Understanding of the chemical effects on the morphology of neutron irradiation-induced solute clusters in Reactor Pressure Vessel steels

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Reactor Pressure Vessel (RPV) steel suffered hardening embrittlement after exposed to neutron irradiation. One of the main reasons that governing the hardening embrittlement is due to the formation solute clusters. Previous studies using Atom Probe Tomography (APT) have shown that the main chemical elements that often found in these solute clusters in RPV steels are Copper (Cu), Manganese (Mn), Nickel (Ni), Silicon (Si), and Phosphorus (P). For irradiated high Cu content RPV steels, it is suggested that the Cu precipitated in an irradiated RPV steel could undergo a martensitic transformation from a fully coherent structure to a incoherent structure, i.e. BCC-3R-9R-FCC/FCT structure. The change of morphology of these copper precipitates has a direct effect on the hardening of the RPV steels. It is important to note that the detail study of the martensitic transformation of Copper precipitates were performed on Iron (Fe)-Cu alloys using Transmission Electron Microscopy (TEM).

In this study, the effects of Mn, Ni and Cu on the morphology of neutron irradiation-induced solute clusters in RPV model alloys are investigated. The model alloys were neutron irradiated at high flux to a dose of ~ 1.0 dpa at ~290 degree Celsius. A spherical aberration-corrected FEI Titan G2 80-200 with Super X Energy Dispersive X-ray (EDX) (ChemiSTEM™) operated at 200kV and equipped with a GIF Quantum 965 Electron Energy Loss Spectroscopy (EELS) has been used to provide independent analyses of the solute clusters that formed in these model alloys. A high number density of nanometer-scaled MnNi(SiCu)-rich solute clusters were observed in all model alloys. However, the morphology changes when Cu were found to be associated with the solute clusters. The detail of these findings will be further discussed.