Feasibility of Combined Ion-Neutron Irradiation for Accessing High Dose Levels

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ABSTRACT:

There have been significant discussions and conference presentations among utilities, the regulator, the US DOE and industry suggesting the application of ion irradiation to neutron irradiated samples to reach higher dose levels relevant to LWR core components. As light water reactors age, the dose levels of key core structural components (baffle former bolts, flux thimble tubes, springs, core shroud, etc.) are reaching levels at which little data exist. To ensure integrity of these components as well as to consider the possibility of a second life extension to 80 years, or a third to 100 years, it will be critical to know what to expect regarding the behavior of relevant alloys at such high doses.

Ion irradiation is playing an increasingly important role in understanding radiation effects in LWR core structural materials. In 2002, the first comprehensive study on the capability of proton irradiation to emulate the irradiated microstructure, radiation hardening and irradiation-assisted stress corrosion cracking (IASCC) susceptibility was published, and demonstrated excellent agreement on all aspects of the microstructure and resulting properties. It has recently been shown that self-ion irradiation at very high dose rates can mimic the fast reactor-generated microstructure in ferritic-martensitic alloy HT9. To determine whether re-irradiating existing neutron-irradiated alloys with ions can achieve microstructures identical or similar to those induced by neutron irradiation alone, stainless steels that are previously irradiated in a reactor to both low and high doses, and for which a characterization of the neutron-irradiated microstructure already exists, are selected. Low dose samples will be re-irradiated using ions to achieve the dose level that matches the high dose samples. Post irradiation examination (PIE) of the ion re-irradiated samples will be conducted to determine whether the irradiated microstructure, irradiation hardening, as well as irradiation-assisted stress corrosion cracking (IASCC) agree with those of the high dose neutron samples.

The objective of this proposal is to assess the feasibility of re-irradiating existing neutron irradiated alloys 304SS and 316SS to high dose levels using ion irradiation, for the purpose of achieving high dose microstructures that represent those from reactor irradiation to those doses. The success of this project would enable the community to evaluate material response at high dose using the existing inventory of reactor-irradiated materials in support of life extension of the current fleet of light water reactors, and the development of high dose radiation-resistant materials for the next generation fast and future fusion reactors.