Nondestructive positron beams probe damage, support safety advances in radiation environments

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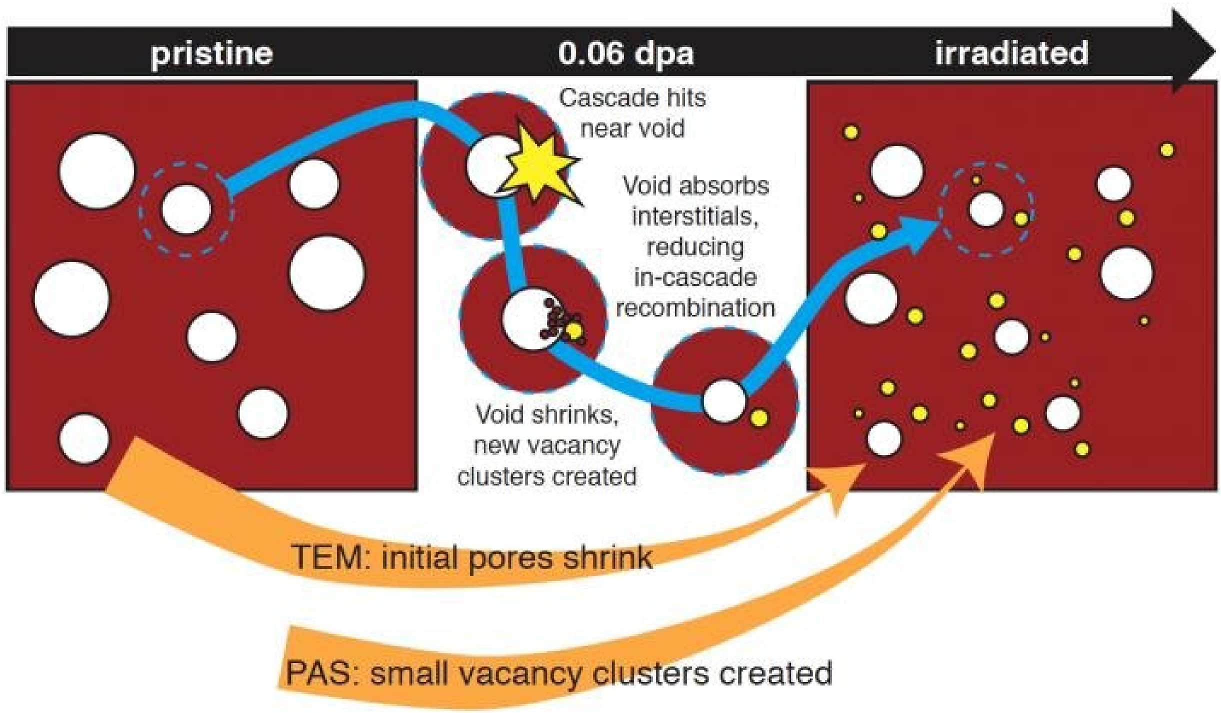

A combination of positron annihilation spectroscopy and transmission electron microscopy reveals new insights into how damage is formed in irradiated materials, suggesting a mechanism in which large holes in the material absorb atoms in interstitial positions in the lattice and shrink, but leave behind more positions that are missing atoms. Credit: Los Alamos National Laboratory.

A multi-institution team has used positron beams to probe the nature of radiation effects, providing new insight into how damage is produced in iron films. This exploration can improve the safety of materials used in nuclear reactors and other radiation environments.

"Positrons do not damage the material and they can reveal defects involving single atoms at very small concentrations," said Blas Uberuaga, a Los Alamos National Laboratory materials scientist on the project. "They are thus one of the most sensitive probes we can use to analyze radiation damage, providing critical data on the nature of the defects in the material and building our understanding of radiation effects." Positrons, a form of antimatter, annihilate when they come in contact with electrons in the material, giving information about the local configuration of atoms.

Radiation damage occurs when high-energy particles smash into materials, knocking atoms out of position and creating defects in the crystal—either positions missing an atom or an atom in between, or interstitial, positions. This collision cascade is akin to a bowling ball slamming into bowling pins, except the ball may be a neutron and the pins are atoms. The defects that are created are ultimately responsible for failure of these materials in many extreme environments such as those present in the walls and various components of nuclear reactors. Thus, it is essential to understand how defects are created and behave in the material in these environments.

With thin films of iron as a model for steel, the team used ion beams—atoms accelerated in a laboratory—to mimic the type of damage that might be created in a reactor.

These films contained a high number of voids, or pores in the material. The team then used a combination of positrons and electron microscopy to look at the material before and after the ion beam damage. By combining characterization techniques utilizing positrons and electrons, they were able to interrogate both very small and much larger defects. Specifically, they were able to elucidate new mechanisms in which the voids already present in the material modified how damage was produced during the collision cascades.

More information: S. Agarwal et al, A new mechanism for void-cascade interaction from nondestructive depth-resolved atomic-scale measurements of ion irradiation–induced defects in Fe, *Science Advances* (2020). DOI: 10.1126/sciadv.aba8437

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