Effect of Helium on Tensile Properties and Microstructure in 9%Cr-WVTa Steel After Neutron Irradiation to 10 15 dpa Between 250 and 450 °C

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Reduced activation martensitic ferritic (RAFM) 8-10Cr-WTaV steels not only offer favorable radiological properties, they also show much less irradiation induced hardening and embrittlement below 400 °C compared to their conventional counterparts, as recent investigations up to about 40 dpa have revealed. However, the negative impact of helium on irradiation embrittlement and its magnitude at different irradiation temperatures is despite various studies still a matter of significant uncertainty. As high energy accelerators are no longer available for a homogeneous implantation of helium in sufficiently thick specimens that allows representative mechanical tests after irradiation, doping with $^{10}$B and $^{nat}$B was used in this study for the helium production to distinguish directly between the B-doping and the helium effects. Four 9Cr-1WTaV heats (EUROFER composition) with <10 wppm $^{nat}$B, 82 wppm $^{nat}$B, 83 wppm $^{10}$B and 1160 wppm $^{10}$B have been irradiated at the mixed spectrum reactor HFR Petten to a damage dose of 15 dpa at 250, 300, 350, 400 and 450 °C. The achieved Helium concentrations were <10 appm He, ~80 appm He, ~415 appm He and ~5800 appm He, respectively. The tensile tests of the standard sized specimens with 3 mm gauge diameter have been performed at a test temperature equal to the irradiation temperature in high vacuum at a strain rate of $1.4 \times 10^{-4}$ s$^{-1}$. While up to a helium concentration of 415 appm all specimens failed completely ductile at all temperatures investigated, the alloy with 1160 wppm $^{10}$B resulting in ~5800 appm He fractured always brittle. In the latter case microstructural analysis showed pronounced segregation of Boron, resulting in a highly nonuniform Helium accumulation in the vicinity of B rich precipitates and boundaries. However at much lower B contents the total elongation is above 11% even at 250-300 °C and slightly decreases with increasing He concentration (up to 415 appm). Metallographic investigations were performed at fractures and structures by means of light microscopy, scanning and transmission electron microscopy as well as hardness measurements. During the irradiation, the microstructure developed He bubbles, dislocation loops and precipitates. Relations between the fracture mode, the microstructure, and the hardening/embrittlement phenomena will be discussed.