Friday Morning, November 13, 2026

Vacuum Technology
Room 315 - Session VT-FrM

Vacuum Technology Pressure Measurement

Moderators: Dr. Julia Scherschligt, National Institute of Standards and Technology, **Mr. Charles Smith**, Oak Ridge National Laboratory

10:30am **VT-FrM-10 High Vacuum MEMS Devices – Advances in Vacuum Technology in Microscale***, **Michał Krysztof**, Tomasz Grzebyk, Piotr Szyszka, Paweł Urbański, Marcin Białas, Jakub Jendryka, Jan Sobków, Paweł Knapkiewicz, Jan Dziuban,* Wroclaw University of Science and Technology, Poland **INVITED**

High and ultra-high vacuum technologies have long been a cornerstone of advanced scientific instrumentation, including electron microscopes, mass spectrometers, and X-ray sources. Traditionally, such systems rely on large vacuum chambers and complex, multistage pumping infrastructures, which inherently limit their miniaturization, portability, and widespread deployment. Despite continuous optimization, the fundamental architecture of vacuum technology has remained largely unchanged for decades.

Recent advances in microelectromechanical systems (MEMS) enable a fundamentally different approach, in which vacuum is generated, maintained, and utilized directly at the microscale. A key breakthrough was achieved at Wroclaw University of Science and Technology with the development of a MEMS-compatible high-vacuum micropump [1]. Fabricated using standard silicon–glass MEMS processes, this integrated pump allows stable vacuum levels on the order of 10^{-7} mbar to be generated in millimeter-scale volumes, eliminating the need for external pumping systems.

This invited talk presents how the availability of such a miniature vacuum pump enabled the development of a family of fully integrated, ultra-compact vacuum devices (Fig. 1). Selected examples include MEMS-based field-emission X-ray sources [2], miniaturized gas analyzers [3] and quadrupole mass spectrometers [4], as well as other electron- and ion-based vacuum microsystems [5]. The technological aspects of integrating vacuum, electron-optical, and nanoelectronics components into sealed MEMS structures are discussed, together with their functional capabilities.

The presented results demonstrate that MEMS technology enables a paradigm shift in vacuum engineering—from large, centralized vacuum installations toward autonomous, application-specific microscale vacuum instruments. This approach opens new opportunities for vacuum technology in space science, materials research, environmental diagnostics, and distributed sensing systems.

References:

[1] Grzebyk, T., Górecka-Drzazga, A., & Dziuban, J. A. (2014). *Sensors and Actuators A: Physical*, *208*, 113–119.

[2] Urbański, P., & Grzebyk, T. (2024). Journal of Microelectromechanical Systems, 33(5), 508–510.

[3] Szyszka, P., Stambulskyi, K., & Grzebyk, T. (2025). EUROSENSORS 2025, Wroclaw, Poland - Sept. 7th-10th 2025: book of abstracts. s. 104-105.

[4] Szyszka, P., Jendryka, J., Sobków, J., Zychla, M., Białas, M., Knapkiewicz, P., Dziuban, J., & Grzebyk, T. (2024). Sensors and Actuators B: Chemical, 411, 135712.

[5] Białas, M., Grzebyk, T., Krysztof, M., & Górecka-Drzazga, A. (2023). Ultramicroscopy, 244, 113653.

11:00am **VT-FrM-12 Cassini - A MEMS Pirani with Range of 9 Order of Magnitude***, **Klaus Bergner**, Kristian Kirsch, Lukas Reger, Andreas Truetzschler,* VACOM, Germany

Many key applications of vacuum technology—such as coating and thin-film processes, surface analysis, and semiconductor manufacturing processes—operate continuously between atmospheric pressure and approximately 10^{-6} mbar. To cover this range completely and with metrological reliability, three measurement principles are combined in practice: capacitive diaphragm sensors (CDG) for high pressure to low vacuum, thermal conductivity measurement (Pirani) for a broad medium vacuum range, and Bayard–Alpert ionization gauges (BAG) for high and ultra-high vacuum. However, the multisensor solution comes with engineering drawbacks: additional connection ports and dead volume, increased maintenance and calibration requirements, risks of errors in the overlap ranges, and higher system costs.

The Pirani sensor traditionally covers the largest single measurement range. Since Marcello Pirani, the principle has been based on the pressure-dependent heat transfer from a heated element to the gas. Classic wire Pirani sensors limit the expansion of the measurement range primarily due to control-related restrictions: To generate sufficient temperature differences at atmospheric pressure, high power levels would be required, which would thermally and mechanically overload the wire; at very low pressures, conservative control often results in a pressure-dependent signal excursion that is too small. Added to this are aging and drift, as well as long thermal time constants.

We present a new MEMS-based approach (Cassini) that specifically addresses these limitations. Central to this approach is pressure-adaptive control: different heating powers and temperatures are used depending on the pressure regime to consistently achieve a large pressure-dependent signal range. A combined control and evaluation method seamlessly links different modes across the various pressure regimes.

With Cassini, we demonstrate that a single, compact MEMS Pirani sensor can continuously cover nine orders of magnitude of pressure, from atmospheric pressure down to 1xE-6 mbar. Measurements in reference gases are calibrated against CDG and BAG standards and demonstrate consistent signal range, low hysteresis, and robust reproducibility.

11:15am **VT-FrM-13 AVS History Committee-Sponsored Talk: From Mercury Columns to Quantum-Based Standards: The Evolution of Vacuum and Pressure Metrology at NIST***, **Jay Hendricks**, Jacob Ricker, Kevin Douglass, Thinh Bui,* NIST

The pursuit of precision in measuring pressure and vacuum has been a cornerstone of scientific and industrial progress for over a century. This presentation provides a brief overview of the trajectory of pressure metrology, tracing its evolution from the early foundations at the National Bureau of Standards (NBS)—now the National Institute of Standards and Technology (NIST)—to the cutting-edge quantum-based innovations of the modern era.

The journey began in the early 20th century, shortly after the founding of the NBS in 1901. Initial efforts focused on establishing primary standards for atmospheric pressure, evolving through the 1920s and 1930s with the establishment of dedicated laboratories for vacuum research. Key historical milestones include the 1948 establishment of the Pressure Section, which formalized the development of primary standards and calibration services for government and industry. From the early use of mercury columns and the development of the McLeod gauge to the creation of altitude chambers for testing Liberty engines, NIST has consistently pushed the boundaries of how we measure the "extremes" of physical quantities.

Today, the Pressure and Vacuum Group at NIST remains a world leader, but the paradigm of measurement is shifting. The redefinition of the International System of Units (SI) has catalyzed a transition toward quantum-based metrology, enabling the realization of fundamental units through the laws of physics rather than physical artifacts. This talk will explore the technical breakthroughs driving this transition, specifically highlighting the Fixed Length Optical Cavity (FLOC) for pressure measurement and the Cold Atom Vacuum Standard (CAVS) for vacuum metrology. By leveraging quantum mechanics and photonics, these methods achieve unprecedented levels of accuracy and precision.

A theme of the presentation will be the intersection of vacuum science and miniaturization. The "NIST on a Chip" program exemplifies this trend, aiming to shrink complex metrology systems into field-deployable formats. This shift from laboratory-bound primary standards to compact, portable devices represents a fundamental change in the metrology ecosystem, allowing high-precision measurements to be conducted in real-world environments.

Finally, the talk will situate these advancements within the broader mission of the International Union for Vacuum Science, Technique and Application (IUVSTA), emphasizing how science transforms our ability to measure and understand the physical world.

11:30am **VT-FrM-14 Fast, Optimal Readout of a Tethered Optomechanical Pressure Sensor***, **Daniel Barker**, Stephen Chen, Yiliang Bao, John Lawall, Jason Gorman,* National Institute of Standards and Technology

We demonstrate a fast readout method for tethered optomechanical pressure sensors. The fast readout method allows mechanical ring-down measurement rates that exceed the total mechanical damping rate. We model the uncertainty of our ring-down measurements with the Cramér-Rao bound, including the effect of thermomechanical noise. Both our data and the Cramér-Rao bound indicate that measurement rates on the order of the mechanical damping rate produce the lowest uncertainty. At low pressures, using the optimal measurement rate allows 10× faster measurements or 3× lower uncertainty compared to allowing our sensor to ring down to the thermomechanical noise floor. Our results allow tethered optomechanical pressure sensors to operate at rates comparable to commercially available pressure gauges, removing an obstacle to adoption of optomechanical pressure sensors in industrial settings.

11:45am **VT-FrM-15 Recent Updates to the NIST Helium Leak Calibration Service***, **Stephen Eckel**, Daniel Barker, James Fedchak, Julia Scherschligt,* National Institute of Standards and Technology (NIST)

The NIST leak rate calibration service is responsible for calibrating helium leaks from roughly 10^{-13} mol/s to 10^{-6} mol/s. Traceability is established through NIST's primary vacuum flowmeters. These constant pressure flowmeters both generate and measure a flow rate of known gas and are traceable to measurements of pressure, temperature, volume displacement, and time. Over the last several years, major upgrades have been completed. In 2024, the vacuum leak system (VALES) — a system designed to hold the NIST working standards under vacuum and in a temperature-controlled environment— was completed. In late 2025, a fully automated flowmeter has been added to the system to allow all leaks to be calibrated against a flowmeter. In this talk, we will present the updated calibration service, discuss the associated uncertainties, and show initial results on the stability of the NIST leaks in the VALES.

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