22nd International Conference on
Diffusion in Solids and Liquids
22 TO 26 JUNE 2026 | RHODES, GREECE

ABSTRACT:

TritiumStopp – H Isotope Barrier Layers for Fusion Reactors

A. Manhard[1], V. Weihnacht[2], F. Kaulfuß[2], M. Zawischa[2], G. Moras[3], T. Reichenbach[3], M. Moseler[3]
[1]Max-Planck-Institut für Plasmaphysik, Boltzmannstr. 2, 85748 Garching
[2]Fraunhofer IWS, Winterbergstr. 28, 01277 Dresden
[3]Fraunhofer IWM, MikroTribologie Centrum µTC, Wöhlerstraße 11, 79108 Freiburg

For a prospective nuclear fusion reactor based on the deuterium-tritium reaction, it is essential to realize a self-sufficient tritium fuel cycle: The short-lived, radioactive tritium must be produced by the fusion reactor itself. This will happen in the lithium-containing breeding blanket surrounding the reactor chamber. In addition to producing tritium, the blanket also absorbs the kinetic energy of the fusion neutrons and converts it into usable heat, and shields the surrounding components from neutrons. Multiple blanket concepts are currently being explored, using either Li-containing ceramic pebbles (e.g., [1]), or liquid lithium alloys (e.g., [2]). Estimates show that, e.g., a blanket constructed from reduced activation ferritic-martensitic steel would lose excessive amounts of tritium due to permeation through the steel [3]. Therefore, hydrogen permeation barrier layers need to be applied to pipes and structural components of a blanket. A useful tritium permeation barrier not only needs to block tritium, but also must be resistant to (thermo)mechanical stress and neutron irradiation, including persistent barrier effectiveness in the irradiated state as well as, ideally, low-activation properties. However, a proven, reliable and scalable concept for these barrier layer coatings does not exist yet, although some older studies exist (e.g., [4]) and multiple research activities were recently started (e.g., [5], [6], [7]).
The TritiumStopp collaboration aims to utilize layers that are already successfully established as hard or wear-resistant coatings, e.g., for machining tools. These coatings inherently possess promising mechanical stability and are fabricated using an industry-adjacent process. Several of these coatings, such as titanium nitride, were previously reported to have favourable barrier properties (see, e.g., [8]). For many candidate layers, this could be confirmed in a high-throughput screening study. The most promising of those currently undergo more detailed permeation testing. First gas-driven permeation measurements are used to provide insight into barrier mechanisms of the different coatings. Finally, we present MD results on collision cascades and resulting structural changes in TiN and tetrahedral amorphous carbon (ta-C). As a next step, these coatings will be subjected to cyclic mechanical stress as well as MeV ion irradiation as a surrogate for neutrons.

[1] F. Cismondi et al., Fusion Eng. Des. 157 (2020) 111640
[2] P. Arena et al., Appl. Sci. 2021, 11(24) 11592
[3] R. Arrendondo et al., Nucl. Mater. Energy 32 (2022) 101228

[4] D. Levchuk et al., J. Nucl. Mater. 328(2-3) (2004) 103-106
[5] J. Engels et al., Int. J. Hydrogen Energy 46(24) (2021) 13142-13149
[6] H. Gardener et al., Front. Nucl. Eng. 2 (2024) 1332377
[7] Y. Shimizu et al., Fusion Eng. Des. 204 (2024) 114506
[8] V. Nemanič, Nucl. Mater. Energy 19 (2019) 451-457