Micro-tensile testing for grain boundary fracture in neutron-irradiated stainless steels

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Irradiation assisted stress corrosion cracking (IASCC) is one of the important issues on nuclear power plant aging management for pressurized water reactors. IASCC initiation threshold stress is an important parameter to predict IASCC initiation and it has been evaluated by constant load SCC tests in high temperature water for neutron-irradiated stainless steels. For accurate prediction of IASCC initiation, formulation of IASCC initiation threshold stress based on the understanding of the IASCC mechanism is necessary. According to the current understanding of the IASCC mechanism, decrease of grain boundary (GB) cohesive strength due to neutron irradiation and corrosion and stress concentration at GBs due to radiation-induced deformation localization might be the important factors for IASCC initiation. In the present study, effects of neutron irradiation on GB cohesive strength was investigated by micro-tensile testing for cold-worked 316 stainless steels neutron-irradiated up to a maximum of 73 dpa.

Micro-bicrystal tensile specimens, typically 8×4×2 μm in size, containing a high angle GB were fabricated by focused ion beam (FIB) micro-processing from stainless steel samples neutron-irradiated to the doses from 12 to 73dpa. The GBs were set at the center of the specimens and perpendicular to the tensile axis. Two slits were introduced from both sides of the specimens and then the cross section of the GBs reduced to 0.3×2 μm to apply a higher stress than elsewhere and to constrain plastic deformation around the GBs during the tensile tests. The specimens were tension tested in a vacuum at room temperature in the FIB-SEM system. After the specimens failed, SEM/STEM fractography was conducted to examine the fracture behavior.

Fully intergranular fracture was confirmed for the specimen that was fabricated from 73dpa irradiated sample, whereas the specimens that were fabricated from unirradiated and 12dpa irradiated samples fractured in the matrix. The specimens for intermediate doses showed partial intergranular fractures. The fracture stress of the 73dpa irradiated specimen was 2600MPa, and the fracture stress increased as the dose decreased. It is confirmed that neutron irradiation weakens GB cohesive strength. The decrease of GB cohesive strength might be attributed to radiation-induced microstructure and microchemistry changes.