Electrochemical Behaviour of Chromate and Phosphate Conversion Coatings on Zinc

X. Zhang(1), T. Bos(2), A.Hovestad(3), E.P.M. van Westing(4), J.H.W. de Wit(1, 4)
(1) Department of Materials Science, Delft University of Technology, Rotterdamseweg 137, 2628 AL Delft, NL
(2) TNO Institute of Industrial Technology, Bevesierweg, 1781 AC Den Helder, NL
(3) TNO Institute of Industrial Technology, P.O. Box 6235, 5600 HE Eindhoven, NL
(4) Netherlands Institute for Metals Research (NIMR) Rotterdamseweg 137, 2600GA Delft, NL

Introduction

Chromate conversion coatings have been used to protect zinc based metals from corrosion for many years and at present, no one alternative has proven itself as reliable as chromate for corrosion protection (1,1). However, environmental concerns make the chromate treatment less attractive. This work is targeted in understanding the protective mechanism of chromate coatings on zinc and subsequently finding alternative solutions.

Phosphate coating is a widely used alternative treatment to increase corrosion resistance and improve adhesion of the paint coatings on zinc, iron and its alloys (2). Phosphate coatings do not work as well as chromate coatings do; anyhow, they are less harmful to the environment. Comparing their electrochemical behaviour will help us to understand more of the mechanism of chromate coatings.

Experimental

Zinc coatings (13 μm thick) were electrodeposited on 1 mm thick carbon steel sheets in alkaline bath with some brighteners and purifiers. The zinc-coated samples were activated in 0.25% HNO_3 solution for 30 seconds and rinsed in deionised water. Chromate coating was carried out on the zinc coatings in a bath containing 200 g/L $Na_2Cr_2O_7$ + 10 g/L H_2SO_4 (pH 1.1- 1.3) for different dipping times. The chromate-coated samples were rinsed in deionised water and dried in an oven at 60 °C for 30 minutes. For the purpose of doing surface analysis, pure zinc sheets (0.5 mm thick) were polished to 1 μm and ultrasonically cleaned in acetone and alcohol for 2 minutes, respectively. The surface of these samples was not pickled in nitric acid and only was half of the area dipped in the chromate bath for 5 seconds.

Phosphate coatings on zinc sheets were obtained from the NedZink Corporation in the Netherlands.

Results and discussions

The thickness of chromate coatings with dipping time 1 minute was about 550 nm and of phosphate coatings about 3 μm, measured by SEM. The Volta potential measured by AFM for the partially chromate-coated zinc sample shows that chromate coatings have a more negative potential than zinc in air. The difference in Volta potential between zinc and chromate coatings is about 50 mV. After immersion in 0.01 M NaCl solution for 24 h, the potential difference increases to 200 mV.

The Volta potential measured by Kelvin probe also shows that the potential of chromate coatings is more negative than zinc (see Fig. 1). The difference in Volta potential between zinc and chromate coatings is about 200 mV in air. When the humidity increases in the chamber, the potential difference between chromate and zinc decreases to around 50 mV. After immersion in 0.01 M NaCl solution for 24 h, the potential difference increases to 400 mV in air. The potential on the zinc side increases due to the formation of zinc oxides/hydroxides. The negative potential of chromate coatings against zinc means that chromates can function as cathodic inhibitors to decrease the oxygen reduction rate (3).

Sequentially scanned cathodic polarization curves show that the corrosion potential of the chromate coatings decreases with time. This proves that chromate coatings have cathodic inhibitive effect on zinc corrosion (4,5). For zinc phosphate coatings the corrosion potential is a little noble against the chromate coatings and it does not significantly change with time, although the cathodic current decreases sequentially. This attributes probably to the corrosion products filling pores of the zinc phosphate coatings and the reaction rate is dominated by oxygen diffusion.

EIS results show that chromate coatings have larger impedance than the zinc phosphate coatings in 0.01 M NaCl solution. The charge transfer resistance for chromate coatings is 2 orders larger than the zinc phosphate coatings.

Conclusion

Chromate coatings on zinc function as cathodic inhibitors on zinc corrosion in aqueous solution. The corrosion resistance of chromate coatings is larger than that of zinc phosphate coatings in quiescent 0.01 M NaCl solution.

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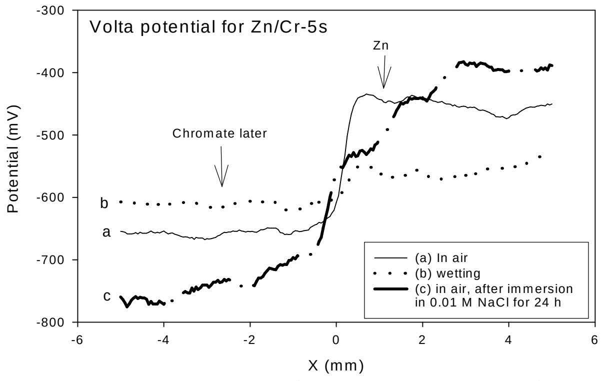

Fig. 1 Volta potentials of chromate layer and of zinc measured by means of Kelvin probe.