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Electroless Ni–P composite coatings

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Abstract

This review outlines the development of electroless Ni–P composite coatings. It highlights the method of formation, mechanism of particle incorporation, factors influencing particle incorporation, effect of particle incorporation on the structure, hardness, friction, wear and abrasion resistance, corrosion resistance, high temperature oxidation resistance of electroless Ni–P composite coatings as well as their applications. The improvement in surface properties offered by such composite coatings will have a significant impact on numerous industrial applications and in the future they will secure a more prominent place in the surface engineering of metals and alloys.

1. Introduction

Electroless plating is a chemical reduction process, which depends on the catalytic reduction of a metallic ion from an aqueous solution containing a reducing agent, and the subsequent deposition of the metal without the use of electrical energy. During the past five decades electroless plating has gained popularity due to its ability to produce coatings that posses excellent corrosion, wear and abrasion resistance. Among the variety of metals that can be plated using this method, electroless nickel has proved its supremacy for producing coatings with excellent corrosion and wear resistance [1, 2]. Electroless nickel processes are grouped as Ni–P, Ni–B and pure Ni, based, respectively, on the reducing agents used (i.e., hypophosphite, borohydride or dialkyl amino borane and hydrazine) in the plating bath. Hypophosphite reduced electroless nickel plating process has received commercial success because of its low cost, ease of control, and ability to offer good corrosion resistance. Although electroless Ni–P deposits give satisfactory performance for several applications, enhancing their performance to suit different end uses warrants further development. This is achieved either by adding additional alloying element(s) or by incorporating hard/soft particles in the Ni–P matrix. A detailed account of electroless nickel composite coating was presented earlier by Feldstein [3]. This review outlines the development of electroless Ni–P composite coatings with the incorporation of various hard and soft particles in the Ni–P matrix to maximise the coating performance to meet the demanding needs of engineering applications. The method of formation, mechanism of particle incorporation, factors influencing particle incorporation, effect of particle incorporation on the coating structure, hardness, friction, wear and abrasion resistance, corrosion resistance, high temperature oxidation resistance and applications are discussed.

2. History of electroless Ni–P composite coating

The idea of codepositing various second phase particles in electroless nickel deposits and thereby taking advantage of their inherent uniformity, hardenability, wear resistance and corrosion resistance, has led to the development of electroless nickel composite coatings. Work dealing with the incorporation of second phase particles in the electroless nickel matrix began in the 1960s [4]. The initial attempts made to produce such deposits were not successful and often resulted in decomposition of the bath. This is not surprising as the methodology pursued for producing the composite coatings were similar to those prevailing in conventional electroplating. Dispersion of finely divided particles increases the surface area loading of the electroless plating bath by 800 times that normally acceptable for conventional electroless plating and this ultimately leads to homogeneous decomposition of the bath [5]. However, with the help of suitable stabilizers, electroless nickel composite coatings were prepared. An essential advantage of preparing composite coatings by electroless deposition compared to electrocodeposition is that the former allows accurate reproduction of the base