TITANIUM ADDITION AND THICKNESS VARIATION RESEARCH IN TUNGSTEN BLOCK BEHAVIOR AS FUSION PLASMA FACING FIRST WALL

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The nuclear behavior of tungsten (W) under fission neutron spectra has been extensively characterized and validated [1]. Due to its exceptionally high melting point (~3700 K), outstanding mechanical strength, and superior physicochemical stability relative to other candidate materials, tungsten is considered one of the most promising options for the construction of divertor components and first wall shielding in tokamak-based fusion systems and fusion–fission hybrid reactors [2].
The primary role of the first wall is to shield the tritium breeding blanket (TBB) from energetic ions originating in the plasma, while simultaneously preserving the neutron economy essential for sustaining the lithium-based breeding reactions:

- Li-6(n, α + T), which is favored by thermal (low-energy) neutrons
- Li-7(n, α + T + n'), which exhibits peak cross-section efficiency within the intermediate energy range of approximately 5.5 to 10 MeV.

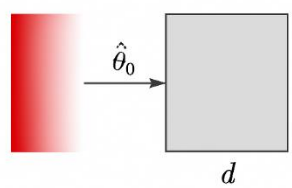
Multiple studies have shown that adding up to 4% by weight of Ti to W can improve its flexural strength and toughness, reduce the brittle-ductile transition temperature (the major deficit of pure W), improve resistance to embrittlement by irradiation, and help to maintain both the stability of nanometric structures at high temperatures, as well as to control the concentration range of embrittlement impurities such as H and He [3]. However, there is a lack of experimental information on the behavior of this material in real environments of neutron fusion irradiation (E=14Mev), and extrapolating the performance of W or W-xTi based on the available information on the response of the material to fission neutrons continues to raise doubts [4]. Therefore, simulation must be used to predict the material's behavior under conditions consistent with the environment generated in D-T nuclear fusion, as is the case in this work.

Methods: Monte Carlo radiation transport simulations were conducted using the MCNP5 code (RSICC, V. 1.4) [5], configured to account exclusively for neutron interactions (MODE N) [6], [7].

The simulated geometry consists of a prismatic column with a 1 cm^2 square incident surface and variable thicknesses, designed to represent a section of the reactor's first wall. Periodic boundary conditions were applied laterally to emulate an infinite wall and eliminate neutron leakage artifacts.

Material compositions included pure tungsten and W–Ti alloys with titanium atomic fractions of x= {0, 2, 4}% . Alloys were treated as ideal mixtures for density calculations, comprising naturally occurring isotopes of tungsten (W-180, W-182, W-183, W-184, W-186) and titanium (Ti-46, Ti-47, Ti-48, Ti-49, Ti-50).

The neutron source was modelled as a monoenergetic flux of 14.1 MeV, representative of D–T fusion reactions in magnetic confinement devices or dense plasma focus (DPF) systems. Neutrons θ_0 were emitted uniformly from a planar source located 1 cm in front of the incidence surface, with a direction vector normal to the surface (see scheme below):



Simulation results were normalized based on either neutron flux or reactor power, depending on the parameter evaluated. To quantify radiation-induced damage and assess titanium's role in primary damage mechanisms, molecular dynamics (MD) simulations—calibrated with experimental data—will be employed and detailed in the manuscript.

References

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