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Addressing the First Wall Challenges for an ICF Pilot Plant

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GenF, a subsidiary of the Thales Group, is a pioneer in the development and commercialization of direct drive inertial confinement fusion (ICF) technology in France. One of the most challenging aspects of fusion power plant development is the design of the reaction chamber, particularly the first wall (FW) material. The FW is exposed to pulsed emissions of X-rays, ions, and neutrons from fusion reactions. Approximately 70% of fusion energy is carried by 14.1 MeV neutrons, which cause displacement damage to the FW, while the remaining 30% is deposited on the FW surface. After ignition, energy is distributed among non-burned ions constituting the fuel target, including deuterium (D), tritium (T), and other elements from the target cover (H and C). Simulations of the irradiation products' energy distribution and spectra allow accurate evaluation of plasma-material interactions [1].

This work presents an assessment of FW material degradation due to physical sputtering by energetic ions in an ICF reactor. The lifetime of the FW is evaluated for various materials (W, WC, LiF, SS 316L, and C), considering target composition, FW thickness, and chamber size using the sputtering yield profiles from the SRIM code. Tungsten shows the most promising results, with a total erosion time of 0.16 years for a chamber radius of 1 m, a FW thickness of 1 cm, a DT fuel mass of 1 mg, and a burn fraction of 0.4. Additionally, 1D simulations with the FESTIM code [2] were performed to assess transient heat transfer and hydrogen isotope diffusion, specifically tritium retention in a plasma-facing component consisting of a thin tungsten coating on SS 316L. The study uses relevant material properties, including trapping parameters (detrapping energies and trap densities) without considering displacement damage in the materials. While tungsten is considered a promising FW material, GenF believes that developing new radiation-resistant materials capable of withstanding large pulsed thermal loads could further increase the reaction chamber's lifetime.

References

[1] J. Alvarez et al., Nuclear Fusion, 51 (2011)
[2] R. Delaporte-Mathurin et al., International Journal of Hydrogen Energy, 63 (2024)