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Demonstrating Industrial Readiness of GARS-based ODS Ferritic Alloys for Stability in Extreme Environments.

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ABSTRACT:

Austenitic stainless steel (316L) alloys and tool steel (D9) alloys have historically been used as duct material in reactor applications but suffer from irradiation assisted stress corrosion cracking (IASSC) and void swelling at high doses. Ducts made of an alternative tool steel (HT-9) show much better swelling resistance where very little swelling was observed up to 155 dpa. However, for the more challenging radiation conditions and temperatures of advanced reactors, new materials with improved tolerance to swelling and other irradiation effects are required, especially at elevated temperatures. Ferritic stainless steels are more resistant to stress corrosion cracking and suffer less swelling than austenitic steels and many tool steels, while maintaining oxidation resistance that is superior to zircaloy. Furthermore, high temperature creep resistance and radiation tolerance of ferritic alloys can be improved by the addition of ODS particles that precipitate as highly stable nano-clusters with proper processing. ODS ferritic alloys cannot be made by conventional melt/solidification processing due to the requirement to maintain well-distributed, but spatially dense nanoscale oxide dispersions. The current method for fabrication of ODS alloy materials consists of making and blending multiple powder types and long-duration (at least 40 hours) mechanical alloying by high energy ball-milling in inert atmosphere. Conventional tube or sheet manufacturing processes, when applied to MA-type ferritic ODS alloys can result in microstructures with anisotropic mechanical properties from alignment of stringers of coarse oxides and led to an expensive, inhomogeneous material with little commercial acceptance that was largely withdrawn from the marketplace in spite of its special performance potential in fission reactors for power generation.

This Phase II project seeks to build upon our promising Phase I results to establish a clear pathway to scale up our gas atomization reaction synthesis (GARS) ODS ferritic stainless steel powder processing to produce bulk shapes of ODS ferritic steel by high capacity thermal-mechanical processing (TMP) and to enable rapid development and adoption of this material with improved high temperature performance, increased reliability, and reduced lifetime costs by U.S. industry for use in nuclear applications. This will be accomplished by investigating industrial scale processing, i.e., vacuum hot pressing (VHP) of GARS precursor powders and warm forging of the VHP compacts that is followed by subsequent heat treatment and characterization of the material performance. The objectives are to: 1.) Demonstrate transferability of promising lab-scale Phase 1 results to industrial operations, 2.) Determine appropriate industrial workflows and processing conditions that could lead to rapid adoption of GARS-based ODS ferritic steels, 3.) Characterize as-produced and as-irradiated materials to determine performance under extreme environments, and 4.) STRETCH goals are to continue working with a US nuclear power industry partner (Westinghouse Electric Co) to test capability of pilgered tube processing of GARS powders from VHP compacts and with a US powder manufacturer, Linde Advanced Material Technologies (AMT) Inc. (formerly Praxair Surface Technologies), to adopt methods relevant to industrial production of GARS precursor powder feedstocks. The success of this proposed project would enable validation of GARS-based ODS alloy performance under extreme temperature and irradiation environments using industrially relevant manufacturing methods to enable a new generation of structural materials for nuclear reactors that could operate at higher temperatures and have longer lifecycles. This will improve US competitiveness and advance U.S. nuclear technologies to meet our growing energy needs.