Sintering and Mechanical Properties of Chromium Boride-chromium Carbide Composites

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Abstract

Several boride sintered bodies such as TiB_2, ZrB_2, and SiB_6 were previously reported. In the present study, the sinterability and physical properties of chromium boride (CrB_2) containing chromium carbide (Cr_3C_2) sintered bodies were investigated in order to determine its new advanced material. The samples were sintered at desired temperature for 1 hour in vacuum under a pressure by hot pressing. The relative density of sintered bodies was measured by Archimedes' method. The relative densities of CrB_2 addition of 0, 5, 10, 15 and 20 mass % Cr_3C_2 composites were 92 to 95 %. The Vickers hardness of the CrB_2 with 10 and 15 mass % Cr_3C_2 composites were about 14 and 15 GPa at room temperature, respectively. The Vickers hardness at high temperature of the CrB_2 addition of 10 mass % Cr_3C_2 composite decreased with increasing measurement temperature. The Vickers hardness at 1273 K of the sample was 6 GPa. The Vickers hardness of CrB_2 addition of Cr_3C_2 composites was higher than monolithic CrB_2 sintered body. The powder X-ray diffraction analysis detected CrB and B_4C phases in CrB_2 containing Cr_3C_2 composites.

Keywords : chromium boride, chromium carbide, sintering, composite

1. Introduction

Several boride sintered bodies such as TiB_2, ZrB_2, and SiB_6 were previously reported [1-12]. Chromium chemical compound of oxide, carbide, nitride, and silicide is the useful industrial materials. Chromium boride phases such as CrB, CrB_2, CrB_4, Cr_2B, Cr_2B_3, Cr_3B_4, and Cr_5B_3 have been registered in the X-ray Cards of the International Center for Diffraction Data (ICDD). Among them, chromium diboride (CrB_2) have proved to be a potentially useful material because of its excellent chemical stability. Then, CrB_2 has various desirable properties, including moderate high melting point, high hardness, good electrical conductivity, low specific gravity, and chemical stability, and it a potential material for high-temperature applications. To date, there have been few reports regarding the properties of chromium boride ceramics. In the present study, samples of CrB_2 containing chromium carbide (Cr_3C_2) were prepared by hot pressing. Influence of the addition of Cr_3C_2 on the sinterability was examined. Also, physical properties of the composites were evaluated.

2. Experimental

CrB_2 powder (purity; 99 %, average particle size; 3 m, Japan New Metal Co., Ltd., Japan) and Cr_3C_2 powder (purity; 99 %, average particle size; 2 μm, Soekawa Chemicals Co., Ltd., Japan) were used as starting materials. The powders were blended in the required ratios and wet-mixed in ethanol for 12 hours using a plastic container together with nylon balls. The mixture sample was dried at 323 K for 24 hours. After drying, the mixture sample powder was packed in a carbon vessel and hot pressing sintered at 1773 K for 1 hour under 30 MPa pressure under vacuum (10^{-4} Pa) atmosphere to prepare composites of about ϕ25 x 5 mm in size. The heating rate was set at 10 K/min. Then, the molded substance was allowed to cool slowly in vacuum atmosphere after sintering at 1773 K for 1 hour. The bulk density of the sintered bodies was measured by the Archimedes' method. The relative density of the sintered bodies was calculated by using the theoretical densities of CrB_2 and Cr_3C_2 from mixing composition, which was estimated by assuming that CrB_2-Cr_3C_2 was merely mixed in each sintered body. The sintered bodies were cut into 5 x 5 x 10 mm blocks and polished with diamond disk for Vickers hardness. High temperature

hardness was measured using high temperature hardness equipment made by Hitachi Corp., Japan in vacuum atmosphere at room temperature to 1073 K. The measurement of Vickers hardness was repeated five times for each sample, under conditions, load: 9.8 N and load time: 30 s. The crystalline phases of the specimens were identified by powder X-ray diffraction (XRD) analysis. The surfaces of the sintered bodies were observed using a scanning electron microscope (SEM) to estimate the microstructures.

3. Results

Sintering properties were compared between monolithic CrB_2 and CrB_2 addition of Cr_3C_2 sintered bodies. The porosity of a CrB_2 and CrB_2 containing Cr_3C_2 sintered bodies at 1773 K for 1 hour were about 5 to 8 %. The containing of Cr_3C_2 significantly increased the Vickers hardness of the composites sintered at 1773 K for 1 hour. An aid quantity of 10 to 15 mass % Cr_3C_2 gave a high Vickers hardness. The CrB_2 with 10 mass % Cr_3C_2 sintered body showed the maximum value of about 15 GPa in comparison with 4 GPa of the monolithic CrB_2 sintered body. The Vickers hardness of sintered body with 20 mass % Cr_3C_2 was low hardness (about 6 GPa). The crystalline phases of composites were determined by powder X-ray diffraction (XRD). The sintered composites exhibited diffraction peaks considered to be relevant to CrB and B_4C, in addition to those relevant to CrB_2. However, the diffraction peaks for Cr_3C_2 disappeared, and those for B_4C. It was also considered that oxygen present in the starting powder as impurity affected the sinterability of CrB_2. In particular, oxygen considered to be present on the starting particle surfaces was reduced by the action of carbon as added aid, to form CO gas. The crystalline phases of composites were determined by powder X-ray diffraction (XRD). The sintered composites exhibited diffraction peaks considered to be relevant to CrB and B4C, in addition to those relevant to CrB_2. However, the diffraction peaks for Cr_3C_2 disappeared, and those for B_4C. It was also considered that oxygen present in the starting powder as impurity affected the sinterability of CrB_2. In particular, oxygen considered to be present on the starting particle surfaces was reduced by the action of carbon as added aid, to form CO gas. It was thus considered, based on the above results and discussion, it became clear that the physical properties of CrB_2 ceramics could be improved by addition of Cr_3C_2.

4. Summary

In the present study, the sinterability and physical properties of chromium boride (CrB_2) containing chromium carbide (Cr_3C_2) sintered bodies were investigated in order to determine its new advanced material. It was found that the relative density of CrB_2 containing Cr_3C_2 sintered bodies became good desification at 1773 K for 1 hour with a press under 30 MPa. The relative densityies of CrB_2 containing 5 to 20 mass % Cr_3C_2 sintered bodies were about 95to 92 %. The Vickers hardness of the CrB_2 containing 10 mass % Cr_3C_2 sintered body showed about 15 GPa. It became clear that the hardness of CrB_2 ceramics could be improved by addition of Cr_3C_2. The Vickers hardness at room temperature of CrB_2 containing Cr_3C_2 composites was higher than monolithic CrB_2 sintering body. The CrB_2 containing 10 mass % Cr_3C_2 sintered body was the highest of Vickers hardness of all specimens.

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