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Electrochemical Study on Galvanic Corrosion Mechanism of Aluminum - Zinc Couples in Atmospheric Environment

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In recent years, steel parts of automobiles are being replaced with lightweight metallic materials like aluminum alloys in the automobile industry to reduce body weight and to improve fuel efficiency. In addition, steel parts being used in automobile body are usually galvanized, which means zinc is plated to improve corrosion resistance, and they are usually joined with aluminum parts. When salts from a snow-melting agent or airborne salts attaches to the automobile body parts, the metallic parts consisting of aluminum and galvanized steels can suffer from atmospheric galvanic corrosion between zinc and aluminum. In the atmospheric environment, the thickness, and the concentration of solution films change simultaneously. Normally, under drying conditions, the thickness decreases, and the concentration increases very much, and the corrosion is accelerated. Therefore, in this study, to clarify the mechanism of the galvanic corrosion between zinc and aluminum in atmospheric environment, the effect of the concentration of the solution, the effect of the thickness of the solution film were studied first, and the effect of the wet and dry cycles, which is similar to the actual situation, was investigated. The effect of the kind of salts is also investigated. To investigate the galvanic corrosion behavior, galvanic current and potential measurement, electrochemical impedance spectroscopy measurement, and surface observation were done. The results of this work clarified the galvanic corrosion mechanism between zinc and aluminum in atmospheric environment. This dissertation consisted of five chapters, and the summary of each chapter is as follows.

Chapter 1, “General Introduction”, mentions the importance of replacement of steel to light-weight material, especially aluminum to solve the global warming and the problem of galvanic corrosion between zinc and aluminum. Especially, the previous works about galvanic corrosion was summarized, and showed the importance to clarify the mechanism of galvanic corrosion between zinc and aluminum. The objectives of the work were stated, and the overview of this dissertation was described.

Chapter 2, “Effect of NaCl Concentration on Galvanic Corrosion of Aluminum - Zinc Couples”, reported the existence of the solution concentration dependence in early stage, and the disappearance in later stage. The dependence was derived by the hydrogen evolution reaction in addition to the oxygen reduction reaction on the aluminum surface due to the negative shift of the corrosion potential of zinc under high concentration solutions (1 M, 2 M NaCl solution). In low concentration solutions (10 mM, 0.1 M NaCl solution), only oxygen reduction reaction occurred. However, the dependence of the concentration of the solution disappeared in later stage. This was due to the suppression of the cathodic reaction on aluminum by the enhancement of the passivity of the aluminum.

Chapter 3, “Effect of Solution Thickness on Galvanic Corrosion of Aluminum - Zinc Couples”, reported the existence of the solution thickness dependence in early stage, and disappearance in later stage. The dependence was derived by the enhancement of the oxygen reduction reaction as the decrease of the solution thickness. In the case of the bulk solution, the hydrogen evolution reaction, in addition to the oxygen reduction reaction occurred on the aluminum, therefore the dependence was not seen. The dependence disappeared in later stage, except for the 50 μm thickness solution film. It was because of the unstable passive film due

to the high pH on the aluminum surface, and the enhancement of the passivity was slower than other thicknesses of the solution.

Chapter 4, “Effect of Wet and Dry Cycles on Galvanic Corrosion of Aluminum - Zinc Couples”, reported the effects of wet and dry cycles on galvanic corrosion of aluminum - zinc couples in 2 M NaCl and MgCl₂ solutions at relative humidity varying from 95% to 75% and 45%, respectively. As a result, it was clarified that the galvanic current in NaCl solution was large during wetting and decreased during drying, and that the galvanic current in the wet condition decreased as the number of cycles increased. On the other hand, in the case of MgCl₂ solution, the galvanic current was about 1/5 smaller than that of NaCl solution from the beginning of the wet and dry cycles. This was explained by the fact that Mg(OH)₂ was formed on the Al surface, and the oxygen reduction reaction rate on the Al surface was reduced by this corrosion product film compared to that in NaCl solution, thereby suppressing the dissolution of Zn.

Chapter 5, “General conclusions”, summarized the results and the key findings of this dissertation.