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ORIGINAL RESEARCH

Polypyrrole coatings for corrosion protection of Al alloy2024: influence of electrodeposition methods, solvents, and ZnO nanoparticle concentrations

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Abstract
Since ZnO nanoparticles increase the electrical conductivity of the polypyrrole (PPy) coatings, an investigation was carried out to evaluate the effect of ZnO nanoparticles loading on the corrosion protection performance of PPy coatings on AA2024 Al alloy in 3.5% NaCl solution. At first, some measurements were carried out to find the best experimental conditions containing the electrodeposition method, electrosynthesis solvent composition, and ZnO nanoparticles' concentration for preparing the optimum PPy coating on Al alloy2024. Three different methods of electrodeposition, namely: cyclic voltammetry, galvanostatic, and potentiostatic techniques were analyzed. The anti-corrosion performance of the PPy coatings was evaluated by electrochemical impedance spectroscopy and Tafel polarization methods. The PPy prepared by potentiostatic method exhibited the best performance against corrosion of Al alloy2024 in 3.5% NaCl solution. Then, different mixtures of H_2O/ethanol were tested as electrosynthesis solvents for preparation of PPy coatings on the alloy by optimized electrodeposition mode (i.e., potentiostatic). In evaluation of the prepared coatings, the pure water was introduced as the optimum solvent in electrodeposition of PPy. The investigation of different ZnO nanoparticles' concentrations proved that the PPy coating containing 0.025% ZnO nanoparticles was the optimum coating against the corrosion of Al alloy in NaCl solution. Finally, the long-term evaluation of the corrosion protection performance of the coatings revealed that the optimum coating provided suitable protection against corrosion up to 14 days after immersion.

Keywords Electrosynthesized polypyrrole · Corrosion protection · Nanoparticles · Electrochemical impedance spectroscopy · Tafel polarization

Introduction

Aluminum alloys such as AA2024 are widely used in aircraft industry because of their superior mechanical properties and low weight. Al alloys contain considerable amount of intermetallic impurities. These impurities make this alloy vulnerable to galvanic corrosion. Until recently, corrosion protection of Al alloys was based on hexavalent chromium (Cr^{6+}) coatings. However, these types of coatings are health and environmental hazard, and have to be replaced. Conducting polymers such as polypyrrole and polyaniline are effectively tested as corrosion inhibitors on non-ferrous metals and serve as reasonable alternative to Cr^{6+} technology [1–3].

Conducting polymers have unique properties which make them suitable for many applications in both industrial and academic fields such as anti-corrosion coatings, sensors, supercapacitors, and batteries [4–6]. Polypyrrole (PPy) as one of the highly used conducting polymers has great advantages such as environmental and thermal stability, low cost, and relatively easy polymerization [7–9]. Polypyrrole is an attractive organic coating for a large number of biological and biomedical applications due to its biocompatibility with the human body tissues [10, 11].

The properties of PPy coatings for corrosion protection of alloy surface strongly depend on the synthesis parameters such as electrodeposition method, solvent composition, and nanosize additives. Cyclic voltammetry (CV), galvanostatic (GS), and potentiostatic (PS) methods are some of the most important techniques for electrosynthesis of PPy coatings reported in the literature [9, 12, 13]. The side reactions cannot occur at the alloy surface in the PS mode due to the application of

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