Nanodispersion Strengthened Metallic Composites with Enhanced Neutron Irradiation Tolerance

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Program: NSUF 1.2 for R&D support with NSUF Access

ABSTRACT:
We will develop and study irradiation-tolerant, nanodispersion-strengthened composite structural materials by innovative manufacturing methods. These nano-composites have prolific internal interfaces between 1D/2D nanodispersoids and the metal matrix; therefore they provide abundant radiation defect recombination venues to rapidly heal radiation damage. We also discovered that 1D/2D nanodispersoids in metal lead to significantly higher creep strength, as dislocations cannot climb over 1D/2D extended obstacles. We have previously developed industrially scalable metal-nanodispersion composite materials. Our *heavy ion* radiation experiments have demonstrated their superior radiation tolerance up to ~100 DPA. In this project, we will confirm their neutron irradiation tolerance (including microstructural and mechanical response to neutron irradiation), and reveal the mechanisms by which radiation defects are absorbed by the interfaces introduced by 1D/2D nanodispersoids. Post-irradiation examination (PIE) of microstructural evolution near these interfaces will provide critical information about the interface strength in terms of radiation defect sinks. Mesoscale simulations of the interactions between radiation defects, dislocations, and different types of interfaces will be performed as theoretical support. This study will provide insights on the role of 1D/2D nano-fillers to improve radiation resistance, enabling better understanding of irradiation damage and its prevention at the nanoscale. The success of this work will guide the design of economical manufacturing methods for advanced nuclear structural materials with enhanced radiation resistance and higher safety margins. Our research combines fundamental studies in radiation materials science with industrialized, low cost manufacturing techniques; thus, it fits well into INL's strategic area of Advanced Nuclear Energy.

Deliverables and Outcomes: We will deliver prototype metal (Al, Zr, and Fe) + 0D/1D/2D nanodispersions (0D oxide, 1D carbon nanotube, oxide and carbide nanowires, and 2D graphene) of fuel cladding and reactor core materials with vastly improved neutron irradiation resistance. The research results of the proposed project will be published as several papers in peer-reviewed, high impact journals.

Research Plan: **(1)** In Yr 1, we will produce metallic nanocomposites with uniform intraganular nanodispersions through the surface diffusion-driven cold welding. Microstructure characterizations and mechanical testing will be performed in all the samples as prepared. Radiation tests will be planned. **(2)** In Yr 2, the neutron radiation will be performed in ATR to targeted doses. ATR neutron irradiation is crucial for predicting the performance of our materials in an actual reactor environment. **(3)** After the irradiated samples have cooled down, their microstructural evolution will be characterized in composite and reference samples. **(4)** We will test the mechanical properties of irradiated nanocomposites using uniaxial tensile tests, and compare to unirradiated control samples. *In situ* mechanical testing in a SEM at INL's IMCL will be used to measure the tensile properties of neutron irradiated nanocomposites and reference materials.