Evaluating Proton Irradiation for Simulating Early Neutron Damage in F/M Steels Using Positron Annihilation Spectroscopy

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Abstract. This study investigates microstructural changes in ferritic/martensitic steels subjected to irradiation. The studied materials include the commercially used 9Cr1MoVNb ferritic/martensitic (F/M) steel T91 and the modern Chinese reduced activation 10Cr1.5W steel SIMP. Both steels were exposed to three radiation environments: neutron irradiation at 260 ± 20 °C and damage level of 0.12 dpa; and proton implantation at room temperature (RT) and 300°C with corresponding damage levels of 0.02. The aim was to compare the radiation response of these materials and to address the feasibility of using proton implantation to simulate neutron-induced damage. Following standard gamma spectrometry to assess post-irradiation activity, the materials underwent microstructural characterization using positron annihilation spectroscopy (PAS). This evaluation revealed superior radiation resistance of SIMP, except low-temperature proton implantation. The results highlighted the influence of temperature on defects mobility and their recombination, as well as the potential stabilization of vacancies by hydrogen. Proton implantation at low temperature was shown to be suitable for simulating fusion-relevant neutron damage in terms of vacancy defect production compared to fission neutron-induced damage.