Microstructural evolution after helium pre-implantation and self-ion irradiation on a dual-phase 12Cr oxide dispersion strengthened alloy

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Ferritic-martensitic oxide dispersion strengthened (ODS) alloys are promising candidate materials for advanced reactors due to their superior swelling resistance and high temperature creep resistance. Stability and morphology changes of the dispersed oxide particles under reactor irradiation are an especially important concern. Since void swelling occurs at high damage levels, it remains unclear whether void nucleation and oxide particle stability, dissolution and regrowth are correlated. In this study, 120 keV helium ion implantation at two different levels, differing by a factor of ten, was conducted at room temperature to induce early void nucleation. The helium-preloaded ODS alloys were then irradiated by Fe^{+2} self-ions to 100 peak dpa at 475°C to simulate neutron damage.

Oxide particle morphology was characterized using transmission electron microscopy. Comparisons were made between the helium-loaded and not-loaded regions in tempered martensite phase. The study shows the complexity of interactions between defect clusters and oxide particles. At the lower helium implantation level, small size helium bubbles promote void nucleation under Fe irradiation, forming small helium-vacancy clusters. Those clusters further attract oxygen solutes, and Ti and Y solutes are sequentially attracted due to high oxygen affinity. When the solute concentration reaches critical level, oxide particle is nucleated, leading to increased oxide particle density in the helium-enriched regions. For higher level helium implantation, however, the oxide particle density is reduced, because the larger he bubbles result in larger surface area of helium-vacancy clusters, which makes it hard to reach critical concentration level for oxide particle to be nucleated. The study is important to reveal the synergistic effects between void swelling and oxide particle stability when helium bubbles are present in ODS systems.

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