P 3: Plasma Wall Interaction I

Time: Monday 14:00–16:00 Location: ELP 6: HS 3

Invited Talk P 3.1 Mon 14:00 ELP 6: HS 3

Influence of Nanosecond Pulsed Plasmas in Liquids on Copper Surfaces — •Pia-Victoria Pottkämper, Oliver Krettek, Katharina Laake, and Achim von Keudell — Ruhr-Universität Bochum

One application of plasmas in liquids is the modification of metal surfaces. In this project a plasma is ignited in water at an electrode using high voltages, nanosecond pulses and fast rise times. The plasma is then used to modify a coppper surface in contact with the plasma-activated liquid. The plasma causes a dissociation of the water molecules, leading to the creation of many different reactive species with varying lifetimes such as molecular oxygen and hydrogen, solvated electrons and hydrogen peroxyde. The created electric field with a short rise time leads to a fast pressure increase at the ignition site and an expansion of a shock wave which transports the reactive species to the surface. Here different reactions may occur that lead to the modification of the copper. It is possible to reduce the surface or to initiate growth of nanostructures depending on the experimental conditions. The changes are monitored via FTIR spectroscopy, SEM and XPS. The creation of uniform CuxO nanocubes has been observed under certain conditions. One application of these structures is the catalysis of the electrochemical reduction of CO2. During this reaction the activity of these catalysts decreases over time. The in-liquid plasma can cause a re-oxidation and therefore the formation of new CuxO nanocubes. It is postulated that by an in-situ in-liquid plasma treatment the lifetime of the catalytic surfaces can be extended.

P 3.2 Mon 14:30 ELP 6: HS 3

Characterization of boron layers on tungsten substrates by picosecond and nanosecond laser-induced breakdown spectroscopy — •Huace Wu, Sebastijan Brezinsek, Rongxing Yi, Anne Houben, Gennady Sergienko, and Yunfeng Liang — Forschungszentrum Jülich GmbH, Institut für Energie- und Klimaforschung * Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany

Boronization is considered in ITER as wall conditioning method for full-W material option. Boron acts primarily as oxygen getter, but can also reduce intrinsic impurity content such as carbon and nitrogen as well as moderately the hydrogen recycling. However, the boron layer thickness, and therefore the lifetime by plasma-induced erosion, is limited, not necessarily toroidal homogeneous, and repetitively boronization needs to be applied to be effective. LIBS as a versatile tool for the investigation of the element composition and is a potential candidate for in-situ investigations of erosion, deposition and material mixing in nuclear fusion devices. At first, we study LIBS in the laboratory on thin boron films (about 100nm) or boron-tungsten layer systems produced by magnetron sputtering on the polished tungsten substrates. Ps (35ps,355nm) and ns (7ns,1064nm) lasers were used to characterize the ablation rate of boron layers as well as matrix effects in the layer system. The ps laser provides a better depth resolution due to the smaller ablation rate. Comparison studies with boron layers (about 10nm) obtained on W substrates in the midplane manipulator of W7-X from boronization will be presented.

P 3.3 Mon 14:45 ELP 6: HS 3

Experimental studies of Hydrogen plasma produced in Pulsed Plasma Accelerator source — •Azmirah Ahmed, Sumit Singha, Pradipta P Kalita, Pallabi Baruah, Nirod K Neog, and Tridip K Borthakur — Centre of Plasma Physics-Institute for Plasma Research (CPP-IPR)

Hydrogen plasma is produced in a Pulsed Plasma Accelerator (PPA) source to simulate the heat loading phenomena of an ELM transient event of fusion devices. A 200 kJ Pulsed Power System (PPS) powers the PPA by delivering a discharge current pulse of 100 kA of half-time period ~ 0.5 ms. An accelerated plasma stream is produced which has a relatively high density and high velocity. An external longitudinal magnetic field of ~ 0.1 T in the observation region is generated using an electromagnet to study its effect on the plasma stream. Calorimetric study, high-speed imaging and OES is carried out for proper optimization of the plasma. The calorimetric study gives the measure of optimized energy density ~ 0.22 MJ/m2 of the hydrogen plasma. The imaging done using a high speed video camera shows the confinement, shape, uniformity and intensity distribution of plasma. The spectroscopic observations shows the emission from Hα and Hβ transitions of hydrogen and also the transitions of different impurity species generated during the plasma production. The interaction of this hydrogen plasma with a fusion relevant tungsten material is then studied by exposing the tungsten target. By using XRD and FESEM techniques, the impact on the material is studied and initial testing shows formation of major and micro cracks on tungsten.

P 3.4 Mon 15:00 ELP 6: HS 3

Laser enhanced copper surface oxide generation by plasma generated reactive oxygen species — •Sascha Chur[1], Robin Minke[1], Marc Böke[2], and Judith Golda[1] — [1]Plasma Interface Physics, Ruhr-University Bochum, D-44801 Bochum, Germany — [2]Experimentalphysik II, Ruhr-University Bochum, D-44801 Bochum, Germany

Copper, a promising catalyst for CO_2 electroreduction, faces challenges of poor selectivity and energy efficiency. Copper oxides enhance selectivity, particularly towards C_{2+} products. Surface morphology significantly influences performance, and our study demonstrates that combined laser and plasma treatment fine-tunes these characteristics for effective functionalization. Treatment with a micro atmospheric pressure plasma jet induces Cu(II) oxides on copper by generating reactive oxygen species. Investigation into prevalent reaction partners produced by the plasma jet revealed atomic oxygen density at 10^{21} m^{-3} (two-photon absorption laser-induced fluorescence). Singlet delta oxygen, at 10^{20} m^{-3} (emission spectroscopy) closely aligned with simulation results, while ozone density, calculated at 10^{21} m^{-3} (absorption spectroscopy), was overestimated by the simulation. X-ray Photoelectron Spectroscopy of treated surfaces demonstrated an increasing Cu(II) oxide ratio with extended treatment. This research provides insights into controlled and precise copper surface modification, applicable in diverse fields requiring tailored material properties. Supported by the DFG within CRC 1316, project B2.

P 3.5 Mon 15:15 ELP 6: HS 3

Data-integrated multiphysics simulations of reactive magnetron sputtering — •Tobias Gergs[1], Luca Vialetto[1,2], Christian Stüwe[1], and Jan Trieschmann[1] — [1]Theoretical Electrical Engineering, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany — [2]Department of Aeronautics and Astronautics, Stanford University, 496 Lomita Mall, Stanford, CA 94305, United States of America

Reactive magnetron sputtering is widely used in science and industry. However, the understanding of the physical kinetics remains incomplete, primarily because the intrinsic length and time scales of the plasma and the surface differ by orders of magnitude. Individual scientific disciplines have frequently concentrated on only one of these aspects in detail (i.e., plasma or surface), while the other aspect may have been considered in a simplified manner. In this work, established and novel methods are combined to adequately describe the coupled plasma and surface physics involved in the sputter deposition of silicon oxide in Ar/O_2 discharges. The dynamics of the plasma are described by 2d3v particle-in-cell simulations with a Monte Carlo transport scheme for charged particles, energetic neutrals, and sputtered atoms. The surface evolution is determined by rate equations for the surface coverage, which account for chemisorption, physisorption, diffusion of adatoms, and physical sputtering. The energy and angular distributions of sputtered particles are incorporated by an integrated machine learning model, which was trained with Monte Carlo simulation data. The influence of process parameters (e.g., admixtures of O_2) on phenomena such as target poisoning is emphasized.

P 3.6 Mon 15:30 ELP 6: HS 3

Low Pressure Plasma Spraying of Tungsten on Plasma Facing Components for Future Fusion Devices — •Gunnar Schmidtmann[1,2], Andrey Litnovsky[1], Jan Willem Coenen[1], Robert Vassen[2], Sebastijan Brezinsek[1], Christian Linsmeier[1], Olivier Guillon[2], and Georg Mauer[2] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik (IEK-4), 52425 Jülich, Germany — [2]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Werkstoffsynthese und Herstellungsverfahren (IEK-1), 52425 Jülich, Germany

Tungsten is currently the baseline plasma-facing material (PFM) for future fusion devices. Despite its advantageous properties, tungsten gets damaged under the extreme plasma conditions, which can lead to a reduced lifetime of the plasma facing components (PFC) or the outage of the whole fusion reactor. As repairing is time and resource intense, Low Pressure Plasma Spraying emerges viable as a fast and affordable solution to restore the PFM and repair damages. Pre-heating of the different substrate materials: Carbon fibre composite, tungsten and Eurofer (T < 740 °C), helped to mitigate residual stresses caused by the thermal mismatch between coating and substrate. Quality parameters such as porosity below 5 % and number of defects were evaluated using digital image analysis. Further characterization was performed to obtain more information on the surface roughness and a coating thickness of at least 100 *m. In future work, selected coatings will be tested under fusion-relevant conditions to obtain a lifetime prediction and to allow to infer further possible improvements.

P 3.7 Mon 15:45 ELP 6: HS 3

Studies of deuterium retention in pre-damaged tungsten with laser-induced ablation quadrupole mass spectrometry — •Christoph Kawan[1,2], Sebastijan Brezinsek[1], Timo Dittmar[1], Thomas Schwarz-Selinger[3], and Erik Wüst[1] — [1]Forschungszentrum Jülich GmbH, Institut für Energie und Klimaforschung - Plasmaphysik, Partner of the Trilateral Euregio Cluster (TEC), 52425 Jülich, Germany — [2]Mathematisch-Naturwissenschaftliche Fakultät, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf, Germany — [3]Max-Planck-Institut für Plasmaphysik, D-85748 Garching, Germany

Future fusion devices based on magnetically confined plasma will operate with the hydrogen (H) isotopes deuterium (D) and tritium (T) as fuel gases and tungsten (W) as wall material. The extreme conditions inside the fusion device damage the wall surface and change the H retention properties. T accumulating in the W wall is a high risk in terms of radiation safety. Therefore, in-situ methods are needed to quantify the amount of H isotopes. Laser-induced ablation quadrupole mass spectrometry (LIA-QMS) is a promising method which can provide H isotope depth profiles in the wall material, potentially also in-situ. Here, LIA-QMS depth profiles on targets with different amounts of D with established methods such as laser-induced breakdown spectrometry (LIBS) and nuclear reaction analysis (NRA) are compared. LIA-QMS shows a higher sensitivity than LIBS (<0.1 at% with 150 nm depth resolution). The absolute amount differs compared to NRA (6 at% QMS, 1 at% NRA), thus requiring an optimized calibration.