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Isothermal oxidation behavior of reactive hot-pressed TiN–TiB_2 ceramics at elevated temperatures

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ABSTRACT

Isothermal oxidation behavior of reactive hot-pressed TiN–TiB_2 ceramics with various TiN/TiB_2 molar ratios of 2/1, 1/1 and 1/2 was evaluated in the temperature range of 500–800 °C in air. TiN–TiB_2 ceramics have a relative density of 97–98.6%. The oxidation weight gains of TiN–TiB_2 ceramics depend upon the composition, oxidation temperature and exposure time. The structure and morphology of oxidized layers of TiN–TiB_2 ceramics were investigated by X-ray diffraction (XRD) and scanning electron microscopy (SEM). During isothermal oxidation of TiN–TiB_2 ceramics, anatase and rutile-TiO_2 form as the oxidized products at 500 °C. However, phase transformation from anatase to rutile occurs at temperatures between 500 and 600 °C, and therefore rutile-TiO_2 becomes the only crystalline phase after oxidation at temperatures of 600–800 °C for 10 h. The oxidation mechanism was proposed with reference to thermodynamically feasible oxidation reactions. The influence of composition on oxidation behavior of TiN–TiB_2 ceramics varies with temperature.

1. Introduction

Design and processing of new materials with excellent high temperature mechanical properties is one of the challenging tasks of modern engineering. Refractory materials such as borides, nitrides, carbides, and combinations thereof are natural candidates for these demanding applications due to their exceptional hardness, chemical inertness, and good thermodynamic stability at very high temperatures. Both titanium nitride (TiN) and titanium diboride (TiB_2) exhibit high hardness, excellent chemical and thermal stability, reliable mechanical performance at ascending temperatures [1,2]. They also possess good electrical and thermal conductivity as compared with those of alloyed metals, thus they can be electrical discharge machined. In consideration of their unique properties, a great number of researches have been carried on TiN and TiB_2 for such potential applications as jet engine parts, armor plates, cutting tools and dies. Along with mechanical strength and machinability, environmental stability is another important criterion for actual applications. Engineering ceramics of TiN and TiB_2 are frequently exposed to high temperatures. Therefore, the high-temperature stability, especially oxidation behavior, is an important property to be understood. There were several reports [3–5] on the synthesis and mechanical performance of TiN–TiB_2 ceramics; however, oxidation behavior of TiN–TiB_2 is not available in the open literature. In the present study, TiN–TiB_2 ceramics were synthesized by reactive hot pressing. The isothermal oxidation behavior of TiN–TiB_2 ceramics with various compositions was investigated in the temperature range of 600–800 °C.

2. Experimental

The TiN–TiB_2 ceramics were produced by reactive hot pressing of titanium, boron nitride and boron powders using the following chemical reactions:

$$3Ti + 2BN \rightarrow 2TiN + TiB_2 \quad (1)$$

$$Ti + 2B \rightarrow TiB_2 \quad (2)$$

Different powders of titanium (10–12 μm, 99.9%), boron nitride (130–150 nm, 99%) and boron (1–1.5 μm, 99.9%) were weighed according to the chemical reactions (1) and (2) to obtain three kinds of TiN–TiB_2 ceramics as given in Table 1. The compositions of TiN–TiB_2 ceramics were designed according to TiN/TiB_2 molar ratios of 2/1 (denoted as NB21), 1/1 (denoted as NB11) and 1/2 (denoted as NB12), respectively. The weighed powders were mixed by wet ball milling for 24 h in a polyethylene bottle with ZrO_2 balls and acetone as media. After mixing, the slurries were dried in a rotary vacuum evaporator, and were screened through a 120-mesh screen. The powder mixtures were heated to 1300 °C and held for 0.5 h, and then followed by hot pressing at 1800 °C for 1 h in vacuum with an applied pressure of 30 MPa.

Specimens for mechanical properties tests were machined into the dimensions of 3 mm × 4 mm × 35 mm and 2 mm × 4 mm

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