FabricationofUltrafineWC-NiHardMaterialsbyRapidSinteringProcess

Hwan-Cheol Kim*, Dong-Young Oh and In-Jin Shon
Department of Materials Engineering, Chonbuk National University

1.Introduction

Most cemented carbides of tungsten utilize cobalt as the binder. But the high cost of cobalt and the low corrosion resistance of the WC-Co cermet have prompted considerable research effort aimed at finding a satisfactory alternative binder phase. It has been shown that by using Ni instead of Co, the corrosion and oxidation resistance of the resulting cermet is improved but the mechanical properties (hardness and toughness) are somewhat lower than those of WC-Co.

Additionally, property improvements can be obtained through microstructural changes, notably by grain size refinement. However, preparation and processing of cemented carbides having a refined grain structure can result in residual porosity attributed to powder agglomeration. Moreover, the use of conventional methods to consolidate nanopowders often results in grain growth. Minimization of grain growth can be achieved if sintering can be carried out at lower temperatures and for shorter times. In this regard, the SPS method has been shown to be effective in achieving this goal. And recently the high-frequency induction-heated sintering (HFIHS) technique has been shown to be effective in the sintering of nanostructured materials in very short times (within 1 minute).

In this work, we report results on the sintering of WC-Ni by two processes: HFIHS and SPS. The goal is to produce dense, ultra-fine WC - x wt.%Ni (x = 8, 10, 12) hard materials in very short sintering times (< 1 min).

2. Experimental procedure

WC powder used in this research was supplied by TaeguTec Ltd. (Taegu, Korea). The powder had a grain size of 0.4 ㎛ and reported to be 99.5% pure. Nano-sized nickel (60~80 nm), obtained from Inframat (Farmington CT, USA) was used as a binder materials. The powders were placed in a graphite die and then introduced into the HFIHS or the SPS system. The system was first evacuated and a uniaxial pressure of 60 MPa was applied. In the case of the HFIHS method, an induced current was activated (frequency of about 50 kHz, 90% output of total power capacity, 15 kW). In the SPS method, a DC current of 2500A was applied. In both cases, the conditions were maintained until the densification rate was negligible, as indicating by the observed shrinkage of the sample. At the end of the process, the current was turned off and the sample was allowed to cool to room temperature.

Compositional and microstructural analyses of the products were made through X-ray diffraction (XRD), scanning electron microscopy (SEM) with energy dispersive spectroscopy (EDS) and field-emission scanning electron microscopy (FE-SEM). Vickers hardness and fracture toughness were measured by performing indentations at a load of 30 kg_f and a dwell time of 15 sec. The structure parameters, i.e. the carbide grain size and the mean free path of the binder phase are obtained by the linear intercept method.

3.SUMMARY

(1) Using high-frequency induction heating sintering and spark plasma sintering method, the densification of WC-Ni hard materials was accomplished using ultra fine powder of Ni and WC.

(2) Nearly fully dense WC-Ni could be obtained within 1 min.

(3) Relative density and mechanical properties of WC-Ni obtained by HFIHS were higher than those obtained by SPS. And WC grain size made by HFIHS was smaller than that made by SPS.

(4) The fracture toughness and hardness values of WC-8Ni, WC-10Ni, and WC-12Ni made by HFIHS were 13 $MPa \cdot m^{1/2}$ and 1950 kg/mm^2, 13.5 $MPa \cdot m^{1/2}$ and 1810 kg/mm^2, 14.4 $MPa \cdot m^{1/2}$ and 1690 kg/mm^2, respectively for 60MPa and an induced current for 90% output of total capacity, 15KW.

(5) The fracture toughness and hardness values of WC-8Ni, WC-10Ni, and WC-12Ni made by SPS were 12.2 $MPa \cdot m^{1/2}$ and 1796 kg/mm^2, 12.9 $MPa \cdot m^{1/2}$ and 1725 kg/mm^2, 13.6 $MPa \cdot m^{1/2}$ and 1597 kg/mm^2, respectively for 60MPa and the electric current of 2500 A