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Ultrahigh Temperature Materials for Hypersonic Systems Readiness

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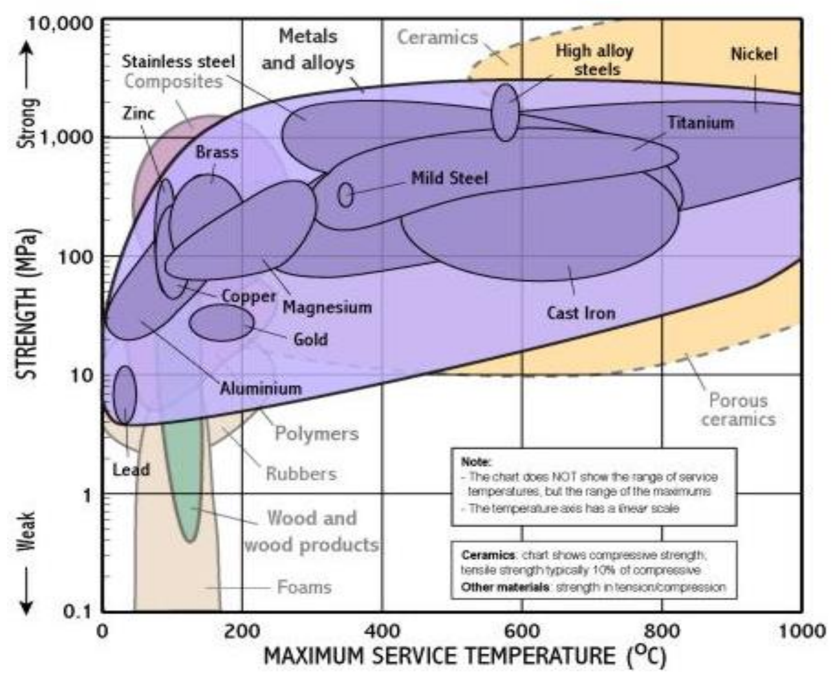
ULTRAHIGH TEMPERATURE MATERIALS FOR HYPERSONIC SYSTEMS READINESS

Naval Postgraduate School

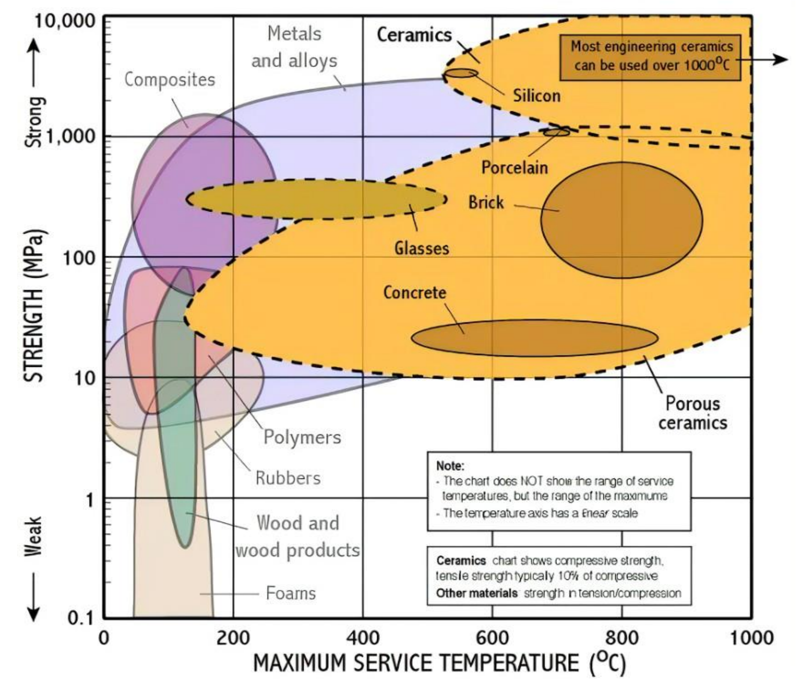
BACKGROUND AND MOTIVATION

To achieve the strategic and operational goals required for the survivability of aircraft traveling at hypersonic speeds, it is imperative to develop new materials that will serve as thermal protection, capable of withstanding extreme heat and oxidative and ablative conditions.

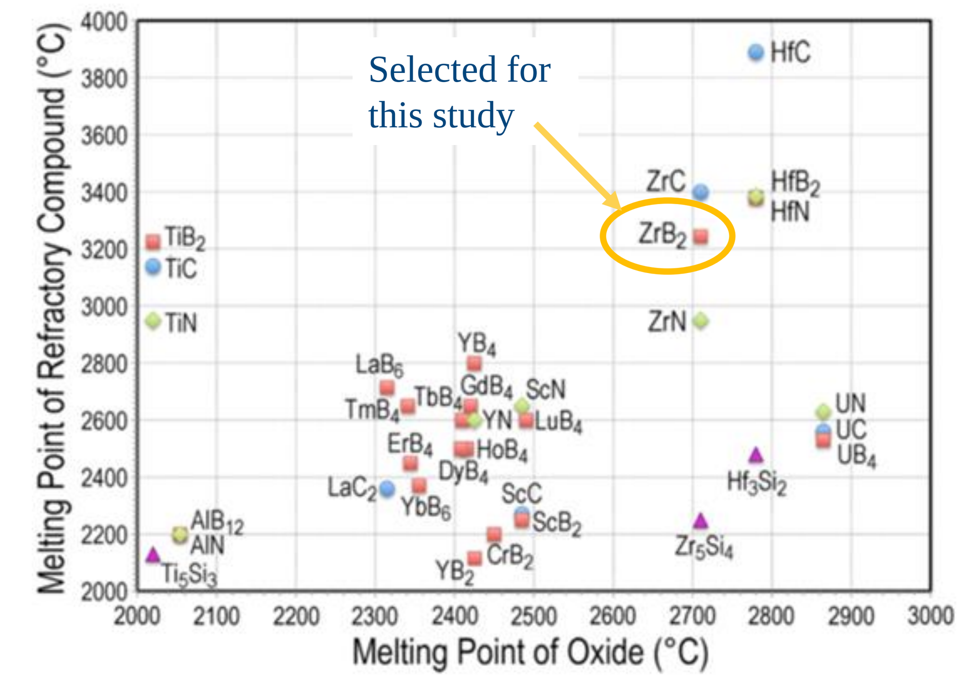
Metallic thermal protection structures, super alloys, and intermetallic compounds have been considered; however, their melting temperatures and susceptibility to oxidation are drawbacks.



Ceramic tiles have been used for aircraft thermal protection; however, their brittleness, low damage resistance and high cost have limited their application.



Ultrahigh temperature ceramics (UHTC) tend to be non-oxide ceramics, such as carbides, borides, and nitrides with melting or decomposition temperatures above 3000 °C.



Source: http://www-materials.eng.cam.ac.uk/mpsite/interactive_charts/strength-temp/NS6Chart.html

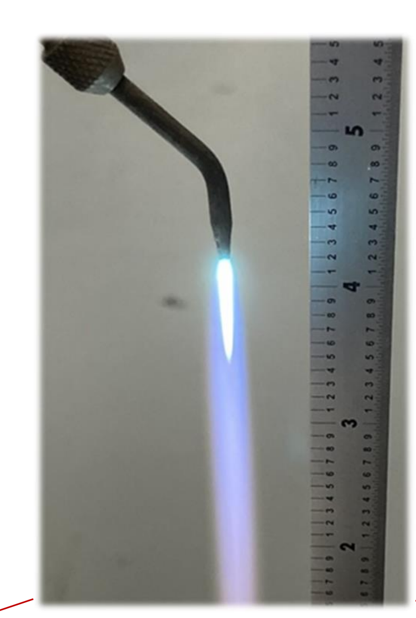
Source: https://www.colorado.edu/lab/ngpdl/research/material-response-ablation/ultra-high-temperature-ceramics

METHODOLOGY

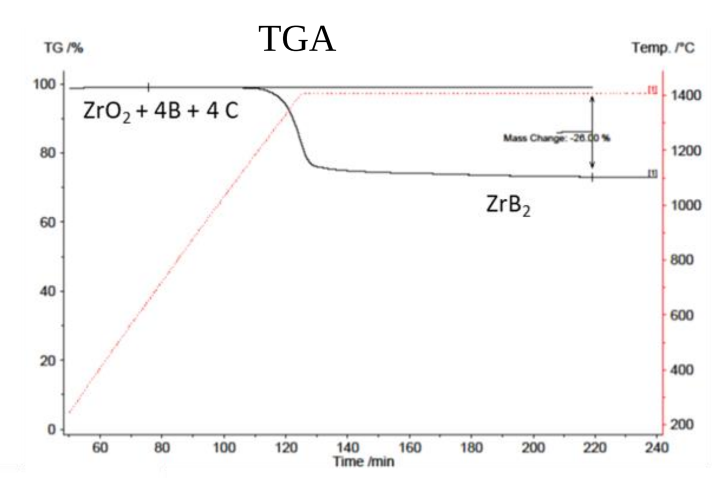
- Employed plasma routes and carbothermal reduction of oxides using diverse precursors as an operational alternative to generate UHTC ZrB_2.
- Employed SMP-10 as liquid precursor of SiC.
- Integrated the UHTC of the previous steps as the surface layer of a composite containing graphitic fibers and carbonaceous matrices.
- Performed technical assessment to determine if the newly achieved composite materials had the chemical makeup and microstructural characteristics desired.
- Evaluated the potential of the composite to withstand oxidative and ablative conditions using an oxygen acetylene torch.

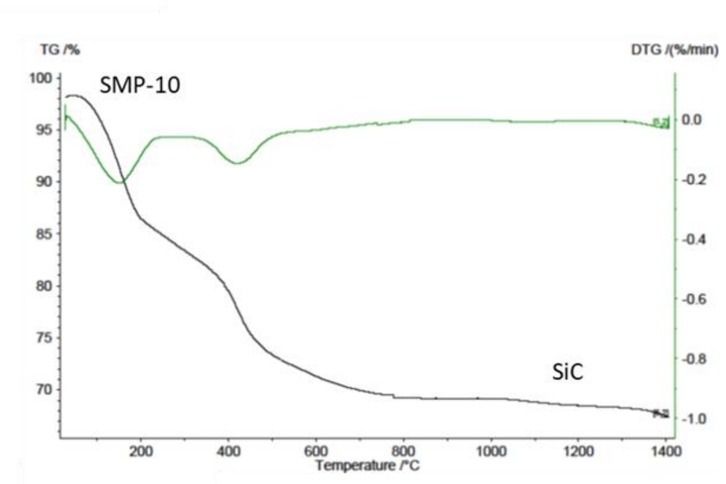
Fabrication of UHTC

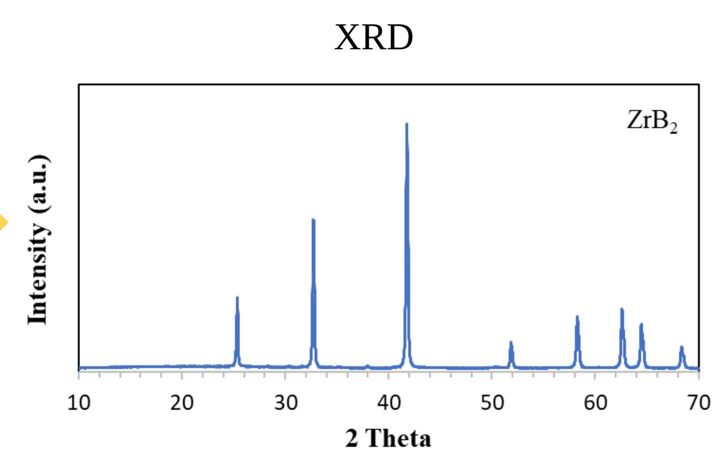
High temperature testing



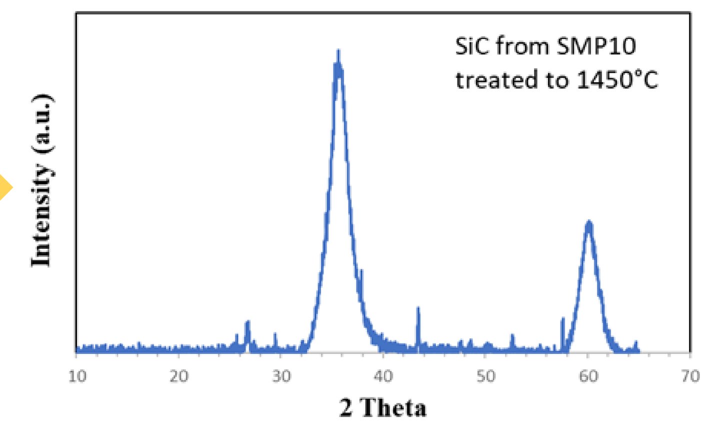
RESULTS

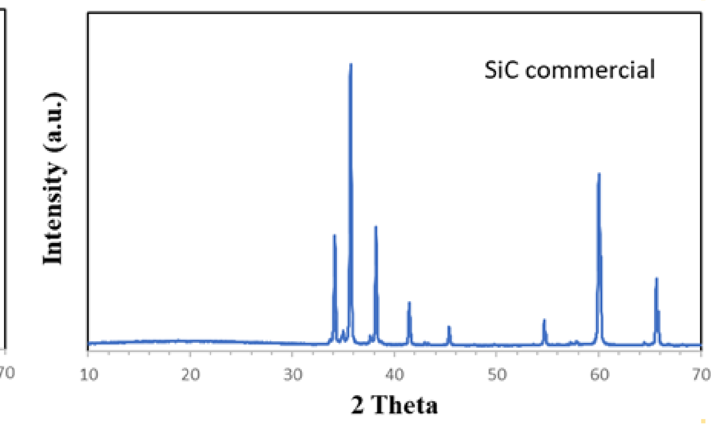


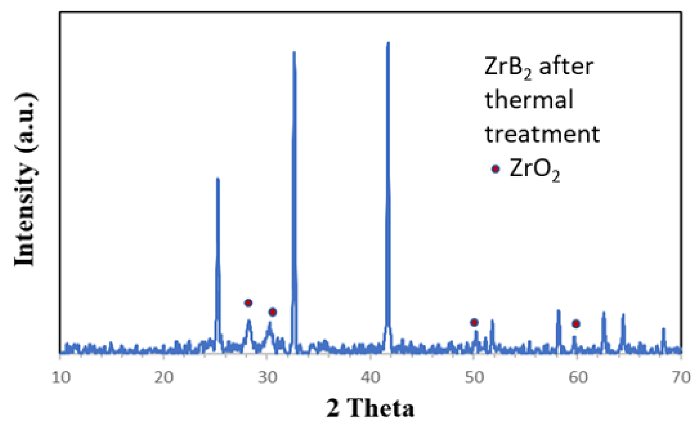


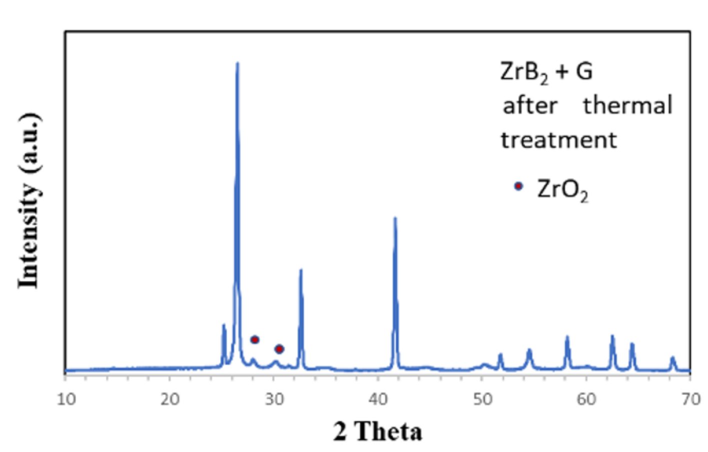


- The use of boron and carbon black and temperatures above 1450 °C reduced ZrO_2 to produce high-purity ZrB_2.
- SMP-10 presented a multistep decomposition that rendered a mixture of three different moissanite (SiC) polymorphs.

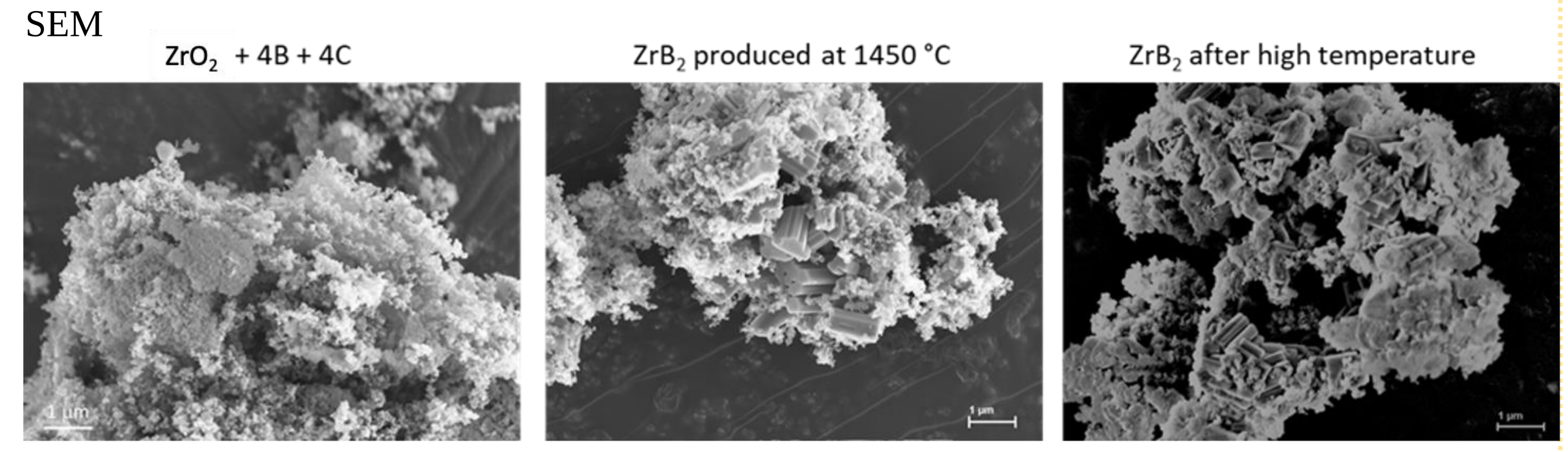


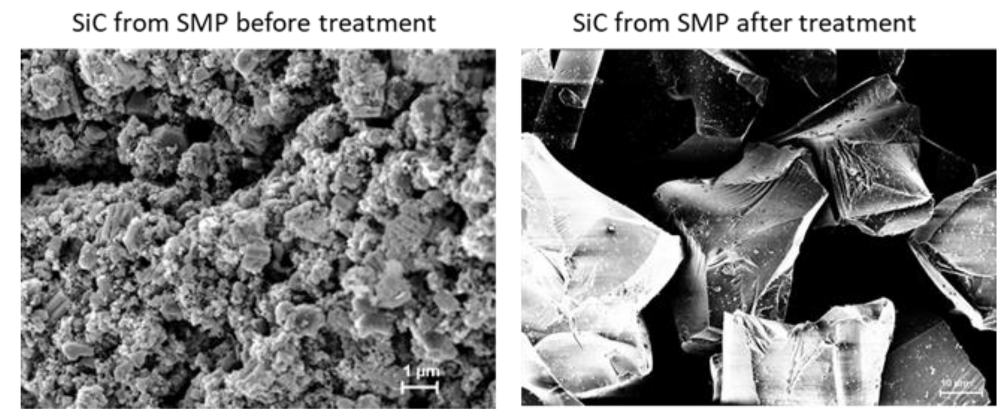






SEM





- SiC from SMP-10 presented the most significant changes in morphological features.
- Only minimal levels of oxidation detected in ZrB_2 samples mixed with graphite.
- CNT mixtures were the most susceptible to changes in chemical composition.

FINDINGS

Carbothermal reduction of zirconium oxide at temperatures in excess of 1450 ºC rendered higher-purity ZrB_2 than the specimens generated by atmospheric plasma fabrication approaches. The use of a liquid precursor (SMP-10) successfully produced diverse polymorphs of silicon carbide. ZrB_2 and its mixture with graphite did not present significant morphological changes after exposure to ultrahigh temperatures; however, ZrO_2 peaks of reduced intensity were detected in their XRD patterns. SiC from SMP-10 produced a glassy sintered byproduct, while commercial SiC did not suffer any changes. Carbon nanotube composite mixtures presented the largest levels of oxidation due to the presence of the Fe catalyst. Of the samples evaluated, ZrB_2 combined with graphitic matrices showed the greatest potential for ultrahigh temperature applications.

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