SINTERING OF HIERARCHICALLY-STRUCTURED BORON CARBIDE FOR TOUGHENING AND MULTI-FUNCTIONALITY

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Boron carbide is light-weight, is thermally stable, has high hardness/stiffness, and is multi-functional (semiconducting, thermoelectric, and high neutron absorption cross-section). Boron carbide has been of interest for applications in extreme environments, including turbine engines, protection armor against impact, heat, and radiation, but such application is currently limited due to its brittleness and low sinterability. The toughening of ceramics has been investigated for many years as a light-weight, thermally/chemically stable alternative to structural materials. Among many methods, ceramic micro-fibers implementation has been effective, and further toughening is expected though engineering of matrices, specifically by implementing intentionally weak interphases to provide locally controlled deformation and thus energy dissipation within matrices. For example, in the past we experimentally studied the potentials of nano-porosity introduction into ceramics on deformation behaviors, by indenting on a model system of anodic aluminum oxide. Normally, porosity in ceramics is regarded as the defect, but we identified that, when pore size is below 100 nm, nano-pores deform in a controlled manner (collapse or shear band, see Figure 1a), contributing to fracture toughness increase. Meanwhile, introduction of nano-porosity resulted in stiffness and hardness decrease.

In this work, a hierarchical micro-structure was designed to increase toughness without compromising stiffness and hardness about a model system of boron carbide (see Figure 1b). The grain sizes were decreased to microns, and a tougher secondary phase (titanium boride) was added to increase stiffness and hardness. "Soft" interphases were introduced to enhance fracture toughness by crack deflection, nanopore compression, and grain boundary sliding. Field assisted sintering technology (FAST) was selected as a fabrication method as FAST enables consolidation in short time at lower temperatures with minimum grain size growth. This engineered boron carbide samples were characterized for their hardness and fracture toughness using micro-indentation, and their micro-structures were inspected using electron microscopy before and after indentation to evaluate the deformation and fracture behaviors. So far, some fabricated samples exhibited maintained hardness and increased fracture toughness by ~50%. In future, we plan to integrate *in situ* chemical reactions on boron carbide powder surfaces during sintering, enhancing densification and possibly decreasing the sintering temperature.

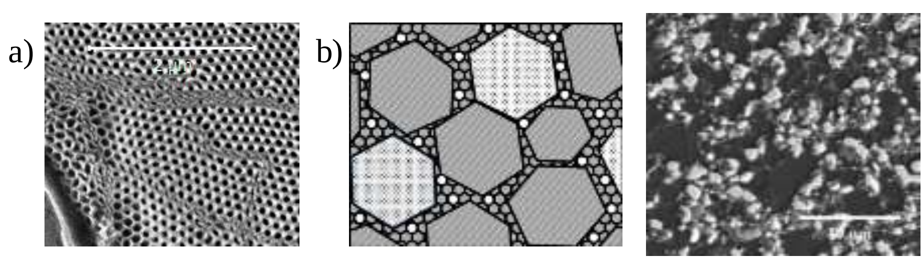

Figure 1. Ceramic toughening by hierarchical structuring.