Re-irradiation of Flux Thimble Tubes Using Heavy Ions

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Abstract:

Flux thimble tubes (FTT) made of cold-worked 316 stainless steel were removed after service for 34 years from a PWR after reaching a maximum damage level of ~100 displacements per atom (dpa). Specimens were extracted from varying axial locations on the FTT to obtain specimens with nominal dpa values of ~0, 38, 72, and 100. The estimated temperature was within 300~320°C range. Comprehensive microstructural characterization was performed for irradiation-induced features on the reactor irradiated specimens, including dislocation loops, nano-cavities, radiation induced clusters and radiation induced segregation (RIS).

An ion irradiation with 9 MeV Ni^{3+} was performed on the 0 dpa sample to a damage level of 38 dpa at 410°C with a damage rate of 8×10^{-4} dpa/s to evaluate the effectiveness of ion irradiation in emulating reactor radiation. The elevated temperature of the ion irradiation was completed to compensate for the increased dose rate compared to the reactor irradiation. The dislocation loops and radiation-induced segregation in the ion irradiated samples matched well with that of the 38 dpa sample irradiated in reactor. The Ni-Si clusters in the ion-irradiated sample were slightly larger than those in the reactor irradiated sample, and nanocavities were absent in the ion irradiated specimen due to the lack of concurrent helium injection. With these preliminary results, ion irradiations were then performed on the reactor-irradiated 38 dpa specimen at different temperatures (390°C and 410°C). A damage level of 34 dpa was added for a combined damage level of 72 dpa. Systematic characterization was performed on the ion-irradiated specimens. The results are compared with the reactor irradiated specimen at 72 dpa to determine the best temperature to capture all the microstructural features including nanocavities, loops, RIS, and clusters/precipitates.