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Ultrasonic-assisted deposition of Ni-P-Al_2O_3 coating for practical protection of mild steel: Influence of ultrasound frequency on the corrosion behavior of the coating

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ABSTRACT

In this paper, the precipitation of nickel-phosphorous (Ni-P) electroless coatings including Al_2O_3 nanoparticles (Ni-P-NA) using ultrasound waves on mild steel has been studied. Deposition process occurred in a lactic plating bath by the autocatalytic method using an ultrasound probe. The effect of radiation frequency on the properties of coatings was investigated, and the optimum frequency was determined. The obtained samples were evaluated for their corrosion resistance, surface morphology, and hardness by electrochemical impedance spectroscopy (EIS), potentiodynamic polarization, and scanning electron microscopy (SEM). The results showed that ultrasound waves caused an improvement in the corrosion resistance and uniformity of the coatings. Furthermore, five different wave frequencies applied during deposition disclosed the remarkable impact of frequency on the smoothness and corrosion resistance of the resultant coatings. On this basis, the Nyquist diagrams showed that the corrosion resistance of the prepared Ni-P-NA coating at an optimum frequency of 75 kHz was 2.59 $k\Omega \cdot cm^2$. This value was about 2.5 times higher than the value obtained for the Ni-P-NA coating deposited without ultrasound power.

1. Introduction

Electroless nickel precipitation is broadly used in various industries, such as electronics, automotive, aerospace, medicine, petrochemical, food, and military industries. These wide applications can be explained by a precise understanding of several properties, including corrosion resistance, high abrasion resistance, uniform coating thickness, and magnetic properties [1]. The electroless method is an excellent way to cover complex parts [2]. The electroless nickel coating process has led to the widespread growth of surface engineering [3], and because of its unique physical and chemical properties, it has usually replaced hard chrome coatings [4]. Its corrosion resistance is excellent, and in most environments, it is better than pure nickel or chromium [5,6]. In addition, the electroless nickel coating has a high coating ability, high strength bonds, good anti-abrasion properties, corrosion resistance, excellent welding capability, good thermal and electrical conductivity, and magnetic properties that can be controlled by heat treatment [7]. In addition to pure Ni coatings, composite coatings are created by adding fine particles in powder form to the plating solution and suspension (deposition) of these particles and their simultaneous deposition along with electroless nickel-based coatings. In this way, due to the juxtaposition of two or more phases, a set of properties is obtained that cannot be achieved by individual components [8]. In addition to hardness and abrasion resistance, good corrosion resistance of the coating is one of the other properties affected by the presence of these particles in the coating [9].

The ultrasound in electrochemistry has been used in various fields, such as sonoanalysis, sonoelectrosynthesis, sonoelectrodiposition, accelerating corrosion studies, wastewater treatment, etc. Ultrasonic radiation brings energy into the system and increases mass transfer due to acoustic microcurrents and cavitation phenomena, especially in the strong ultrasound region (20-100 kHz) [10]. The study of the effect of ultrasound on electrocoating has been one of the first

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