Metallurgical and Materials Engineering *Technical paper*
Association of Metallurgical Engineers of Serbia AMES *DOI: 10.30544/244347*

CREATION OF Ni-B/Ni-P ELECTROLESS COATING ON THE WC PARTICLES WITHOUT SURFACE ACTIVATOR

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Received 30.04.2017
Accepted 23.11.2017

Abstract

One of the methods for improving metal-ceramic interface and suppression of agglomeration is the formation of a monolayer electroless coating on the particles. Investigations indicated that Ni-B monolayers should be first formed to develop in the next process an electroless Ni–P coating with the morphology of cauliflower. It was possible to produce a Ni-B layer on WC particles when a bath was heated at a temperature of 95 °C by using sodium borohydride and an appropriate stabilizer. Following this process, the Ni–P electroless coating was deposited on WC particles at 85 °C. In this way, two layers of electroless coating of Ni–B/Ni–P on the WC ceramic particles without using the surface activator were produced successfully. The coating morphology and surface analysis were performed by scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). The results showed that only the degreasing with acetone as a surface preparation of ceramic particles is sufficient to make a Ni–P or Ni–B coating. Electroless Ni–B coating with appropriate adhesion to the surface produces an acceptable surface for the electroless Ni – P coating formation.

Keywords: Ni–B/Ni–P; Coatings, Electroless; WC particles; No surface activator.

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Introduction

Composites have attained particular attention in various industries, due to their high mechanical and corrosion properties. There are problems such as weak ceramic-ceramic and metal-ceramic bonding in the composite containing ceramic particles. One of the methods for solving these problems is the use of a monolayer electroless nickel-phosphorus coating on the particles. The electroless nickel-phosphorus coating was first introduced in 1946. It is superior to conventional electroplating coating, due to forming homogenous and complete coating throughout the surface of the particle. Electroless nickel–boron coatings were developed by initial Schlessinger's and Brown's studies in 1955 [1]. In a recent decade, those have become an appropriate alternative to electroless nickel-phosphorus coatings. They can make a homogenous coating with more strength and hardness than those of electroless nickel-phosphorus. Also, these coatings can form a coating on ceramic without any initial activation [2]. Other advantages include heat resistance up to 870 *°C*, high hardness and no sensitiveness to hydrogen embrittlement [1]. However, in some cases, for instance, coating formation on the particles, nickel-phosphorus coating has more importance, due to their exceptional properties.

Wu et al. [3] used electroless nickel coating as the self-lubricating layer on the constituent particles of the ceramic cutting tools. In this method, the particles are put together using the powder metallurgy process. A layer of electroless nickel reduced the required temperature for powder metallurgy process as well as improved the bond between the particles. In this way, the hardness and the performance of the tool were also developed. *Jafari et al.* [4-6] produced an electroless nickel coating on the particles used in the high-velocity oxygen fuel (HVOF) process that reduces the porosity and increases the fracture toughness of the coating. Beyond this, the electroless nickel-boron coating was applied on the composites of liquid metal matrix composites [7]. In this method, the electroless coating on the reinforcement particles eliminates the porosity at the interface of metal–ceramic. Recent studies about the electroless coating of nickel-boron and nickel-phosphorus on the surface of ceramic particles show that coating requires different activation methods on the particles, such as palladium activation [8]. However, an acceptable morphology and good adhesion of the coating a have not been achieved.

In this study, for electroless nickel-boron coating,the conditions are optimized for coating a layer of nickel-phosphorus on the surface of particles without using a special surface preparation, achieving an acceptable morphology. To create an electroless coating of nickel-phosphorus on the particle was created using a layer of electroless nickel-boron, instead of a surface activation, resulting in double layers of electroless nickel-boron/nickel-phosphorus coating. For this purpose, the electroless coating was applied on two baths of nickel-boron, and nickel-phosphorus. The morphology of the surfaces was analyzed by scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX) analysis.

Experimental

In this investigation, WC particles of a size of < 4 µm were used. The X-ray analysis is shown in Fig.1.

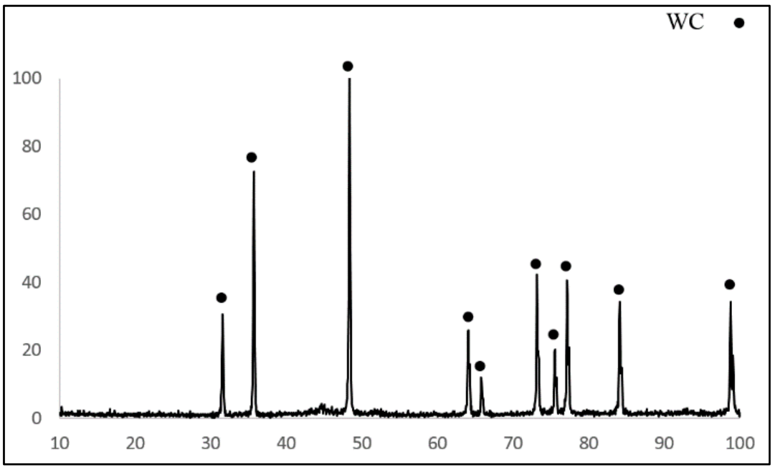

Fig. 1. X-ray diffraction pattern of WC particles.

Particles were first sonicated in an acetone solution for 20 min to clean the surface of the particle and then were twice rinsed with deionized water. The particles were added to 100 mL deionized water, and the obtained mixture was heated to 90 °C. It was required one liter of electroless solution to make electroless nickel-boron coating on 10 g of WC powder. Firstly, nickel chloride, ethylenediamine and sodium hydroxide were added to 500 mL of deionized water under stirring condition. Then the volume of solution was increased to 900 mL using deionized water, and the temperature of the solution was raised to 90 °C. Finally, the mixture containing WC particles together with sodium borohydride powder, lead nitrate solution, and 10 mL of deionized water was added to an initial solution of the electroless bath. The used materials and their concentrations are given in Table 1.

Table 1. Materials used for 1 liter of alkali electroless nickel-boron bath.

Component	Bath composition	Concentration
Nickel source	Nickel chloride (g/L)	20
Reducing agent	Sodium borohydride (g/L)	0.58
Complexing agent	Ethylenediamine (mL/L)	59
Stabilizer	Lead nitrate (g/L)	0.01
pH adjustor	Sodium hydroxide (g/L)	37
pH		13.5

Restraining decomposition of nickel chloride and sodium hydroxide is essential. The ideal temperature to form a coating of cauliflower morphology is 95 °C [1]. The bath was activated by adding a reducer and stabilizer agents and coating process was started. Particles should be heated to 95 °C before adding to the bath to prevent a thermal shock and making suitable adhesion between particle's matrix and coating. The deionized water (10 mL) was added to the bath in 10 min intervals to compensate evaporated water. After the coating process, the solution was left in a static state to precipitate on the particles and then the solution was slowly drained out. Particles twice rinsed by deionized water and acetone solution were used for rapid drying of particles.

An electroless nickel-phosphorus bath was established from required materials to make a two-layer coating, as given in Table 2 [9].

Table 2. Materials used for electroless nickel-phosphorus bath.

Parameter	Value
Bath composition (mL/L)	
Slotonip 71–1 (Basic solution)	166
Slotonip 72 (Nickel solution)	70
Slotonip 76 (Stabilizer)	7
pH	4.5-4.7

The solution was heated at 85 °C, and then nickel-boron coated particles with the concentration of 10 g/L were added to the bath and coating process was continued for 1 h. Deionized water was added to the bath to compensate the evaporated water during the coating process. The same step as electroless nickel-boron coating process was carried out to complete the nickel-phosphorus coating process.

Results and discussion

Nickel-boron coating has different morphologies, in which broccoli and cauliflower are appropriate morphologies by accomplished investigation [10]. Fig. 2.a shows the formed coating on the WC particles having morphologies of broccoli and cauliflower. The obtained morphology compared with other similar studies [11, 12] exhibited that the coat had appropriate appearance and homogeneity. Formation of electroless nickel-boron coating enlarged the WC particles size. In fact, in addition to increasing of particles size due to coating formation, some of the particles were agglomerated, although they had no direct mutual connection due to the presence of electroless nickel-boron coating (Fig. 2.b). Figure 2.c shows EDS analysis of particles indicating the existence of nickel and boron on WC particles. The WC particles with electroless nickel–boron coating were agglomerated after processing in the electroless nickel-phosphorus bath, as shown in Fig. 3.a-c. The coating exhibits full cauliflower morphology in two different magnifications, which are the most appropriate structure for electroless nickel-phosphorus coating. Fig. 3.d shows EDS analysis of particles indicating the existence of nickel and phosphorus on WC particles, which is in accordance with the literature results [13, 14].

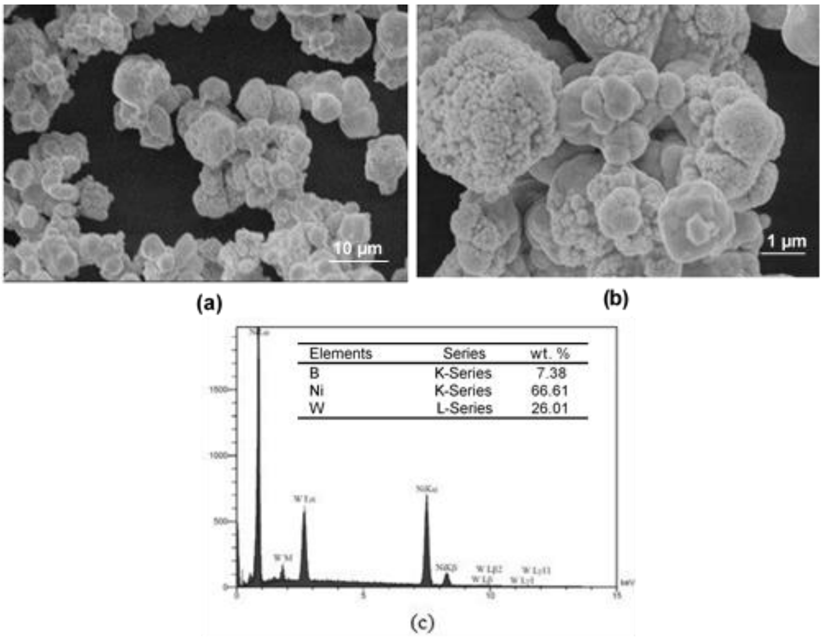

Fig. 2. (a), (b) SEM image of the morphology of electroless nickel-boron coating with two different magnifications, (c) EDS analysis of coating.

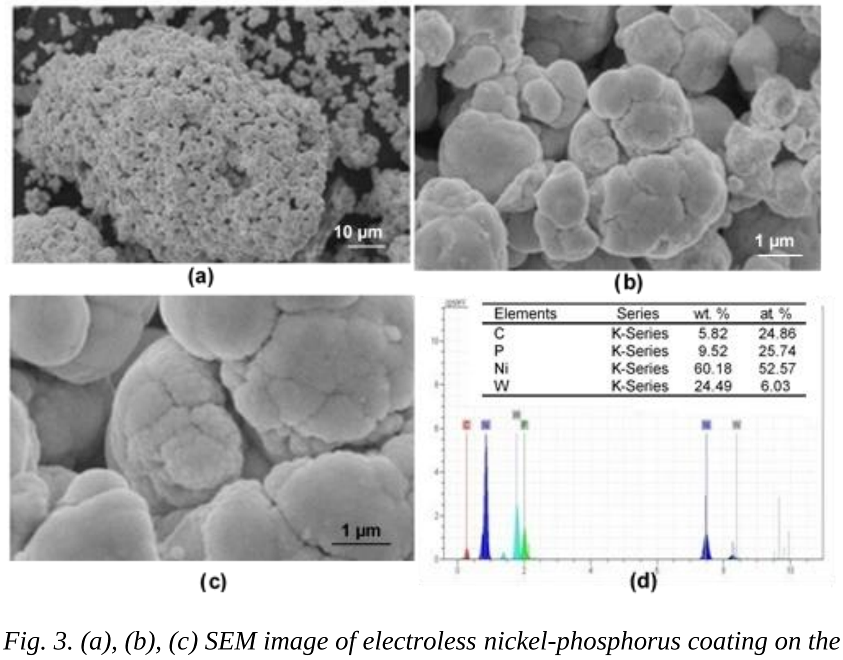

Fig. 3. (a), (b), (c) SEM image of electroless nickel-phosphorus coating on the electroless nickel-boron coated WC particles in different magnifications, (d) EDS analysis of coating.

Conclusions

In this study, two coatings of nickel-boron and nickel-boron/nickel-phosphorus were achieved on the WC particles using the electroless deposition method. Electroless nickel–boron coating, as an initial layer, improves coating adhesion and the cauliflower morphology was achieved. Moreover, by applying an electroless coating of nickel-boron, the surface activation of WC particles was eliminated. The resultant product can be used in powder metallurgy processes, thermal spraying processes like HVOF and manufacture of metal matrix composites in a liquid state.

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