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Direct comparison of gas- and ion-driven permeation through EUROFER

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The ion-driven permeation facility TAPAS provides a monoenergetic, mass-filtered ion beam to charge permeation samples with hydrogen isotopes, preferentially deuterium. Ion flux densities of the order of 10^20 D/m^2s can be reached at energies as low as 70 eV/D. In addition, it is possible to apply hydrogen gas pressure up to a few Pa, to measure gas-driven permeation at pressures comparable to the neutral gas pressure in fusion reactors. On the downstream side, ultra-high vacuum and a sensitivity-boosted quadrupole mass spectrometer allow detection of even very small permeation signals. We used this facility to directly compare gas- and ion-driven permeation on the same EUROFER sample, without breaking vacuum. Gas-driven permeation was mostly surface-limited within the investigated pressure range up to about 2 Pa, at temperatures of 500 to 700 K. At 800 K, a sharp transition to diffusion-limited boundary conditions was observed. Ion-driven permeation exhibited pronounced superpermation spikes after switching on the ion beam, even after very short breaks in the irradiation. This indicates rapid re-oxidation of the D-irradiated surface. Intentional oxygen seeding also induced superpermeation. Despite the low ion energy of only 70 eV/D, pronounced sample ageing was observed during the ion beam experiments. Also, gas-driven permeation was substantially reduced after the sample saw prolonged exposure to the ion beam. Post-experiment microscopy revealed strong surface modifications in the ion-irradiated beam spot, and pronounced surface oxidation on the non-irradiated parts of the surface.

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