Neutron irradiated tungsten bulk defect characterization by positron annihilation spectroscopy

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Nuclear conditions in D-T fusion reactors will produce 14 MeV neutrons that will induce damage throughout the bulk material in plasma facing components. Relatively few studies have investigated neutron irradiated tungsten plasma facing components (PFC). However, as neutron irradiation increases the trapping sites for tritium retention, it is important to characterize neutron damaged PFCs in order to correlate damage to retention. Positron annihilation spectroscopy (PAS) is a non-destructive technique that is uniquely suited to interrogate defects in bulk materials, however, analyzing radioactive samples using PAS is more challenging. Polycrystalline ITER grade tungsten samples were irradiated at nominal temperatures of 500, 800, and 1100°C by neutrons from 0.18 dpa to 0.74 dpa (displacements per atom) in the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL). A gadolinium thermal neutron absorber was used to preferentially increase the proportion of fast neutrons interacting with the specimens, in order to increase the fidelity to fusion reactor conditions. Samples were analyzed at the Safety and Tritium Applied Research (STAR) facility at Idaho National Laboratory (INL).

Positron annihilation lifetime spectroscopy (PALS) was used to investigate the size of vacancy type defects in the irradiated tungsten samples with respect to irradiation temperature. Lifetime measurements can be influenced by stray radiation emitted by the samples, however if the positron source is significantly stronger than the sample, the sample influence is mitigated. Coincidence Doppler broadening (CDB) PAS measurements provide information about the relative defect concentration for the various samples. CDB is also sensitive to the chemical state at the positron annihilation site. PAS results from these tungsten samples are compared to results from tungsten samples exposed to thermal neutron mixed spectrum (~0.3 dpa). Positron lifetime measurements show lifetimes as large as 500 ps, which is indicative of large vacancy clusters. The competition of defect production by neutron irradiation versus the defect recombination resultant in the high temperature samples is elucidated.