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Ion-driven Permeation Experiments and Modelling

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Basic permeation and retention data are required for the following materials: Tungsten, RAFM steels, copper alloys (CuCrZr), doped tungsten materials or tungsten alloys, and functionally graded materials foreseen to be used in first-wall or divertor components. Apart from the data for pristine materials, data for radiation-damaged materials need to be determined because permeation and retention of hydrogen isotopes will be strongly affected by lattice damage and transmutation due to neutron irradiation. In addition, the influence of interfaces on diffusion and permeation is a topic that deserves further attention, because those will be present between W and CuCrZr in divertor components, or between W and RAFM steels at the first wall.

This proposal aims at determining, assembling, and evaluating data needed for a sound assessment of hydrogen permeation in fusion-relevant materials. It further aims at expanding our knowledge of parameters affecting hydrogen permeation in fusion-related materials, including temperature, temperature gradients, microstructure and irradiation-induced defects.

Ion-driven permeation (IDP), which will likely dominate permeation at plasma-facing surfaces in a fusion device, requires a dedicated set-up with a well-characterized, monoenergetic, mass-selected, high-current ion beam. The ion-driven permeation experiment PERMEX-II has been commissioned at IPP Garching at the beginning of 2020. After thorough testing and further qualification, it will be available for IDP measurements in the second half of 2020.

Measurement will focus on the materials EUROFER97 and tungsten. EUROFER97 samples will be prepared following the identical sample preparation procedure as used in Forschungszentrum Jülich, Germany (FZJ) for GDP measurements and ion-driven permeation of deuterium will be studied as a function of incident ion energy and sample temperature. Permeation experiments will be complemented with measurements of D retention after ion loading at SIESTA (Second Ion Experiment for Sputtering and TDS Analysis) followed by in-vacuo thermal desorption spectroscopy (TDS) or ex-situ nuclear reaction analysis (NRA), respectively. These experiments will be performed in close coordination with FZJ (A. Houben) to allow comparison of GDP and IDP in EUROFER. In addition, IDP in tungsten and in radiation-damaged tungsten are planned.

If time allows and samples become available it is conceivable to perform IDP experiments with EUROFER foils covered with tungsten surface layers. This will provide additional data for studying (also theoretically) the influence of specific material interfaces on permeation. Experimental data of D permeation in EUROFER97 and tungsten will be compared to modelling from the diffusion-trapping code TESSIM and/or TMAP. Further modelling activities aim at a description of permeation across material interfaces and calculation of trapping cross-sections for continuous Trap-Diffusion Models from first principles.

Primary author: JACOB, Wolfgang

Presenter: JACOB, Wolfgang

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