Development of Advanced Ceramics for Future Protection Technologies

S&T Campaign: Materials Research
High Strain Rate & Ballistics
Ceramics & Transparent

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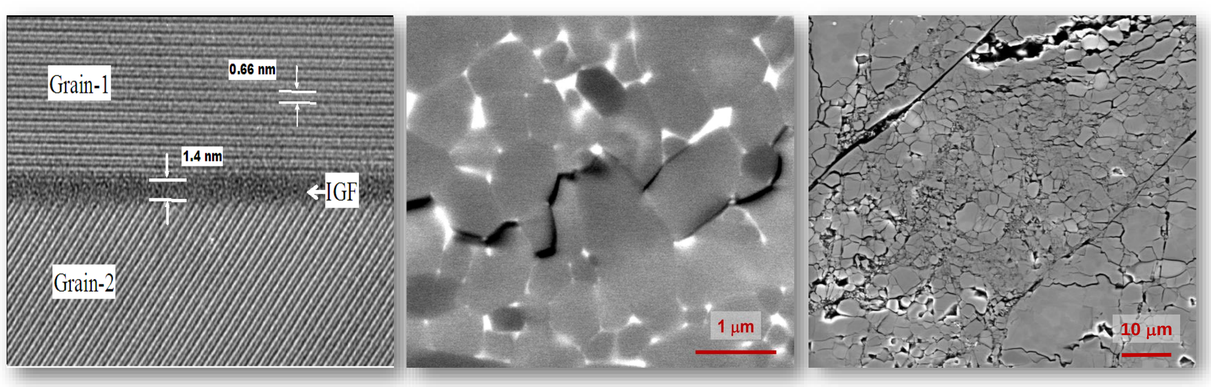
Research Objective

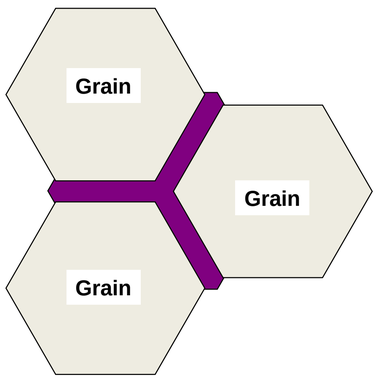
- **Improve the inelastic behavior and fracture resistance of low density, high hardness boron-based ceramics by creating quasi-liquid grain boundary (gb) films through improved powder processing and dispersion of secondary phases.**
- **Creation of such gb films in boron-based ceramics have not been previously achieved and success would be a significant step forward to achieving the desired improvements in mechanical behavior.**

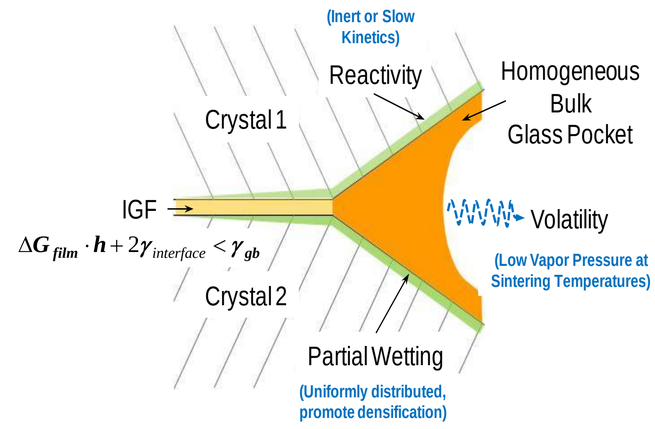


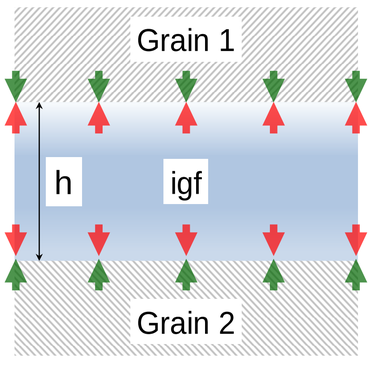
1. HRTEM image of a nanoscale quasi-liquid gb film in a ceramic. 2. Improved fracture resistance due to crack-deflection mechanism. 3. Improved inelastic behavior due to gb sliding.

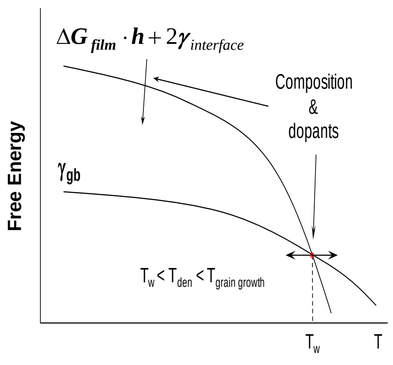
Challenges

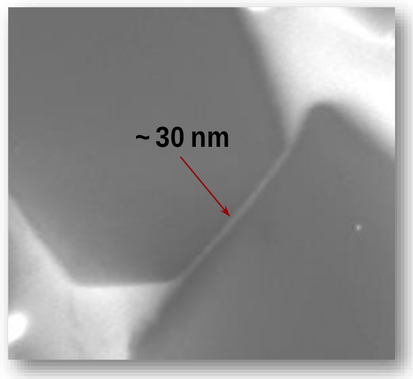
- **Potential barriers to forming stable gb films are unknown (magnitude of dispersive attractive versus steric repulsive forces).**
- **Which second phase additives and processing conditions promote both the formation of stable gb films and densification?**
- **What is the best method for introducing these additives into boron-based ceramic powders? Effect of surface oxide layers?**







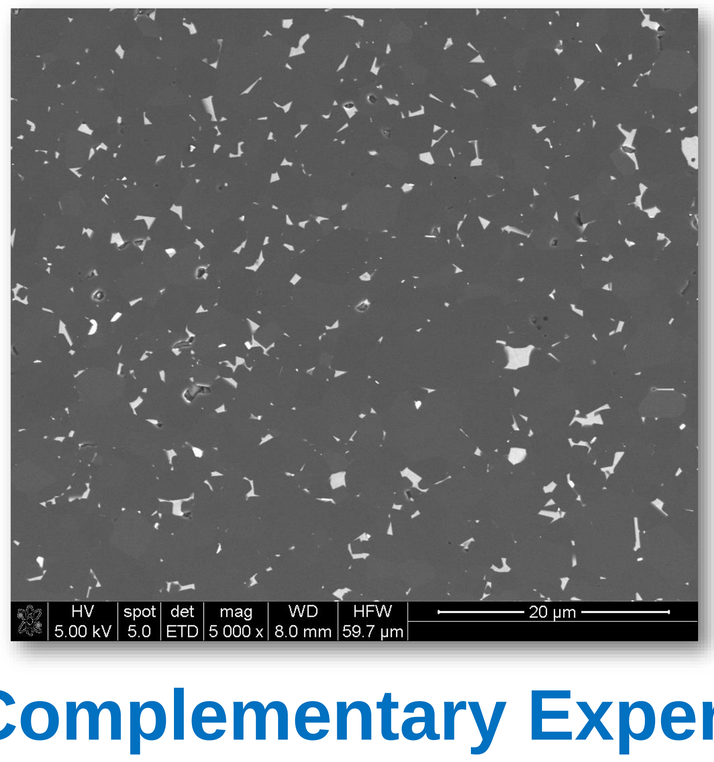




1. Schematic of gb film between grains. 2. Challenges to forming a stable gb film and densification. 3. Balance of attractive and repulsive forces for stable gb film.
4. Thermodynamic condition for stable gb film. 5. Apparent gb film.

ARL Facilities and Capabilities Available to Support Collaborative Research

- **Traditional and Colloidal Powder Processing**
- **Pressureless and Pressure-Assisted Densification (Furnaces, Hot-Presses, HIP, and SPS)**
- **Analytical Electron Microscopy (SEM, TEM, STEM, EELS, EDS, BSED)**
- **Raman Microscopy (7 wavelengths, deep UV – near IR)**
- **Thermal Analysis (DTA, TGA, DSC, Dilatometry)**
- **CALPHAD**
- **Small-Scale Mechanical Characterization (FIB, AFM, Nanoindentation)**
- **Low- and High-Rate Microindentation**
- **ASTM Physical and Mechanical Properties (Density, Elastic Moduli, Hardness, Tensile and Compressive Strength, Fracture Toughness)**
- **Instrumented sub-scale Ballistic Testing and Post-Mortem Characterization (Flash X-ray Radiography, Photon Doppler Velocimetry, X-ray Computed Tomography, Destructive)**
- **Effect of several additives and their mixtures on the densification of boron carbide and boron suboxide has been characterized. Al2O3- based mixtures show promise for achieving both consolidation and gb film formation.**



SEM image of a polished boron carbide cross-section showing the distribution of an Al_2O_3 – based additive (bright phase). Partial wetting is observed leading to the possibility of gb film formation.

Complementary Expertise / Facilities / Capabilities Sought in Collaboration

- **Structure of Grain Boundaries in Boron-based Ceramics**
- **High-Temperature Colloid Chemistry**
- **High-Temperature Atomistic Models**
- **Determination of "Long-Range" Attractive and Repulsive Forces at Interfaces Separated by Thin Films**
- **Sub-Angstrom Resolution Electron Microscopy with High-Temperature Heating Stage**
- **Atom Probe Computed Tomography**