Accepted Manuscript

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PII: S0955-2219(17)30841-5
DOI: https://doi.org/10.1016/j.jeurceramsoc.2017.12.031
Reference: JECS 11636

To appear in: *Journal of the European Ceramic Society*

Received date: 23-11-2017
Revised date: 13-12-2017
Accepted date: 16-12-2017

Please cite this article as: Kurbatkina VV, Patsera EI, Levashov EA, Timofeev AN, Self-Propagating High-Temperature Synthesis of Refractory Boride Ceramics $(Zr,Ta)B_2$ with Superior Properties, *Journal of The European Ceramic Society* (2010), https://doi.org/10.1016/j.jeurceramsoc.2017.12.031

Self-Propagating High-Temperature Synthesis of Refractory Boride Ceramics $(Zr,Ta)B_2$ with Superior Properties

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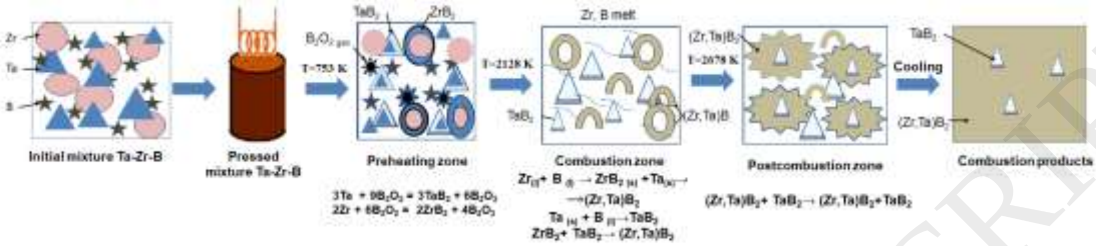
Graphical abstract



Abstract: The macrokinetic features of combustion in the Ta-Zr-B system were studied. Combustion is characterized by spin mode, suggesting the limiting role of gas-phase mass transfer of reagents. The mechanism of chemical reactions and phase formation in combustion wave was discussed. Primary layers of tantalum and zirconium borides were detected in the preheating zone at temperatures below the melting point of the reagents. After zirconium and boron melt, the temperature in the combustion zone reaches its maximum and zirconium diboride precipitates out of the oversaturated solution. Powders with a grain size of 1-3 μm were fabricated and hot-pressed into dense ultra-high-temperature ceramics (UHTCs). Boride ceramics with the record-setting hardness of 70 GPa, Young's modulus of 594 GPa, and elastic recovery of 96% were obtained. The measured heat conductivity of the solid solution (Zr,Ta)B2 was equal to 35-42 W/m·K. Plasma torch tests demonstrated high oxidation resistance of the obtained ceramics at 2900-3000°C.

Keywords: UHTC; SHS; ZrB2; TaB2; solid solutions

Introduction

The tasks related to designing the novel types of power generation systems, high-speed transport vehicles, and space vehicles have spurred searching for the materials that are characterized by record-setting melting points and maintain their mechanical properties and oxidation resistance at temperatures above 2000°C [1-4]. The construction materials to be used in high-temperature oxidative media are mostly represented by compositions based on SiC, Si_3N_4, oxide ceramics, and C/C composites thermally protected with silicon carbide [1-6]. Carbon–carbon composites have been recently increasingly used in aviation and aerospace industries due to their extremely high sublimation temperature, low density, thermal expansion