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Novel H_2Pc/Epoxy nanocomposites: Electrochemical and mechanical property investigation as anti-corrosive coating

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ABSTRACT

In this study, H_2Pc/Epoxy nanocomposite coating was fabricated for anti-corrosion applications. The electrochemical, cross-cut adhesion, impact resistance, bend test, contact angle, scanning electron microscopy (SEM) and thermogravimetric analysis (TGA) analysis were employed to evaluate the performance of new nanocomposites. Corrosion monitoring was achieved in saline solution (3.0 wt.% NaCl). The improvement of the corrosion performance of the epoxy coating containing H_2Pc particles by comparison with neat epoxy resin was confirmed by the high coating resistance. Degradation of H_2Pc/Epoxy nanocomposite coating was observed after 14 days. It was found that H_2Pc particles improved the cross-cut adhesion, impact resistance and thermal stability of epoxy resin.

1. Introduction

The incorporation of pigments into the coating matrix promotes the anti-corrosion character of coatings [1–3].

The use of traditional inorganic pigments in costing formulas has many disadvantages such as weakness in layer adhesion and impact resistance. Moreover, they do not give the adequate protection against corrosion [4]. Recently, most efforts have been made for using nanomaterials to enhance the anti-corrosion coating performance [5].

The nanocomposite coatings are synthesized from a combination of polymer with nanomaterials [6].

Nanomaterials make the polymer resin have many unique advantages. Several studies have shown the use of many nano-particles such as TiO_2, SiC, and WC in improving the performance of coatings [7–9].

The main role of this material is to increase the efficiency mechanically and reduce the holes size in the polymer matrix [10]. Many nanocomposited coatings were reported to exhibit better performance in comparison with the traditional coatings [11–13].

In recent years, phthalocyanines have been paid much attention since their application improved the optical property and endowed other special function to coatings [14].

In this study, we develop for the first time H_2Pc/Epoxy nanocomposite coating. The protective performance of the H_2Pc/Epoxy coating to the carbon steel substrate exposed to saline solution was examined.

2. Experimental details

2.1. Synthesis of H_2Pc

Scheme 1 represents the method for synthesis H_2Pc particles [15]. The average size of prepared H_2Pc particles is nearly 1.4 nm.

2.2. Materials

For the coatings, carbon steel sheets (120 mm × 18 mm × 2 mm) from Egyptian iron & steel company were used as substrates. Metallic surfaces were cleaned according to ASTM G3–14 prior the coating [16].

Bisphenol epoxy resin (DY-128) and the curing agent (dimethylaminopropylamine) were purchased from Eric Lee Shandong Deyuan Co., Ltd.

Analytical grade NaCl (Merck) and doubly distilled water were used to prepare saline solution (3.0 wt.% NaCl, pH 6.8).

2.3. Preparation of H_2Pc/Epoxy nanocomposites

1.0 wt.% H_2Pc was dispersed in the epoxy resin utilizing automatic pigment muller (Arvind Engineering Co.). The prepared H_2Pc/Epoxy nanocomposite was diluted by adding xylene solvent. The coating films were coated by spin coating and were dried at room temperature. The final thickness of coated films was about 35 μm.

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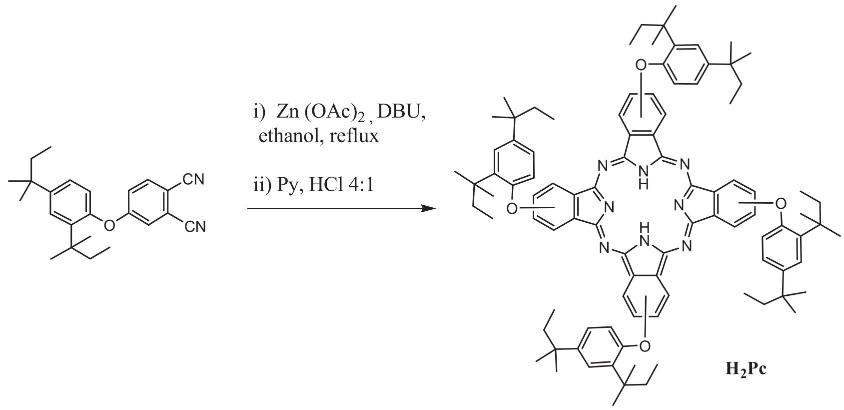

Scheme 1. Preparation of tetrakis[4-(2,4-bis-(1,1-dimethylpropyl)phenoxy)] phthalocyanine (H_2Pc).

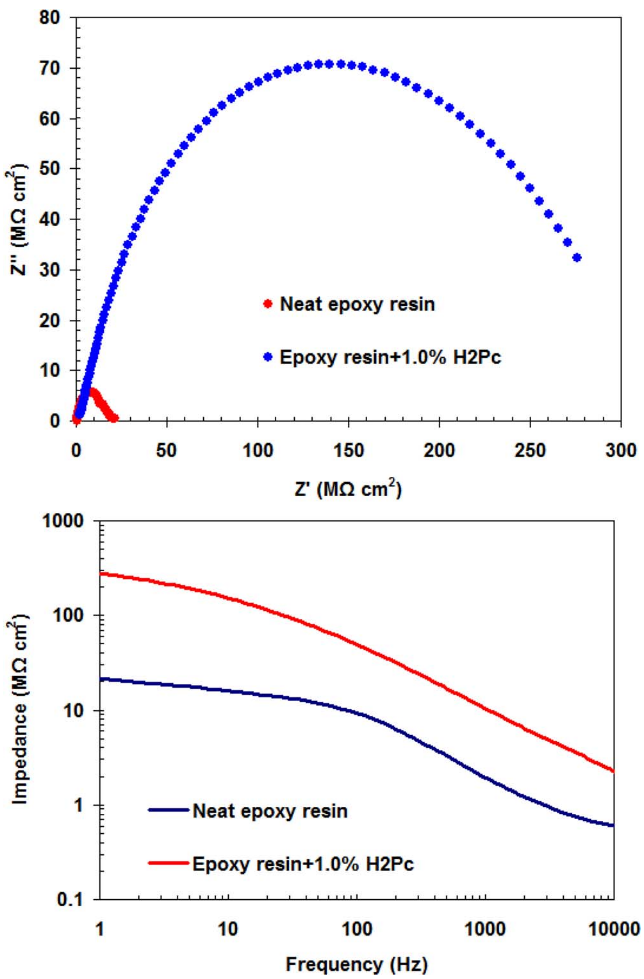

Fig. 1. Nyquist and Bode plots for the epoxy-coated steel with and without H_2Pc in 3.5% NaCl solution at 298 K.

2.4. Corrosion tests

The corrosion tests were achieved in 3-electrodes cell, which composed of C-steel (working electrode), platinum (counter electrode) and saturated calomel electrode (reference electrode). The corrosion tests were carried out by electrochemical impedance spectroscopy (EIS) at the open circuit potential in the 1.0 Hz- 10^4 Hz frequency range using EG&G 273 Potentiostat/Galvanostat. The small amplitude (10 mV) was used in this test. The data of EIS data were analyzed using the Thales software.

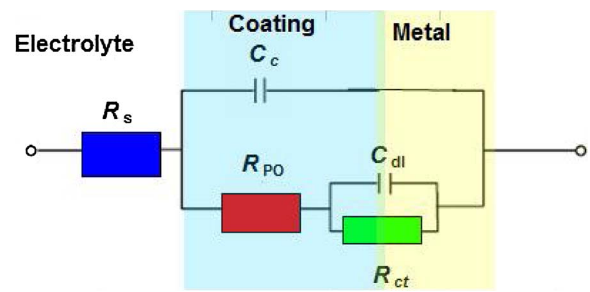

Fig. 2. Equivalent circuits models for neat epoxy resin.

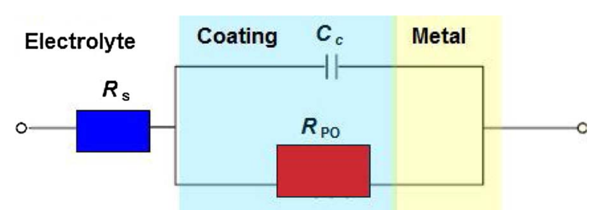

Fig. 3. Equivalent circuits models for H_2Pc/Epoxy coating.

Table 1
Fitting impedance parameters of the epoxy-coated steel in 3.5% NaCl solution with and without H_2Pc at 298 K.

EIS parameters	Epoxy resin	Epoxy resin + 1.0% H_2Pc
R_{PO} MΩ cm^2	12.5	293.2
$C_c \times 10^{-11}$ F cm^{-2}	1.27	0.05
R_{ct} MΩ cm^2	6.3	–
$C_{dl} \times 10^{-11}$ F cm^{-2}	2.52	–

2.5. Mechanical tests

Mechanical experiments include cross-cut adhesion, impact resistances, bend test and contact angle were carried out according to ASTM standards (ASTM D 3359-87, ASTM D2794, ASTM D522 and ASTM D7334).

The TGA inspections were carried out using TGA-550 TA Instruments (Temperature range 10–1000 °C, heating rate = 10 °C min^{-1} – nitrogen atmosphere).

2.6. SEM analysis

The SEM images for epoxy-coated steel with and without H_2Pc after 7 days of immersion in saline solution (3.0 wt.% NaCl) was recorded using scanning electron microscopy (Model JEOL JSM6510).