U.S. DEPARTMENT OF ENERGY
NUCLEAR ENERGY RESEARCH INITIATIVE
ABSTRACT

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Institution: **Pacific Northwest National Laboratory**

Collaborators: **General Electric Corporate Research, University of Michigan, Washington State University, Framatome-France**

Title: **Novel Concepts for Damage-Resistant Alloys in Next Generation Nuclear Power Systems**

The successful development of next generation nuclear power systems must address and mitigate several materials degradation issues that now strongly impact existing light water reactors (LWRs) and that will limit structural materials performance at the more aggressive radiation exposures envisioned for various advanced reactor concepts. Although previous fast reactor and fusion device programs have focused on the development of improved structural materials for their relevant conditions, there has been no comparable effort directed toward the conditions unique to LWRs. Novel, non-traditional approaches are necessary to create durable damage-resistant alloys and establish the foundation for advanced reactor designs. Proposed research will develop and test two new damage-resistant alloy concepts that offer strong promise to delay or eliminate the time-dependent evolution of hardening, stress corrosion cracking, void swelling and embrittlement in reactor core components. Materials design will be based on mechanistic understanding of radiation damage and use two fundamental approaches: (1) lattice perturbation to catalyze defect recombination and (2) controlled defect manipulation through dynamic metastable microstructures. The intrinsic ability of the host matrix to resist displacement damage survival will be optimized in the first concept. This approach involves the introduction of two classes of "oversized" elements that interact with point defect migration and reduce their detrimental impact on microchemical and microstructural evolution. One novel "oversize" approach is the addition of small amounts of inert solutes such as Pt and Os, already demonstrated to significantly improve environmental cracking resistance. The second "oversize" approach focuses on reactive solutes such as Hf and Zr that showed promise in earlier studies to reduce segregation and void swelling, but were limited by precipitation reactions. Dynamic metastable microstructures tailored to resist damage accumulation will be investigated and optimized in the second concept. Unique intermetallic second phases with inherent instabilities under irradiation will be used to create a dynamic microstructure resistant to radiation hardening, swelling and embrittlement. A key aspect of designing this dynamic microstructure will be to ensure the complex, radiation-induced changes do not promote environmental cracking.

The proposed research strategy capitalizes on unique national laboratory, industry and university capabilities to generate basic material science results with immediate impact to next generation nuclear power systems. This proposed work will be integrated with fundamental research funded

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by the DOE Office of Basic Energy Sciences (BES) at Pacific Northwest National Laboratory (PNNL) and with focused international projects funded at PNNL, General Electric Corporate Research & Development Center (GECRD) and University of Michigan (UM). This leveraged approach will facilitate the revolutionary advances envisioned in NERI by creating a multi-faceted effort into the basic and applied science necessary to drive mechanistic understanding and promote development of next generation materials that meet advanced reactor performance goals.