P 6: Plasma-surface interaction

Time: Tuesday 11:00–12:55 Location: b302

Invited Talk P 6.1 Tue 11:00 b302

Predictive modelling of beryllium erosion, transport and deposition during H, He and DT plasmas in ITER — •Juri Romazanov[1], Sebastijan Brezinsek[1], Andreas Kirschner[1], Dmitriy Borodin[1], Alina Eksaeva[1], Richard A. Pitts[2], Vladislav S. Neverov[3], and Christian Linsmeier[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung – Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, 13067 St.-Paul-lez-Durance Cedex, France — [3]National Research Centre Kurchatov Institute, Moscow, Russia

Beryllium (Be) will be the main chamber armor material for the international thermonuclear fusion reactor ITER, which is currently under construction in France. We present a comparison of the Be erosion for different plasma conditions, including the baseline DT burning plasma scenario with power gain Q=10, as well as the low-power hydrogen (H) and helium (He) plasmas foreseen in the ITER pre-fusion power operation (PFPO) phase. It is shown that in the latter ones, the gross erosion is two orders of magnitude smaller. Another important finding is the difference in Be migration: in the DT baseline scenario 90% of the eroded Be is redeposited in the main chamber, while in the H and He cases the redeposition is reduced to 44 and 56%, respectively. The remaining Be is deposited in the divertor. Finally, it is shown that in DT the erosion is dominated by Be self-impact, while in H and He the sputtering by energetic charge-exchange neutrals (CXN) dominates.

P 6.2 Tue 11:30 b302

The impact of surface morphology on the erosion of metallic surfaces -modelling with the 3D Monte-Carlo code ERO2.0 — •Alina Eksaeva[1], Dmitry Borodin[1], Juri Romazanov[1], Andreas Kirschner[1], Arkadi Kreter[1], Beatrix Göths[1], Marcin Rasinski[1], Bernhard Unterberg[1], Sebastijan Brezinsek[1], Christian Linsmeier[1], Espedito Vassallo[2], Matteo Passoni[2,3], David Dellasega[2,3], Michele Sala[3], and Federica Romeo[3] — [1]Forschungszentrum Juelich GmbH, Institut fuer Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), Juelich, Germany — [2]Istituto per la Scienza e Tecnologia dei Plasmi, CNR, Milano, Italy — [3]Dipartimento di Energia, Politecnico di Milano, Via Ponzio 34/3, 20133 Milan, Italy

The surface roughness has a vital impact on the erosion of plasma-facing components. The 3D Monte-Carlo code ERO2.0 is a versatile tool for describing the erosion and transport of impurities in the plasma. A model describing the surface roughness effect on erosion was implemented into the ERO2.0 code. A series of plasma experiments on surface roughness effect on the erosion have been carried out at the linear plasma device PSI-2. Experiments show in the case of molybdenum a reduction of the net erosion by up to 40% (rel. to the smooth case) due to the surface roughness of Ra = 600 nm, which is in line with ERO2.0 predictions. For the case of the JET ITER-like wall divertor (W-coated tiles) model shows the reduction of the net erosion by the factor of 2 for the surface roughness of 10 mcm scale; increased deposition in shadowed from the plasma areas is observed.

P 6.3 Tue 11:55 b302

Determination of the energy distribution of sputtered atoms from polished metallic surfaces by high resolution spectroscopy — •Stephan Ertmer, Oleksandr Marchuk, Sven Dickheuer, Sebastijan Brezinsek, Philippe Mertens, Marcin Rasiński, and Arkadi Kreter — Forschungszentrum Jülich GmbH - Institut für Energie- und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Knowledge of the energy distribution of sputtered atoms for ions at low impact energies is essential for different applications. We modelled the distribution from the line shape emitted by sputtered aluminium (Al) and tungsten (W). Mirror-polished Al and W samples were exposed to an argon (Ar) plasma ($T_e = 3\,\mathrm{eV}$; $n_e = 3.5 \times 10^{18}\,\mathrm{m}^{-3}$) in the linear plasma device PSI-2. The plasma ions were accelerated to impact energies of 30 to 160 eV onto the target by biasing. The line of sight of a high resolution spectrometer (resolving power $\lambda/\Delta\lambda = 7 \times 10^5$) was directed parallel to the target normal. The energy distribution of the sputtered atoms was modelled from the detected line shape using the Doppler-shifted-emission model [1] with an extension considering instrumental broadening and Zeeman splitting. The results show good agreement with the Thompson energy distribution. For an increase in the impact energy of the Ar^+ ions, we observe an increase in the high energy tail of the sputtered atoms distribution function. Furthermore, the reflection of light at the targets surface was modelled from the line shape and the surface binding energies were determined.

[1] S. Dickheuer et al. *Phys. Plasmas* **26**, 073513 (2019)

P 6.4 Tue 12:10 b302

Ion-induced secondary electron emission coefficient of clean and dirty metal surfaces analysed in an ion beam experiment — •Rahel Buschhaus[1], Maik Budde[2], and Achim von Keudell[1] — [1]Experimentalphysik II, Ruhr-University Bochum — [2]Department of Applied Physics, TU Eindhoven

In glow discharges the generation of secondary electrons at surfaces play an important role for ignition and maintenance of a plasma. The ion-induced secondary electron emission coefficient (iSEEC) γ depends on the chemical state of the surfaces and is defined as number of released electrons per incident ion. Depending wether metal surfaces are clean or „dirty“, e.g. oxidized, the γ coefficient varies [1]. The elementary plasma processes on surfaces are mimicked by sending quantified beams of ions to metal foils in an ultra-high vacuum reactor. Different thin metal foils are exposed to an ion beam of argon or metal ions, which are extracted from an inductively coupled plasma discharge (ICP). This ion beam is mass and energy selected (2eV-5keV) before reaching the metal foil. The unique feature of the here presented experiment is the possibility of analysis of surface processes induced by single and multiple ionized argon and/or metal ions and their oxides within a broad energy and mass range. For determination of the iSEECs a collector system based on current measurements is used [2]. We will present γ of different clean and dirty metal surfaces. The emission of electrons will be induced by either argon or metal ions within a broad energy range. [1] A. V. Phelps *et al. Plasma Sources Sci. Technol.* **8** R21 (1999) [2] A. Marcak *et al.*, *Rev. Sci. Instrum.* **86**, 106102 (2015)

P 6.5 Tue 12:25 b302

Interaction of low-energy electrons with metallic walls — •Franz Xaver Bronold and Holger Fehske — Institut für Physik, Universität Greifswald, 17489 Greifswald,

The interaction of electrons with the walls of the discharge vessel is an important surface process in technological low-temperature plasmas. It affects, for instance, the operation modii of dielectric barrier discharges, Hall thrusters, and divertor plasmas in fusion devices. Little is however known quantitatively about the process because it occurs at energies below 50 eV which are hard to access experimentally. There are only a few attempts to measure probabilities for electron absorption, backscattering, or secondary emission in this energy range. A few years ago we presented therefore an approach for calculating the probabilities from a semi-empirical microscopic model and applied it to dielectric walls [1]. The approach is based on an invariant embedding principle for a function $Q(E\eta|E'\eta')$ summing up the backscattering trajectories arising from the interaction of the incoming electron with the excitations and imperfections of the wall. Now we apply the approach to a metallic wall where the dynamic interaction of the penetrating electron with the metal's Fermi sea and the scattering on imperfections determines the absorption, backscattering, and secondary emission probabilities. Numerical results for the electron absorption probability of a Cu surface are in good agreement with experimental data indicating that the semi-empirical modeling captures in this case the low-energy scattering physics also rather well. [1] F. X. Bronold and H. Fehske, Plasma Phys. Control. Fusion **59**, 014011 (2017)

P 6.6 Tue 12:40 b302

Deuterium Retention and Surface Modification of Tungsten Alloys produced by Powder Injection Moulding after Deuterium Plasma Exposure — •Robert Krug[1], Sören Möller[1], Steffen Antusch[2], Marcin Rasinsky[1], Arkadi Kreter[1], Marius Wirtz[1], and Bernhard Unterberg[1] — [1]Forschungszentrum Jülich, Institut für Energie- und Klimaforschung,52425 Jülich, Germany — [2]KarlsruheInstitute of Technology, Institute for Applied Materials, P.O. Box3640, 76021 Karlsruhe

In this work, we investigate the behaviour of the surface near region (first few μm) of different PIM produced tungsten alloys under deuterium plasma exposure. For this, the samples are exposed to a deuterium plasma with a total fluence of $\approx 5 \cdot 10^{25}\mathrm{m}^{-2}\mathrm{s}^{-1}$ at a temperature of 200°C in the linear plasma device PSI-2.
In preliminary studies it was determined, that especially preferential sputtering of the alloying particles and the plasma interaction with the carbon based binder have the most impact on the plasma behaviour of PIM alloy materials.
These surface modifications due to the plasma are investigated by Focussed Ion Beam and Scanning Electron Microscopy (FIB-SEM), the change in material composition by Secondary Ion Mass Spectrometry (SIMS) and the deuterium depth concentration in the first few μm by Nuclear Reaction Analysis (NRA).