

Characterization of corrosion behavior of ISO 5832-1 austenitic stainless steel coating by polypyrrole

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Abstract

In the present work, polypyrrole (PPy) coatings were obtained by cyclic voltammetry and galvanostatic deposition on ISO 5832-1 surgical stainless steel samples. Two different pyrrole concentrations were used: 0.1 M and 0.5 M. The electrochemical behavior was evaluated using potentiodynamic polarization tests in phosphate buffered saline solution (PBS) at 37°C. The morphology of the PPy films was evaluated by scanning electron microscopy (SEM). The polymeric films composition was evaluated by X-ray Photoelectron Spectroscopy (XPS). The PPy-0.5 M condition presented the best corrosion resistance.

Keywords: corrosion, polypyrrole, surgical stainless steel, conductive polymeric film.

Introdução

The austenitic stainless steel ISO 5832-1 was developed for biomedical applications, presenting superior corrosion resistance than the conventional AISI 316L grade [1]. Notwithstanding, it is prone to pitting and crevice corrosion in contact with the body fluid. Conductive polymer films can act as anodic inhibitors, accelerating and stabilizing the formation of protective oxides on the surface of metallic materials. Polypyrrole (PPy) is a conductive polymer with good chemical stability. It can be electropolymerized on the surface of stainless steels, improving their corrosion properties [2].

The aim of the present work was to investigate the corrosion behavior of PPy-coated ISO 5832-1 stainless steel samples. The PPy films were obtained by cyclic voltammetry and galvanostatic deposition, using solutions with pyrrole concentrations of 0.1 M and 0.5 M.

Experimental Procedure

The sample area exposed to the electrolyte was 0.45 cm². The samples were ground using SiC emery papers with grain sizes up to grit 2400. Surface finishing was given by polishing with alumina abrasive paste (6 µm). Cyclic voltammetry was used to electropolymerization of PPy-0,1 M films on ISO 5832-1 surgical stainless steel surface. The PPy-0,5 M film was deposited galvanostatically on the metallic substrate. The deposition procedure lasted 3600 s at an optimum current density of 4.5x10⁻⁵ A.cm⁻². The surface morphologies of the PPy-0,1 M and PPy-0,5 M coatings were examined using scanning electron microscopy. The chemical structure of the PPy films was evaluated using XPS (ThermoFisher Scientific, K-alpha⁺, operating with Al-Kα radiation source). Binding energy calibration was based on C1s at 284.8 eV. The corrosion behavior of the substrate, PPy-0,1 M and PPy-0,5 M coated ISO 5832-1 specimens were evaluated in PBS solution at 37°C. The experimental procedure was based on an initial monitoring of the open circuit potential (OCP) for 1 h in order to ensure a steady-state condition. Then, potentiodynamic polarization tests were conducted using a

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Autolab M101 potentiostat/galvanostat. The tests were carried out using a conventional three-electrode cell setup with a Ag/AgCl reference electrode, platinum wire as the counter-electrode and the PPy-coated samples as the working electrodes.

Results and Discussion

Figure 1.a shows a SEM micrograph of the PPy-0,1 M coated steel. The PPy-0,1 M coating covered completely the metallic substrate, exhibiting clusters distributed within the film matrix, as shown in Fig. 1.a. Figure 1.b shows SEM micrograph of the PPy-0,5 M coated ISO 5832-1 stainless steel. This condition resulted in a compact, homogeneous and less defective film when compared to the PPy-0.1 M condition. The defects are indicated by circles in Figure 1.b.

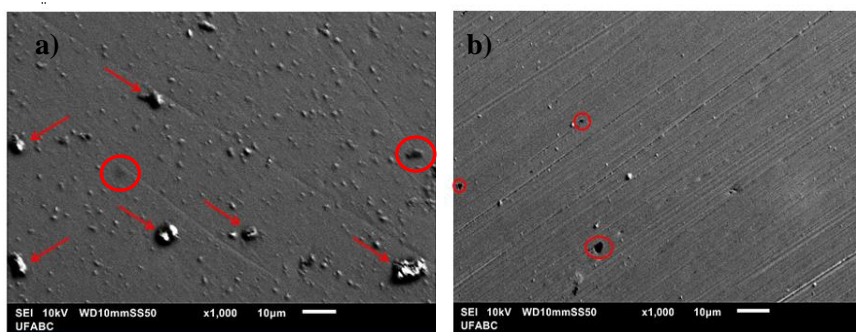


Figure 1: SEM micrograph of the a) PPy-0.1 M and b) PPy-0.5 M coated ISO 5832-1 stainless steel.

PPy-0.1 M XPS survey spectra is shown in Fig. 2.a. where the main elements were identified. Peaks not identified were referred to electron Auger peaks. PPy-0.5 M XPS survey spectrum is shown in Fig. 2.b. as well its main elements present in film. For both conditions the presence of carbon and nitrogen is due to the chemical structure of the polypyrrole molecule. Oxygen is present in film composition and its origin is related to the use of sodium salicylate as a dopant in the electropolymerization process of the pyrrole molecule. Silicon was detected in PPy-0.1 M film which is related to a superficial contamination of the sample. Sodium was identified in PPy-0.5 M film due to its presence in dopant molecule (sodium salicylate). PPy-0.5 M atomic fraction of nitrogen positive charge (19.18% at.) is higher when compared to PPy-0.1 M atomic fraction (11.63% at.), so the film composed of PPy-0.5 M presented a higher doping level.

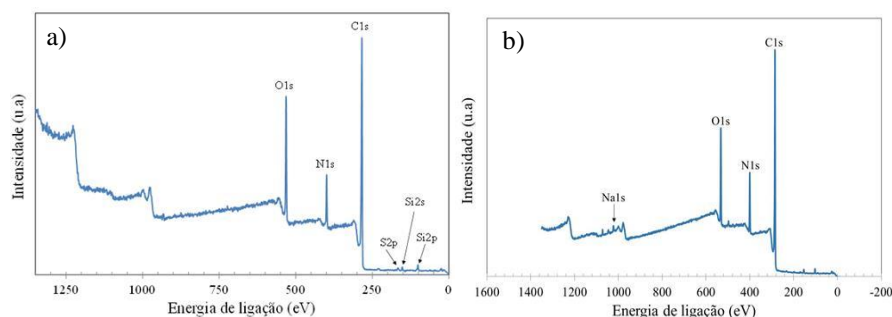


Figure 2: XPS survey spectra of a) PPy-0.1 M film and b) PPy-0.5 M.

Potentiodynamic polarization curves of the PPy-0.1 M and PPy-0,5 M coated and uncoated ISO 5832-1 surgical stainless steel are shown in Fig.3. The corrosion potentials of substrates

coated by PPy-0.1 M ($E_{\text{corr}} = -0.39$ V) and PPy-0.5 M ($E_{\text{corr}} = -0.21$ V) were shifted to anodic values when compared to the uncoated substrate ($E_{\text{corr}} = -0.72$ V). This effect was observed by González and Saidman for AISI 316L stainless steel coated by a PPy film electropolymerized on its surface [3]. E_{corr} values for sample coated by PPy-0.5 M presented the highest value. The PPy-0.5 M sample has shown a superior protective behavior when compared with the PPy-0.1 M likely due to the presence of fewer defects in the deposited film as shown in Fig. 1.b. Passive current density for PPy-0.5 M ($I_{\text{pass}} = 0.76 \mu\text{A}\cdot\text{cm}^{-2}$) presented a lower value when compared to the PPy-0.1 M condition ($I_{\text{pass}} = 0.81 \mu\text{A}\cdot\text{cm}^{-2}$) and substrate ($I_{\text{pass}} = 5.01 \mu\text{A}\cdot\text{cm}^{-2}$) values.

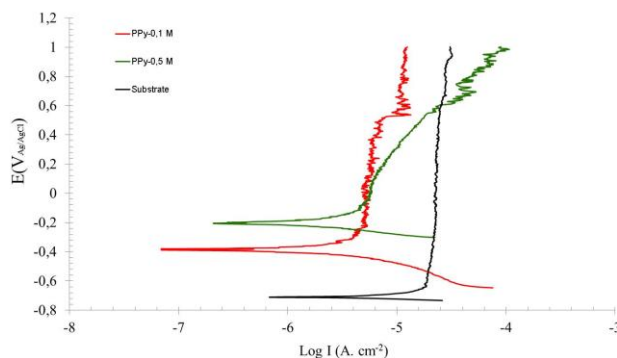


Figure 3: Potentiodynamic polarization curves of the uncoated, PPy-0,1 M and PPy-0,5 M coated ISO 5832-1 stainless steel in PBS solution at 37° C.

Conclusion

PPy-0.1 M and PPy-0.5 M films were successfully deposited on the surface of ISO 5832-1 stainless steel specimens. The PPy-0.1 M and PPy-0.5 M films presented a homogeneous morphology, but with the presence of superficial defects, especially for the PPy-0.1 M condition. XPS results confirmed the presence of characteristic chemical bonds for the PPy film. The PPy-0.5 M condition presented a higher doping level (19.18% at.) due to the higher monomer concentration in solution. The corrosion resistance of the substrate coated by PPy-0.1 M and PPy-0.5 M was affected by the surface defects. These results can be related to penetration of the electrolyte through the coating defects impairing its protective ability. The PPy-0.5 M condition presented the highest corrosion resistance.

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