Positron Annihilation Spectroscopy to Better Understand Void Formation in Neutron Irradiated Fe-Cr Alloys

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Positron annihilation spectroscopy (PAS) is a powerful, non-destructive technique used to characterize the defect properties of materials. Small-sized defects, from Angstroms to approximately 30nm, can be detected at low concentrations using PAS. The positron energy can be adjusted to probe either the bulk material or sample surface, making PAS versatile for characterizing both neutron irradiated materials and ion irradiated materials. During PAS, positron trapping occurs due to a lack of protons and electrons at the defect site. The lack of protons results in lower potential energy and Coulomb repulsion, causing positrons favor these areas. Positron lifetimes increase compared to defect free materials due to the lack of electrons for the positron to annihilate with in these voids. There are two main types of PAS, Positron Annihilation Lifetime Spectroscopy (PALS) and Doppler Broadening Spectroscopy (DBS). PALS results can be correlated to defect/void size and defect type. DBS can be used to obtain information about the types of defects present and is very sensitive to defect size and concentration.

Our work focused on Doppler Broadening Spectroscopy. Several samples were irradiated at the Advanced Test Reactor at Idaho National Laboratory. These samples were irradiated at a wide range of irradiation temperatures, from 300°C to 550°C, and a variety of different doses were obtained, from 0.01 dpa to 10 dpa. We utilized DBS to develop a better understanding of defect formation in materials exposed to low doses (0.01 dpa and 0.1 dpa) at irradiation temperatures of 300°C and 450°C. The goal of this work is to develop a better fundamental understanding of the evolution of nanoscale and sub-nanoscale defect clusters in neutron irradiated Fe-Cr alloys. These defect clusters are too small to identify using other experimental microstructural analysis techniques, such as high-resolution transmission electron microscopy, and are not stable enough to identify using atom probe tomography, which makes PAS an ideal technique for this work. PAS is essential for developing a fundamental understanding of void nucleation and void incubation processes.