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Review

Tribology of electroless nickel coatings – A review

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ABSTRACT

Electroless coating is different from the conventional electrolytic coating as the former does not require any electricity for its operation. The advantages include uniform coating and also nonconductive materials can be coated. Electroless nickel coatings possess splendid tribological properties such as high hardness, good wear resistance and corrosion resistance. For this reason, electroless nickel has found wide applications in aerospace, automobile, electrical and chemical industries. Quest for improved tribological performances has led many researchers to develop and investigate newer variants of electroless nickel coatings like Ni–W–P, Ni–Cu–P, Ni–P–SiC, Ni–P–TiO_2, and so on. Also the enhancement of tribological characteristics through modification of the coating process parameters has remained a key point of interest in researchers. The technological advancement demands the development of newer coating materials with improved resistance against wear and tear. Electroless nickel has shown huge potential to fit in that space and so the study of its tribological advancement deserves a thorough and exhaustive study. The present article reviews mainly the tribological advancement of different electroless nickel coatings based on the bath types, structure and also the tribo testing parameters in recent years.

1. Introduction

In the middle of the twentieth century, a revolutionary method of coating technique was developed by Brenner and Riddell [1]. Popularized as the "Electroless Coating", the method did not require any electricity. Since then it has evolved into a mature subject of research and development today due to its wide range of applications. Electroless nickel coatings are the more popular variant of electroless coatings which possess some distinct collection of properties (Table 1). Electroless coatings find their use in almost every domain. From simple knitting needles to the mighty aerospace applications, their range of applications is continuously broadened. Primary uses for electroless nickel coatings are shown in Fig 1. However, the main applications of electroless nickel coatings are based on its properties viz. wear resistance and corrosion resistance. Moreover, some recent uses of electroless coating include application in MEMS, electromagnetic interference (EMI), in powder metallurgy, as membrane reactors, minimizing fouling in heat exchangers and reduction of bacterial adhesion.

Few metal coatings applied by electro-coatings can match the thickness uniformity of an electroless nickel finish. Because these protective coatings are chemically applied, they create deposits of highly consistent depth across all surfaces, including edges and complex interior geometries. Each option in the electroless coatings family also delivers bonus properties that improve component performance. Electroless coating can be broadly classified into three categories viz. alloy and poly-alloy coatings, composite coatings and pure metallic coatings.

2. Coatings for tribology based applications

2.1. Alloy and poly-alloy coatings

The incorporation of additional metal elements into the electroless deposits can be an important means of enlarging the range of chemical, mechanical, physical, magnetic, and other properties attainable. A number of alloys can readily be deposited by combining metals that are independently deposited electrolessly from similar baths; an example being nickel and cobalt from alkaline hypophosphite solutions. Also, and more importantly, certain metals that cannot themselves be deposited by the autocatalytic mechanism can be induced to co-deposit with an electrolessly depositing metal. For tribology based applications several binary, ternary and other poly-alloys have been described in the literature which includes:

- *Binary alloys*
  - Ni–P [2–13]
  - Ni–B [14–19]
- *Ternary alloys*
  - Ni–P–B [14,20],
  - Ni–W–P [2,21]

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