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# Modelling marker erosion at the divertor region of the ASDEX Upgrade tokamak using the ERO2.0 code

S. Saari[1], A. Hakola[1], J. Karhunen[1], A. E. Järvinen[1], J. Likonen[1], C. Baumann[2], H. Kumpulainen[2], J. Romazanov[2], M. Balden[3], K. Krieger[3], ASDEX Upgrade Team[4], EUROfusion Tokamak Exploitation Team[5]
[1] VTT, Finland, [2] Institut für Energie und Klimaforschung – Plasmaphysik, Forschungszentrum Jülich GmbH, Germany, [3] Max-Planck-Institut für Plasmaphysik, Germany,
[4] See author list of H. Zohm et al, 2024 Nucl. Fusion https://doi.org/10.1088/1741-4326/ad249d
[5] See author list of E. Joffrin et al, 2024 Nucl. Fusion https://doi.org/10.1088/1741-4326/ad2be4
e-mail (speaker): antti.hakola@vtt.fi

Understanding erosion of plasma-facing materials (PFMs) is the key in assessing the lifetime of wall structures in future fusion reactors. The largest power and particle loads typically occur at the divertor region, which has also been the focus of our studies on the ASDEX Upgrade (AUG) tokamak. Here we concentrate on an experiment carried out at the low-field-side (outer) divertor of AUG during low-density, high-temperature deuterium (D) L-mode plasma discharges [1]. The DIM-II divertor manipulator of AUG allowed obtaining discharge-resolved information on the erosion and deposition characteristics of the exposed samples.

In this contribution, we will discuss interpretative modelling of the measured erosion patterns using the Monte Carlo code ERO2.0. The data originates from small marker samples with tiny gold (Au) marker spots on molybdenum (Mo)-coated graphite samples on tungsten (W) tiles. Both 1×1 $\text{mm}^2$ and 5×5 $\text{mm}^2$ marker spots, poloidally distributed around the outer strike point (OSP), were used to give information on gross (1×1 $\text{mm}^2$) and net (5×5 $\text{mm}^2$) erosion of Au; gold was used as a proxy for tungsten due to the full-W wall of AUG.

Compared to earlier efforts (see [2]), several improvements were implemented to the modelling setup and the input data of the simulations. Background plasmas were constructed using the onion-skin model (OSM) of the DIVIMP code, based on the available Langmuir probe (LP) data for the poloidal electron density and temperature profiles at the OSP region.

The results for Au net erosion for the large marker spots are shown in Figure 1. They indicate good correspondence between the experimental and simulated erosion profiles: a peak around the OSP and a gradual but distinct decrease in erosion rates when moving away from it, especially on the scrape-off layer (SOL) side (positive values). The application of the new and more accurate presentations of the sputtering and reflection data for Au, provided by the SDTrimSP code, was found to have a key role in significantly improving the agreement with experimental data with respect to earlier simulations with simplified approximations. The remaining discrepancies can be attributed to the missing LP data in the vicinity of the OSP, thus creating uncertainties in the reconstructed OSM profiles.

Replacing the underlying Mo layer with a W one, as would be the case for divertor components on AUG, did not introduce any noticeable changes in the simulated erosion profiles. In contrast, our results clearly indicate net erosion to be suppressed by factor of 5 if instead of individual markers the entire top layer was covered with Au. This can be explained by the restricted toroidal extent of the markers, allowing part of the eroded atoms to migrate outside of the markers before being deposited. Consequently, net erosion of the markers will be overestimated compared to a toroidally continuous tile surface. A further drop in net erosion by a factor of 6 is observed in the case of toroidally elongated W surfaces, suggesting that using small Au markers as proxies for AUG tungsten tiles may overestimate the interpreted net erosion of the latter by more than an order of magnitude.

Our simulations also predict a predominantly toroidally oriented re-deposition pattern downstream of the marker spots, albeit the modelled surface densities are 1-2 orders of magnitude lower than those on the marker spots. Light impurities appear to play the largest role in marker erosion: nitrogen, carbon, and boron, typical impurities on AUG, account for >75% of the obtained net erosion.

Our results have provided new insights on the physics of PFM erosion at the divertor and we are now confident that the underlying models are mature enough to be applied to H-mode plasmas. However, the impact of marker geometry and material on the resulting erosion profiles need to be taken into account when extrapolating the outcomes towards ITER.

[1] A. Hakola et al., Nucl. Fusion **61** (2021) 116006
[2] A. Hakola et al., Nucl. Mater. Energy **25** (2020) 100863

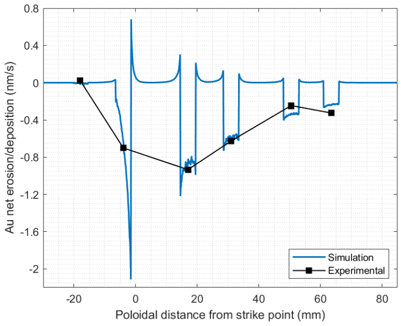

Figure 1. Simulated and experimental net -erosion profiles of the 5×5 $\text{mm}^2$ gold marker spots.