Development of Ultra High Temperature Ceramics for Extreme Environments and Their Potential for Nuclear Applications

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Ultra high temperature ceramics (UHTC's) exhibit a unique set of properties which make them attractive for use in a number of extreme environments. UHTC's are loosely defined as any ceramic with a melting point above 3000°C. This group of materials is populated primarily by transition metal carbides, borides, and nitrides. Of these materials, carbides and borides have received the most attention depending on the exact application. Borides will be the primary focus of this presentation. A great deal of the research performed on transition metal borides has been geared toward their use in hypersonic aviation. Not only do they possess high meting points, but they also exhibit high hardness (~20 GPa), high elastic modulus (>500 GPa), low electrical resistivity (<10 μΩ·cm), high thermal conductivity (>100 W/m·K), high strength (>1 GPa), and better oxidation resistance than transition metal carbides or refractory metals. This unique set of properties make them good candidates for structures such as leading edges and certain engine components for hypersonic aircraft. Some of these same properties make them attractive for use in nuclear applications as well. The research performed at Missouri University of Science and Technology has followed a number of paths. One focus has been on understanding the intrinsic thermal, electrical, and mechanical properties of the transition metal borides over a broad temperature range. Understanding the intrinsic properties has allowed a better understanding of how structural and chemical changes affect material properties. This knowledge has led to the development of materials with previously unseen properties. This research has also illuminated the potential to tune the properties of the borides. Properties ranging from thermal conductivity to strength can be tailored at temperatures of interest. For example, the thermal conductivity can be tuned from ~30-140 W/m·K through the addition of only a few atomic percent tungsten. The development of reactive processes to produce these materials even allow for other properties uniquely interesting to the nuclear field, such as neutron absorption cross section, to be tailored.