INL/MIS-19-54262-Revision-0

Super-hard & Ultra-incompressible Ceramic Synthesis and Consolidation

June 2019

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Super-hard & Ultra-incompressible Ceramic Synthesis and Consolidation

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Objective: Accelerate development & deployment of advanced armor to provide better protection at lower weights

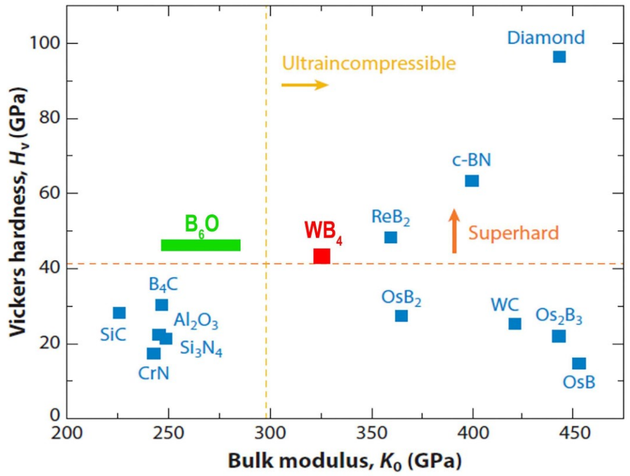
Approach

Target: High e⁻ density ceramics

- Hardness > 40 GPa H_v
- Bulk Modulus > 300 Gpa

Materials Focus:

- Tungsten Tetraboride (WB_4)
- Boron suboxide (B_6O)



Challenges

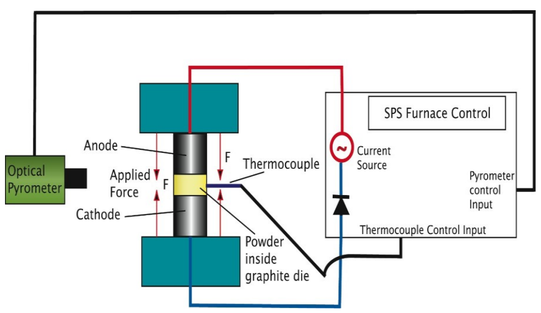
Powder Synthesis:

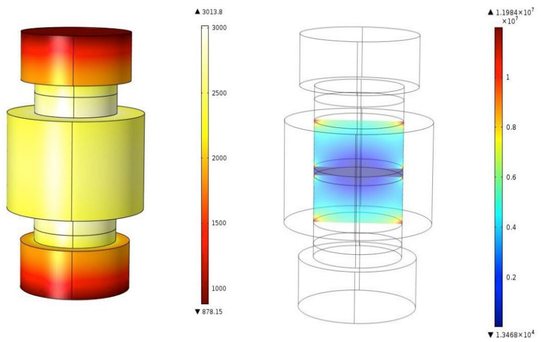
- WB_4 & B_6O are exotic ceramics and unavailable commercially
- High quality/economical synthesis routes needed

Consolidation:

- Full consolidation of high T ceramics challenging for traditional processes
- Spark Plasma Sintering (SPS) is an efficient/practical means for full densification
- *SPS creates localized heat within material increasing heating rate and uniformity*

BUT… the kinetics are not well defined, thereby limiting industrial scale-up

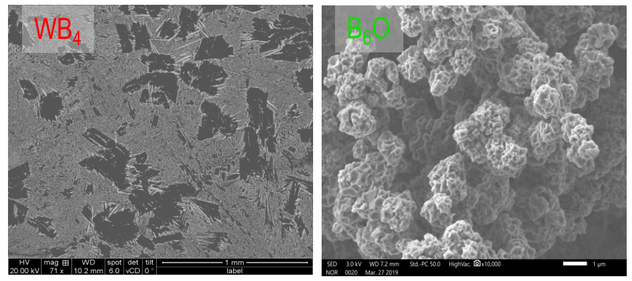




Key Results & Achievements

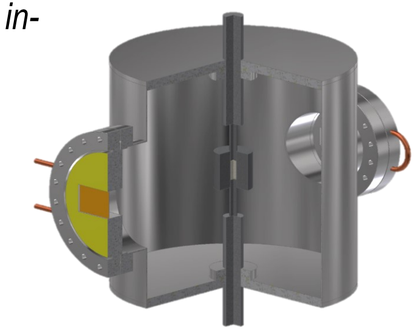
1) **Synthesis** & **Scale-up** of high quality WB_4 & B_6O in powder form (FY18)

- Quality of phase, stoichiometry, and chemical purity
- Current B_6O production ~100g max batch equivalent to ~1/2 of a 3 inch, fully dense tile



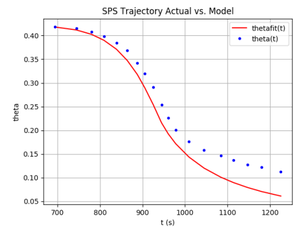
2) Specialized, "first-of-a-kind", µSPS **Design** for *in-Operando* measurements (FY19)

- Enables real-time kinetic measurements
- In fabrication by external vendor
- X-ray transparent windows engineered to withstand sample temperatures up to 2300°C



3) **Developed** multi-physics continuum model for SPS (FY19)

- Plans to further optimize with tailored µSPS experiments
- Use as preliminary tool for process scale-up



Future Work

1) Utilize Advanced Photon Source (ANL) to image & measure time-resolved material behavior in SPS (FY20)

2) Further characterize kinetics of B_6O formation (FY19 & 20)

3) Optimize SPS model for process scale-up to tiles (FY20)

4) Ballistic testing of SPS B_6O and WB_4 tiles (FY20