Rapid Sintering Process of Ultra Fine WC-Co Hard Materials by High-Frequency Induction Heating

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1. Introduction

Tungsten carbide-cobalt hard materials are widely used for a variety of machining, cutting, drilling, and other applications. Recently, nanocrystalline WC-Co cemented carbides have been developed by a spray conversion process (SCP). The advantage of SCP is that the WC particle size can be reduced below 100 nm. However, when these nanopowders are sintered, the grain size of WC in the WC-Co cemented carbides increases significantly due to fast diffusion through the liquid phase during conventional liquid-phase sintering. The WC grain size grows from less than 100 nm to 500 nm or larger during the sintering process. Thus the control of grain growth during sintering remains a technical barrier and is one of the keys to the commercial success of nanostructured WC-Co composites. In this work, we report on results obtained by a new process, High-Frequency Induction-Heating Sintering (HFIHS), a method which combines short-time, high-temperature exposure with both pressure application and induced current. The goal of the research is to produce dense nanophase WC-Co hard materials within 1 minute, using HFIHS.

2. Experimental procedure

WC-Co powder used in this research was supplied by Nanotech Co. (Korea) and was produced by a spray conversion process. The average crystallite size is <200 nm according to the specification by the vendor. .The powders were placed in a graphite die and then introduced into the high-frequency induction heated sintering system. The system was first evacuated and a uniaxial pressure of 60 MPa was applied. An induced current was then activated and maintained until densification was observed, as indicating by the observed shrinkage of the sample. At the end of the process, the current was turned off and the sample cooled to room temperature at a rate of about 600 ℃/min.

In pressureless sintering, the compaction was conducted by using a die with an inner diameter of 12.1 mm. The uniaxial cold-compaction of the powder for pressure of 120MPa was achieved. The density was measured by measuring the dimensions and the mass of the specimens and the green density of the sample was about 52%.

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 and a dwell time of 15 s. 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 a developed high-frequency induction heated sintering method, the rapid densification of WC-Co hard materials was accomplished using ultra fine powders with 260 nm size within 1 minute.

2) The relative density of the composite was 99.5% for the applied pressure of 60MPa and the induced current for 90% output of total capacity.

3) The grain size of WC−Co hard materials is about 260 nm and the average thickness of the binder phase determined is about 11nm. The fracture toughness and the hardness of this work 12 $MPa{\cdot}m^{1/2}$ and 1992 kg/mm^2, respectively.

4) Using pressureless sintering, we produced dense WC−Co hard materials with a relative density of 97% without applying pressure.

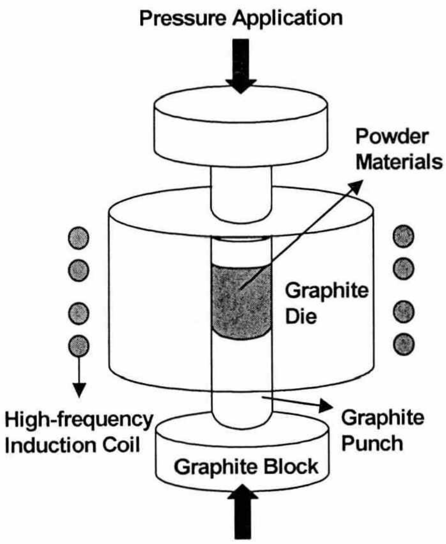

Fig. 1. Schematic diagram of apparatus for high−frequency induction heated sintering.

Table 1. Physical and mechanical properties of WC-Co composites.

Properties	Sintered WC−Co
Relative density (%)	99.4
Vickers hardness (Kg/mm^2)	1992
Fracture toughness ($MPa{\cdot}m^{1/2}$)	11.9
Grain size (nn)	258
Mean free path (nn)	11.6

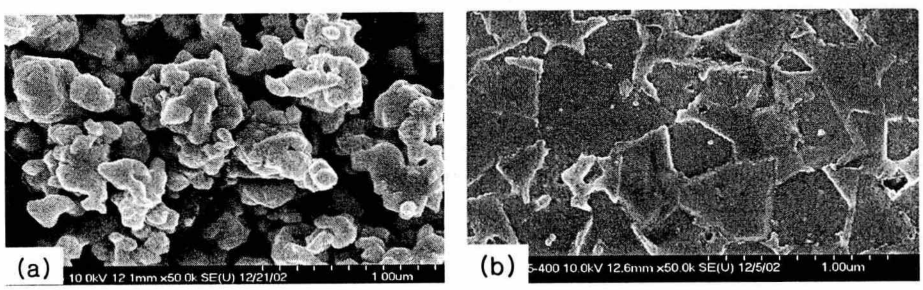

Fig. 2. Field Emission Scanning Electron Microscope image WC−Co hard materials: (a) raw materials (b) after sintering.