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Effect of nano-ZnO particles on the corrosion resistance of polyurethane-based waterborne coatings immersed in sodium chloride solution via EIS technique

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ABSTRACT

Nano-composite coatings were formed by incorporating 3 wt% nano-ZnO in a polyurethane-based waterborne coating. The nano-ZnO based composite coatings were applied on standard phosphated steel panels by cathodic electrodeposition. The electrodeposited nano-composite coatings were then baked for 20 min at 165 °C. To investigate the corrosion resistance of the coatings, the coated panels were immersed in 3.5 wt% NaCl solutions for 2880 h (120 days). The improvement in corrosion performance of the composite coatings was evaluated using electrochemical impedance spectroscopy technique. It was found that the films containing nano-sized ZnO particles show a corrosion resistance of 2 orders of magnitude higher than that of the neat films.

1. Introduction

Electrochemical corrosion could be defined as electrochemical degradation, occurring at the metal–solution interface where the metal is oxidized (anodic reaction) and species from the solution such as oxygen (cathodic reaction) are reduced [1]. Electrochemical corrosion of metals is a spontaneous process because most metals are inherently unstable [1,2].

The three major corrosion control methods used are the corrosion inhibitors, the cathodic protection and the barrier protection. The purpose of barrier protection is to separate the metal substrate from the corrosive environment. Organic coatings are the best candidate to create such a barrier against corrosive species [1–3]. They are widely used in corrosion protection of metallic substrates [3].

It is generally accepted that the coating efficiency in corrosive environments depends upon the barrier properties, the adhesion properties of the coating and the degree of environment aggressiveness [3–5]. The barrier properties of the coatings mostly depend upon the integrity of the binder and upon its adhesion to the substrate. The presence of some particles like pigments or fillers could improve these properties. Moreover, pigments change the appearance of the coatings and help to improve many other properties of such as UV resistance, corrosion resistance and mechanical properties like scratch and abrasion resistance. Unfortunately, conventional pigments at high doses have some disadvantages such as loss of impact resistance and optical properties, poor adhesion, reduced coating flexibility, inferior abrasion and scratch resistance, early delamination and increase in coating viscosity. Incorporation of nano-size pigments and fillers in the coating is a modern approach to overcome these disadvantages and even to improve the performance [6–9].

In this research, the improvement of the resistance to corrosion due to the presence of nano-ZnO in an aromatic polyurethane based waterborne coating has been investigated.

2. Experimental

2.1. Materials

Nano-ZnO (Oxylink 3102) with a mean particle size of less than 50 nm as zinc oxide dispersion in water (40 ± 1 wt%), density (g/ml) of 1.4–1.5, pH value of 8.1–8.6, was kindly provided by Bühler Company, Switzerland. The nano particles (3 wt%) were dispersed in the waterborne resin dispersion using a Hielscher UP400S ultrasonic processor. The waterborne resin dispersion and the pigment paste (Cathoguard 500) were commercial grades from BASF Co. Germany, in the mixing ratio of 1:6 respectively. The resin dispersion had a solid content of 40 ± 2 wt%, and the solid content of the pigment paste was 66 ± 2 wt%. The paint films were deposited on phosphated steel panels at 190 volts for 3 min at an active anode to cathode ratio of 1:6. The films were then rinsed by DI water and

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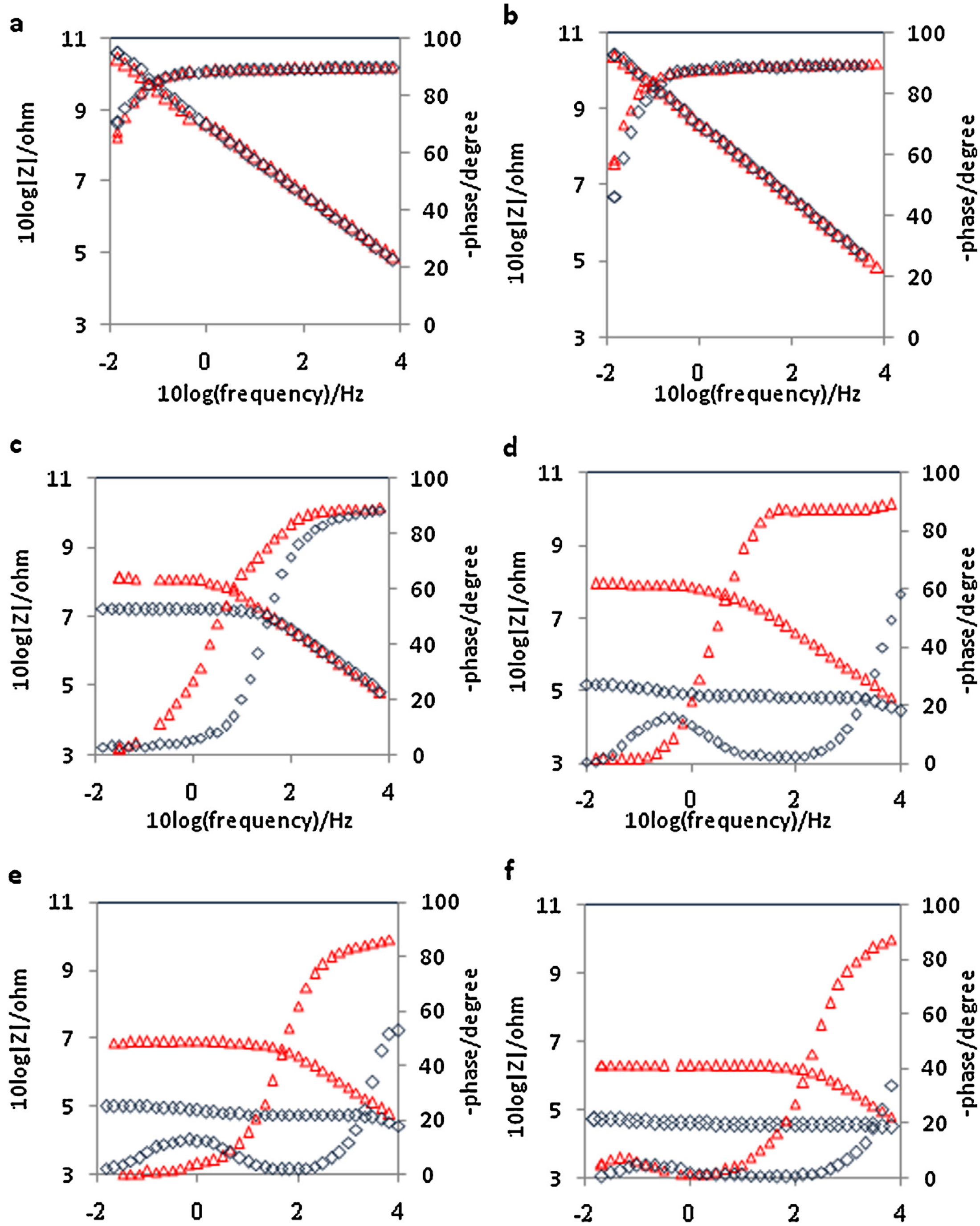

Fig. 1. Bode plots for different immersion times in NaCl solution: after (a) 96 h, (b) 360 h, (c) 720 h, (d) 1080 h, (e) 1536 h, and (f) 2880 h immersion; ◇: neat coating; △: nano-ZnO filled coating.

baked for 20 min at 165 °C in an electrical laboratory oven. The dry film thickness was 20 ± 1 μm. More details on the preparation of the electro-coating bath have been mentioned elsewhere [10].

2.2. Equipment

An IVIUM Technologies electrochemical impedance spectrometer (EIS) was used to study the electrochemical and corrosion behavior of the coatings. After running the EIS experiments, data were analyzed using Zview software. For each point there were two samples and the values of the graphs are in average but the Bode and the Nyquist graphs are the typical.

The coated panels were immersed in 3.5 percent NaCl aqueous solution for 2880 h (120 days) and characterized by using EIS technique. A three electrode cell arrangement was used for measurements. The working electrode was the coated steel panel. The suface area of the working electrode in contact with NaCl aqueous solution is equal to 1 cm^2. The auxiliary electrode was made of graphite, and the reference electrode was a saturated calomel electrode. The volume inside the test electrolyte glass cell was

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