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Analysis of Irradiation-Induced Defects Using Positron Beam Techniques

In solid-state physics and materials science, positrons serve as highly sensitive and non-destructive probes for detecting vacancy-like defects. When positrons are trapped in open volume defects, their annihilation rate decreases due to the lower local electron density –this can be effectively measured by Positron Annihilation Lifetime Spectroscopy (PALS). Complementary to this, Doppler Broadening Spectroscopy (DBS) provides access to the electron momentum distribution at the annihilation site, while Coincidence Doppler Broadening Spectroscopy (CDBS) enables further insight into the chemical surroundings of such defects. This in turn allows the identification of vacancy-solute atom complexes and the detection of precipitates. While conventional techniques utilizing radioactive sources like ^{22}Na lack spatial resolution, advanced beam-based methods enable depth- and laterally resolved studies. The NEPOMUC facility at FRM II, the world's most intense positron source with up to 10^9 moderated positrons per second, supports depth-resolved and three-dimensional defect analysis.

This contribution presents an overview of state-of-the-art positron annihilation techniques, emphasizing the unique capabilities of the NEPOMUC positron beam facility. A particular focus is placed on the application of (C)DBS with a scanning positron microbeam for spatially resolved defect imaging, allowing 3D mapping of defect distributions induced by mechanical, thermal or irradiation treatments. Case studies include the characterization of materials for nuclear applications. Finally, recent advancements will be highlighting and future directions in the positron-based investigation of fusion-relevant materials will be presented.

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