INTERNATIONAL NUCLEAR ENERGY RESEARCH INITIATIVE

Enhanced Radiation Resistance through Interface Modification of Nano-Structured Steels for Gen IV In-Core Applications

PI (U.S.): Todd Allen, University of Wisconsin, Madison (UW)

PI (ROK): Jinsung Jang, Korea Atomic Energy Research Institute (KAERI)

Collaborators: Texas A&M University (TAMU), Seoul National University (SNU)

Project Number: 2009-002-K

Program Area: AFC R&D

Project Start Date: October 2009

Project End Date: September 2012

Project Abstract

International collaborative research of three years is will be conducted through collaboration among UW, TAMU, and KAERI in collaboration with SNU to investigate the enhancement of the radiation resistance of in-core candidate materials for Gen IV reactors. Although austenitic stainless steels have good high-temperature mechanical properties, fair compatibility with various coolants, and abundant field experience that is captured in material's databases, they are restricted from applications as certain high dose in-core components of future nuclear reactors due to their poor radiation resistance, specifically to swelling and possibly to brittle failure at lower temperatures.

In this project, nanocrystalline austenitic steels created by equal channel angular pressing (ECAP) of an Fe-14Cr-16Ni alloy, are suggested to improve the radiation resistance of austenitic steels with the radiation resistance attributed to a reduced grain size and drastically increased grain boundary area, with high angle grain boundaries acting as sinks for radiation-induced point defects. Grain boundary engineering will be also pursued to modify and improve the grain boundary character distribution to reduce radiation-induced cavity growth as well as to improve the interface related properties, such as high-temperature mechanical properties. To estimate the radiation resistance of the ECAP processed and grain boundary engineered alloys, helium and proton irradiation tests will be conducted for temperatures up to 600°C. The effects of nano-sized precipitates in HT-UPS steels and nano-sized oxide dispersoids in oxide dispersion-strengthened alloy with the nanocrystalline and grain boundary engineered austenitic steels will be also investigated.

For the characterization of the nanocrystalline, grain boundary engineered, and ion irradiated samples, researchers will utilize x-ray diffraction, differential scanning calorimetry, various electron microscopy techniques to include FE-SEM, HRTEM, STEM/EDS/EELS, and analytical techniques with neutron sources such as high resolution powder diffraction and small angle

neutron scattering. Nanoindentation techniques, bulge tests, and high-temperature tensile tests will be also conducted to evaluate the mechanical behavior of the samples.

For these studies, participating organizations from the United States and the Republic of Korea will contribute relevant expertise and facilities to the research team to investigate the fundamental mechanisms of grain boundary enabled radiation tolerance. The optimal conditions of material and processing will be established for enhanced radiation resistance without compromising mechanical properties or compatibilities. After screening with ion irradiation tests of nanocrystalline alloy samples with optimum performance, a proposal will be submitted to the Advanced Test Reactor National Scientific User Facility program to evaluate the neutron irradiation resistance of the materials.