Vacuum Technology
Room Central Hall - Session VT-ThP
Vacuum Technology Poster Session

VT-ThP-1 Surface Characterization and Vacuum Performance of AISI 1020 Low-Carbon Steel for High-Performance Vacuum Systems*, **Aiman Al-Allaq,*** Old Dominion University*; M. Mamun, M. Poelker,* Thomas Jefferson National Accelerator Facility*; A. Elmustafa,* Old Dominion University

The Cosmic Explorer, a next-generation gravitational wave observatory, will be very large with evacuated interferometer arms ten times longer than Advanced LIGO operating today, 40 km each. Consideration is being given to building this extremely large vacuum system using comparatively inexpensive low-carbon steel, commonly used today for natural gas delivery. But besides reduced cost, low-carbon steel offers a vacuum advantage, too. Low-carbon steel has a much lower hydrogen outgassing rate compared to stainless steel. In addition, studies performed worldwide within the gravitational wave observatory community suggest low carbon steel – particularly with a magnetite surface coating – may provide a more rapid pump down, possibly reaching acceptable vacuum conditions with only an 80 °C heat treatment. At Jefferson Lab, we plan to construct a new spin-polarized electron source using low-carbon steel, which we hope operates at a much lower pressure than our photoguns built using stainless steel. In support of this objective, we are performing studies related to water outgassing, pump down times, and ultimate pressure achieved using low-carbon steel. Some of these studies seek to understand if material surface transformations occur following different heating protocols. Small coupons made of AISI 1020 low-carbon steel were characterized using SEM, AFM, XRD, and EDS after various heat treatments. The results showed minimal oxidation up to 150 ˚C, with layered magnetite and hematite developing at higher temperatures. A steam-treated sample exhibited vertical grain orientation, while thermal oxidation favored lateral oxide colony formation. Tests on magnetite-coated and bare low-carbon steel chambers demonstrated that the magnetite-coated chamber consistently achieved lower pump down pressure and lower throughput water outgassing rates, supporting the idea that magnetite coating can improve the vacuum performance of low-carbon steel. Ongoing research at Jefferson Lab focuses on characterizing bare and magnetite-coated low-carbon steel chambers to explore their feasibility in next-generation vacuum systems, such as those required for the Cosmic Explorer project, and for spin-polarized electron guns where improved vacuum will help sustain reliable beam delivery.

VT-ThP-3 Commissioning of the New NIST High-vacuum Calibration Standard*, E. Newsome, D. Barker, J. Fedchak, **Julia Scherschligt,*** National Institute of Standards & Technology

We report our efforts toward commissioning NIST’s new ionization gauge calibration system (IGCS). Ionization gauges are critical to applications operating in the high-vacuum and ultra-high vacuum ranges. These gauges determine pressure in a vacuum chamber by first ionizing gas molecules in the vacuum via collisions with electrons emitted from a cathode, then collecting the ions on a wire, and measuring the subsequently generated current. Because the conversion of ion current to pressure depends on gauge geometry, collection efficiency, electrode potential, and other factors, individual gauge sensitivity will vary and, in general, requires calibration to achieve the best measurement accuracy. In the range of 0.1 Pa to 10^{-7} Pa, the IGCS calibrates ion gauges by comparing the gauge reading to a known pressure step using the dynamic expansion technique. We describe the design of the IGCS, focusing on improvements over NIST’s previous high-vacuum standard. We also present initial tests of the IGCS and calibration results for NIST gauges.

VT-ThP-4 Developing an Extreme Environment Vacuum System for ITER's Ion Cyclotron Heating Antenna*, J. Clark, **Charles Smith III,*** Oak Ridge National Laboratory

The ITER project is designed with the goal of demonstrating the feasibility of fusion energy, and to advance the technological understanding of fusion for future commercial reactors.In order to achieve a “burning plasma”, various heating methods, such as Neutral Beam, Electron Cyclotron Heating, and Ion Cyclotron Heating (ICH) are employed in the ITER fusion device. Each of these technologies require high vacuum environments to ensure safe and efficient operation; however,ICH, in particular, poses unique issues in developing a vacuum system.

The proximity of the ICH antenna, and associated vacuum pumping system of the ICH Removable Vacuum Transmission Line (RVTL) Rear Windows,to the ITER Tokamak necessitates a vacuum system that is able to withstand dynamic magnetic fields in excess of 500 mT and activation of up to 10^4Gy. Vacuum technology and hardware layouts that have become common across ITER vacuum systems are not operablein this extreme environment. To develop a functional vacuum system for the ITER ICH antenna’s RVTL Rear Windows, it must be designed with hardware and an arrangement that tolerates the environment and meets pressure requirements without significant increase inevacuation time.

VT-ThP-5 Secondary Electron Yield Measurements of Vacuum Insulators*, **Minh Pham,** R. Goeke,* Sandia National Laboratories

Ceramics are commonly used for high voltage insulation in vacuum systems. The vulnerability of its high voltage standoff is a flashover of the insulator surface. The principal mechanism for this breakdown is a secondary electron emission (SEE) avalanche. In this process, some electrons striking the insulator surface produce more electrons which strike the surface again producing additional electrons. This process continues until a flashover of the insulator surface occurs and the high voltage standoff is lost. We have developed a test stand to measure SEE yields as function of incident electron energy using very small doses of electrons to minimize surface charging of the insulators. This system utilizes a Hemispherical Grid Retarding Field Analyzer to capture all the secondary and backscatter electrons in an Ultra High Vacuum environment, ensuring an accurate measurement of SEE yield. By firing quick small pulses of electrons enables us to analyze insulating samples before the surface becomes charged which will alter the electron emission process. Results from our measurements on ceramic insulators will be

presented.

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VT-ThP-6 An Enhanced, High-Vacuum System and Related Testing of Unique, Prototype Sensor Hardware for the ITER-DRGA Project*, C. Marcus, T. Biewer,* ORNL*; J. Brindley,* Gencoa, UK*; A. Jugan,* North Carolina State University*; C. Klepper,* ORNL*; P. McCarthy,* Gencoa, UK*; **Brendan Quinlan**,* ORNL

The ITER Diagnostic Residual Gas Analyzer (DRGA) performs fusion neutral gas analyses. The ROI comprises low-amu species (1 thru 6), and includes the isotopic profiles of hydrogen and helium [1]. There are challenges in obtaining accurate measurements. First, the method sensitivity must suffice to resolve trace amounts accurately (≤1%). Second, the gas signal must be free of bias caused by the latent presence of these gases to acquire accurate measurements. For the lightest gases, backstreaming a fraction of the pumped gas load can be a source of such latency effects. This phenomena is attributed to modest inertia due to their lowest weight and smallest size. As a result, collisional effects create a reverse flow into the analysis region, which can contaminate the real-time measurement. To fully eliminate this adverse effect, a conductance-limiting device – or orifice – has been installed in the high-vacuum pumping system of the present DRGA prototype. It is intended to eliminate backstreaming by increasing the back pressure within the inter-pump volume (IPV).

An added benefit of the orifice-restricted pumping concept is that the upstream pressure increase is beneficial to the DRGA plasma cell used optical gas analysis. These sensors are attached to the IPV in the present DRGA design. The glow discharges will typically have a brighter light emission with increasing plasma cell pressure. For the DRGA, one of the glow discharge sources being evaluated for this system is a prototype made by Gencoa Limited (UK), which has been designed to exhibit satisfactory immunity to fringing fields, simulated for the tokamak environment. Also, the unique circuitry control for the input power control of the cell, when coupled with the specialized magnetic confinement of the plasma, have optimized the profile shapes of line emissions of interest for these isotopes, of which some emission lines are difficult to deconvolute.

Described herein are two ITER-DRGA related concepts: Vacuum system testing to validate elimination of light gas backstreaming and test results from using the prototype light source and a modified, Penning cathode.

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[1] C.C. Klepper et al., 2022 IEEE-TPS 50 (12) 4970

VT-ThP-7 Quantum State Specific Collision Dynamics of Vibrationally Excited Nitric Oxide at Collision Energies Over Five Orders of Magnitude*, Chatura Perera, A. Suits,* University of Missouri-Columbia*; H. Guo,* University of New Mexico

Collision studies involving the open shell nitric oxide (NO) molecule have been central in many detailed investigations of molecular reaction dynamics as a prototype system for probing inelastic collisions. These processes have proven a powerful means of investigating molecular interactions, and much current effort is focused on the cold and ultracold regime where quantum phenomena are clearly manifested. Here I present our recent work on state-to-state spin-orbit changing collisions of highly vibrationally excited NO molecules prepared in single rotational and parity levels at v=10 using stimulated emission pumping (SEP). This state preparation is employed in a near-copropagating beam geometry that permits very wide tuning of the collision energy, from far above room temperature down to 2 K where we test the theoretical treatment of the attractive part of the potential and the difference potential for the first time. We have obtained differential cross sections for state-to-state collisions of NO(v=10) with Ar/Ne in spin-orbit excited manifold using velocity map imaging. Overall good agreement of the experimental results was seen with quantum mechanical close-coupling calculations done on coupled-cluster potential energy surfaces. Probing cold collisions of NO carrying ~2 eV of vibrational excitation allows us to test state-of-the-art theory in this extreme nonequilibrium regime. The current experimental setup is now modified to permit a near-counterpropagating geometry for the molecular beams which allows us to look into really high collision energies to study chemistry in high temperature hypersonic flows. This takes us to a new direction where vibrationally inelastic processes may appear and the latest results along these experiments will also be presented.

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