ABSTRACT

Electroless coating is a chemical deposition technique that allows for uniform application of metal or alloy coatings onto a wide range of substrates, both metallic and non-metallic, regardless of their shape or complexity. Unlike electroplating, it operates without the need for an external electric current and relies on controlled redox reactions to reduce metal ions from the solution onto the substrate. This thesis focuses on the development, characterization, and optimization of electroless Ni-W-P-Ce coatings on low-carbon steel (AISI 1010) for multifunctional applications.

For development of the coating, different coating conditions were explored, and a neutral bath (pH 7.5) stabilized with thiourea was identified to exhibit superior performance in terms of bath stability, deposition rate, coating microstructure, and microhardness. Next, the bath composition was optimized to maximize the overall coating performance, and a novel hybrid multi-objective optimization approach was adapted by combining an artificial neural network (ANN) with a metaheuristic algorithm. Among the evaluated algorithms, red fox optimization (RFO) proved most effective, yielding an optimized coating with a surface roughness of 0.12 µm, microhardness of 726 HV, 64% reduced fouling weight, surface free energy of 15.97 J/m2, and 98.73% corrosion protection efficiency.

Next, a comprehensive suite of characterization techniques, including microhardness, surface roughness, deposition rate, scratch and wear resistance, corrosion resistance, biofilm formation, surface morphology, structural analysis, and compositional analysis, were employed to thoroughly investigate the influence of cerium incorporation in Ni-W-P-Ce coatings. An optimal Ce concentration of 8 mg/L was identified, which significantly enhanced the functional performance of the coatings. Subsequent annealing at various temperatures revealed a trade-off among the properties, indicating that careful thermal treatment can balance the mechanical, chemical, and structural attributes. Further studies explored the effects of substrate surface preparation methods, including activation with different agents (HCl and PdCl2), polishing to various surface roughness levels, and modifying bath loading conditions. Among these, HCl activation was more effective than PdCl2 activation, enhancing adhesion through micro-roughening. Polishing with finer grit (1500 grit) promoted controlled nucleation and uniform coating growth, resulting in superior adhesion and enhanced mechanical properties. Additionally, an optimal bath loading of 0.88 dm2·L-1 was identified, effectively balancing the deposition rate and bath stability.