THE EFFECTS OF IRRADIATION, ANNEALING AND REIRRADIATION ON RPV STEELS

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Atom probe field ion microscopy and atom probe tomography have firmly established that a high number density of ultrafine copper-, manganese-, nickel- and silicon-enriched precipitates are produced in copper-containing pressure vessel steels by neutron irradiation [1]. These precipitates are a primary cause of the degradation in the mechanical properties of these materials during service in a nuclear reactor. The mechanical properties of these steels may be recovered by annealing the pressure vessel at a temperature of ~450°C for a few days [2]. This annealing procedure permits the lifetime of the reactor to be extended. In this atom probe tomography study, the number density, size, and composition of these ultrafine precipitates have been studied through two irradiation and annealing cycles.

The composition of the JRQ steel used in this atom probe tomography study was Fe-0.14 wt % Cu, 0.18% C, 1.42% Mn, 0.84% Ni, 0.24% Si, 0.51% Mo, 0.12% Cr, and 0.017% P. The alloy was characterized after neutron irradiation to a fluence of 5 x 10^{23} n m^{-2} (E>1MeV) (I) and after subsequent annealing for 168 h at 460°C (IA). The alloy was also characterized after re-irradiation to a fluence of 0.85 x 10^{23} n m^{-2} (E>1MeV) (IAR). This IAR material was also given a subsequent annealing treatment of 168 h at 460 °C (IARA). All irradiations were performed at a temperature of 288°C. These alloys were characterized with the Oak Ridge National Laboratory local electrode atom probe.

Atom probe tomography revealed that neutron irradiation (I) produced a high number density of copper-, manganese-, nickel- and silicon-enriched precipitates. After annealing at 460°C (IA), the number density of these intragranular precipitates significantly decreased. Some copper-enriched precipitates were observed on a grain boundary. After re-irradiation (IAR), a high number of significantly smaller copper-enriched precipitates was observed. The high number density of ultrafine copper-precipitates was not observed after the second annealing treatment (IARA). However, some larger copper-rich precipitates were observed. Phosphorus segregation was also observed at dislocations. Full details of the size, number density and composition of the precipitates in the different conditions will be presented.

Research at the Oak Ridge National Laboratory SHaRE User Center was sponsored by the Division of Materials Sciences and Engineering, U.S. Department of Energy, under contract DE-AC05-00OR22725 with UT-Battelle, LLC and by the Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission under inter-agency agreement DOE 1886-N695-3W with the U. S. Department of Energy.

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