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ARTICLE

Effect of Ni Content on Microstructure and Properties of WC-Ni Composites Prepared by Electroless Plating and Powder Metallurgy

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Abstract: WC-Ni composite powders were prepared by electroless plating with a simplified chemical method. The morphologies of original, pretreated WC powder, WC-Ni powders and surface morphologies, fracture surface and composition of WC-Ni composites were analyzed by FE-SEM. EDS and XRD. Different contents of Ni doped WC composites were prepared after sintering. The relative density and properties of the WC-Ni composites were also discussed. Results show that the WC powder is uniformly covered by Ni particles. After powder metallurgy (PM), the fabricated composites perform a well-dispersed surface morphology. With the increasing of Ni content bending strength enhances without reducing hardness. Trans-granular fractures are observed on the fracture surface of the WC-Ni composites.

Key words: WC-Ni composites; electroless plating; powder metallurgy

Tungsten carbides are widely employed in tribological fields because of their good performance and good wear resistance[1−5]. For cemented carbides, the properties can be modified by the presence of a second phase[6]. Cobalt, as the second phase, shows good wettability and adhesion with tungsten carbides, and the dissolution of WC in the Co phase results in WC-Co cemented carbides with high hardness, high strength, and high wear resistance[7-11]. Due to the high cost of cobalt, the use of Fe or Ni to replace cobalt possible in WC-Co cemented carbides has been studied to improve the binding strength[12,13]. And Ni as the most promising substitute of Co has been viewed by many scientists. WC-Ni alloys were prepared using high-frequency induction-heated sintering which acquired a significantly high hardness nevertheless of the complex process and facility[14]. WC-Ni powder and WC-Ni cemented carbides were produced using powder metallurgy. While this experiment involves ball milling and liquid phase which may lead to the nickel grow up to large size aggregates and affect the properties of composites after sintering[15].

In this study, a new process was used to reduce the costs and simplify the preparation process of WC-Ni cemented carbide. Electroless nickel plating was performed on the WC powder surface, followed a simple pretreatment of WC powder at room temperature assisted with ultrasonic. After powder metallurgy, an additive-induced refined microstructure and enhancement of the properties, such as relative density, micro-hardness, and bending strength was also analyzed.

1 Experiment

Commercial WC powder (grain diameter of 3.0 to 5.0 μm) were used. The non-catalytically active surface was pretreated prior to electroless plating in order to produce

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surface defects. WC powders were immersed in a mixed aqueous solution of hydrofluoric acid (60 mL/L) and nitric acid (30 mL/L) during pretreatment (activation). The whole procedure was assisted with ultrasonic wave. Pretreated powders were washed 3 times using deionized water, and then dried. Table 1 shows the composition of the used solutions. Four different nickel contents of powders were prepared in the study. The mass fractions of nickel were 3%, 5%, 7%, and 9%. Hydrazine hydrate (80 mL/L) was added to the plating solution, and the chemical reaction started at room temperature. pH value of solution was maintained between 11 to 12 by adding NaOH. In order to obtain uniformly dispersed particles and reduce agglomeration, electroless plating was performed via an ultrasonic bath (model: JK-450B; frequency: 40 kHz; power: 400 W). The experimental schematic diagram is shown in Fig.1.

The powders were subsequently dried in a DHG series heating and drying oven (DHG-9070) at 40 °C for 2 h. The Ni-coated WC powders were compacted into a size of 40 mm × 8 mm under a pressure of 331 MPa by a 769YP-60E tablet machine. The green compacts were placed in a pipe furnace (GSL-1700X), and pre-sintered at 500 °C for 2 h using hydrogen as a protective gas. Polyvinyl alcohol vaporized and escaped during this pre-sintering process. Then the green compacts were sintered by liquid phase sintering (LPS) in vertical vacuum sintering furnace (KGPS-100) at 1800 °C for 2 h and used argon as a protective gas. The sintering process is shown in Fig.2 including sintering temperature and holding time.

Table 1 Composition of the electroless nickel plating bath

Chemical	Formula	Concentration/g·L^{-1}
Nickel sulfate	$NiSO_4·6H_2O$	1.38~4.43
Sodium citrate	$Na_3C_6H_5O_7·2H_2O$	24
2,2-Dipyridyl	$C_{10}H_8N_2$	0.02~0.04

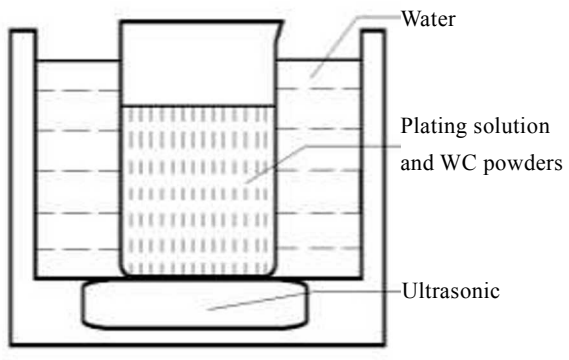

Fig.1 Schematic diagram of the ultrasonic aided plating device

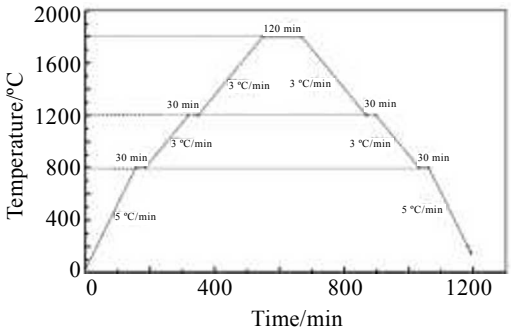

Fig.2 Sintering temperature and holding time of liquid phase sintering (LPS)

The relative densities of the WC-Ni composites were measured using Archimedes' principle. Polished sintered specimens were subjected to Vickers micro-hardness testing by MH-3L, which measured from the center to the specimen edges with a loading force of 2.94 N held for 15s. The three point bending test performance was measured by slow loading at a speed of 0.5 mm/min until specimens was broken using the MTS-809 machine. Size of test specimens was 35 mm×8 mm×4 mm.

The morphology of the original WC, pretreated WC and WC-Ni composite powders and the phase of the WC-Ni composites after sintering were analyzed by scanning electron microscopy (SEM-UL) with 5.0 kV, energy dispersive spectroscopy (EDS) with 15.0 kV and X-ray diffraction (XRD), respectively.

2 Results and Discussion

2.1 Morphologies of WC-Ni composite powders

Fig.3 presents the scanning electron microscopy (SEM-UL) morphologies of the original WC powder, WC powders after pretreatment, and WC powders after electroless Ni plating via simplified pretreatment. Fig.3a shows that the powders are uniformly distributed in the field of view. Based on high-magnification SEM image, the powders are mostly polygonal particles with a grain diameter of 3.0 to 5.0 μm and show a smooth mechanical surface. Fig.3b displays the SEM morphology of WC powders after pretreatment. The original particles have mostly etched to be irregular shapes. These irregular particles are uniformly dispersed with the polygonal particles, as seen in the high-magnification surface morphology image. Compared with the original particles, the etched surface of particles exhibits excellent activity, which resulted from the increased superficial area and surface defects in the form of steps. Generally speaking, successful palladium-free electroless plating is dependent on the catalytic ability of the surface to plate. Catalytic capacity is expressed by the magnitude of activity, which is