Nano-Scale Interpenetrating Phase Composites for Industrial and Vehicle Applications

Nano-scale interpenetrating phase composites (IPC's) have been previously demonstrated at the lab scale (both in the literature and at Oak Ridge National Laboratory) with co-continuous structures consisting of both metal and ceramic phases of nano-scale size. These materials have a characteristic length scale associated with the contiguous phases to create a structure that resembles an intertwined network of micro/nano fibers of the various constituents leading to a novel class of structural or functional materials. Thin film lab scale IPC's have been produced which show increased mechanical, electrical, and thermal properties through alteration of microstructure, choice of preforms (composition and structural characteristics), introduction of additional elements, and choice of processing temperatures and times. Current and previous work has used low or room temperature approaches such as electrochemical metal infiltration of a metal into a nanoporous ceramic substrate or electroless infiltration of a metal into a compaction of nanostructured ceramic powders. Yet, these methods are limited by difficulties in infiltrating the preform due to low wetting between the metal and ceramic phases and inability to fill closed pores within the preform. These issues have lead to inhomogeneity in the nanostructure of the infiltrated materials and a reduction of desired performance.

This nanomanufacturing concept definition study will explore the technical and economic feasibility of producing nano-scale IPC components of a usable size for actual testing/implementation in a real application. Along with the current common low temperature processing techniques identified above, a high temperature process developed by Fireline TCON will be evaluated for development and testing of various components. This alternate process utilizes high temperature displacement reactions in which a sacrificial oxide is reduced by a metal to form a co-continuous metal/ceramic composite family of IPC materials. Actual industrial sized components have been produced by this method and shown to be effective for use in molten metal contact applications where increased abrasion/wear resistance and corrosion resistance are required. The length scale of current TCON material microstructures varies from ≈100 nm to several microns, but through preliminary work, it has been postulated that metallic additions to the microstructure (Fe, Cu, Ti, etc.) may lead to further reduction to the nanostructure size range. Additionally, further R&D will be performed by evaluating substrate choice (such as the nanoporous ceramic compactions used above) and variation in processing conditions to produce nano-scaled IPC's. Application of these materials would be in high wear/corrosion resistant refractory shapes for industrial applications, lightweight vehicle braking system components, and in lower cost/higher performance military body and vehicle armor.

Project Partners:

Oak Ridge National Laboratory
Oak Ridge, TN
Principal Investigator: James Hemrick
(hemrickjg@ornl.gov)

Fireline TCON, Inc.
Youngstown, OH

For more information contact:
EERE Information Center
1-877-EERE-INF (1-877-337-3463)
www.eere.energy.gov

U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy

March 2009