HIGH DOSE NEUTRON IRRADIATION-INDUCED MICROSTRUCTURE EVOLUTION IN PM2000 AND MA957 ODS STEELS

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Oxide Dispersion Strengthened (ODS) steels are candidate materials for the cladding-duct structures in Gen. IV sodium-cooled fast reactors and the plasma-facing first wall of the fusion reactor where the operating conditions are unprecedented: 150-200 displacements per atom (dpa) neutron dose at elevated temperatures. The fine dispersion of nano-oxides in the ODS steels enhance their high temperature creep strengths by blocking dislocation glide/climb and by pinning grain boundaries which makes grain boundary sliding difficult. Further, the interface of these particles with the matrix act as traps for the point-defects (PDs), thereby enhancing the PD recombination rates and improving the irradiation tolerance. With decades of research into optimizing the chemistry/processing routes of ODS steels, numerous alloy variants have emerged internationally. It is now well-accepted that the stability of the nano-dispersoids under irradiation will ultimately control the in-service alloy performance. Several ion irradiation studies show that the dispersoid stability is affected at lower irradiation temperatures where they can be ballistically dissolved, while elevated temperature (T>300-350 °C) favors their re-formation. However, understanding the consequences of irradiation damage occurring in a fusion or fast-fission system requires exposing the ODS alloys to relevant neutron irradiations. Two well-known ODS variants, (i) 14%Cr based MA957 and (ii) 20%Cr-5.5%Al based PM2000 were irradiated in the High Flux Isotope Reactor (HFIR) to doses > 50 dpa (~10 years in HFIR) at 300°C. The irradiation temperature was specifically chosen to be within the regime where ferritic steels suffer irradiation-induced embrittlement (T< 350°C). Using state-of-art conventional and analytical scanning transmission electron microscopy (STEM), high-throughput energy dispersive X-ray spectroscopy (STEM-EDX), energy-filtered TEM and atom probe tomography (APT) techniques we will reveal the differences in the evolution of the irradiation-induced defects like the dislocation loop microstructure with focus on irradiation-induced segregation on the loops, the distribution of the embrittling Cr-rich α’ phase and insights into the dispersoid behaviour during this long-term neutron exposure.

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