MATERIALS ENGINEERING SEMINAR

"Novel Ultra High Temperature Material Processing, Characterization, and Modeling"

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Purdue MSE Ph.D. Final Exam

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ABSTRACT

For many applications within the defense, aerospace, and electricity-producing industries, available material choices for high-performance devices that fulfill necessary requirements are limited. Choosing a metallic material or a ceramic material may be optimal for only some of the required properties. For instance, choosing a metal may optimize ductility but compromise oxidation resistance, yield strength, or creep resistance. Of potential interest, ceramic-metal (cermet) composites can address several fundamental concerns such as high temperature mechanical toughness and stiffness and oxidation/corrosion resistance. However, cost-effective, scalable manufacturing of complex-shaped, high-temperature cermets can be challenging.

A cermet of interest is niobium and yttrium oxide, Y_2O_3. Both materials exhibit high melting points with similar coefficients of thermal expansion. Basic thermodynamic calculations suggest that these materials are chemically compatible, and that Y_2O_3/Nb cermets may be generated by reactive melt infiltration using the potential Displacive Compensation of Porosity (DCP) process. With the DCP process, a liquid fills a porous perform, and a displacement reaction occurs to produce products of larger solid volume. This reaction yields the cermet of interest, formed in a reduced-stress condition, while maintaining a generally near net shape and high relative density.

In order to get to the point of designing cermet components for various applications, a focus of this work has been to create a Y_2O_3/Nb composite by hot pressing powders at high temperatures at the predicted stoichiometric ratios, and then characterizing the thermal and mechanical properties. The reduction reaction between liquid yttrium and solid niobium (IV) oxide (NbO_2) was then characterized to evaluate kinetic mechanisms affecting the reaction rate which is necessary for future DCP-based cermet component manufacturing.

Lastly, the mechanical behavior of this cermet was modeled and compared to another cermet processed using liquid metal infiltration using a temperature-dependent elasto-visco-plastic self-consistent model. The effects of cooling from processing temperatures, as well as thermally cycling of these cermets, were quantified. As high temperature experiments can be time intensive with high costs, it is advantageous to have a computationally efficient, desktop design tool to quantify the impacts of changing processing and use conditions on material performance.

Date: Thursday, July 6, 2023
Time: 12:00 P.M. (noon)
Place: ARMS 1021 or via link:
https://purdue.webex.com/meet/sandhage?_ga=2.7481778.1263977867.1687271301-1119626400.1668028656

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