P 22: Plasma Wall Interaction III

Time: Friday 9:00–10:30 Location: KH 01.012

Invited Talk P 22.1 Fri 9:00 KH 01.012

ERO/ERO2.0 modelling for tokamaks, stellarators and linear plasma devices — •Juri Romazanov[1], Henri Kumpulainen[1], Christoph Baumann[1], Sebastian Rode[1], Andriy Tarasenko[1], Andreas Kirschner[1], Georgii Timkovskii[1], Dmitry Matveev[1], Sebastijan Brezinsek[1], JET team[2], and W7-X team[3] — [1]Forschungszentrum Jülich GmbH, IFN-1, 52425 Jülich, Germany — [2]See the author list of "Overview of T and D-T results in JET with ITER-like wall" by C.F. Maggi et al. Nucl. Fusion 64, 112012 (2024). — [3]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

This contribution summarizes PWI research using the ERO2.0 code for erosion and material migration in magnetic confinement fusion devices. Code validation is demonstrated using experiments in the linear plasma device PSI-2, where B sample exposures were analyzed using spectroscopy of atomic B and molecular BD emission. Another validation study was conducted at JET, where interpretative plasma reconstructions were combined with predictive W modelling across all plasma regions and compared with experimental W profiles inferred from multiple diagnostics. Predictive studies are presented for several future devices. These include assessments of replacing C with W PFCs in W7-X, W erosion and prompt redeposition in ITER during limiter ramp-up and diverted operation with neon seeding, and lifetime predictions for diagnostic first mirrors. We conclude with EU-DEMO results and discuss challenges stemming from extrapolating plasma profiles to reactor walls.

P 22.2 Fri 9:30 KH 01.012

Initial predictive modeling of plasma-wall interactions using ERO2.0 for W7-X with tungsten wall divertor — •Georgii Timkovskii[1], Juri Romazanov[1], Sebastijan Brezinsek[1,2], Daniil Ryndyk[1], Henri Kumpulainen[1], and W7-X Team[3] — [1]Forschungszentrum Jülich GmbH, IFN-1 - Plasma Physics, Jülich, Germany — [2]Mathematisch-Naturwissenschaftliche Fakultät, HHU Düsseldorf, Düsseldorf, Germany — [3]Max-Planck-Institut für Plasmaphysik, 17491 Greifswald, Germany

Plasma-wall interaction (PWI) is a critical aspect of fusion device operation, influencing material lifetime, fuel retention, and overall plasma performance. In addition to interpretive modelling used to analyze and understand physics experiments, predictive modeling with validated codes like ERO2.0 becomes essential for anticipating system behavior and guiding design or operational decisions as required for an exchange of the wall material in Wendelstein 7-X (W7-X). ERO2.0 is a fully kinetic Monte Carlo code dealing with PWI processes at the surface and incorporating phenomena such as drifts, ionization, and impurity-ion collisions in the plasma. While there have been multiple ERO2.0 studies of stellarators - including cases with some tungsten components - no systematic investigation exist for a fully metallic stellarator with a tungsten divertor. In this work, PWI and impurity transport for the W7-X stellarator are studied with focus on the planned wall material exchange from a carbon wall to a tungsten wall. The influence of the resolution of existing 3D grids on the resulting PWI and impurity transport is analyzed.

P 22.3 Fri 9:45 KH 01.012

Spectroscopic Time-of-Flight Spatial Distribution Measurements of Neon-Sputtered Monocrystalline W at the Linear Plasma Device PSI-2 — •Merlin Klein[1], Oleksandr Marchuk[1], Marc Sackers[1], Arkadi Kreter[1], and Sebastijan Brezinsek[1,2] — [1]Forschungszentrum Jülich GmbH, IFN-1 — [2]HHU Düsseldorf, Faculty of Mathematics and Natural Sciences

Tungsten (W) is a plasma-facing material (PFM) for fusion reactors. By erosion W atoms can enter the plasma and cool it through radiation losses. The quantity and spatial distribution of sputtered W atoms from PFMs therefore has a direct impact on reactor performance. For energy impacts in the keV range, the sputtered W atoms follow a cosine angular distribution. For lower energies, as typically exist in the divertor region as well, experimental data shows a discrepancy to existing models.

In this experiment, poly- and monocristalline (111) W is exposed to a linear Neon plasma at kinetic energies of about 100 eV. Further excitations of W atoms sputtered into the plasma column allow for the acquisition of multiple line shapes in a spectroscopic time-of-flight (ToF) measurement. The total sputtering yield can be deduced from multiple acquisitions. In this ToF measurement it is possible to differentiate between angular distributions of sputtered W flux, while all other experimental parameters stay fixed.

These new experimental results show deviations in angular distributions between lattice structures and their orientations which can be used to support modelling of low temperature plasma-wall interactions.

P 22.4 Fri 10:00 KH 01.012

Near-surface hydrogen inventory response to picosecond laser pulses in tungsten. — •Maria Popova, Dmitry Matveev, Sebastijan Brezinsek, Christoph Kawan, and Erik Wüst — Forschungszentrum Jülich GmbH, Institute of Fusion Energy and Nuclear Waste Management - Plasma Physics, 52425 Jülich, Germany

Tungsten is a leading plasma-facing material; neutron damage creates traps for hydrogen isotopes. Near-surface fuel inventory and release can be probed with LIA-QMS.

A FEniCS/FESTIM framework for picosecond laser pulse trains is presented, addressing depths <1 mm. Transient heat conduction is coupled to a near-surface trapping-detrapping scheme. Coarse ablation is represented as removal of a surface layer, tens of nanometers thick, at the start of each pulse, updating thermal and hydrogen boundary conditions. Per-pulse release is obtained from the desorption-flux integral; initial fuel distributions are taken from NRA depth profiles on proton-irradiated and self-damaged, deuterium-decorated tungsten.

Results indicate that heating-induced release dominates for the first ~10 pulses; subsequent ablation mostly removes a layer partially depleted by prior heating. Including a simple defect-annealing term enables comparison to LIA-QMS depth reconstructions with good agreement.

P 22.5 Fri 10:15 KH 01.012

Fabrication of tungsten fibre-reinforced composites by combining Chemical Vapour Deposition and Field Assisted Sintering — •Patrick Scholz[1], Alexander Lau[1], Jan Willem Coenen[1], and Florian Kleemiss[2] — [1]Forschungszentrum Jülich GmbH, Institut of Fusion Energy and Nuclear Waste Managment - Plasmaphysics (IFN-1), Jülich 52425, Germany — [2]Institut für Anorganische Chemie, RWTH Aachen, Landoltweg 1a, 52074 Aachen, Germany

Many promising materials for high-temperature or oxidizing environments, including chromium aluminium carbide (Cr_2AlC), titanium aluminium carbide (Ti_2AlC), and self-passivating metal alloys with reduced thermo-oxidation (SMART), are limited by their inherent brittleness, restricting their suitability as structural components. Tungsten fibre-reinforced tungsten has demonstrated that embedding ductile fibres in a brittle matrix can produce pseudo-ductile fracture behaviour below the ductile-to-brittle transition temperature (DBTT). To transfer this toughening concept to these alternative matrices, the tungsten fibres must be protected from direct interaction with embrittling species, particularly chromium and carbon. This work investigates sacrificial tungsten coatings deposited by chemical vapour deposition (CVD). These coatings act as controlled sinks for matrix ingress during sintering, ensuring that the fibres remain unaffected. The study focuses on determining the coating thickness required for reliable fibre incorporation into each matrix system and evaluating the resulting mechanical performance.