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Short Communication

Effect of BN grain size on microstructure and mechanical properties of the ZrB_2–SiC–BN composites

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ABSTRACT

ZrB_2–20 vol.%SiC composites containing 10 vol.% h-BN particles (ZSB) with average grain sizes ranging from 1 μm to 10 μm were hot-pressed. The fracture toughness of the ZSB composites was higher than reported results of monolithic ZrB_2 (2.3–3.5 MPa $m^{1/2}$) and SiC particle reinforced ZrB_2 composites (4.0–4.5 MPa $m^{1/2}$). The improvement in the fracture toughness of the ZSB composites was due to the high aspect ratio of h-BN and weaker interface bonding, which could enhance crack deflection and stress relaxation near the crack-tip. Compared with the flexural strength of the ZrB_2–SiC composites, the reduction in the flexural strength of the ZSB composites was attributed to the weaker interface bonding and the lower relative density. Furthermore, improvement in toughness and the reduction in the strength were valuable to improve the thermal shock resistance of the ZSB composites. The ΔT_c of ZSB5 material is 400 °C which is higher than ZrB_2–20%SiC and ZrB_2–15%SiC–5%AlN.

1. Introduction

As we known ultra-high-temperature ceramics, transition metal diborides show a number of excellent properties such as high melting temperature, high strength, high thermal and electrical conductivity, and chemical stability [1]. Therefore, these ceramic-based composites are potential candidates for a variety of high-temperature structural applications such as thermal protection systems for leading edges [2]. In recent years, Synthesis, microstructure and property characterization of ternary Zr–Al(Si)–C compounds have been extensively investigated, and Zr–Al(Si)–C compounds show high promise for application in ultra-high-temperature applications [3–6]. However, zirconium diboride (ZrB_2) is especially promising, as it has an excellent combination of mechanical, physical, chemical and oxidation resistance properties, a desired property in the aerospace industry [7]. It is known that the addition of appropriate amounts of SiC particles not only enhances the mechanical properties, but also improves the oxidation resistance of ZrB_2 by promoting the formation of silicate-based glasses that inhibit oxidation at temperatures between 800 °C and 1700 °C [8]. Although these ZrB_2–SiC composites have many advantages, their intrinsic characteristics such as low fracture toughness (premature failure due to brittle fracture), low toughness-induced poor thermal shock resistance are still obstacles for them to be used widely, especially for applications in extreme environment [9]. One possible route has been to overcome these deficiencies by incorporating the second phase additions with a higher aspect ratio (e.g., flakes or rods/whiskers) into the ZrB_2 based composites [10]. Hexagonal-BN (h-BN) is conferred as white graphite as its low hardness and higher aspect ratio. Multilayer materials in which h-BN serves as one of component layers have been studied extensively [11]. However, h-BN as a third phase adding to ZrB_2–SiC matrix composite was rarely reported, especially considering effect of BN grain size on microstructure and mechanical properties of ZrB_2–20 vol.%SiC composite.

The research results show that high-temperature thermal shock resistance of structural ceramics is the main factor which determines the life of materials [12]. Therefore, the reliability of the use of ceramic materials and thermal shock resistance studies has been the main research direction of the high-temperature structural ceramics.

In this work, ZrB_2–20 vol.%SiC containing 10 vol.% h-BN composites (ZSB) were fabricated by hot-pressing. The effect of h-BN grain size on the microstructure and the mechanical properties of the ZSB composites were systematically investigated. And the thermal shock resistance of ZSB material with h-BN grain size of 5 μm was tested. The purpose of this paper is to aid materials engineering design for the development of new materials, quality assurance, and characterization assessment of durability.

2. Experimental

Commercially available ZrB_2 with a mean size of about 3 μm, SiC with a mean size of about 2 μm and graphite flake (mean diameter and thickness are 15 μm and 1.5 μm, respectively) were

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