Fabrication of Nanostructured WC/Co Alloy by Chemical Processes

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Abstract

New manufacturing processes, such as thermochemical, mechanochemical and chemical vapor condensation processes have been developed to obtain nanostructured WC/Co materials. Nanoscale size WC/Co composite powders of near 100-150nm can be synthesizes by thermochemical and mechanochemical processes using water soluble precursors. Non-agglomerated and nano sized WC powder can be synthesized by the chemical vapor condensation process using metallorganic precursors as starting materials. In this paper, the scientific and technical issues on synthesis and consolidation of nanostructured WC/Co alloys produced by new chemical processes are introduced.

Keywords : nanostructured, WC/Co, Chemical process

1. Introduction

Traditionally WC/Co hard alloys are widely used for wear resistance machine parts or tools material. They have superior mechanical properties such as wear resistance, high temperature strength and elasticity modulus, etc[1)-2)]. The reduction of the particle size of tungsten carbides provides a marked improvement in the mechanical properties such as hardness, wear resistance and even transverse rupture strength of WC/Co cemented carbide. If the composition of alloys is fixed, the important factors which affecting properties of materials are the particles size, the homogeneity of microstructure and purity of initial powders. Thus, in order to increase mechanical properties of the WC/Co material, it is necessary to make the WC and Co particle size as small as possible and also to make their mixture more homogeneous. Various techniques for the preparation of nanostructured WC/Co powders have been developed. Among them, chemical process is a rapidly growing field with a great potential in the industrial applications, because of versatile application to most kind of materials and can usually produced a large amount of powders with relatively low cost. Such chemical processes, as thermochemical[3)]and mechanochemical processes[4)], using liquid starting materials are more beneficial than conventional processes using solid starting materials. These methods allow the production of components homogeneous mixing states and offer homogeneous sintered body microstructures. Nano sized WC powder can be synthesized by the chemical vapor condensation (CVC) process. CVC process was adapted for forming the nanosized clusters by homogeneous condensation from decomposed metal-organic precursor in the gas phase. And it has been reported to be appropriate for synthesizing high purity and non-agglomerated nanostructured particles with superior functional properties.

In this paper, the scientific and technical issues on synthesis of nanostructured WC/Co alloys by chemical processes and consolidation were reviewed.

2. Experimental and Results

To produce nanophase WC/Co composite powders directly from solution state, disolved metallic salt, ammonium metatungstate(AMT), are added in cobalt nitrate aqueous solutions. Prepared solutions were spray dried using rotary atomizer in the hot air stream, and the spray dried powders were desalted and dehydrated at 750℃ under the air atmosphere. To produce the nanophase WC/Co composite powders, two different processes, thermochemical and mechanochemical process, were used. In thermochemical process, the calcined precursor powders were reduced, carburized and decarburized in flowing H_2, CO/H_2 and CO/CO_2 at 800℃, respectively. And mechanochemical method, the calcined precursor powders were mixed with carbon by ball milling and directly carburized in flowing Ar, H_2. Nano sized WC powder was also synthesized by the CVC process. For powder preparation the easily decomposed precursor contained W components was used as starting materials. Solid tungsten hexa-carbonyle($W(CO)_6$) were used as precursor and it was contained in the precursor evaporator to vaporize the solid precursor and feed into the reaction zone. The evaporated precursor was directly injected into the reaction furnace by He gas and carburized with CH_4, H_2 gas to form the nanophase WC particles. The synthesized WC particles were collected at cooling zone.

The nanostructured WC/Co composite powder produced by the thermochemical process has composite particles with a spherical morpology and agglomerated shell structured. Each of combined particles of 40-50um in diameter consists of several millions of WC grains connected with each other with Co binder forming a continuous net work of fine inclusions less than 60nm in diameters. The nanostructured WC/Co composite powder produced by the mechano-chemical process has different morpologies due to the being crushed during ball milling. The powder forms are less agglomerated than the one of thermochemical process. TEM micrographs of the WC/Co powder produced by the mechanochemical method is presented in Figure 1. It has uniform distribution of WC and Co particles, with particles consisting of small discrete network of fine WC grainss, of less than 150nm in size.

The shape of WC powder formed by CVC process was spherical on the whole, and the particle size was very fine, as seen in TEM micrographs of Figure 2. It was about 10-20nm in diameter and loosely agglomerated each other. Almost all of the phases were tungsten carbide, but there was a small amount of W_2C phase. When the free carbon remained, the carbon was formed as a coated layer. This carbon layer is formed around the particles when the powder is synthesized. It is expected that tungsten carbide can be promoted if this carbon layer diffuses into W_2C by the proper heat treatment. As reaction temperature increased, particle size was increased but the agglomeration was decreased. The specific surface of area reached maximum at 800~1,000℃ and then decreased due to the size increasing. And the surface area of the WC particles was calculated from TEM micrographs by assuming the WC particles as perfect sphere shape. Relative specific surface area, which is the ratio of the surface area of WC size measured by TEM **:** the surface area calculated by BET result, was increased to 1.0 as temperature was increased. As the particles was nearly spherical shape in the TEM micrographs, the WC particles were separated and non-agglomerated.

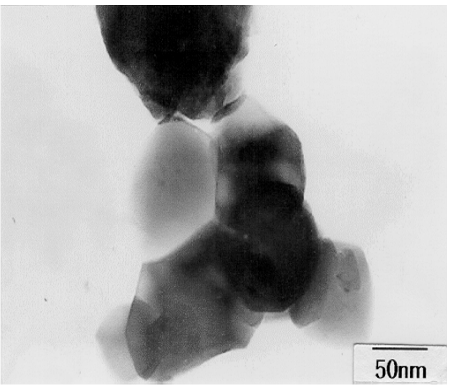

Fig. 1. TEM micrograph of WC/Co powder produced by mechanochemical process

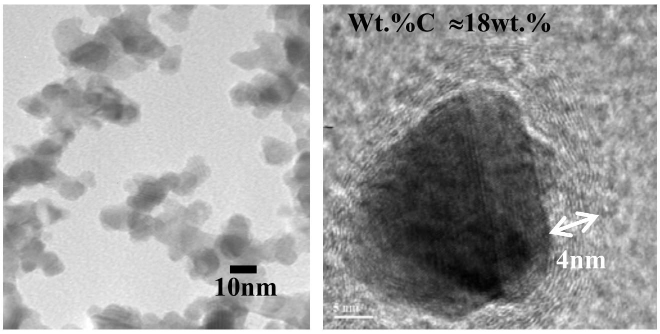

Fig. 2. TEM micrograph of WC/Co powder produced by CVC process

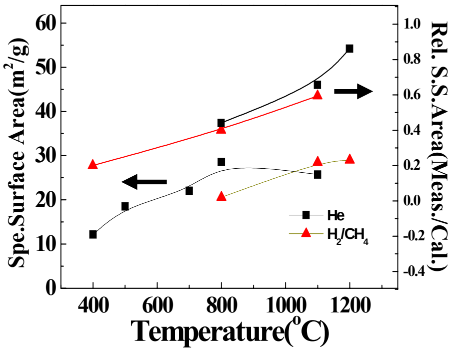

Fig. 3. The variation of specific surface area and relative specific surface area(measured from TEM:calculated from BET results) with reaction temperature.

3. Summary

Nanostructured WC/Co powders in homogeneous state of mixed component particles 60-150nm in size were synthesized by thermochemical and mechanochemical process. The WC/Co powder produced by the thermochemical process was a spherical morpology and agglomerated shell structured. However, the WC/Co powder produced by the mechanochemical process was less agglomerated than that of thermo-chemical process. Nanostructured WC powder was also synthesized by CVC process using. The size of the synthesized powder was about 10~20nm. The synthesis of WC powders was promoted increasing the reaction temperature. The size of the powders was increased but agglomeration of powders was decreased with increasing temperature.

4. References

1. A. bock, W.D. Schubert, B. lux, Powder Metallurgy Industry, Vol. 24, No. 1, p 20(1992)
2. F.V.Lenel;Powder Metallurgy Principles & Applications, MPIF, Princeton, NJ, (1980)
3. B.K.Kim, G.G.Lee, G.H. Ha, D.W.Lee ; Metals and Materials, Vol. 5, No. 2, p109(1999)
4. G.H.Ha, B.K.Kim ; Powder Metallurgy, Vol. 45, No. 1, p29(2002)