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Processing High Strength Low Oxide and Metal Impurity ZrB_2 Ceramics Using Boron Carbide and Spark Plasma Sintering

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Abstract

Zirconium diboride is an ultra-high temperature ceramic (UHTC) with attractive material properties for use in extreme hypersonic flight environments and energy applications. The diboride phase is the basis for high temperature oxidation resistant UHTC composites using secondary phase reinforcements that also enhance high temperature properties of ZrB_2-based composites. However, the mechanical properties are limited by the impurity content found in the diboride source powder. Thus our work focuses on developing a methodology to process the high purity ZrB_2 using spark plasma sintering (SPS) and computational thermodynamics analysis coupled with high-resolution atomic scale electron microscopy. A clear path towards processing ultra-high purity ZrB_2 ceramics is presented using a combined experimental and thermodynamically assisted processing method through thermal treatments and oxide reducing agents carbon and boron carbide (B_4C). Computational thermodynamic phase diagrams consisting of the Zr-O-C ternary and Zr-B-C-O quaternary are developed to predict and explain the microstructures found after SPS. Scanning electron microscopy (SEM) and scanning transmission electron microscopy (STEM) analysis shows evidence of SPS-unique grain boundary cleaning and the potential to use current to further improve ZrB_2+B_4C purity. The effect of current density and computational simulations of predicted temperature during SPS will also be discussed.