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Impact of ultrasound frequency on the corrosion resistance of electroless nickel-phosphorus-nanodiamond plating

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ABSTRACT

The nickel-phosphorus (Ni-P) and nickel-phosphorus-nanodiamond (Ni-P-ND) coatings were deposited on mild steel via electroless plating without ultrasound and under ultrasonic agitation with different frequencies of 25, 50, 75, 100, and 150 kHz. The as-prepared coatings were characterized using scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), and X-ray diffraction (XRD). The corrosion performance of the fabricated layers was evaluated in 3.5 wt% NaCl solution by electrochemical impedance spectroscopy (EIS) and potentiodynamic polarization. Results of the corrosion tests demonstrated that deposition under ultrasonic power provided coatings with higher stability in the corrosive environment. The corrosion rate decreased with increasing ultrasound frequency from 25 to 75 kHz but increased with further increase in frequency. This introduced 75 kHz as the optimum ultrasound frequency for electroless plating of Ni-P. It was also observed that the corrosion resistance of the proposed coating was improved through the incorporation of 40 ppm nanodiamond into the Ni-P matrix.

1. Introduction

Electroless nickel-phosphorus (Ni-P) coatings are broadly applied to various metallic substrates to modify their surface properties, such as electrochemical behavior and hardness. This type of coating is frequently used in multiple fields, including chemical electronics, aerospace, mechanical, and oil-gas industries [1–7]. It has been reported that Ni-P coatings express practical anti-corrosion features, wear resistance, uniformity of deposit, and high abrasion [8,9]. Thanks to such characteristics, Ni-P films could provide an efficient protective barrier for different metals, particularly steel alloys as one of the most used metals in the industry [10–15]. Because of the cathodic nature of this coating towards steel substrate, the risk of developing galvanic cells with a large cathode-to-anode area ratio at the cracks of the coating should be taken into account [16]. It is known that the addition of particles, especially nanoparticles, to the Ni-P matrix enhances the characteristics of the surface, depending on the nature of the additive [17–19]. Within this framework, various nanoparticles such as Si_3N_4 [12], SiC [20], graphene [21], MOF [22], and ZrO_2 [23] have recently been reported to improve the corrosion and wear resistance of the Ni-P coating. It is believed that the presence of nanoparticles provides nanocomposite coatings with fewer cracks and porosity, resulting in improved corrosion protection. Moreover, ultrasound-assisted electrodeposition of Ni coatings has been proposed because of advantages like increased deposition rate and reduced internal stress of the resulting coating [24–26]. In this regard, many works have been carried out on the ultrasonically prepared Ni-P coatings on different types of substrates. However, the number of reports on the influence of ultrasound power frequency is limited. On this basis, the present work provides a systematic study on the electroless deposition of Ni-P and Ni-P-nanodiamond (Ni-P-ND) coatings under ultrasound waves imposed in a wide range of frequencies.

2. Experimental

2.1. Materials

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