

Electrochemical and spectroscopical studies of polypyrrole synthesized on carbon steel from aqueous medium



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ABSTRACT

Polypyrrole films were deposited electrochemically on carbon steel from sodium saccharinate aqueous medium using cyclic voltammetry, potentiostatic and galvanostatic techniques. X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM) and normalized tape test show that the polypyrrole coating is homogeneous and adherent to carbon steel surface with globular structure. The adherence rate depends closely on the applied current densities. The corrosion protection performance of the coating was investigated by potentiodynamic polarization technique, open circuit potential over time, and electrochemical impedance spectroscopy (EIS) in 3% sodium chloride solution.

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1. Introduction

The corrosion protection using conductive polymers such as polyaniline (PAni), polypyrrole (PPy) and polythiophene (PT) has been reported by many researcher teams [1–4]. The advantages offered by these organic coatings are: good adhesion to the metal surfaces, high corrosion resistance and no toxic compared to paints based chromates pigments such as zinc chromate, zinc tetroxy chromate and strontium chromate [5,6].

The PPy is one of the most promising conducting polymers because of their high conductivity (~ 1 S/cm), stability and ease of synthesis. It can be chemically or electrochemically deposited on a metal surface from organic and aqueous media [7–16]. Several studies reported the capacity of PPy as coating against corrosion of oxidizable metals. Herrasti and Ocon [17] showed the corrosion protective effect of PPy on stainless steel by producing a shift of corrosion potential to positive direction and reducing the oxidation

current. We showed in our previous work that PPy coating prevents corrosion by isolation and charge transfer mechanism [18,19]. Recently, a broader concept based on anion-exchange through the polymer backbone structure was reported to explain metal passivation [20–22]. Kowalski et al. [23] suggest a PPy bilayer coating for the carbon steel, which inner layer is doped with heteropolyanions of $\text{PMo}_{12}\text{O}_{40}^{3-}$ and HPO_{42}^{-} and the outer with dodecylsulfate ions $\text{CH}_3(\text{CH}_2)_{11}\text{OSO}_3^{-}$. This system is a new approach of ability to polymers self-healing to repair artificial defects, and restore the passive state of an underlying metal substrate. Indeed, the outer layer is stable enough in the polymeric matrix to form a permselective barrier membrane for migration of small anions, from either the inner layer or from the corrosive medium. It provides an electrochemical barrier for the ingress of Cl^{-} responsible for passive layer breakdown. In the same manner, the ion selectivity of the outer layer causes the mobile MoO_4^{2-} anions to become trapped in the inner layer, which simply means that they can be consumed in the interfacial process Fe/PPy regenerating of passive film. González et al. [24] have also manufactured duplex coatings of PPy on carbon steel with different morphologies synthesized from salicylate medium with good anticorrosive properties.

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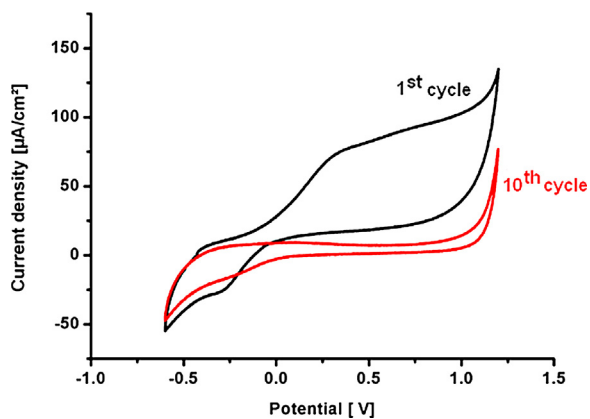


Fig. 1. Electrochemical behavior of CS electrode in 0.1 M saccharinate aqueous solution. (1st and 10th scans). Scan rate: 100 mV s^{-1} .

We have already studied the corrosion protection of iron [25] and stainless steel [19] by polypyrrole coatings. In the present paper, we investigate several electrochemical and spectroscopical techniques to study the electrodeposition of PPy on carbon steel from saccharinate aqueous medium and its behavior in NaCl corrosive solution.

2. Experimental

Pyrrole monomer (Aldrich) was distilled under nitrogen, sodium saccharinate ($\text{C}_7\text{H}_4\text{NNaO}_3\text{S}\cdot 2\text{H}_2\text{O}$) and NaCl (>99%) were purchased from Merck and used as received, and water was distilled twice before use.

The electrochemical experiments for the preparation of PPy coating were performed in a one compartment cell with three electrodes connected to Voltalab PGZ301 potentiostat/galvanostat with pilot integration controlled by VoltaMaster 4. The working

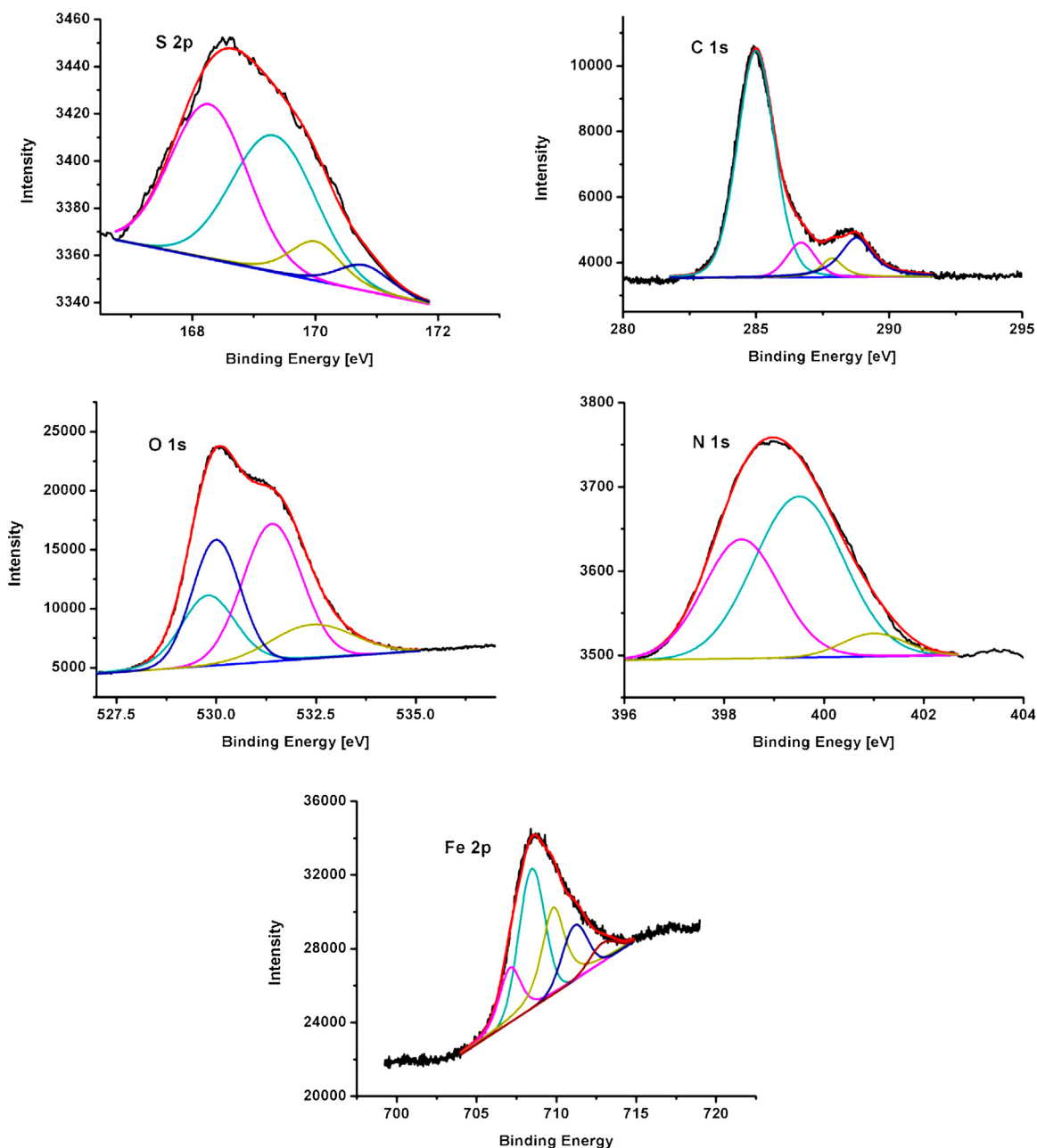


Fig. 2. XPS analysis of CS electrode polarized in 0.1 M $\text{C}_7\text{H}_4\text{NNaO}_3\text{S}$ during 10 cycles (a) C 1s, (b) N 1s, (c) S 2p, (d) Fe 2p and (e) O 1s.

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