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An Electrochemical Study on the Corrosion Inhibition of Stainless Steel by Polyaniline Film

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Abstract: Polyaniline (PANI) film was electrosynthesized on 304 stainless steel by cyclic voltammetry using aqueous oxalic acid as supporting electrolyte. The potential sweep rates were changed to achieve the PANI film with different thickness and structures. Protective properties of the PANI film for corrosion of stainless steel in 3% NaCl aqueous solution were investigated by monitoring potentiodynamic polarization curves and electrochemical impedance spectroscopy (EIS). The results showed that the PANI film which was formed with lower sweep rate led to more positive shift of corrosion potential and greater charge transfer resistance, reflecting higher inhibition for corrosion of the stainless steel.

Keywords: Corrosion inhibition, stainless steel, polyaniline film, electrochemical study.

Use of conducting polymer such as polyaniline and polypyrrole as anti-corrosion coatings was attracted much interest recently[1-4]. These polymers act as anodic protection and significantly reduce the corrosion rate of metals. PANI film can be produced by both chemical and electrochemical methods. The advantage of the electrochemical synthesis is a direct synthesis of a polymer on the metal surface without any organic additives. It is advantageous in studying of a pure polymer protection mechanism. As reported previously, the thickness of PANI film used to be controlled by adjusting the number of potential cycles, while the sweep rate was kept constant[3-4]. In the present work, however, different sweep rates are adopted to control the thickness and structure of the polymer film during the electrochemical synthesis process. Finally, the anti-corrosion performance of the PANI film thus produced is studied.

Electrochemical measurements were performed in a standard three-electrode cell by using CHI650A Potentiostat / Galvanostat. A 304 stainless steel disk (φ=3mm) was used as working electrode. The counter electrode was a Pt plate and reference electrode was a saturated calomel electrode (SCE). PANI film was electrochemically synthesized in 0.2 mol/L oxalic acid + 0.1 mol/L aniline solution by cyclic voltammetry method between -0.2 and 1.1 V (*vs*. SCE) for 15 times of potential cycles at the sweep rate of 0.02, 0.05 and 0.1V/s, respectively. Since the stainless steel is not as active as pure iron, the PANI film can be directly electrosynthisized on the stainless steel surface without prepassivation.

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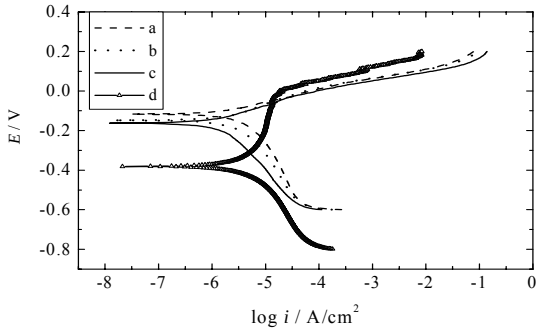
The potentiodynamic polarization curves and electrochemical impedance spectroscopy were recorded with PANI film-covered or uncovered stainless steel in a 3% NaCl aqueous solution to study the inhibition of PANI film on corrosion of the stainless steel. The impedance data were collected in the frequency rang of 100000~0.1 Hz and a 5 mV amplitude of sinusoidal voltage signal was applied. All experiments were carried out at 18±1°C.

Results and Discussion

Figure 1 shows the polarization curves for stainless steel covered and uncovered with PANI film. It can be observed from **Figure 1** that when the steel surface is covered with PANI film, the corrosion potential presents an obvious shift to the positive direction and the corrosion current density decreases, compared to the situation of the steel which is uncovered with PANI film. Another observation is that the film formed at different sweep rates corresponds to different extents of corrosion potential shifts. Obviously, the smaller the sweep rate is, the more notably the corrosion potential shifts positively. In other words, there is an inverse proportion of corrosion potential shift to the sweep rate in film formation. The positive shift in the corrosion potential indicates an efficient protection of the metal surface by the PANI film.

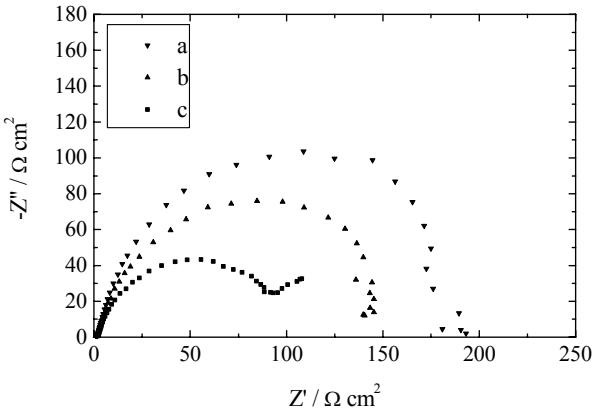
Figure 1 Potentiodynamic polarization curves for stainless steel covered (a, b, c) and uncovered (d) with PANI film in 3% NaCl solution



Sweep rate: 0.001 V/s. PANI film was synthesized with different sweep rate: a-0.02, b-0.05, c-0.1 V/s.

As pointed out earlier in the present work, the PANI film with varying thickness and structure can be obtained by applying different sweep rates during the electrosynthesis of the film. The Nyquist diagrams in **Figure 2** show that the stainless steel electrode covered with different thickness of PANI film exhibits different values of electrochemical transfer resistance (R_{ct}). As can be expected, with the decrease of the sweep rate in the electrosynthetic process, PANI film will become thicker and more compact. Therefore, the R_{ct} value increases gradually, and the PANI film imposes a certain inhibition to the corrosion process of the steel. By comparison, it can be found that the EIS data are consistent with the Tafel curves of each PANI film-covered steel electrode in **Figure 1**.

Figure 2 Nyquist plot for stainless steel covered with PANI film in 3% NaCl solution PANI film was synthesized with different sweep rate: a-0.02, b-0.05, c-0.1 V/s.



In summary, with the number of cycles unchanged, the slower the sweep rate is, the thicker the formed PANI film is, and the denser the structure of PANI is. Tafel curves show that the protective action of the polymer promotes a change of the corrosion potential to more positive values for stainless steel. EIS measurements show that R_{ct} will increase with the decrease of the sweep rate. The observations of the present results pointed out the remarkable capability of PANI to protect steel against corrosion in 3% NaCl solutions. More intensive work in this respect is in progress.

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