O 78: Vacuum Science & Technology: Theory and Applications I

Time: Thursday 10:30–12:15 Location: HSZ/0401

Invited Talk O 78.1 Thu 10:30 HSZ/0401

The Wendelstein 7-X plasma vessel vacuum system from a scientific perspective — •Georg Schlisio[1], Torsten Bräuer[1], Stylianos Varoutis[1], Paul McNeely[1], Dirk Hartmann[1], Chandra Prakash Dhard[1], Dirk Naujoks[1], Victoria Hak[1], and the W7-X team[2] — [1]Max-Planck-Institut für Plasmaphysik, Teilinstitut Greifswald — [2]See author list of O. Grulke et al. Nuclear Fusion, 64(11), 112002 (2024)

Wendelstein 7-X (W7-X) is the world's most advanced stellarator, a long-overlooked concept for magnetic confinement fusion. Fusion devices require excellent vacuum conditions to minimize impurity influx and charge-exchange losses during high-temperature plasma operation. The W7-X plasma vessel vacuum system comprises the main vessel, 254 vacuum ports, and several auxiliary diagnostic vacuum systems, the largest of which is the Neutral Beam Injection (NBI) system.

We describe the W7-X plasma vessel vacuum system and its instrumentation for total and partial pressure measurements. A key parameter for valve and gauge calibration, as well as for exhaust quantification, is the effective plasma-vessel volume; we outline an approach for determining this volume with sufficient precision. We also report experimentally derived pumping speeds of the turbomolecular pumps (TMPs) and cryo vacuum pumps (CVPs), which are essential inputs for modelling and exhaust analysis.

As an application of these capabilities, a recent study of gas-species transport in the sub-divertor region is shown, comparing experimental measurements with modelling results.

O 78.2 Thu 11:00 HSZ/0401

Pulsed Molecular Beam Reactive Scattering for Investigation of Surface Chemical Reactions — •Oleksandr Arsatiants, Tobias Hinke, Kevin Bertrang, and Ueli Heiz — Chair of Physical Chemistry, Technical University of Munich, Lichtenbergstr. 4, 85748 Garching, Germany

Molecular beam reactive scattering (MBRS) is a powerful technique for investigating surface reactions on defined surfaces in UHV, providing complementary results to single-cycle experiments like thermal desorption spectroscopy (TDS) [1]. Pulsed MBRS is especially promising, as it can be used to investigate surface reaction kinetics under quasi steady-state conditions [2-5]. For molecules with complex MS fragmentation patterns, however, the short time scales present a challenge due to mass switching delays. Ongoing work on automation of p-MBRS measurements for rapid mass switching will be presented.

[1] F. Zaera, Surf. Sci. Rep. 72 (2), 59-104 (2017).

[2] P. N. Brier, J. N. Fletcher and P. A. Gorry, Surf. Sci. 365 (2), 525-534 (1996).

[3] P. Bond, P. N. Brier, J. Fletcher, P. A. Gorry and M. E. Pemble, Chem. Phys. Lett. 208 (3-4), 269-275 (1993).

[4] P. Bond, P. N. Brier, J. Fletcher, W. J. Jia, H. Price and P. A. Gorry, Surf. Sci. 418 (1), 181-209 (1998).

[5] M. D. Rötzer, M. Krause, T. Hinke, K. Bertrang, F. F. Schweinberger, A. S. Crampton and U. Heiz, Phys. Chem. Chem. Phys. 26 (18), 13740-13750 (2024).

O 78.3 Thu 11:15 HSZ/0401

Advancing Ultra-Clean Deposition of Fragile Molecular Building Blocks via Electrospray-Based Controlled Ion Beam Deposition — •Andreas Walz[1,2], Annette Huettig[1,2], Michael Walz[1,2], Hartmut Schlichtung[1,2], Patrick Lawes[2], and Johannes V. Barth[2] — [1]pureions GmbH, Gilching, Germany — [2]Technical University of Munich, Physics E20, Garching, Germany

The fabrication of functional nanostructures from organic, inorganic, or bio-relevant molecular building blocks regularly requires clean and gentle deposition in vacuum. Conventional approaches such as thermal evaporation (MBE, OMBE) are restricted to volatile species, while solution-based deposition techniques offer versatility but frequently suffer from impurities.

Controlled Ion Beam Deposition (CIBD) in UHV, equipped with an electrospray ionization (ESI) source overcomes these limitations by granting access to a broad class of large, reactive, and fragile species including functionalized organic molecules, graphene nanoribbons, proteins, and DNA. Efficient ion transfer and mass selection is ensured through fully digitally driven ion guides and a digital quadrupole mass filter (dQMF) with "virtually unlimited" mass range. Control over kinetic energy and dose allow for soft-landing or, when desired, reactive landing of the building blocks.

We present advances in ES-CIBD instrumentation and exemplary STM/AFM characterization of depositions. The technology provides a high degree of control during depositions, clean layers of mass selected molecules and access to otherwise low processability material.

O 78.4 Thu 11:30 HSZ/0401

Temperature-Programmed Spectroscopy: A Novel Tool for Kinetic and Mechanistic Studies for Processes on Surfaces — •Robert Bavisotto and Wilfred Tysoe — Department of Chemistry and Biochemistry, University of Wisconsin-Milwaukee, Milwaukee, WI 53211, USA

Advances in computational chemistry have facilitated the integration of theoretical calculations to complement experimental findings. However, since computational methods depend on many approximations and variables, they require careful validation, which in the case of experimental validation can be challenging or unfeasible. For example, activation barriers are often predicted using climbing nudged elastic band calculations, whose benchmarking has traditionally relied on temperature-programmed desorption, a technique inherently sensitive only to processes that produce gas-phase products. To establish a surface-selective experimental approach capable of probing kinetic processes directly on surfaces without requiring gas-phase products, a suite of innovative spectroscopic techniques is introduced. These methods, collectively referred to as temperature-programmed spectroscopy (TPS), rely on precise control of sample conditions, enabling surface spectroscopic data to be collected quasi-continuously. These novel analytical tools can be easily combined with existing spectroscopic methods, such as IR or XPS, without the need for new capital equipment. This capability enables the detection of subtle changes over short time intervals, thereby facilitating kinetic measurements of surface-based processes that were previously unverifiable.

O 78.5 Thu 11:45 HSZ/0401

Traceable outgassing rate measurements of sticky gases — •Matthias Bernien[1], Annas bin Ali[1], Janez Šetina[2], and Karl Jousten[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Berlin, Germany — [2]Inštitut za kovinske materiale in tehnologije (IMT), Ljubljana, Slovenia

In the semiconductor industry, the outgassing of components in vacuum must be well controlled. These contaminants are monitored using quadrupole mass spectrometry. However, quantitative measurements of the amount of contamination are challenging as quadrupole mass spectrometers (QMSs) inherently lack stability of their sensitivity. To provide comparability and traceability of outgassing rate measurements, processes and transfer standards must be established. PTB together with IMT and industrial partners have developed and characterized outgassing reference samples for dodecane and water. These reference samples consist of a reservoir sealed with an elastomer through which the liquids permeate into vacuum. The reference samples provide well-defined outgassing rates that are used to calibrate QMSs in situ for water and hydrocarbon contaminants. When using sticky gases like water and dodecane, a significant amount of gas molecules adsorbs on the inner surfaces of the vacuum chamber. A numerical model is utilized to simulate the dynamics of the adsorbed phase and the gas phase.

O 78.6 Thu 12:00 HSZ/0401

A dynamic analysis of the static friction in microscopic Hertzian contacts: Size effects and 2D-material assisted superlubricity — •Ahmed Uluca[1,2], Pierce Sinnott[1,2], and Graham Cross[1,2] — [1]School of Physics, Trinity College Dublin, Dublin, Ireland — [2]CRANN, Trinity College Dublin, Dublin, Ireland

Friction governs how objects start to move, yet our understanding still relies on empirical laws that vary across materials and length scales. To build a more fundamental picture, we focus on the interfacial shear strength (ISS)-a concept adapted from fracture mechanics that describes friction in terms of shear stress over the contact area.

We developed a mesoscale dynamic analysis method capable of probing contact radii from tens of nanometers to micrometers with sub-

nanometer displacement and 10-nanonewton force resolution. Starting from static contact, we gradually increase lateral oscillation amplitude while tracking contact radius and laterally stuck zone radius. This enables us to monitor the transition from sticking to sliding in real time while simultaneously measuring contact radius.

Using diamond-fused silica pairs, we map ISS across pressures from tens of MPa to several GPa and compare the results with theoretical models spanning from the Peierls (lattice) stress to the upper bound of a perfectly commensurate interface. Our findings reveal a pressure and scale dependent shear strength that is consistent with the dislocation emission models, extended to include the effects of deformation mode, nanoroughness, junction growth and interfacial modification by graphene layers.