Advanced Characterization of Low-dose Neutron Irradiated T91 and HT9 Alloys

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ABSTRACT:

The radiation-induced microstructural modifications significantly change the mechanical properties of reactor structural materials. Therefore, understanding the microstructural evolution and its effects on the degradation of mechanical properties is crucial to the development of advanced alloys that can be employed in future nuclear systems. At low dose, in particular, information about the initial formation and growth of radiation-induced microstructural modifications is a valuable reference for the establishment of a reliable theory or even a model that accounts for the defect evolution at very early stages of development. To help accomplish this goal, quantitative microstructural characterizations must be completed for various types of alloys and test specimens from the simplest pure iron to the most complex ODS alloy with various radiation temperature and dose conditions. In previous projects, we have compeleted the neutron irradiation of a well-designed matrix of samples as well as the PIE of some model alloys. In order to expand the database we have been developing for years, the focus of this project is the PIE of two commercial alloys, T91 and HT9, representatives of 9w%Cr and 12w%Cr ferritic-martensitic steels, which have been exposed to multiple irradiation conditions.

In this work, good use will be made of the unique capability of the Microscopy and Characterization Suite (MaCS) at the Center of Advanced Energy Studies (CAES) to accomplish our experimental objectives. The irradiated samples will be accessed from the Hot Fuel Examination Facility (HFEF), then decontaminated and prepared in the Electron Microscope Laboratory (EML). Scanning transmission electron microscope, STEM, will be employed to characterize the type, size and density of dislocation loops, dislocations and bubbles/voids. The radiation-induced segregation and large-scale precipitates such as carbides will also be measured by the analytic function of the STEM. The Local Electrode Atom Probe (LEAP) will be applied to quantitatively measure the evolution of the nano-scale precipitates such as α' and G phases. The atom probe tips will be manufactured by the focused ion beam (FIB). As all these microstructural modifications affect the mechanical properties of the irradiated samples. The neutron-irradiated samples are usually small in size, limiting the ability to perform conventional mechanical properties measurements. Therefore, the nanoindenter will be used to obtain the elastic modulus and nanohardness of all sample conditions. All the data will be carefully analyzed to correlate the microstructure changes with the alteration in mechanical properties. The results will not only reveal the microstructure-property relationship in commercial high Cr-content ferritic-martensitic steels due to neutron irradiation exposure, but also expand the neutron irradiated Fe-Cr base alloy database that will guide the development of prospective advanced ferritic-martensitic steels that are qualified for future nuclear applications.