

# Chapter 18

## Roughness Optimization of Electroless Ni–B Coatings Using Taguchi Method

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### ABSTRACT

*In this paper, the authors present an experimental study of roughness characteristics of electroless Ni-B coatings and optimization of the coating process parameters based on  $L_{27}$  Taguchi orthogonal design. Three coating process parameters are considered viz. bath temperature, reducing agent concentration, and nickel source concentration. It is observed that concentration of reducing agent together with bath temperature play a vital role in controlling the roughness characteristics of the coatings. The analysis yields the optimum coating parameter combination for minimum roughness. A reduction of about 15% is observed in roughness at the optimal condition compared to the initial condition. The microstructure, composition, and the phase content of the coating are also studied with the help of scanning electron microscopes energy dispersive X-ray analysis, and X-ray diffraction analysis, respectively.*

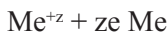
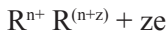
### INTRODUCTION

In the middle of the last century, Brenner and Riddell (1950) discovered a revolutionary coating process, which does not need electricity and hence is popularized as electroless coating. Electroless

plating is an autocatalytic process where the substrate develops a potential when it is dipped in electroless solution called bath that contains a source of metallic ions, reducing agent, complexing agent, stabilizer and other components. Due to the developed potential both positive and negative ions are attracted towards the substrate surface and release their energy through charge

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transfer process. The basic chemical reactions for electroless plating are given by the following expressions (Riedel, 1991):



where 'R' indicates the reducing agent and 'Me' indicates the metal to be deposited on a substrate.

Among the various types of electroless plating, electroless nickel has gained immense popularity due to its ability to provide a hard, wear resistant and corrosion resistant surface (Mallory & Hadju, 1991; Riedel, 1991). Hypophosphite reduced Ni-P coating (Agarwala & Agarwala, 2003; Hari Krishnan, John, Srinivasan, Praveen, Ganesan, & Kavimani, 2006; Sahoo, 2008) has already been widely accepted and the quest for achieving a superior hard and wear resistant surface has brought Ni-B coatings at the focus of research (Delaunois, Petitjean, & Lienard, 2000; Dervos, Novakovic, & Vassiliou, 2004; Krishnaveni, Sankara Narayanan, & Seshadri, 2005; Anik., Körpe, & Şen, 2008). Aerospace, automotive, chemical and electrical industries utilize electroless nickel–boron plating due to its good solderability and lubricity, high hardness, high wear and abrasion resistances (Mallory & Hadju, 1991).

For Ni-B deposition reducing agents such as sodium borohydride or dimethylamine are commonly used among which the reduction efficiency of the former is much higher. However the high reduction efficiency makes borohydride baths prone to instability particularly at lower pH. Hence borohydride baths are generally alkaline and the control of pH is very important to avoid the spontaneous decomposition of the bath solution. The properties of sodium borohydride reduced electroless nickel coatings are often superior to those of deposits reduced with other boron compounds or with sodium hypophosphite (Delaunois & Lienard, 2002). The principal advantages of borohydride-reduced electroless nickel deposits

are its hardness and superior wear resistance in the as-deposited condition which increases even more with heat treatment (Delaunois & Lienard, 2002; Oraon, Majumdar, & Ghosh, 2008). Thermochemical and heat treatments are also found to modify the electrochemical properties of Ni-B coatings (Kanta, Vitry, & Delaunois, 2009). The physiochemical properties of electroless Ni-B coatings have been considerably modified by the addition of ions like tungsten (Drovosekov, Ivanov, Krutskikh, Lubnin, & Polukarov, 2005). Search of improved tribological properties has led to the formation of duplex coatings of Ni-P and Ni-B (Sankara Narayanan, Krishnaveni, & Seshadri, 2003) and three component coatings of Ni-B-P (Ivanov, 2000; Jiang, Xiao, Hu, Peng, Zhang, & Wang, 2009). Composite coatings with improved wear resistance have been formed by incorporating several particles in Ni-B coatings, viz. diamond, alumina and silicon carbide (Mallory & Hadju, 1991). When tribological characteristics are of primary concern the design engineer must find innovative methods for integrating a base material having certain bulk properties with a properly functioning surface and electroless Ni-B coating has proved to be a good tribological material.

The present study addresses the surface roughness characteristics of electroless Ni-B coatings. Roughness is a measure of the texture of the surface. Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces. Roughness is often a good predictor of the performance of a mechanical component, since irregularities in the surface may form nucleation sites for cracks or corrosion. It also affects other functional attributes of machine components like friction, wear, light reflection, heat transmission, lubrication, electrical conductivity, etc. Although roughness is usually undesirable, it is difficult and expensive to control the same in manufacturing. Decreasing the roughness of a surface will usually increase exponentially its

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