The Use of Neutron Irradiation Preconditioning Followed by Self-Ion Irradiation to Characterize the Irradiation Response of Nuclear Reactor Structural Materials

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ABSTRACT:

The proposed work has the primary objective of determining the value of neutron preconditioning (defined as neutron irradiations followed by ion irradiations at a similar irradiation temperature) as a tool to characterize high dose irradiation effects in material development programs for fast and light water reactor core structural materials applications. As a side effect of this work, pure ion irradiations as a characterization tool will also be assessed. There is a strong need within the US-DOE transmutation fast reactor program and also within industry to select fuel clad and duct materials that will be resistant to irradiation doses of 300+ dpa, and advanced LWR concepts are also considering an entirely new class of core support materials. Both require substantial amounts of radiation effects characterization to determine an appropriate material. Currently, ion irradiations are considered the only way to achieve doses beyond ~50 dpa in a practical time frame relevant to an alloy development program. However, there is uncertainty as to whether ion irradiations can be sufficiently effective at characterizing the response of materials to high dose neutron irradiation. There are numerous studies underway to assess the viability, but other options that could replace or supplement pure ion irradiations should be explored in parallel. As a means to try to ensure that neutron-relevant microstructures are produced during ion irradiations, materials can first be neutron irradiated to lower doses to generate the correct starting microstructure and especially microchemistry. This procedure is known as neutron preconditioning. Although the concept is not new, there has never been a detailed systematic study to assess how well it works, and the prior studies were performed using outdated ion irradiation techniques that focused only on void swelling. It is envisioned that neutron preconditioning would not replace pure ion irradiations, but rather it would supplement it, and a comprehensive alloy development program would use pure ion irradiations, pure neutron irradiations, and neutron preconditioning followed by ion irradiations as tools to characterize high dose radiation resistance. The important question is how much closer neutron preconditioning microstructures are than ion irradiations to that of pure neutron irradiations. To determine the value of neutron preconditioning for a comprehensive alloy development program using modern ion irradiation and microstructural analysis methods, an in-depth experimental comparison of the effects of pure ion irradiation, neutron preconditioning, and pure neutron irradiation would be performed on the microstructure on tempered ferritic-martensitic (TFM) steels and oxide dispersion strengthened (ODS) ferritic alloys that are relevant to advanced fast reactor and LWR concepts. Recommendations on the value of preconditioning and how to integrate it into an alloy development program will be made.