NEUTRON DIFFRACTION STUDY OF GAMMA- AND NEUTRON-IRRADIATED W-Ni HEAVY ALLOY

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W-Ni heavy alloys are promising radiation-resistant materials for nuclear and plasma-facing applications, where phase stability and bulk lattice response are decisive for long-term performance. In the present work, neutron diffraction was used as the main structural method to compare the irradiation-induced changes in a W-rich W-Ni heavy alloy after gamma irradiation and neutron irradiation. The initial alloy was identified as a two-phase system consisting of dominant cubic W with space group Im-3m and secondary tetragonal WNi_4 with space group I4/m. Because neutron diffraction probes the sample volume rather than only the near-surface region, it provides a more reliable basis for evaluating bulk phase stability and lattice-parameter evolution in irradiated heavy alloys.

Neutron diffraction measurements were performed at room temperature at the Frank Laboratory of Neutron Physics, Joint Institute for Nuclear Research, using the Real-Time Neutron Diffractometer installed on beamline 6a of the IBR-2M pulsed reactor. The diffraction profiles were treated by the Rietveld method using the FullProf suite. For the gamma-irradiated series, samples exposed to 620, 1239, 2712, and 3566 kGy were analyzed. For the neutron-irradiated series, the corresponding fluence range was from 9.7×10^{12} to 3.2×10^{14} n/cm². In both irradiation series, the refined diffraction patterns confirmed preservation of the same W + WNi_4 phase composition, without evidence of a radiation-induced crystalline phase transition.

The gamma-irradiated samples demonstrated a phase-specific structural response. The main W phase showed a gradual lattice contraction, with the cubic parameter decreasing from 3.1698 Å in the initial state to 3.1681 Å at 3566 kGy, while the unit-cell volume decreased from 31.85 to 31.798 Å³. This indicates comparatively stable behavior of the W matrix and suggests that the gamma-induced structural response is mainly accommodated by point-defect formation, local relaxation, and redistribution of internal strain. In contrast, the WNi_4 phase exhibited non-monotonic and anisotropic behavior: the a and c parameters changed in different directions, and the unit-cell volume varied from 116.224 Å³ in the initial state to 116.547 Å³ at the highest gamma dose.

A different trend was revealed after neutron irradiation. The W phase expanded rapidly after the first irradiation step: the lattice parameter increased from 3.1699 Å to 3.1716 Å at 9.7×10^{12} n/cm² and then approached a quasi-saturated value of about 3.1721 Å at the highest fluence. The corresponding unit-cell volume increased from 31.85 to 31.919 Å³. The WNi_4 phase was again more sensitive, with the unit-cell volume increasing from 116.224 to 117.045 Å³, while its tetragonal axes changed anisotropically. These results show that gamma and neutron irradiation affect the W matrix differently, producing lattice contraction in the gamma-irradiated series and lattice expansion in the neutron-irradiated series, whereas the secondary WNi_4 phase remains the most structurally sensitive component in both cases.

Overall, neutron diffraction proves that the irradiation response of W-Ni heavy alloy is governed mainly by phase-dependent lattice-strain evolution and defect accumulation rather than by phase transformation. The comparative analysis also shows that the type of irradiation strongly influences the direction and magnitude of lattice-parameter changes in the W matrix, while the WNi_4 phase and phase-boundary regions act as more responsive structural zones under both gamma and neutron exposure.

Keywords: Neutron diffraction; W-Ni heavy alloy; gamma irradiation; neutron irradiation; Rietveld refinement; lattice parameters; phase stability.

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