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CONCURRENT AND SEQUENTIAL HYDROGEN ISOTOPE IMPLANTATION AND SELF-ION IRRADIATION IN NICKEL

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Microstructural changes associated with radiation damage are fundamental factors influencing the lifetime of structural materials used in nuclear reactors. Materials for fusion reactors will be exposed to high energy neutrons that result in atomic displacement cascades and transmutation reactions which may produce significant quantities of gaseous elements including hydrogen. Plasma facing materials will also be exposed to high flux, low energy plasma ions including hydrogen isotopes. Neutron and ion irradiation induced materials property degradation has been seen to accelerate in the presence of hydrogen; however, the mechanisms involved and the role that hydrogen plays are not well understood.

In this study, nickel was irradiated with 10 keV D^+ to a total fluence of 2.3 x 10^{17} D^+/cm^2 and 3 MeV Ni^{3+} to a total fluence of 6.2 x 10^{14} Ni^{3+}/cm^2 (resulting in approximately 4 dpa total). The self-ion irradiation and gaseous implantation was performed sequentially, in both forward and reverse order, as well as concurrently, followed by post-irradiation annealing. The experiments were conducted at the In-situ Ion Irradiation TEM facility at Sandia National Laboratories, where a 6 MV Tandem accelerator and a 10 kV Colutron ion accelerator are connected to a TEM, and the evolution of radiation-induced defect structures were monitored in real time through video recordings. Such experiments provide insight into mechanisms involved in irradiation induced defect evolution and the associated effects of hydrogen isotopes.

In all sequences of self-ion irradiation and hydrogen isotope implantation, nanometer sized dislocation loops were created. These loops exhibited no statistical difference in the size and distribution with irradiation sequence and no cavity formation was seen in any case at room temperature. These preliminary results suggest that hydrogen isotope implantation at room temperature has little or no effect on the final defect structures that result from self-ion irradiation, regardless of the sequence of irradiation. The experimentally characterized defect structures observed during irradiation and gaseous implantation will be fed to multiscale models to better understand the role that hydrogen plays in mechanical property degradation of nuclear reactor materials.

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