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고주파유도가열연소합성에 의한 초미세 WC 초경재료의 제조

Fabrication of Ultra-Fine WC by High-Frequency Induction Heated Combustion Synthesis

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1. Introduction

Tungsten carbide-cobalt hard materials are widely used in tools for machining, cutting, drilling and other applications. Cemented carbides are usually prepared by consolidating WC powders with the cobalt binder by conventional sintering techniques at temperatures near the melting point of cobalt. In view of its high melting point, WC is difficult to sinter without the addition of Co or another low-melting binder. The binder facilitates sintering by the presence of a liquid phase. However, the advantage of the addition of the binder (gained in the sintering process) is counteracted by deleterious effects on the cemented carbides. The binder phases are inferior to the carbide phase in chemical characteristics. Corrosion and oxidation attacks occur in the binder phase. In this work, we report on the simultaneous synthesis and properties of dense ultra-fine WC using elemental reactants of W and C.

2. Experimental procedure

Powders of 99.9% pure tungsten (with average sizes of 0.4㎛ and 4.3㎛, Korea Tungsten Co., Teagu, South Korea) and 99.9% pure activated (amorphous) carbon (< 20㎛, Kojundo Chemical Co. Osaka, Japan) were used as starting materials. The tungsten and carbon ratio was varied from 1:1 to 1:2 for the case of 0.4㎛ tungsten and from 1:1 to 1:1.3 for the case of 4.3㎛ tungsten to investigate the effect of stoichiometry on the microstructure and mechanical properties of the WC product. Tungsten and carbon powder mixtures were first milled in a high-energy ball mill. The weight ratio of ball-to-powder was 30:1 and the powders were milled for 10 hrs.Milling resulted in a significant reduction of grain size.The grain size and the internal stress are calculated by Strokes and Wilson's formula. The average grain size measured by this equation was about 45nm and for the powder with an initial size of 0.4㎛ and 73nm for the 4.3㎛ tungsten.

The relative density of the synthesized sample was measured by the Archimedes method. Microstructural information was obtained from product samples which had been fractured or etched, using a Murakami's reagent for 1-2 min at room temperature. Compositional and microstructural analyses of the products were made through X-ray diffraction and scanning electron microscopy with energy dispersive spectroscopy. Vickers hardness was measured by performing indentations at a load of 10 kg_f and a dwell time of 15 s.

3. Summary

Using high-frequency induction combustion, the simultaneous synthesis and densification of binderless WC hard materials was accomplished using milled elemental powders of W and C. The process was achieved within 2 min. When a stoichiometric W:C ratio (1:1) was used, the product contained the sub-carbide, W_2C. This is attributed to the loss of carbon through interaction with surface oxides. With the use of excess carbon, products containing the WC phase only can be obtained. The final product had a relative density of 98.5% and a grain size of 0.43-0.6㎛, when synthesized under an applied pressure of 60 MPa. The fracture toughness and hardness values for the dense WC are 4.4-4.8MPa·m$^{1/2}$ and 2552-2708kg/mm^2, respectively.

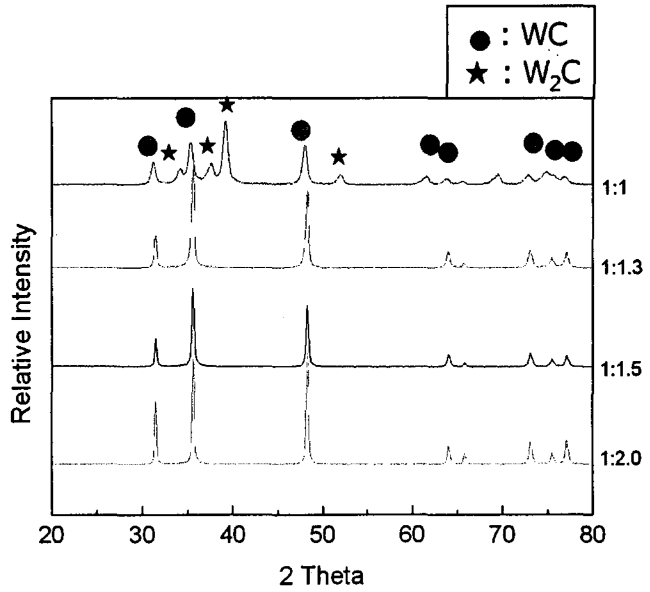

Fig. 1. XRD patterns of WC hard materials after combustion synthesis with various W vs C ratio (W : 0.4 μm, 60MPa, 90% output of total power).

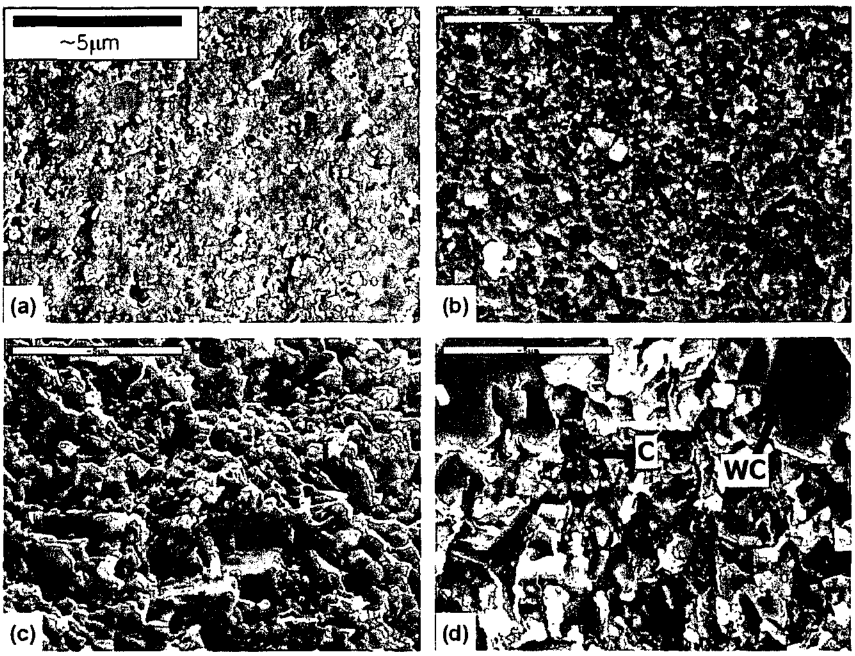

Fig. 2. Fracture surface images of the WC hard materials with various W vs C ratio (a)1:1, (b)1:1.3, (c)1:1.5, (d)1:2.0 (W : 0.4 μm, 60MPa, 90% output of total power).