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The corrosion performance of polyaniline on nickel plated mild steel

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Abstract

Electrochemical synthesis of polyaniline (PANI) was achieved on Ni plated (1 μm) mild steel (MS/Ni) and unplated mild steel (MS). The synthesis was carried out under cyclic voltammetric conditions from 0.1 M aniline containing oxalic acid solution. AC impedance spectroscopy (EIS) and anodic polarization curves were used to evaluate the corrosion performance of PANI coated and uncoated electrodes in 3.5% NaCl. It was observed that Ni plating reduced drastically the corrosion rate of mild steel and exhibited an efficient barrier property on MS. However, the porosity of nickel plating increased for longer periods. It was found that polymer film decreased the porosity of Ni coating by catalyzing the passivation of this layer with time and that PANI top coat could provide significant protection efficiency to MS/Ni electrode. While PANI coated mild steel (MS/PANI) showed a protection property against the attack of corrosive products. Its lifetime was limited for extended periods. It was found out that corrosion resistance of Ni plating with PANI top coat (MS/Ni/PANI) was higher for much longer periods with respect to the one observed for mild steel.
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1. Introduction

In industry, the plating of mild steel and iron by metals like nickel, chrome, zinc has been widely used to protect them against corrosion, for many years [1–3] and thin top coat phosphatation and chromatation on electrodeposited metal coatings have improved the corrosion resistance of the substrates. The nickel plating on mild steel has been generally applied for longer periods, which exceed the car lifetime in automobile industry and for the fabricated parts such as nails and bolts. At the same time, this plating has a widespread decorative application in such components as spanners, exhaust pipes, etc. [4–6].

The electrodeposition of conductive polymers on mild steel, nickel and copper might be an inexpensive alternative treatment that enables using electrodeposition baths in industry thereby reducing the overall

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pollution in environment [7–11]. Therefore, polyaniline coatings have been studied successfully for many years, an account of having in various application areas the effect of preventing mild steel corrosion [12–19]. However, the primary effect of an organic coating such as polyaniline has not permanently been impenetrable. In this case, a second line of defence such as blends or pigments or top coatings increases greatly the length of the diffusion pathways for oxygen and water, thereby, decreasing the permeability of the coating [20–22].

The aim of the present study was to synthesize electrochemically polyaniline (PANI) films on Ni plated MS and unplated MS electrodes. Electrochemical synthesis of polyaniline was carried out from 0.1 M monomer containing oxalic acid solution. The corrosion performance of these polymer films synthesized on different substrate was investigated in 3.5% NaCl. It was compared with the AC impedance diagrams and anodic polarization curves of PANI films obtained on nickel plated MS and bare MS.

2. Experimental

All electrochemical experiments were performed in a single compartment cell with three electrode configurations. The reference electrode was Ag/AgCl (sat., KCl) electrode and the counter electrode was a platinum sheet with surface area of 2 cm^2. In this study, A CHI 604 model electrochemical analyzer (serial number: 6A721A) under computer control was used in electrochemical experiments. All electrode potentials were referred to the Ag/AgCl electrode. The working electrode was a mild steel surface (MS) measuring 0.501 cm in the radius and with the following composition (wt.%): C (0.098), Mn (0.35), S (0.031), P (0.017) and Fe (99.334). Mild steel electrodes were embedded in thick polyester block. In order to remove any existing passive film, the surface of working electrodes were polished using up to 1200 grade emery paper prior to each experiment, and before electropolymerization, rinsed in 1/1 ethanol/acetone mixture, washed with bi-distilled water and dried.

Nickel plating (MS/Ni) was carried out using a bath based on $NiSO_4$ (30), $NiCl_2$ (1.0) and H_3BO_3 (1.25) by wt.% and pH was between 5.6 and 6.2. The thickness of plating was determined by estimation of the passing charge amount applying 7 mA constant current and the thickness of Ni plating was estimated to be approx. 1 μm. Ni anode using for the plating was taken as 0.64 cm^2 surface areas (99.9% purity) and all nickel plating was obtained by stirring the solution under atmospheric condition.

Aniline was freshly distilled and stored in the dark. All the chemicals were analytical grade from Merck. PANI coats were electrochemically synthesized on MS and MS/Ni using cyclic voltammetry in the 0.1 M aniline solution containing 0.3 M oxalic acid.

The corrosion performances of these coating were examined in 3.5% NaCl solution by electrochemical impedance spectroscopy (EIS) and anodic polarization measurements. The EIS measurements were obtained in the frequency range from 10^5 to 10^{-3} Hz using the amplitude of 7 mV.

3. Results and discussion

Cyclic voltammograms recorded for mild steel (MS) and nickel plated mild steel (MS/Ni) electrodes in oxalic acid solution are given in Fig. 1. All measurements were taken at scan rate of 50 mV s^{-1}. The active dissolution of MS and MS/Ni started at around −0.50 and −0.10 V, respectively. The passivation of these electrodes was completed at around 0.00 V for MS and at around 0.40 V for MS/Ni. Their charge amounts were 4.76×10^{-2} and 2.94×10^{-3} C, respectively. The passivation mechanism was based on

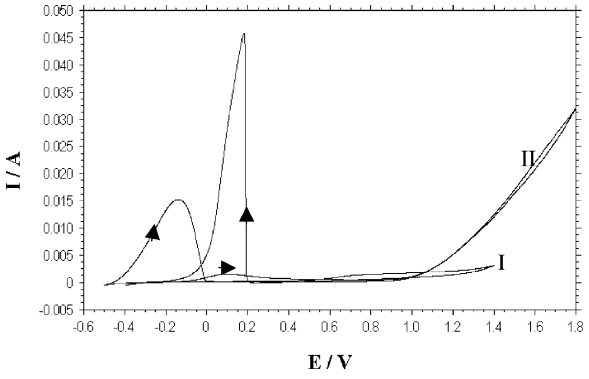

Fig. 1. The cyclic voltammograms recorded for MS (I) and MS/Ni (II) electrodes in 0.3 M oxalic acid solution, scan rate was 50 mV/s.

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