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Evaluation of metal cation effects on galvanic corrosion behavior of the A5052 aluminum alloy in low chloride ion containing solutions by electrochemical noise impedance

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ABSTRACT

The effects of metal cations on the galvanic corrosion behavior of the A5052 aluminum alloy in low chloride ion containing solutions (tap water) were examined by electrochemical noise impedance. The electrochemical noise impedance and conductance were calculated by the power spectral density (PSD) of the galvanic current and potential. The oscillations in the galvanic current correlate well with the oscillations in the potential. The total charge (summation of galvanic current) during galvanic corrosion tests was suppressed by the addition of Ca^{2+}, while it was increased with Mg^{2+} addition. Only a small effect on mean impedance and conductance was observed in solutions with Cu^{2+} and Mg^{2+}, while addition of Ca^{2+} strongly influences both the mean impedance and conductance. These results may be explained by the passive film structure changes due to the metal cations. The results obtained in this study indicate that metal cations play a very important role in the corrosion behavior of A5052 aluminum alloys in tap water.

1. Introduction

Aluminum alloys show high corrosion resistance in a wide range of environments and together with their high strength/weight ratios. These properties have been made aluminum alloys widely used. The high corrosion resistance is due to protective oxide films, passive films, formed on the alloys. Generally, the corrosion rate of aluminum alloys depends on the concentration of chloride ions and the pH of the particular environments, and it is considered that only little corrosion of aluminum alloys occurs in very dilute chloride solutions such as tap waters and fresh water. There are only few studies focused on the corrosion of aluminum and aluminum alloys in tap water [1–9].

Some of the authors here have also investigated the effect of metal cations on the corrosion behavior of aluminum alloys in model tap waters [10–16], and found that the corrosion behavior of A3003 strongly depends on the kinds of metal cations in the environments. The effect of metal cations has been explained by using the metal cation hardness concept which is based on a hard and soft acid and base, HSAB, concept [17,18]. According to the HSAB concept, the hard metal cations in a solution attract the electron pair of oxygen atoms in H_2O or OH in the passive film. Therefore, as hard metal cations in the solutions adsorb on the oxygen atoms of H_2O or OH in the passive film, they may be more easily replaced with the proton of H_2O in the passive film (when compared with softer metal cations). From a surface analysis by Auger electron spectroscopy (AES) and X-ray photoelectron spectroscopy (XPS) after immersion corrosion tests, the harder metal cations were found to be incorporated in the oxide films [14–16].

The aluminum alloys are widely used in heat exchangers especially in automotive applications. There are many reports focused on the corrosion of the alloys used here [19–21]. Because of limitations on copper resources, aluminum alloys are used in air conditioners and home heating systems. When using aluminum alloys in home heating systems, which used tap water, galvanic corrosion must be taken into account. There are many reports of galvanic corrosion of aluminum in high concentration solutions such as 5 mass% NaCl solutions [22–24]. Murer et al. reported numerical modeling of the galvanic coupling of aluminum and aluminum alloys, and used results of a scanning vibrating electrode technique to propose a model to explain the results [25]. However, no reports have focused on effect of metal cations on galvanic

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corrosion of aluminum alloys in low chloride ion containing solutions (fresh or tap waters). In this study, electrochemical noise analysis and impedance techniques are applied to evaluate the effect of metal cations on galvanic corrosion of an aluminum alloy in low chloride ion containing solutions.

2. Experimental

2.1. Specimens

Aluminum sheets (20 × 30 mm, thickness 1.2 mm) of A5052 aluminum alloy were used as specimens and Table 1 shows the chemical composition. Before the tests, specimens were chemically etched in 0.1 kmol m^{-3} NaOH solutions and then cleaned in ethanol and in doubly distilled water in an ultrasonic bath. After cleaning, the specimens were sealed by silicone resin, to ensure that a 15 mm × 15 mm area on one side would be in contact with the solutions.

2.2. Solutions

The low chloride ion containing solution used was 0.5 kmol m^{-3} H_3BO_3 - 0.05 kmol m^{-3} $Na_2B_4O_7$ (borate, pH = 7.4) with four different salts mixed into the solution (Table 2), as following: 1 mol m^{-3} NaCl (Na), 0.3 mol m^{-3} $CaCl_2$ + 0. 4 mol m^{-3} NaCl (Ca + Na), 0.3 mol m^{-3} $MgCl_2$ + 0.4 mol m^{-3} NaCl (Mg + Na), and 0.3 mol m^{-3} $CuCl_2$ + 0.4 mol m^{-3} NaCl (Cu + Na). The corrosion behavior of aluminum alloys strongly depends on the pH of solutions, and the pH of tap water is closed to neutral. The total ion

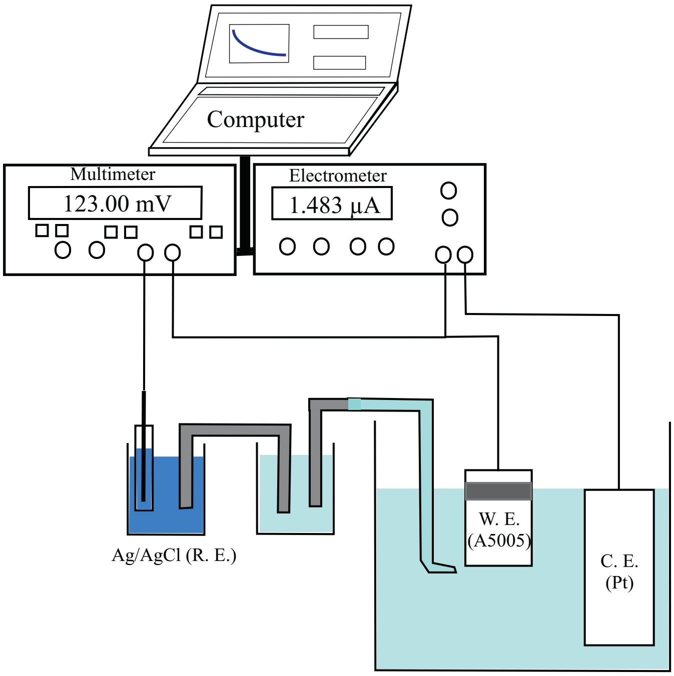

Fig. 1. Schematic outline of the galvanic corrosion test equipment and experimental setup.

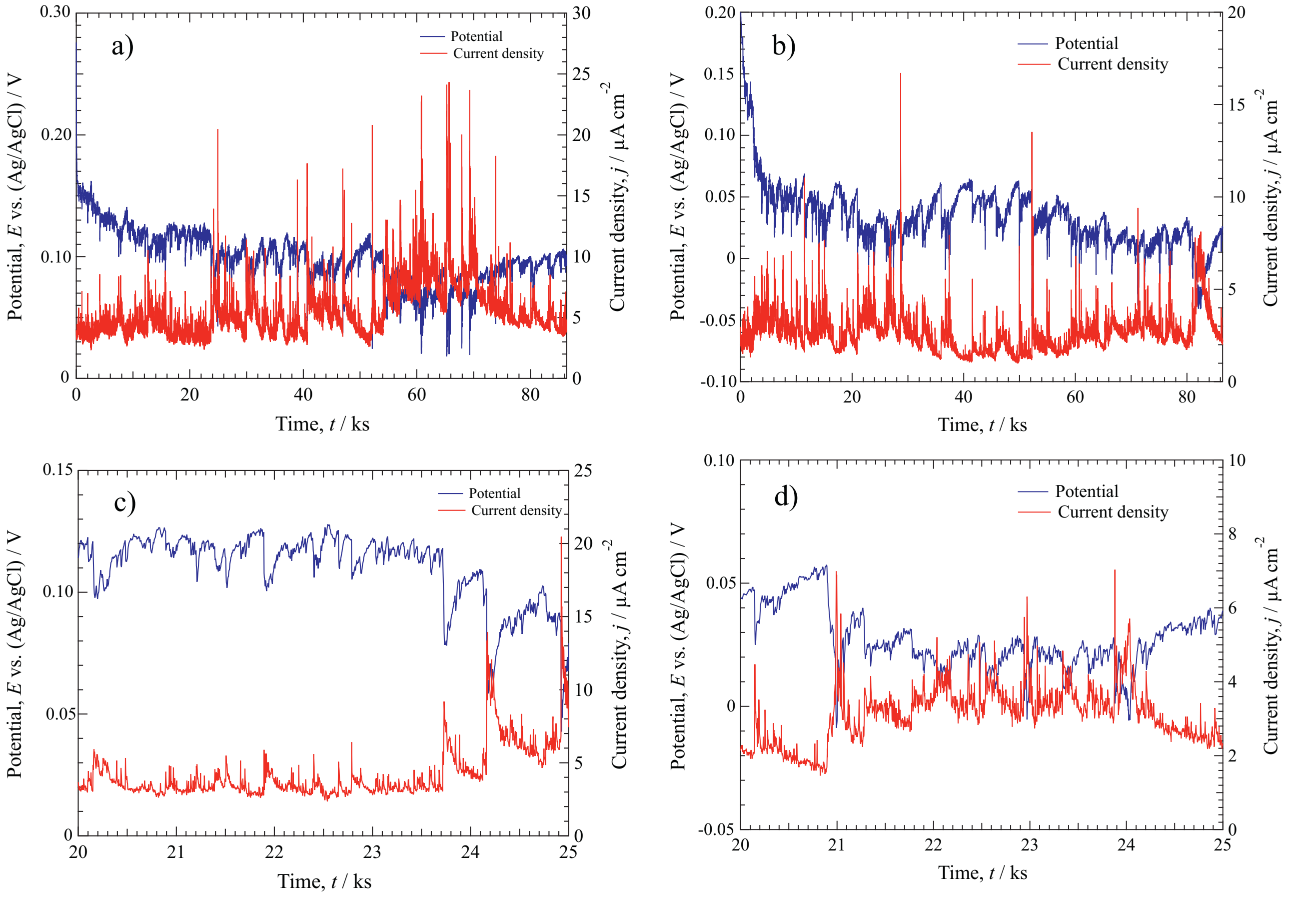

Fig. 2. Changes in potential and current density during galvanic corrosion test in borate with a) and c) 1.0 mol m^{-3} NaCl, and b) and d) 0.3 mol m^{-3} $CaCl_2$ + 0. 4 mol m^{-3} NaCl.