Optimization of Source and Shielding for an *In-Situ* Doppler Broadening Positron Annihilation Spectroscopy Instrument

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Coincidence Doppler Broadening Positron Annihilation Spectroscopy (CDB-PAS) is a powerful non-destructive tool for determining the relative defect concentration and defect chemistry in solid state materials via the total momentum acquisition in coincidence from 511keV photons in the plane normal to the detector's surface[1,2]. Here we describe the design of a gamma-induced positron source, in which the positrons are created within the material-of-interest (henceforth 'target'), thus providing signals related to the bulk defects within the target. The prototypical targets for this instrument are nuclear reactor materials (fuel rods, cladding, pressure vessel, etc.), in which neutron-induced bulk damage, especially from fast neutrons, is a considerable concern. The planned installation location for this instrument is in the East Radiography Station (ERS) of the Neutron Radiography Reactor (NRAD) at Idaho National Lab (INL).

We designed the instrument using the Monte Carlo N-Particle (MCNP) software. Neutron and photon fluxes from the NRAD east beam-line were calculated and used as input for the instrument design[3]. Neutrons entering the ERS bombard the experimental chamber which contain the target. The neutrons pass and induce damage to the target as well as interact with the thermalizer, (n,γ) converter, and reflector regions of the chamber. High energy photons from the (n,γ) conversion serve as the source of positrons via pair-production within the bulk volume of the target. The photons that result from annihilation within the target are detected by two n-type high purity germanium (HPGe) detectors.

Primary concerns for the design are to ensure adequate positron production in the target, useful signal/noise ratio at 511keV, acceptable background rate at all energies so as not to incur excessive dead time, and tolerable radiation damage from neutrons. At NRAD the target material may be irradiated continuously for ~weeks. From our designs, we expect to obtain statistically significant measurements of the S- and W-parameters by collecting the data over the course of hours, thus providing an *in-situ* measurement of void development during neutron bombardment. Construction of the apparatus as designed herein is commencing.

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