Vacuum Technology Division
Room On Demand - Session VT-Contributed On Demand
Vacuum Technology Contributed On Demand Session

VT-Contributed On Demand-1 Study on Copper Thermal Spray Coating to Mitigate Electron Cloud Effect in SuperKEKB*, Mulee Yao,* SOKENDAI, Taiwan*; Y. Suetsugu, K. Shibata, H. Hisamatsu, T. Ishibashi, S. Terui,* KEK, Japan

To investigate the effect of the copper thermal spray coating on reducing the secondary electron yield (SEY) and verify its feasibility for accelerators as a countermeasure against the electron cloud effect (ECE), we coated the aluminum substrates (A6063) with copper powder by thermal spraying and measured their SEY, roughness, surface composition and outgassing rate. To establish the best coating parameters for the beam pipes of the SuperKEKB positron ring, we tested different spray conditions, such as particle size of copper powder, substrate surface treatment, spray angle and temperature, and exposure of the coating to electrons. Now we have produced a straight aluminum beam pipe with copper thermal spray coating that can be installed in the SuperKEKB, in order to observe the effect on reducing the ECE in the near future. In the study of the relationship between SEY and roughness, we found that the SEY was inversely proportional to the Sdr (developed interfacial area ratio) or Sa√Spd in the simulation, where Sa is arithmetical mean height and Spd is density of peaks. But the experimental results from the thermal spray sample were not consistent with it. The most probable reason is the limitation of the roughness measuring instrument on the fine and complex surface like thermal spray coating.

VT-Contributed On Demand-4 NIST on a Chip: Photonic and Quantum-Based Sensors for Metrology and Beyond*, Jay Hendricks,* NIST

This talk will briefly outline the NIST on a Chip (NOAC) Program.The unifying theme of the program is aimed at the development of standards and sensors that are small, deployable, that don't require calibration back at NIST.The core the idea of NOAC is that quantum-based measurements, or measurements based on fundamental physics, when employed in sensors and standards, are invariant.In the NIST on a Chip embodiment, the standards lab, or in this case "NIST", is "on a chip"and is powerful to industry and society as it means that large networks sensors (or sensors "integrated" into a product or device) can be deployed and trusted to provide accurate measurements without costly re-calibration. The overall strategy of the program is to first identify working prototype of laboratory scale devices and standards and then, overtime, build prototypes that can be further miniaturized to the chip scale. The successful program means that measurement technology enables high quality measurements to be done "outside the National Metrology Institute" but owed to base properties of nature and are therefore directly tracible to the international system of units known as the SI. Nested within this idea is the development of quantum-based standards for SI traceability. Given time example of lab scale and early prototypes of miniaturized versions will be presented.

VT-Contributed On Demand-7 Improving Temperature Uniformity of Stainless-Steel Components in Thin Film Processing Equipment*, Sudarshan Natarajan,* *D. Sabens, A. Murugaiah,* Momentive Technologies

This presentation outlines the characteristics, potential applications, and benefits of the Momentive Technologies stainless-steel encapsulated thermal leveler. Target applications include temperature uniformity improvement in wafer carriers or pedestals and other internals in chemical vapor deposition (CVD) or atomic layer deposition (ALD) equipment.

Momentive Technologies offers highly crystalline graphite known as thermal pyrolytic graphite (TPG), which exhibits 4X thermal conductivity than copper. Pedestals or wafer carriers or other internals of high temperature and corrosive thin film processing equipment can be manufactured by stainless steel alloys. But the temperature uniformity of these parts are severely limited by the poor thermal conductivity of the alloys. Momentive technologies recently developed stainless alloy encapsulated TPG leveler addresses this issue of temperature non-uniformity. Results of the temperature uniformity improvement and thermal cycle stability of the newly developed leveler are presented.

VT-Contributed On Demand-10 Particle Tracing the ISO Gauge*, Martin Wüest,* *F. Scuderi,* INFICON Ltd., Liechtenstein*; B. Jenninger, A. Stöltzel, P. Kucharski,* CERN, Switzerland*; O. Teodoro, R. Silva, N. Bundaleski,* Nova School of Sciences and Technology, CEFITEC, Portugal*; C. Illgen,* Physikalisch-Technische Bundesanstalt, Germany*; J. Šetina,* Institute of Metals and Technology, Slovenia*; K. Jousten, M. Bernien,* Physikalisch-Technische Bundesanstalt, Germany*; F. Boineau,* Laboratoire national de métrologie et d'essais, France*; M. Vičar,* Czech Metrology Institute, Czechia

In the framework of the EURAMET project 16NRM05 a novel ionization gauge was developed. The goal was to develop a more stable ionization gauge that could be suitable for standardization. The gauge design was completely developed by computer simulations. To increase the reliability of the simulation results, three different software packages were used in parallel (COMSOL, OPERA, SIMION). With these codes the gauge design was refined and experimental features explained. Despite different treatment and methods used in the ionization module of the simulation codes, the results agree very well with the experimental results.

Acknowledgement:

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VT-Contributed On Demand-13 Three-Dimensional Analysis and Design Assessment of the Mast-U Double Beamline Cryogenic Pumping System*, Xueli Luo,* *S. Hanke,* Karlsruhe Institute of Technology, Institute for Technical Physics, 76021 Karlsruhe, Germany*; A. Shepherd,* Culham Centre for Fusion Energy, Abingdon, Oxfordshire, OX14 3DB, United Kingdom*; C. Day,* Karlsruhe Institute of Technology, Institute for Technical Physics, 76021 Karlsruhe, Germany

The MAST upgrade program (MAST-U) is an ongoing nuclear fusion project in Culham Centre for Fusion Energy (UK), aiming to resolve important plasma physics questions and develop advanced divertor designs. In addition, as part of the MAST-U Enhancements project, MAST-U will be used to test steady state operation with current driven by a novel double beamline neutral beam injection (NBI) system. With one axial beamline and one off-axial beamline at 10.6 degrees, this unique design could have greater possibilities and flexibilities in the plasma heating, control and diagnostics.

Fig. 1. Sketch of the MAST-U double beamline NBI system design.

However, as shown in Figure 1 (Please see the supplemental file Figure_1.pdf), this novel NBI system is very complex with many sub-systems. The focus of this paper is the analysis and design assessment of its cryogenic pumping system. Two aspects were systematically studied by simulations with the test Monte Carlo simulation code ProVac3D developed in KIT. First, the dependency of the density profiles along the double beamlines to the in-vessel cryopump was obtained by changing the capture coefficient of the cryopump as a whole in the simulation. Combined with simulation results using the MCNP code, we can estimate the total pumping speed needed to fulfil the requirement of the density profiles. Secondly, different configurations of the cryopump were simulated and a conceptual design, which could deliver the right total pumping speed, was proposed. In order to simulate such a complex system and have high precision for so many simulations in reasonable computation time, all simulations were carried out in supercomputer Marconi-Fusion by using 2560 cores in parallel to simulate 10^{11} test molecules. Obviously, the simulation results obtained in this study will be extremely useful to the success of the challenging tasks of MAST-U.

ACKNOWLEDGEMENTS

This work has been carried out within the framework of the EUROfusion Consortium and has received funding from the Euratom research and training programme 2014-2018 and 2019-2020 under grant agreement No 633053 and from the RCUK [grant number EP/T012250/1]. This work was partially supported by the EUROfusion project VAC_ND in the supercomputer MARCONI-FUSION at CINECA, Italy. The views and opinions expressed herein do not necessarily reflect those of the European Commission.

**VT-Contributed On Demand-16 Cost Description and Characterisation of Gases used in immiscible gas Enhanced Oil Recovery processes (IGEOR)*, Ofasa Abunumah*, *P. Ogunlude, E. Gobina,* The Robert Gordon University, UK

The cost implication of gases used in the oil industry has been characterised through data mining and experimentally. About 70% of oil is trapped in reservoir pores globally due to the limitation of primary oil recovery processes. Consequently, certain gases are injected into reservoir pores to displace the trapped oil in a process calledImmiscible GasEnhanced Oil Recovery (IGEOR). Common gases injected are CH_4, N_2, Air & CO_2. The flow mechanisms, such as surface energy, permeability and momentum have been extensively studied by investigators. However, only a few studies have implicated or coupled injected gas cost. No experimental investigation that simultaneously studies the 4 commonly used gases. Nevertheless, the injectant cost is a major part of the operating expense (OPEX) cost centre.It is expected that the gas cost competitiveness of the gases would aid reservoir screening and gas selection in IGEOR applications. Therefore a study is needed to bridge this knowledge gap. From the literature review, it was indicated that the displaced oil is proportional to injected gas volume. It is therefore expected that competition could be tied to gas dynamics in pore surfaces for the respective gases. e

Methodology and Materials

Materials: 5 analogous reservoir porous core samples with different structural parameters, such as micro and macro surface area. 4 IGEOR gases (CH_4, N_2, Air, CO_2) were selected.

***Operating Condition*:** Temperature range 293-673K andPressure range 20-300KPa.

Procedure: Gas was injected into the core samples at a set pressure and temperature. Permeate flow rates, temperature and pressure collected as steady state.

Data ming : 353

Experimental Data: 1,097 runs and 8,777 data.

***Gas Cost Types*:** Market, Field and experimental gas cost

Result

Analyses of the field and experimental data show thatIGEOR gases can be characterised. All three cost types were found to be strongly correlated to the 6 gas thermophysical properties (R^2).It was found that **CO_2**is the least expensive gas for all 3 gas cost categories, and thus the most competitive. The **Air** EOR process is the most sensitive to cumulative injectant cost.The slope of the graph between gas cost and properties indicated that 9 of the relationship are inversely correlated with the gas properties, while 8 are positively correlated.

Market cost CO_2 > Air> N_2 > CH_4.

Field project gas cost:CO_2 > Air> N_2 > CH_4.

Experimental project gas cost: CO_2 > N_2 > Air > CH_4..

Contribution to Practice: Engineers can apply this knowledge to select the best IGEOR gas for a given reservoir or porous surface. The discovered competitiveness of CO_2 would further incentivise the Carbon Capture and Sequestration (CCS) programmes to reduce greenhouse gases.

VT-Contributed On Demand-19 Vacuum level Sensing Using Optical Refractive Index*, Kevin Douglass*, *J. Ricker,* NIST

Towards the goal of quantum-based traceability of the Pascal, NIST has developed an optical pressure measurement system where traceability is achieved through accurate quantum mechanical calculations of the refractivity virial coefficients of . To bridge the gap in quantum standards between the NIST Fixed Length Optical Cavity (FLOC) and the Cold Atom Vacuum Standard (CAVS) we are pushing the limits in low pressure sensing. We will discuss recent results and ultimate low-pressure limit.

VT-Contributed On Demand-22 Simulation of the Operation of an Ion Pump*, Tiziano Isoardi*, *P. Manassero, L. Bonmassar,* Agilent Technologies, Italy

An ion pump is a system that is capable to produce the ultra-high vacuum. The basic element of this pump is the Penning trap which confines free charged particles in a cylindrical space. This can be done using a combination of an electrostatic-multipolar and a magnetic-dipolar field which allows to trap electrons and to accelerate ions towards one of the two cathodes. The ultra-high vacuum is reached because the ion-cathode collisions generate sputtering phenomena of chemically active Titanium film on anode to which gas molecules from the trap are attached. The process is fed by electrons generated by secondary emissions due to the ion-cathode collisions. These electrons have an elevated total energy (equal to the potential of the cathode) with respect to the ionization potential that allows them to ionize gas molecules more than once until they lose all their energy forming a non-neutral plasma. This mechanism should lead to an exponential increase of the current until the complete emptying of gas molecules, but actually the current stabilizes almost immediately (tens of milliseconds). This means that there is some phenomena that prevent the current exponential growth. In order to investigate the current behavior, we studied all phenomena that occur inside the pump through repeated Monte Carlo simulations of single electrons inside the trap, by studying all the single charge interactions. It is known that in a non-neutral plasma there is a maximum charge density that can be achieved which depends on the magnetic field magnitude and on the single charge mass. This is called Brillouin limit and can be easily calculated. So we built simulations at the Brillouin limit approximating the plasma as an electrically charged cylinder (taking into account the influence of plasma on the electric field) considering steady-states at different pressures of a single gas (N2 or H2). After that we built a parameterization to calculate the ionization frequency for a single electron that we used to obtain the current at the cathodes. The current values resulting from simulations closely match the experimental data (see attached Fig.1-3). According to the results of the simulation the plasma absorbs a large fraction of the energy of the free electrons generated at the cathode until they can not ionize the gas molecules. This means that the energy loss in the plasma is responsible for the saturation of the current. When the Brillouin limit is reached the current is stabilized to a value that depends essentially only from the density of the gas and decreases together with the residual pressure of the gas in the trap.

VT-Contributed On Demand-25 Experimental Characterization of a NEG Pump of Novel Size - A Step to its Application in the DEMO Neutral Beam Injectors*, Stefan Hanke*, *C. Day, T. Giegerich, X. Luo,* Karlsruhe Institute of Technology (KIT), Germany*; F. Siviero, M. Mura, A. Ferrara, E. Maccallini, P. Manini,* SAES Getters, Italy*; E. Sartori, M. Siragusa, P. Sonato,* Consorzio RFX, Italy

A fusion reactor requires powerful heating systems among which the neutral beam injectors (NBI) are the most powerful ones. Operation of NBI systems requires very high pumping speeds in the order of several 1000 m^3/s at relatively moderate pressures of 0.02 Pa to manage the high gas flux in the neutralizer part of the NBI. In the past large customized cryopumps were used. A very promising concept for future NBI applications is based on high capacity getter materials. The material candidate is ZAO® developed by SAES Getters, Italy, providing a performance for the pumping of hydrogen approximately two orders of magnitude higher compared to conventional getter materials.

In a systematic technology development over 6 years, the concept of a NEG pump for NBI was developed within the European Fusion Programme to develop a demonstration fusion power plant (DEMO). It started with the comprehensive characterisation of the material and its properties, in particular at pressures which were significantly higher than in previous UHV applications of getter materials. With the time the knowledge was expanded not only regarding pumping and regeneration characteristics of ZAO® itself but also concerning the heating, thermal management, assembly to larger units for scalability and control of these units during operation. The recent step was the design, manufacturing and operation of a NEG pump which is of relevant size to answer all the DEMO NBI relevant questions, to demonstrate the use of ZAO® in a large pump and to confirm the scalability of the chosen design.

The resulting NEG pump of novel size contains 16 kg of getter material, it was tested in the dedicated test facility TIMO at KIT. The paper describes the design of the pump and presents the experimental results, in particular a systematic investigation of sorption characteristics (depending on pressure, gas flux, getter temperature, loading of the getter with gas) and the regeneration behaviour.

VT-Contributed On Demand-28 Shenzhen Synchrotron Radiation Facility Project*, Dongbai Sun*, *G. Liu, R. Si, Y. Cui, B. Yang, Z. Zhou,* Institute of Advanced Science Facilities, Shenzhen, China

A new synchrotron radiation facility is currently in the planning stage and will be constructed in Shenzhen, China, by the Institute of Advanced Science Facilities, Shenzhen（IASF）. The proposed synchrotron light source consists of a 0.2 GeV linac, a full energy booster ring, and a 3 GeV fourth-generation diffraction-limited storage ring which is based on a seven-bend achromat (7BA) to achieve a low emittance of <100 pm·rad. It delivers X-ray synchrotron radiation with a broad range of energies and a brightness in the order of 10^{21} phs/sec/mm^2/mrad^2/0.1BW. Besides, 27 beamlines of various methods covering scattering/diffraction, spectroscopy, and imaging have been proposed for the primary phase. The new synchrotron light source is believed to be one of the most essential large-scale science and research facilities in Shenzhen and provides a fundamental platform to serve researchers around the world, and to contribute to industrial development in China's Greater Bay Area.

VT-Contributed On Demand-34 Progress Towards Comparison of Quantum and Classical Vacuum Standards*, **Daniel Barker**, N. Klimov, E. Tiesinga, J. Fedchak, J. Scherschligt, S. Eckel,* National Institute of Standards and Technology (NIST)

We present our progress towards a comparison of NIST's cold atom primary vacuum standard and a dynamic expansion vacuum standard. The cold atom vacuum standard (CAVS) converts the loss rate of atoms from a magnetic trap to a vacuum pressure using *ab initio* calculations of the quantum atom-molecule collision cross-section. To validate the CAVS, we have constructed a new flowmeter and dynamic expansion system that can produce low-uncertainty pressures in the ultra-high-vacuum range that is required for atom trapping. We present initial studies of systematics in both the CAVS and flowmeter. We will also discuss prospects for comparisons of both the CAVS and flowmeter to deployable quantum vacuum sensors.

VT-Contributed On Demand-37 NIST's New Flowmeter for the Extremely-High Vacuum*, **Stephen Eckel**, D. Barker, J. Fedchak, E. Newsome, J. Scherschligt, R. Vest,* NIST

At NIST, we have been developing a new, fully-automated, low-outgassing, constant-pressure flowmeter capable of measuring flows to better than 0.5% over the range from 10^{-13} mol/s to 10^{-9} mol/s. While based on the design of the constant-pressure flowmeter used at NIST to calibrate leaks and high vacuum and ultra-high vacuum pressure gauges, our design incorporates several novel features. To achieve measurement of such low flows, our design uses both small variable volumes (<15 mL each) and ultra-small displacements (0.25 mL max). By constructing our variable volumes from low outgassing materials like titanium and designing the flowmeter to be fully bakeable, we achieve <10^{-15} mol/s outgassing rates. The leak that generates the flow is a stainless steel sintered standard leak element. We measure its stability and its conductance (approximately 26 nL/s for N_2) over 4 decades of pressure. We present comparisons to our current flowmeter over the overlapping operating range of about 10^{-11} to 10^{-9} mol/s. When coupled to an orifice flow standard with a 40 L/s conductance for N2 and a 99/1 flow splitter, the combined system can generate partial pressures as low as 10^{-11} Pa, extending NIST's measurement capability into the extremely-high vacuum (XHV) regime. The first application of the flowmeter will be to measure loss rate coefficients of the newly developed cold-atom vacuum standard (CAVS).

VT-Contributed On Demand-40 Jefferson Lab Injector Beamline Upgrade*, **Marcy Stutzman**,* Thomas Jefferson National Accelerator Facility

Jefferson Lab is in the midst of an upgrade of the injector beamline. The upgrade has several goals, all of which support upcoming high profile parity violation experiments such as SOLID and Moeller. First, we are developing several paths toward a higher voltage electron source. With highly polarized beam at 200 keV out of the electron gun rather than the current 130 keV operational voltage, the Coulomb repulsion effects in the beam will be minimized, and photocathode damage due to ionization within the cathode/anode gap can be mitigated. Secondly, the only warm RF accelerator cavity at CEBAF, the Capture, and the first SRF accelerator cavity, called the quarter cryo module, will both be replaced by a graded SRF booster module. The booster has two graded cavities to accelerate non-relativistic electrons from the polarized source to energies up to 10 MeV. However, the higher gun voltage of 200 keV is required for this booster to work well. Finally, in support of these upgrades, the entire injector beamline has been redesigned, and the vacuum upgrades for this system and their impact on the performance of the electron source will be discussed.

VT-Contributed On Demand-43 Gas Transmission Rate of Elastomer Seal With a Divided Back-Up Ring Seal*, **Masaharu Miki**, Y. Miki,* EM Technical Lab Inc., Japan

It was presented in the last AVS (VT-TuP4) that the elastomer seal with the back-up ring seal has very low Helium gas transmission rate, which is about less than 10% of the case without the back-up ring seal. Then divided back-up ring seal which is made of some parts was studied. That is because it is less manufacturing cost than non-divided back-up ring seal, especially, in case that the shape of elastomer seal is not a circle but a complicated shape like a horseshoe.

Air gas transmission rate of an elastomer seal with a divided back-up ring seal was evaluated from the ultimate pressure measured. It was found that the divided back-up ring seal has the same performance as a non-divided back-up ring seal. And when a divided back-up ring seal has some space between the parts, it gets worse performance according to the amount of the space. It means that when it has little space between the parts, it gets about 100% performance of a non-divided back-up ring seal, and when it has 10% space of all, it gets about 90% performance of a non-divided one.

Performance of divided back-up ring seals which have some space between the parts were measured and a model to explain the performance of the back-up ring seals has been constructed.

Furthermore, performance of some divided back-up ring seals which are made of some different materials are evaluated.

VT-Contributed On Demand-46 Thermal Evaluation of a Fixed Length Optical Cavity Pressure Standard*, **Jacob Ricker**, J. Hendricks, K. Douglass,* NIST

Over the past few years, NIST has constructed and tested several Fixed Length Optical Cavity (FLOC) Pressure Standards for measuring gas pressure using refractometry. This refractometry technique has been shown to have similar uncertainty to the current NIST primary standards. However, to achieve this performance they must have uncertainties of temperature measurements on the order of 1 mK. This is easy in a static environment; however, pressure standards need to be able to measure more than one pressure, so pressurization/compression/flow of gas molecules is required. The NIST Fixed Length Optical Cavity (FLOC) pressure standard was designed to accommodate pressure changes while being able to accurately determine the temperature of the gas molecules and glass cavity by using a Platinum Resistance Thermometer (PRT).

From the ideal gas law and thermodynamics, we can estimate the temperature rise due to pressurization of the gas molecules to increase the temperature by 120 K when going from vacuum to atmospheric pressure. However, due to the small heat capacity of gas this quickly dissipates into the surrounding environment.This results in a small, but measurable temperature rise that is significantly larger than our uncertainty.Physical measurements and computer modelling were used to predict the temperature of the FLOC and allow placement of a PRT to provide accurate measurements of the gas temperature to within an uncertainty of 0.5 mK.

VT-Contributed On Demand-49 Stability of Bakeable Capacitance Diaphragm Gauges*, **Julia Scherschligt**, D. Barker, S. Eckel, J. Fedchak, E. Newsome,* NIST

Capacitance diaphragm gauges (CDGs) are workhorse transfer standards for NIST and other metrology labs around the world. Here, we present a stability study of bakeable CDGs, which are useful in vacuum systems with low outgassing or base pressure requirements. In our studies, a set of three bakeable CDGs was baked in a vacuum furnace at 450 C for about 20 days to reduce hydrogen outgassing. After assembly into a NIST transfer standard, the CDGs were baked again at 110 C to reduce water outgassing. After the initial 450 C bakeout, we found that the calibrations of the CDGs shifted by about 15%. However, after the first 110 C bakeout, the CDGs calibrations remained extremely stable, with <0.2% (k=2) change after each subsequent bake. We performed additional tests, which included dropping a 10 kg weight from a height of 30 cm nearby the gauges, venting the system, completely disassembling, sonicating with acetone and ethanol, and reassembling the system. With this expanded regimen, the gauges drifted further, but no more than 0.6% (k=2). These bakeable CDGs are thus remarkably stable, provided they are temperature stabilized when being used. They now form the transfer pressure standard for our new extremely-high vacuum (XHV) flowmeter, being developed as part of our new cold atom vacuum standard (CAVS) program.

VT-Contributed On Demand-52 Outgassing of A36 Carbon Steel Vacuum Chambers*, **James Fedchak**, J. Scherschligt,* NIST-Gaithersburg

A36 steel is a low-carbon (mild) steel commonly used as a structural steel in the US. Secondary refining processes reduce the hydrogen content in mild steel, making these steels excellent candidates as materials for ultra-high vacuum chambers because of their potential to be low-outgassing.Previously we measured and compared the H_2 and water outgassing rates for 7 identical vacuum chambers constructed of common vacuum materials and heat treatments: 304L, 316L, 316LN-ESR (electroslag re-melt), titanium, aluminum vacuum-fired 316L, and vacuum-fired 316LN-ESR. These chambers are of identical geometry and are from the same manufacturer. In the present study, we measure the hydrogen and water outgassing rate of an A36 chamber with similar geometry to these 7 chambers.We show that the A36 chamber produces one of the lowest outgassing rates compared to any of these vacuum materials.Thus, A36 may be an excellent choice for ultra-high or extreme-high vacuum applications.Compared to stainless-steel such as 304L or 316L, mild steels are more corrosive and magnetic, but the are inexpensive, have excellent properties for welding and machining, and, as we will show, have excellent outgassing properties.This makes them a good candidate for large vacuum systems such as future gravity wave detectors. In this presentation, we will present outgassing results for the A36 chamber and compare these results to the seven other chambers mentioned above.

VT-Contributed On Demand-55 An in-Situ and in-Vivo Characterization Facility for Ion-Gas-Neutral Interactions With Surfaces (IGNIS-2) Under Fusion-Relevant Vacuum Conditions*, **Ethan Kunz**, C. Jaramillo, H. Schamis, M. Parsons, S. Kolecki, M. Fredd, C. Smith, M. Nieto, J. Allain,* Pennsylvania State University

The study of plasma-facing materials (PFMs) in the field of fusion plasma material interaction research involves testing new materials hypothesized to sustain the intense neutron radiation, particle flux, and heat flux of future plasma-burning thermonuclear fusion reactors. Studies involving long-term evaluation of tokamak first wall materials encounter issues with contamination when vacuum is broken on the system and the samples are transported for ex-situ analysis. Therefore, there is a need for facilities capable of simulating key aspects of the fusion environment and analyzing the surface morphology and chemistry of the sample without the necessity of exposure to the ambient environment. However, relevant vacuum conditions that mimic fusion devices are critical to enable interpretation in ex-vessel facilities designed to test and qualify candidate PFMs including background ambient pressure (partial H2O), working gas pressure (D2 at mTorr ranges), wall conditioning (e.g. B, Li) and radiative gas shielding (e.g. N, Ne).

In this work, we present the design of the Ion-Gas-Neutral Interactions with Surfaces (IGNIS-2) facility, currently being built at the Pennsylvania State University. IGNIS-2 is the fourth generation of a series of advanced experimental surface science facilities developed by Allain et al. [1]. Surface modification and ion beam irradiation with ion energies ranging from 50 to 5000 eV and current densities up to 7 mA cm-2 will be performed in this facility. IGNIS-2 will use in-situ characterization to accurately study the surface evolution under exposure to simulated fusion conditions. Characterization techniques include high-pressure X-Ray Photoelectron Spectroscopy (XPS) using a monochromated X-Ray Source, Ion Scattering Spectroscopy (under forward and backward scattering configurations), UV-Vis-NIR reflectance spectroscopy, Multi-Beam Optical Stress Sensor (MOSS), mass spectrometry, and in-situ erosion measurements.

IGNIS-2 will be composed of multiple vacuum stages which will be interconnected via a subway system that will allow sample transfer within stations in-vacuo, retaining the characteristics of the modified surfaces without exposure to air and contamination. The system will also be integrated with a glovebox with in-vacuo capabilities for the preparation of samples for air sensitive processes. Additional stations in the system will host capabilities for thin film deposition and liquid metal application, including a lithium dropper and contact angle measuring station designed in conjunction with the NSTX-U Liquid Metal research being conducted at Penn State.

[1]Allain, J.P., Nieto, M., Hendricks, M.R., Plotkin, P., Harilal, S.S., Hassanein, A. (2007): Review of Scientific Instruments, 78, 11, 113105.

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