential (OCP) was measured. The polarization potential range was from −0.3 V to the OCP until the pitting breakdown potential, E_b, and the potential scanning rate was 0.3 mV s^{-1}. The corrosion current densities were obtained by fitting the cathodic branches of the polarization curves by a CView software.

The surface composition of the aluminum alloy samples was analyzed with an ESCALAB-250 X-rays photoelectron spectrometer (USA), and the spectra were fitted by a XPSPEAK 4.1 software. A LEO-1450 SEM (USA) with a Kevex SuperDry energy dispersion spectroscope (EDS) was used to observe and analyze the corroded surface and the corrosion products.

3. Results and discussion

3.1. Potentiodynamic polarization test

Fig. 1 shows the polarization curves of AA 2024-T3 in 0.58 g L^{-1} NaCl (pH 10) solution with the additions of 0.1 g L^{-1} $LaCl_3$ and different concentrations of SDBS. In the basic solution without inhibitors, the alloy showed the behavior of active corrosion. With 0.1 g L^{-1} $LaCl_3$ addition, the corrosion potential of the alloy kept almost unchanged, but both the cathodic and the anodic polarization current densities decreased, indicating that $LaCl_3$ in this system is a mixed inhibitor. Previous studies [9,14–16] have showed that La^{3+} may inhibit the cathodic reduction of oxygen at the active regions on aluminum surface by forming oxides or hydroxides of lanthanum, thus decreasing the corrosion rate. After the addition of SDBS, the corrosion potential moved to the negative direction and an obvious passivation range is seen. Pitting happened at higher potential. That is, the addition of SDBS inhibited the active dissolution of the aluminum alloy and passivation was promoted. As the SDBS concentration increased, the corrosion potential E_{corr} decreased gradually and the pitting potential E_b increased to a peak value then decreased. When the SDBS concentration was 0.42 g L^{-1} the difference between E_{corr} and E_b reached the maximum and the E_b value was also the highest, indicating that the best inhibition was obtained with the addition of 0.1 g L^{-1} $LaCl_3$ plus 0.42 g L^{-1} SDBS [17].

Fig. 2 shows the polarization curves of AA 2024-T3 in 0.58 g L^{-1} NaCl (pH 10) solution with the additions of 0.42 g L^{-1} SDBS and different concentrations of $LaCl_3$. In the solution with 0.42 g L^{-1} SDBS, the corrosion potential of aluminum alloy moved obviously to the negative direction, which might originate from some obstruction of the cathodic sites [18], indicating that SDBS inhibited the cathodic process effectively. On the other hand, with the addition of SDBS, the polarization behavior of aluminum alloy changed

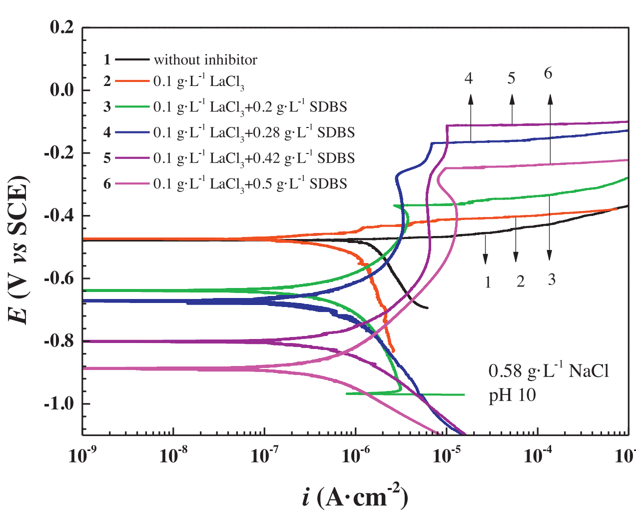

Fig. 1. Potentiodynamic polarization curves of AA 2024-T3 after immersion in 0.58 g L^{-1} NaCl solution (pH 10) with 0.1 g L^{-1} $LaCl_3$ and various concentrations of SDBS for 30 min.

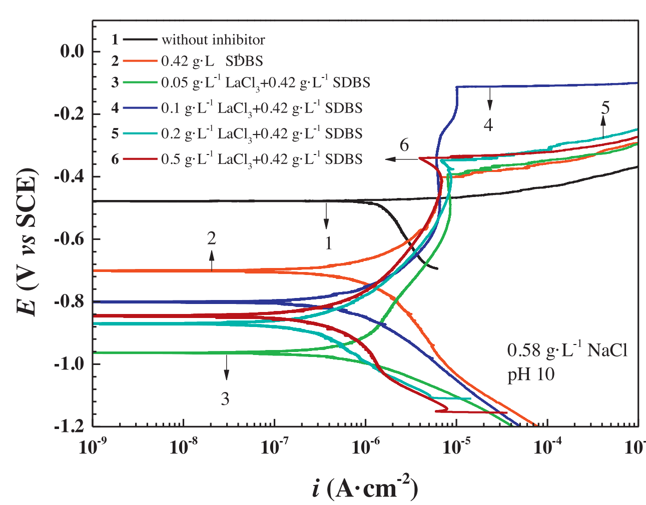

Fig. 2. Potentiodynamic polarization curves for AA 2024-T3 after immersion in 0.58 g L^{-1} NaCl solution (pH 10) with 0.42 g L^{-1} SDBS and various concentrations of $LaCl_3$ for 30 min.