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Corrosion behavior of aluminum alloy 2024-T3 by 8-hydroxy-quinoline and its derivative in 3.5% chloride solution

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Abstract: The corrosion behavior of aluminum alloy 2024-T3 was studied in 3.5% NaCl solution with two fluorescence quinoline compounds named 8-hydroxy-quinoline(8HQ) and 8-hydroxy-quinoline-5-sulfonic acid(HQS). The open circuit potential(OCP) test result indicates that both compounds change the alloy corrosion potential by adsorbing on the electrode surface. Polarization measurements show that 8HQ is a mixed type inhibitor by blocking the active sites of the metal surface, while HQS is a corrosion accelerator by activating the cathodic reaction. Changes of the impedance parameters in the electrochemical impedance spectroscopy(EIS) are related to the adsorption of 8HQ on the metal surface, which leads to the formation of a protective layer. The impedance diagram in the solution with HQS is similar to the one without additional organic compounds. The morphology and composition of the protective layer were studied by using SEM/EDS. The result confirms the function of the additions that the effect of 8HQ is due to the insoluble aluminum chelate, $Al(HQ)_3$, to prevent adsorption of chloride ion, while the effect of HQS is to break down the oxide film.

Key words: aluminum alloy; corrosion behavior; 8-hydroxy-quinoline; 8-hydroxy-quinoline-5-sulfonic acid; electrochemical impedance spectroscopy

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1 Introduction

Aluminum alloys are widely used in the aeronautical industry and marine engineering due to their light mass and advantageous mechanical properties. However, these alloys have a low resistance against corrosion because of the presence of alloying elements which can locally break down the passive film and allow the attack of aggressive ions like chloride ions that can initiate pitting or crevice corrosion[1−4].

Generally, localized corrosion can be prevented and corrosion degree can be decreased by using corrosion inhibitors that can form a resistant oxide film on the metal surface to prevent aggressive ions. A number of corrosion inhibitors have been developed for this purpose. Chromates, which are passivating inhibitors, are recognized as being very efficient to inhibit the corrosion of aluminum and aluminum alloys[5−7]. The functions of this inhibitor are related to the interaction of chromate with the passive film and the formation of an insoluble chromium oxide Cr_2O_3 that can repair the defects of the passive film[8−9]. But the strong oxidizing properties of Cr(VI) and its carcinogenesis make chromates harmful to the environment, therefore it is necessary to obtain a new corrosion inhibitor for aluminum and its alloys to replace chromates. Cerium has been proved to be a viable replacement for chromates[10−11], which acts as a cathodic inhibitor by forming a cerium rich layer to inhibit the cathodic reaction[12]. Phosphate is another inorganic corrosion inhibitor replacement of chromates [13]. It is usually used in conversion coating baths to form insoluble phosphate-aluminum layer and reduce significantly the hydration rate of Al oxide[14].

Some organic compounds have been also used as corrosion inhibitors which often contain nitrogen, oxygen, sulfur and ring system. Benzotriazole(BTA) is a well known inhibitor[15]. It absorbs on the metal surface

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Corresponding author: LI Song-mei; Tel/Fax: +86-10-82317103; E-mail: songmei_li@buaa.edu.cn by chemical bond to act as an anodic inhibitor preventing chloride or other aggressive ions interacting with the metal. Other organic amines containing nitrogen are also considered aluminum corrosion inhibitors in neutral and acidic medium[16].

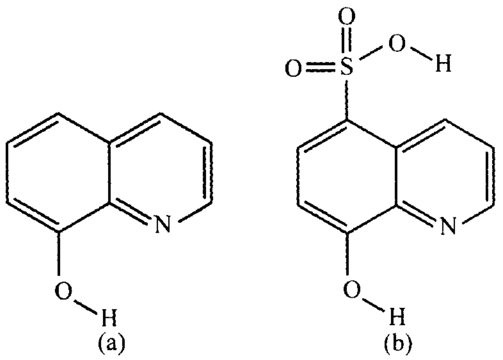
In our previous study[17], 8-hydroxy-quinoline and its derivative 8-hydroxy-quinoline-5-sulfonic acid were used as corrosion sensors for aluminum alloys, which were added into acrylic or epoxy coatings. They were sensitive to the corrosion product Al^{3+} or pH value during corrosion process by changing their fluorescence character. Some researchers have found that 8-hydroxy-quinoline is effective for preventing pitting corrosion of aluminum alloys by forming an insoluble chelate complex layer. GARRIGUES et al[18] investigated the corrosion inhibition of pure aluminum by 8-hydroxy-quinoline in neutral and acidic chloride solutions. They concluded that 8-hydroxy-quinoline acts on the passive alumina layer to prevent the adsorption of chloride ions and the destruction of aluminum oxide film.

The present study was designed to investigate corrosion behavior of AA 2024-T3 in 3.5% sodium chloride solution by 8-hydroxy-quinoline and 8-hydroxy-quinoline-5-sulfonic acid. Polarization measurements were employed to discuss the effect of 8HQ and HQS. Electrochemical impendence spectroscopy(EIS) was used to investigate the mechanisms, and surface analysis (SEM/EDS) were used to observe the microstructure.

2 Experimental

2.1 Material

Corrosion inhibition investigations were performed on AA2024-T3 (nominal composition: 4.5% Cu, 1.5% Mg, 0.6% Mn, 0.2% Fe, 0.06% Si, 0.08% Zn, 0.03% Ti, balance Al), supplied in the form of a 1 mm thick plate. Exposed specimens were prepared by cutting coupons of 50 mm × 30 mm from the plates. Before testing, specimens were mechanically polished with 1200 grit SiC paper, and then with 1.5 μm diamond paste. They were finally rinsed with distilled water. 8-hydroxy-quinoline(8HQ) and 8-hydroxy-quinoline-5-sulfonic acid(HQS) were analytical grade reagent (purity >99%) and the compound structure was shown in Fig.1. The concentration of 8-hydroxy-quinoline was 3.8×10^{-3} mol/L, which is near the solubility limit. For comparison the concentration of 8-hydroxy- quinoline-5-sulfonic was 3.8×10^{-3} mol/L too. The corrosion medium was a 3.5% solution of NaCl (reagent grade).



(a) (b)

Fig.1 Molecule structures of 8HQ (a) and HQS (b)

2.2 Electrochemical measurements

Electrochemical measurements were carried out using an EG&G Princeton Applied Research Parc Model 2273. A three-electrode configuration was employed with AA2024-T3 acting as working electrode, a platinum panel as the auxiliary electrode and a saturated calomel electrode(SCE) as reference. The area of working electrode was 10 mm×10 mm, and the same disposing process as above was taken before testing. The OCP was measured for 10 h. The potentiodynamic polarization measurement was performed from −0.6 V (vs OCP) to 0.25 V (vs OCP). EIS measurements were carried out by applying to the cell a 10 mV sine wave with frequencies in the range of 100 kHz−5 mHz.

2.3 Surface analysis

The surface analysis of AA2024-T3 was investigated by means of SEM (JEOL SEM5800) equipped with an EDS probe (accelerator voltage was 20 keV) after 4 d of immersion in the corrosive medium with or without fluorescence compounds.

3 Results and discussion

3.1 Electrochemical behavior of AA2024-T3 in 3.5%NaCl solution containing 8HQ and HQS

The variations of the open circuit potential of AA2024-T3 with time in a 3.5% neutral chloride solution in presence of 8HQ or HQS at room temperature are shown in Fig.2. Under the experimental condition, two features can be distinguished from the obtained curves. Firstly, for two kinds of solution, the open circuit potential shifts in the anodic direction and then reaches steady-state values. The corrosion potential in the solution with 8HQ moves from −0.86 V to −0.83 V, while in the solution with HQS the corrosion potential strongly shifts to more positive value, from −0.75 V to −0.69 V. Secondly, the whole evolution of the OCP