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To cite this article: Masanori Hattori *et al* 2009 *Meet. Abstr.* **MA2009-02** 1792

EIS Study on Coating Degradation under UV Irradiation

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Introduction

Polymer coating protects a variety of steel structures against corrosion. If the degradation of polymer coating progresses and the protectiveness decreases, the underlying steel corrosion will start. Accordingly, the chemical and mechanical stabilities of the polymer coatings are very important for corrosion protection of steel. It is well known that UV irradiation enhances the degradation of polymer coatings. For relatively thin polymer coating, we can know the degree of degradation from the surface appearance because cathode blisters are observed on the coating surface at early stage of substrate steel corrosion. On the other hand, for heavy duty coating, since blisters are not readily formed due to high mechanical strength of the coating, it is not easy to detect onset of underlying steel corrosion from surface appearance. In this study, EIS has been applied to monitor the deterioration process of heavy duty coatings under condition of UV irradiation.

Experimental

The epoxy and polyester-urethane paints were coated by spray on the substrate steel (SS400) after the surface was polished with #400 SiC paper. Epoxy of 100 μm thick was coated as primer and two different top coats, polyester-urethane and epoxy, of 100 μm thick were used. The corrosion tests were carried out using a weather sunshine meter (WSM) where the test specimens were exposed to a cyclic condition of 12min-wetting and 48min-drying at 63°C and 50%RH under UV irradiation. Under the wet condition, tap water of 20°C was sprayed to the specimen surface. For comparison, an immersion test in 0.5 M NaCl solution was also carried out at 45°C. The samples were removed from the corrosion chambers at 3384, 4800 and 7608h, and the EIS were measured in 0.5 M NaCl solution at 25°C.

Results and Discussion

In the WSM test of polyester-urethane /epoxy (PU/E) coating, the discoloration was observed at 2062h and many cracks appeared on the surface at 6550h. The thickness was not changed even at the end of the WSM test. On the other hand, for the epoxy/epoxy (E/E) coating, the top coat was getting rough after 2062h, partially removed and the primer was directly exposed after 6550h. The results of EIS are shown in Fig.1. In the case of PU/E coating, the impedance did not change except that it was slightly increased in the low frequency range after 6550h, in spite of formation of the cracks on the surface. This increase might be due to deposition of silica originated from the test solution. For the E/E coating, there was clearly the decrease of impedance, compared with the unexposed coating. The decrease was attributed to reduction of the coating thickness which was caused by removal of the top coat. However, a resistive component which usually indicates the occurrence of the coating delamination and underlying steel corrosion did not appear at low frequency, though the coatings deteriorated so much. The delamination test after the WSM confirmed that both PU/E and E/E were not delaminated at all and the rusts were not observed on the substrate steel surface with the naked eye.

The EIS results of the immersion test in 0.5M NaCl solution are shown in Fig.2. Some blisters and underlying steel corrosion were observed for both the PU/E and E/E coatings after 4800h, unlike the WSM test. The impedance decreased drastically at low frequency and the coating resistance appeared after 3384h, though the blisters were not observed for both the coatings at this point. For the PU/E coating, the impedance did not change after 3384h. On the other hand, for the E/E coating, the coating resistance decreased and blisters were observed with the naked eye at 4800h. At 7608h, the impedance increased again, probably due to formation of rusts.

In the WSM test, the degradation of the polymer coatings themselves was accelerated by UV irradiation, especially for the E/E coating. However, the EIS for the PU/E and E/E coatings was not changed except that the E/E coating capacitance increased by thinning of the coating. The EIS indicated that the delamination and underlying steel corrosion did not occur until 6550h under UV irradiation. From the facts that the delamination occurred at relatively early stage in the immersion test, the wetting period of 12min each cycle employed in the WSM test might be too short for onset of coating delamination and steel corrosion. The wetting time period each cycle, rather than wetting/drying ratio, are an important for occurrence of underlying steel corrosion. The influence of the wetting time is discussed.

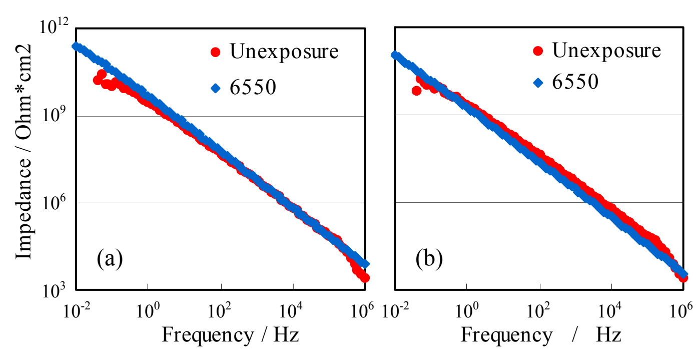

Fig.1 Change of EIS for polymer-coated steels exposed to weather sunshine meter, (a); polyester-urethane/epoxy, (b); epoxy/epoxy

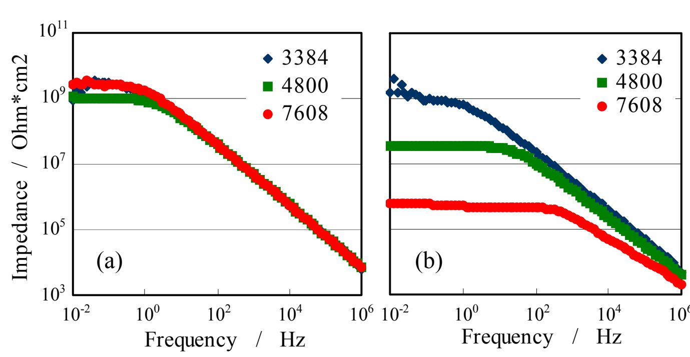

Fig.2 Change of EIS for polymer-coated steels immersed in 0.5M NaCl solution, (a); polyester-urethane/epoxy, (b); epoxy/epoxy