Effect of Helium on Swelling and Bubble and Cavity Evolution in Dual Ion Irradiated HT9 Steel

David Woodley[1]
Zhijie Jiao[1]
Kai Sun[1]
Gary Was[1]

[1]University of Michigan, 2355 Bonisteel Blvd, Ann Arbor, MI 48109

With the transition to the next generation of nuclear reactors, the environment within the core that structural materials will be exposed to will become more extreme. Ferritic-martensitic steels are leading candidates for use in these designs due to their improved resistance to radiation damage, especially swelling at high damage levels. However, the process of cavity nucleation and growth is not well understood but is known to be influenced by temperature, other microstructural features and helium generation from transmutation reactions. Dual ion irradiations were performed at the Michigan Ion Beam Laboratory on alloy HT9. A defocused 5 MeV Fe^{++} beam and a degraded ~2 MeV He^{++} beam were used for irradiations to a damage level of 188 dpa at 460℃ with helium-to-dpa ratios of 0, 0.06 and 4 appm He/dpa and at several damage levels up to 650 dpa at 460℃ at a helium-to-dpa ratio of 4 appm He/dpa. Without the addition of helium, a unimodal distribution of cavities developed. With the addition of a small amount of helium, a bimodal distribution developed with both bubbles and cavities clearly visible. With increasing helium, the densities of both bubbles and cavities increased. The effect on average size was more complicated with an increase in the average bubble size, but a decrease in the average cavity size. The combined effects of these processes are most clearly understood by examining the different stages of irradiation. At low damage levels during incubation, the predominate driver of swelling is the cavity density. At high damage levels after the onset of growth-dominated swelling, the predominate driver of swelling is cavity size. This leads to the effect that at low damage levels, higher helium-to-dpa ratios result in higher swelling while at higher damage levels, the highest swelling is observed for the case with no helium. The bubble and cavity evolution depends on both He content and dpa. The dependences will be presented and discussed.