Materials Science & Engineering and Metallurgical Engineering Graduate Seminar

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Computational Design, Processing and Properties of Nanostructured TiB ceramics

Metal borides are hard and wear resistant materials and very little research has been directed to exploit their many attractive attributes. Specifically, in the Ti-B system, TiB is an orthorhombic compound and it is a hard ceramic with a metal-like electrical conductivity, similar to the other boride, TiB2. This ceramic is of particular interest because of its highly compact three-dimensional network of stiff nanowhiskers and ease in situ formation. Therefore, it likely to be a competitive alternative to engineering ceramics such as Si3N4, SiC, and Al2O3. To date, there has been little systematic research regarding the synthesis, kinetics, and mechanical properties of bulk TiB ceramic by spark plasma sintering. In this research, an alloy design approach to identify promising compositions and processing temperatures to enable the synthesis of TiB-based nanoceramics, embedding a ductile metallic phase, is developed. The approach involved CALPHAD calculations of phase fields of ternary and quaternary systems of Ti-B-Fe-Mo to identify the compositions and processing temperature ranges. A thermodynamic database, having optimized parameters, is established. The Johnson-Mehl-Avrami-Kolmogorov model is applied to describe the behavior of TiB formation during sintering. A relatively high fracture toughness (8.9 MPa$\sqrt{m}$) and flexural strength (932 MPa) are achieved which makes TiB ceramic quite competitive and attractive for engineering applications. Further improvements in mechanical properties are feasible by optimization of the aspect ratio of TiB whiskers and ductility of residual metallic phase. Our findings serve as a good example to follow for alloy design and processing of new materials, especially the overall theoretical and experimental framework that is necessary for alloy design and processing of metal-ceramic materials including composites, cermets, ceramics.

Jun Du is a fourth-year Ph.D. working on computational designing, processing, and characterizing of TiB-based ceramics under the supervision of Dr. Chandran, in the Department of Metallurgical Engineering, University of Utah. He has contributed 7 papers on the popular journals and 2 presentations in MS&T conference.