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Ion-Driven Permeation and Modelling

Content

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A high-performance ion-driven permeation set-up was constructed at IPP Garching. The TAPAS installation is part of the SIESTA high current ion source assembly and is fed by a high-intensity, mass-filtered ion beam (typically D3+). With recent upgrades to the ion source as well as to the optics in the TAPAS beam line, the deuteron flux density could now be raised to approximately 1020 D/m2s. Thanks to feedback regulation of the ion source, the ion flux can be kept stable even during extended experiment times of several days.
As a first benchmark, a 25 µm thick recrystallized W foil was successfully exposed to the D3+ ion beam at various temperatures between 580 and 900 K. A temperature-independent permeation current was obtained for temperatures of 650 K and higher, indicating that permeation likely occurs with diffusion-limited boundary conditions on both sides. At 580 K, indication for ageing of the sample was found, most likely due to ion-induced subsurface damage. Analysis of lag times indicates that trapping still plays a role in permeation transients, since the effective diffusion coefficient was considerably lower than extrapolations from high-temperature experiments documented in literature [1, 2]. First quantitative modelling attempts of permeation transients using the diffusion-trapping model TESSIM-X [2] were successful.
First tests also show that it may be possible to measure gas-driven permeation at low pressures in the same device as ion-driven permeation, thus enabling a direct comparison of both methods in one device.
Upcoming efforts go towards measuring layered samples consisting of W and Fe-2Ni alloy as a model system for the W-matrix interface in tungsten heavy alloys. The system will be investigated by TESSIM-X modelling [2] as well as by experiments.

[1] R. Frauenfelder, J. Vac. Sci. Technol. 6(3) (1969) 388-397
[2] G. Holzner et al., Phys. Scr. T171 (2020) 014034
[3] K. Schmid et al., J. Nucl. Mater. 426 (2012) 274-253

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