Behavior of Spark Plasma Sintering and Characterization of Cu-TiB_2 Composite

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1. Introduction

Copper and copper-based alloys are widely used as electric and electrode materials due to their good conductivity. However, in the case of the precipitation hardened copper alloys with high strength, there is a problem that the mechanical property decreases rapidly due to the presence of a coarse precipitate phase at high temperature. This problem, limits the application of the copper alloy such as electrical contacts and resistance welding applications.

There has been several efforts to develop the copper alloys which exhibit a good mechanical properties even at elevated temperature. Copper metal matrix composites(CMMCs) of reinforcing ceramic particles such as oxides, borides and carbides in the copper matrix were developed as electrode materials because the ceramic particles are stable at high temperature. The TiB_2 was also found to be a potential candidate for reinforcement of the copper alloy because of its high melting point, hardness, thermal conductivity as well as electrical conductivity.

Recently, lots of attention has been focused on self-propagating high temperature synthesis(SHS), one of the in situ processes to produce metal matrix composites(MMCs). SHS is extremely attractive due to short time of synthesis, low energy consumption and high purity of products. Spark plasma sintering(SPS) is a newly developed process which makes sintering of high quality materials in short periods possible by DC pulse charging the intervals between powder particles with relatively high sintering pressure. SPS systems offer many advantages (e. g. rapid sintering, less sintering additives, uniform sintering, low running cost, easily operation) over conventional systems like hot press (HP) sintering, hot isostatic pressing (HIP) or pressureless sintering. It can be applied to many advanced materials such as functionally graded materials(FGM), fine ceramics, amorphous materials and nano-composites.

In the present study, in situ formation of TiB_2 particles in a copper matrix through combination of mechanical treatment and subsequent SHS were investigated. Additionally the sintering behavior were studied by SPS together their microstructure and mechanical and electrical properties

2. Experiment

Titanium(99.5% Purity, 10 ㎛, irregular), amorphous boron(94% Purity, <1 ㎛) and copper powders(99.5% purity, 40 ㎛, dendrite) were used as raw materials. To produce Cu- 40 wt.%. TiB_2 powder, Ti, Cu and B elemental powders were mixed for 30min using turbula mixer. The mixtures were treated in a high energy ball mill(AGO-2, planetary ball type) with ball acceleration of 600 ㎳. Balls and vials made of stainless steel were used. The diameter of the balls was 5 ㎜ and the powder to balls ratio was 1:20. The vials were evacuated and subsequently filled with argon up to 0.3 MPa.

Powder obtained via mechanical treatment of the intial mixture were subjected to SHS

reaction. SHS was carried out by igniting with tungsten wire under argon atmosphere applying an electric current. Produced SHS-product with 40 wt.% of TiB_2 was diluted with copper to obtain various Cu-TiB_2 composition. Powders were spark plasma sintered in a vacuum atmosphere. A graphite mold of 15㎜ in diameter was used. The applied pressure and sintering temperature were 50MPa and 950℃, respectively. It should be noted that effective temperature of the sample was usually 50℃ higher than temperature measured by a thermocouple inserted in the mold wall.

3. Results and Discussion

Fig.1 shows XRD patterns of SHS powders after a preliminary mechanical treatments for 2, 5 and 30min. TiB_2 phase was formed by mechanical treatment and subsequent SHS regardless of the time of the preliminary mechanical treatment.

TiB_2 particle size in SHS powders decreased with increasing time of preliminary mechanical treatment(Fig. 2).

Particle size of SHS powder after a preliminary mechanical treatment for 30min was smaller than 150 nm.

Changes of hardness of sintered specimens for 30min at 950℃ is shown in Fig. 3. As the time of preliminary mechanical treatment increased, the hardness of specimens sintered for 30min at 950℃ increased from 168 to 203 Hv.

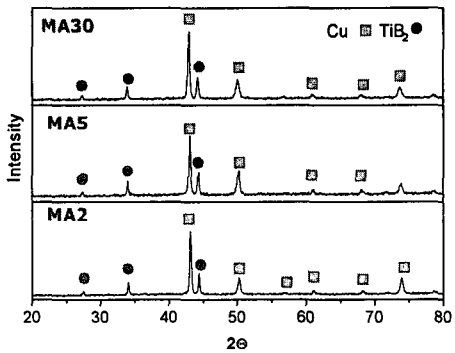

Fig.1 XRD patterns of SHS powders after preliminary mechanical treatment for 2, 5 and 30 min (Cu-40 wt. % TiB_2) .

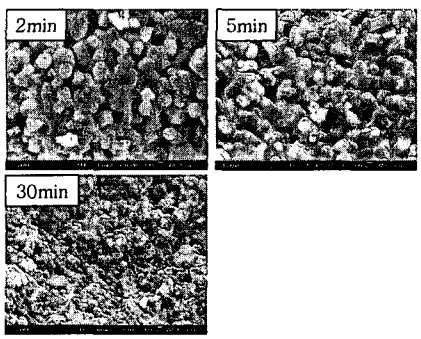

Fig. 2. SEM images of SHS powders after preliminary mechanical treatment for 2, 5 and 30min (Cu-40 wt.% TiB_2).

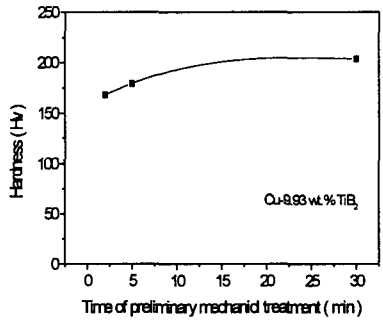

Fig. 3. Changes of hardness of specimens sintered for 30min at 950℃ with time of preliminary mechanical treatment (Cu-9.93 wt.% TiB_2).