Surface & Coatings Technology 265 (2015) 32–37

Contents lists available at ScienceDirect

Surface & Coatings Technology

journal homepage: www.elsevier.com/locate/surfcoat

Catalytic role of surface pre-treatment of noble-metal-like tungsten carbide powder on electroless deposition of nickel

Fei Xue [a,b], Liu Zhu [b,*], Jinfang Wang [b], Zhibiao Tu [b]

[a] College of Materials and Textiles, Zhejiang Sci-Tech University, Hangzhou 310018, China
[b] Department of Mechanical Engineering, Taizhou University, Taizhou 318000, China

ARTICLE INFO

Article history:
Received 3 October 2014
Accepted in revised form 28 January 2015
Available online 7 February 2015

Keywords:
WC powder
ENP
Specific chemical activation pretreatment
Surface defects
Noble-metal-like catalytic performance

ABSTRACT

In this paper, tungsten carbide (WC) powder without noble-metal activation pretreatment has been coated with a thick layer of nickel (Ni) particles by ultrasonic-assisted electroless plating process at room temperature. The surface morphologies and composition of original WC powder, pretreated WC powder, Ni-coated WC powder prepared in different electroless nickel plating (ENP) baths and worn WC–Ni composite powder were analyzed by field emission scanning electron microscopy (FE-SEM) and energy dispersion spectrometry (EDS). The results suggest that the initial WC powder, whether or not pretreatment, are both able to initiate ENP successfully. WC itself is considered to have noble-metal-like catalytic performance to induce ENP under the system of sodium hypophosphite as reducing agent. The surface defects created by specific chemical activation pretreatment not only effectively enhance the catalytic ability, but also improve binding force of WC substrate and Ni coating. Moreover, the composition of ENP bath is a key factor which can regulate the growth rate and adsorption rate of Ni particles to maximize the catalytic activity of WC powder.

1. Introduction

Ceramic–metal composite powder which combines the desirable properties of ceramics and metals is widely employed to improve the surface performance of components to meet the increasingly stringent service conditions by thermal spraying or laser cladding technology [1–3]. The characteristics of the powder feedstock have a strong influence on the coating quality [4,5]. The core–shell structure can effectively reduce the often-occurred decomposition of carbide/sulfide ceramics powder in thermal spraying or laser cladding process, resulting in a notable promotion of mechanical properties and tribological behavior [5–9]. Usually, the composite powder can be prepared by mechanical mixing, ball milling, precipitation, sol–gel, reduction, and electroless plating [10–12]. It is well-known that electroless plating is an advanced method for producing uniform coating materials over all surfaces, regardless of shape, size, and electrical conductivity. However, the traditional electroless plating technology usually involves the noble-metal activation pretreatment due to the non-catalytic activity of ceramic substrate [13–15], which greatly limits its application in other places. To solve this issue, the replacement of precious metal with non-noble metal (such as Ni, Ag, NiO) activation pretreatment has been proved to be an effective way [16–18]. More recently, Luo et al. [19–21] put forward the electroless plating of carbide ceramics powder (Cr_3C_2, WC, SiC) with a specific chemical activation pretreatment method that can induce the surface of carbide ceramics powder to develop defects by themselves and cause lead metallic nickel to grow on the powder surface during room temperature ultrasonic-assisted electroless plating.

In this paper, Ni-coated original and chemical pretreated WC composite powder has been successfully synthesized by ultrasonic-assisted electroless plating process at room temperature. The noble-metal-like catalytic performance of WC and catalytic role of surface pre-treatment for electroless nickel plating (ENP) were discussed in detail.

2. Experimental procedure

The initial WC powder with average grain sizes of 10 μm was purchased from XIAMEN GOLDEN EGRET SPECIAL ALLOY Co., Ltd. Then, the WC powder was pretreated by immersing into the specific chemical activation fluid of 30 mL/L hydrofluoric acid (HF), 40 mL/L nitric acid (HNO_3), and 3 g/L ammonium fluoride (NH_4F). The pretreatment process was carried out with reinforcement of ultrasonic wave for 30 min at room temperature. Table 1 gives the composition of ENP bath. The bath consists of an aqueous solution of metal ion, reducing agent, stabilizer agent, and complexing agent. Nickel sulfate ($NiSO_4 \cdot 6H_2O$) is the main salt. Sodium citrate ($Na_3C_6H_5O_7 \cdot 2H_2O$), boric acid ($H_3BO_3$) and sodium hypophosphite ($NaH_2PO_2 \cdot H_2O$) act as the complexing agent, stabilizer agent, and reducing agent respectively. Table 2 shows the design of experiment and condition in this paper. For Experiment-1, the ENP baths (Bath-A and Bath-B) began to bubble after 1.5 h, and

* Corresponding author. Tel.: +86 57688662346.
E-mail address: zhuliu@tzc.edu.cn (L. Zhu).

http://dx.doi.org/10.1016/j.surfcoat.2015.01.066
0257-8972/

Table 1
Composition of the electroless nickel plating bath.

Chemical	Concentration (g/L)	
	Bath-A	Bath-B
$NiSO_4 \cdot 6H_2O$	25	25
$Na_3C_6H_5O_7 \cdot 2H_2O$	80	50
$NaH_2PO_2 \cdot H_2O$	25	35
H_3BO_3	25	25

Table 2
Design of experiment and condition.

Experiment	Pre-coated powder	Condition	
		Bath-A	Bath-B
1	No-addition	Water bath at 90 °C	
2	No-addition	Ultrasonic-assisted at RT	
3	Pretreated WC	Same as above	
4	Pure WC	Same as above	

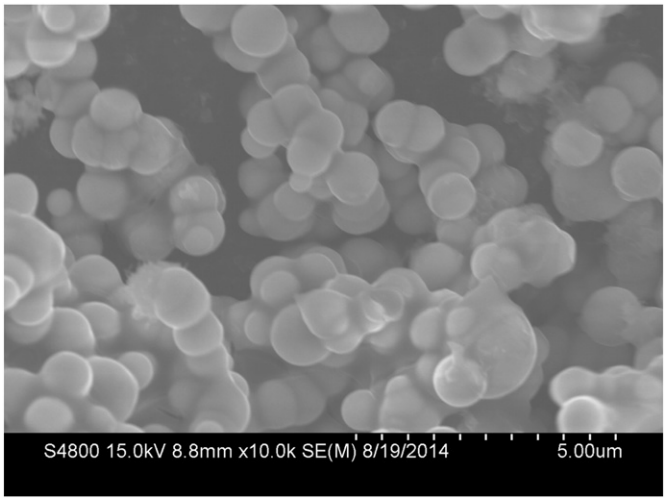

Fig. 2. FE-SEM images of decomposed nickel particles.

quickly darkened, the reaction lasted less than 20 min. In addition to Experiment-1, other electroless plating processes were all assisted by ultrasonic at room temperature. For Experiment-2, the baths remained clarified even after 12 h, besides, pH almost did not changed, with only negligible decline. However, the phenomenon in Bath-A and Bath-B (see Experiment-3) was different. After 5 min incubation period, the reaction started and became stronger with numerous bubbles from the baths. The color of Bath-A just became shallow, while Bath-B turned to be turbid black. The entire reaction approximately lasted 1 h and 40 min, respectively. In Bath-A, Experiment-3 and Experiment-4 had the same phenomenon. After plating, the composite powder was cleaned with deionized water for several times and dried in a vacuum oven at 120 °C for 4 h. The surface morphologies were observed by FE-SEM, and the corresponding chemical composition was analyzed by EDS.

3. Results and discussion

As shown in Fig. 1, the surface FE-SEM images of original and pretreated WC powder were observed in order to study the change of surface morphology caused by specific chemical activation pretreatment. With a low resolution (see Fig. 1a and c), it can be noticed that

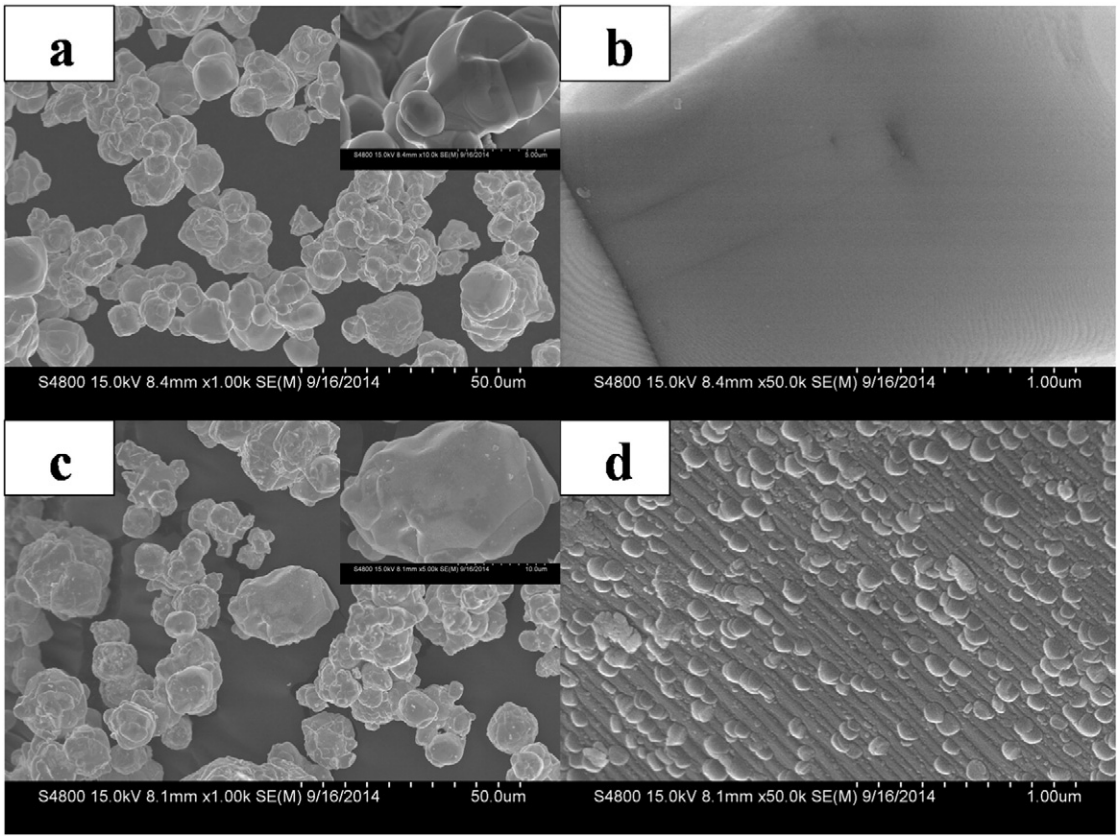

Fig. 1. FE-SEM images of (a) and (c) original WC powder; (b) and (d) chemical activation pretreated WC powder. The insets are WC particle enlargements.