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Reaction Synthesis and Mechanical Properties of B_4C-based Ceramic Composites

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Abstract

In this investigation, B_4C based ceramic composites were fabricated by in-situ reaction hot pressing using B_4C, TiC and SiC powder as starting materials. The reaction synthesized composites by hot pressing at 1950 °C was found to posses very high relative density. The reaction synthesized B_4C composites comprise B_4C, TiB_2, SiC and graphite by the reaction between TiC and B_4C. The newly formed TiB_2 and graphite was embedded both inside grain and at grain boundary of B_4C. The mechanical properties of reaction synthesized B_4C-TiB_2-SiC-graphite composites were more enhanced compared to those of monolithic B_4C.

Keywords : B_4C, composite, reaction synthesis, mechanical property

1. Introduction

B_4C based ceramics exhibits many attractive properties for structural materials such as high melting point, low density, good chemical stability, high wear resistance, and high hardness, which enables them to be used for wear resistant parts, light weight armor, and cutting tool [1-4]. However, B_4C-based ceramics have some major problems such as low strength and fracture toughness compared with other competitive engineering ceramics such as Si_3N_4 and SiC. Furthermore, B_4C-based ceramics have very poor sinterability due to its low self diffusion coefficient. Many researches have been performed to improve the mechanical properties as well as sinterability of B_4C-based ceramics [3-12]. The studies reveal that it would be a challenge to achieve both improvements in sinterability and mechanical properties. Therefore, in this study, reactive sintering process was performed to prepare fully dense B_4C-based ceramic composites by adding SiC and TiC into B_4C matrix at a relatively low temperature. The effect of adding SiC and TiC on sinterability and mechanical properties of B_4C-based ceramic composites was investigated.

2. Experimental and Results

In this study, B_4C, TiC, and SiC powder were used as starting materials. B_4C, SiC, and TiC powder were mixed with a composition of B_4C : SiC : TiC = 50~75 : 20 : 5~30 in wt. % using SPEX™ mill for 10 min in Ar atmosphere. B_4C-based ceramic composites were fabricated by hot pressing at the temperature range of 1950 °C under 40 MPa for 0.5 h in Ar atmosphere. After the fabrication process, phase identifications of fabricated B_4C-based ceramic composites were done by X-ray diffraction (XRD) method with Cu-k radiation. The polished surface of fabricated B_4C-based ceramic composites was electrochemically etched in 20% HNO_3 solution, and then examined by scanning electron microscope (SEM). The three-point bending tests were performed to measure the toughness by single edge notched beam method of B_4C-based ceramic composites specimen with dimensions of about 3 x 4 x 25 mm.

Fig.1 shows XRD patterns of fabricated B_4C-based ceramic composites by hot pressing. The crystalline phases in B_4C-based ceramic composites comprise B_4C, TiB_2, SiC, and graphite. With increasing TiC content in starting

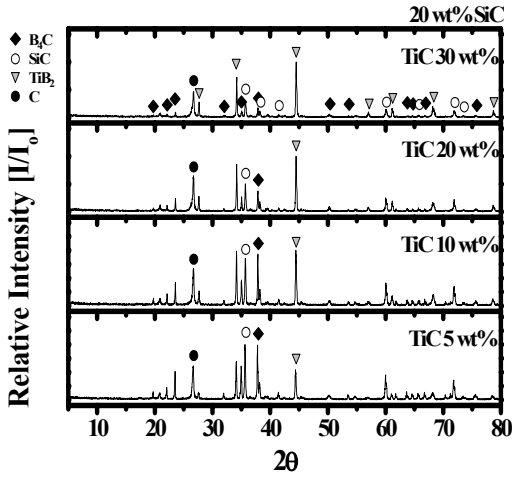

Fig. 1. XRD patterns of B_4C composites fabricated by hot pressing at 1950 °C.

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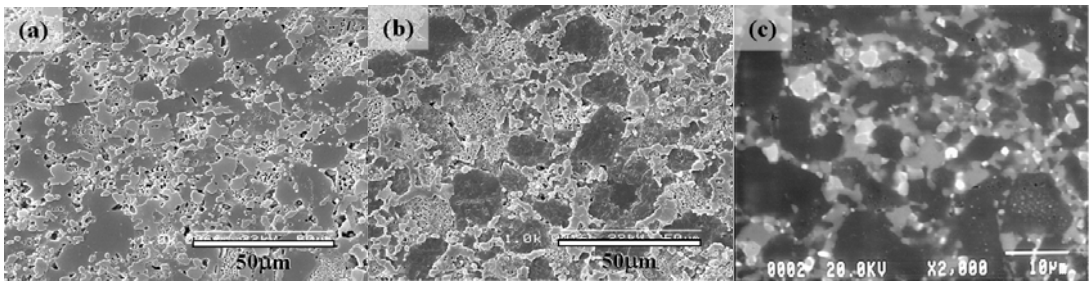

Fig. 2. SEM microstructures of B_4C composites by hot pressing of (a) 75 w/o B_4C:20 w/o SiC:5 w/o TiC, (b) 70 w/o B_4C: 20 w/o SiC: 10 w/o TiC, and (c) back scattered SEM microstructure of (b).

materials, intensities of XRD peaks for TiB_2 and graphite increases as shown in Fig. 1. Fig. 2 shows the SEM microstructures of fabricated B_4C-based ceramic composites. SiC and newly formed phases were relatively well distributed inside B_4C grain as well as along the B_4C grain boundaries. With increase TiC content, newly formed phases and SiC dispersions formed another interconnected matrix along with B_4C matrix. From the EDS analysis, dispersions as shown in Fig. 3(c), the gray colored and white colored phase were identified as SiC and newly formed TiB_2 phase, respectively. Fig. 3 shows the flexural strength and fracture toughness of B_4C-based ceramic composites fabricated in this study.

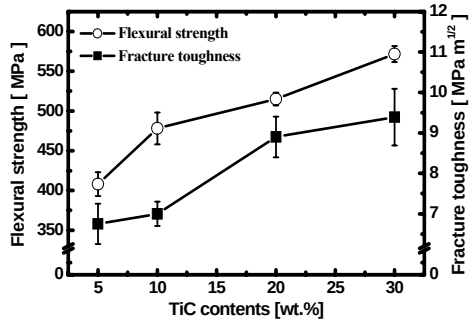

Fig. 3. Flexural strength and fracture toughness of B_4C composites fabricated by hot pressing.

Both flexural strength and fracture toughness of B_4C-based ceramic composites almost linearly increase with the content of TiC in the starting material. For the B_4C-based ceramic composites with TiC content of 30 wt.%, flexural strength and fracture toughness were about 570 MPa and 9.5 $MPam^{1/2}$, respectively.

3. Summary

In this study, B_4C-TiB_2-SiC-graphite composites were synthesized by reactive hot pressing using B_4C, TiC and SiC powder as starting materials. The mechanical properties of reaction synthesized B_4C-TiB_2-SiC –graphite composites fabricated in this study showed significant improvements compared to those of monolithic B_4C and other B_4C-based ceramic composites reported in the previous studies. The flexural strength and fracture toughness of these in-situ B_4C synthesized composites were 400-570 MPa and 6-9.5 $MPam^{1/2}$, respectively. The enhanced fracture toughness of B_4C based ceramic composites are considered to be due to the severe crack deflection at the phase boundary between B_4C matrix and dispersions consisting of SiC and TiB_2, which occur by residual stress from the difference in thermal expansion coefficients of B_4C, SiC, and TiB_2 upon cooling from the fabrication temperature.

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