The effects of B4C network microstructure on the thermoelectrical properties of spark plasma sintered SiC

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Thermoelectric (TE) devices convert waste heat to electricity and can be used in industrial waste heat recovery utilizing TE materials which may play a vital role in developing sustainable and renewable energy-harvesting technologies. TE materials should have high electrical conductivity and Seebeck coefficient as well as low thermal conductivity for a high dimensionless figure of merit, ZT, which represents the efficiency of TE conversion. Since these properties are related to each other, e.g. a high electrical conductivity results in a high thermal conductivity value, different composite approaches or doping must be maintained for optimization of these properties. Our recent studies explored the effects of transitional metal carbide/boride network microstructures on the TE properties of SiC and B_4C which revealed simultaneous improvement of electrical and thermal conductivities with conductive network and increased phonon scattering, but deterioration of the Seebeck coefficient due to the metallic nature of the network microstructure. To minimize this problem, a B_4C network microstructure was implemented to the SiC matrix in this study, aimed to increase the electrical conductivity with minimal Seebeck coefficient loss thanks to the semiconductor nature of B_4C.

Polycrystalline bulk samples of SiC with B_4C network structures were prepared by a simple dry particle coating method followed by spark plasma sintering (SPS). 1–8 vol.% B_4C-coated SiC granules were consolidated in an SPS furnace (HP 25D, FCT GmbH, Germany) at 2000°C by applying 40 MPa pressure under a vacuum atmosphere with a 5-minute holding time. Phase and microstructure analyses were carried out on polished surfaces of the sintered bulk samples. Electrical conductivities and Seebeck coefficients of the samples were measured simultaneously by the four-point probe method between 323 and 923 K. Thermal diffusivity and heat capacity values were measured by the laser flash analysis and differential scanning calorimetry, respectively, to calculate the thermal conductivity. Density values were obtained by using the Archimedes method at room temperature.

The implementation of the conductive B_4C network microstructures given in the figure (light phase is SiC matrix, dark phase is B_4C network) improved the electrical conductivity of SiC simultaneously with the decrease in thermal conductivity due to the increased phonon scattering with increased grain boundary concentrations. Optimization of B_4C content resulted in a minimal decrease in the Seebeck coefficient resulting in a composite with increased ZT values and TE performance.

To conclude, SiC granules were successfully coated with 1–9 vol.% B_4C powders and then spark plasma sintered to obtain conductive B_4C network microstructures to improve the TE performance of SiC by simultaneously increasing electrical and decreasing thermal conductivities while limiting the decrease in the Seebeck coefficient to a minimum.
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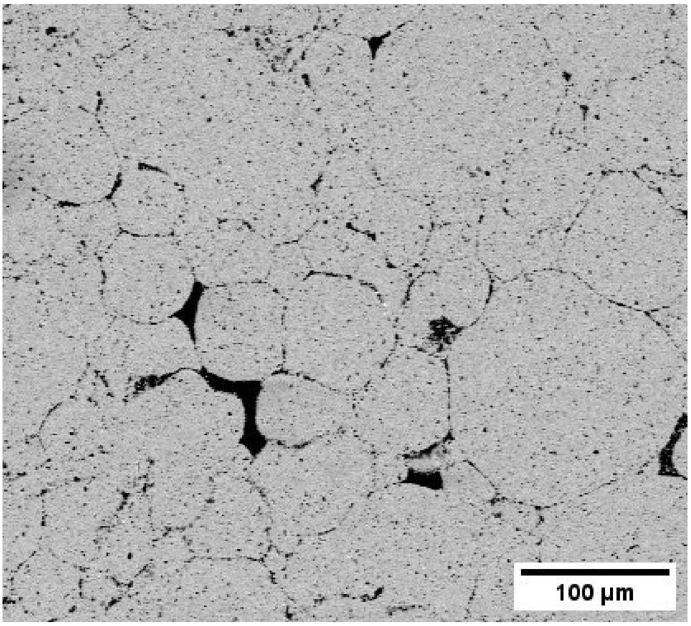
Graphic:



Keywords:

SiC, B_4C, Network-microstructure, SPS, Thermoelectric

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