Contribution ID: **25110** Type: **Extended Abstract**

Irradiation Dose and Temperature Effects in Tungsten Carbide Fusion Reactor Shielding

Tuesday, 4 November 2025 10:35 (7 minutes)

Compact spherical fusion tokamaks require robust neutron shielding to protect superconducting cores from radiation-induced degradation within tight spatial constraints (~50 cm). Tungsten carbide (WC) is a prime candidate shielding material due to its excellent neutron and gamma attenuation properties, but its response to neutron irradiation is not fully understood. This study examined WC's irradiation-induced lattice swelling, defect evolution, and thermal transport degradation using tungsten ion irradiation (0.13–13 dpa; 100–400 ℃). Grazing Incidence X-ray Diffraction showed significant initial lattice expansion (1.3% at 0.13 dpa, 100 ℃), decreasing with higher temperatures and doses, ultimately transitioning to lattice contraction at high dose (13 dpa). Transmission Electron Microscopy and FIB-SEM revealed pronounced grain boundary cracking in coarse-grained WC and enhanced resistance in fine-grained WC due to refined microstructure. Preliminary Transient Grating Spectroscopy results demonstrated a dramatic reduction in thermal diffusivity (order-of-magnitude drop at lowest dose), highlighting substantial microstructural damage. This work informs WC shielding optimisation and future irradiation studies for advanced tokamak designs.

Technical Track

Fusion and Advanced Reactors

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Session Classification: Student Competition