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Isolation of Radiation-Induced Segregation in Proton-Irradiated Austenitic Stainless Steels

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Microstructural effects (radiation hardening) and microcompositional effects (radiation-induced segregation (RIS)) have both been identified as potential contributors to irradiation-assisted stress corrosion cracking (IASCC). However, the role of either in IASCC is unclear. Potentially, if either can be removed preferentially, then microchemical and microstructural changes created during irradiation may be separated and thus their roles in IASCC isolated. Post-irradiation annealing at intermediate temperatures (400-650°C) has been investigated as one method of separating RIS from irradiation hardening in proton-irradiated high-purity 304L and commercial-purity 304 stainless steels. Model simulations of post-irradiation annealing indicate that microstructural features such as dislocation loops are removed faster than RIS. Simulations also predict that there exist time-temperature combinations that will significantly reduce the dislocation loop population while leaving the grain boundary segregation essentially unaffected. Samples of high purity and commercial purity stainless steels have been irradiated with 3.2 MeV protons at 360°C to 1.0 dpa and then annealed at temperatures between 500°C and 650°C for times varying between 45 minutes and 5 hours. Hardness, RIS, and dislocation densities were measured before and after annealing. The hardness and dislocation densities decreased with increasing annealing time and temperature while the amount of RIS did not change significantly from the pre-annealed condition for anneals up to 600°C for 90 minutes. Annealing at 650°C for 45 minutes removed the irradiation-induced hardness and dislocation population entirely, while only 33% of the as-irradiated RIS remained. However, annealing at 600°C for 90 minutes completely removed the microstructural changes while leaving 83% of the RIS. The rate of removal of both dislocation loops and RIS during post-irradiation annealing is in agreement with model simulations and experimental data from similar studies. The separation of microstructural and microchemical effects after annealing at 600°C for 90 minutes may permit the isolation of the role of RIS in IASCC.

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