## Vacuum Technology Division
## Room C120-122 - Session VT-MoM

### Vacuum Measurement, Partial Pressure, and Gas Analysis

**Moderators: James Fedchak**, National Institute of Standards and Technology, **Yev Lushtak**, Lawrence Berkeley Lab

8:20am **VT-MoM-1 30 Years of Active and Combination Cold-Cathode Gauges***, **Martin Wüest,*** INFICON Ltd., Liechtenstein

It is 30 years since the first high vacuum active total pressure gauges appeared on the market.

Previously the sensors were operated via a cable by a controller. Due to miniaturization of electronics, it became possible to reduce the size of the electronics box such that it could be mounted directly on the feedthrough of the sensor. Not long after the active gauges, the first high vacuum combination sensors appeared on the market, where two different sensors were combined in one package.

We will trace the development of inverted magnetron gauges from their invention in the 1950s, to the active and combination sensors available since 1993/1994 to today's self plasma optical emission spectroscopy gauges.

8:40am **VT-MoM-2 Enabling Vacuum Process Monitoring with Time-of-Flight Spectroscopy***, **Kristian Kirsch,*** VACOM Vakuumkomponenten & Messtechnik GmbH, Germany

The increasing complexity of industrial vacuum processes requires broader and deeper knowledge of the vacuum itself. A crucial aspect for increasing quality demands is the necessity of in-situ monitoring and control of pressure and residual gas composition within vacuum processes. A consequence of advanced process control is the reduction of production errors, prevention of failures or major damage in combination with increased operating time. Traditional monitoring devices like hot cathodes or quadrupole mass spectrometers are both only able to measure either pressure or residual gas composition. Therefore, these devices are only conditionally suited for complete process control of vacuum processes. With our novel wide-range vacuum monitor NOVION® industrially available pressure and gas analyzation is possible.

In this talk we present the fundamental principles of the novel vacuum monitor and explain the compact combination of well-known time-of-flight spectroscopy with our own patented ion trap. Within different application cases we discuss advantages and limits of this technology and demonstrate with one single device wide range gas analysis, simultaneous measurement of total and partial pressures, leak detection for Helium and detection of air leaks. With these combined capabilities the novel vacuum monitor is able to quickly capture the complete pressure and gas composition measurement at various stages of the vacuum process chain.

9:00am **VT-MoM-3 Remote (100 meters) RGA Operation for High Energy Physics Experiments***, W. Fletcher, A. Nikitin, D. RioPousa, M. Aitken, J. Leslie, S. Johnson, G. Jennings,* MKS Instruments, Inc. Mass Spectrometry Solutions Group, UK*; **Gerardo Brucker,*** MKS Instruments, Inc. Mass Spectrometry Solutions Group

Residual gas analyzers(RGA) are widely considered essential vacuum monitoring instrumentation for both high and ultra-high vacuum processes. High Energy Physics vacuum installations sometimes place RGA sensors within ionizing radiation environments, which can degrade the semiconductor and other components of their control/analysis subsystems. To protect all vulnerable components from such harsh conditions, the electronics control unit (ECU) must be remotely located with respect to the quadrupole mass filter (QMF) subsystem. In such a configuration, the QMF and ECU may be connected via long transmission cables. Bridge cable assemblies include mixed communication paths for conveying (1) information (mass and ion currents), (2) control signals (electrode biases) and (3) power (filament current supply and quadrupole RF drive). The cable assembly must also comprise a coaxial transmission line as required for efficient RF delivery. Critical to the operation *is the delivery of* precisely controlled two phase RF supply signals to the quadrupole subsystem, as required to generate repeatable mass spectra. The RF supply signal amplitude is of the order of hundreds of volts peak ($V_{pk}$) and its frequency is typically a few MHz. With modern vacuum installation projects demanding cable lengths exceeding 50 meters, our engineering team recently developed a patented methodology for (1) conveying a time-varying voltage signal from ECU to QMF including (2) monitoring and adaptively controlling an amplitude of the time-varying voltage signal at the QMF. A physical length of the transmission line configured to correspond to an electrical length substantially equal to a positive integer multiple of one-half wavelength of the time-varying voltage signal allows the transmission line to operate resonantly and adaptively control the amplitude of the time-varying voltage signal from the ECU for cable lengths exceeding 100 meters.

9:20am **VT-MoM-4 Prospects for Wide-Range, Primary Pressure Sensing with Tethered Optomechanics***, **Daniel S. Barker**, Y. Bao, J. Lawall, J. Gorman, J. Scherschligt,* National Institute of Standards and Technology

We present our initial tests of the pressure sensing performance of silicon nitride membranes and trampolines. The damped motion of these micromechanical systems is calculable using the kinetic theory of gases and can be measured with optical interferometry. We assess the accuracy at which kinetic theory predicts the sensor response via comparison with a capacitance diaphragm gauge transfer standard. The intrinsic thermomechanical damping of our current devices restricts their linear operation to the medium vacuum range (0.1 Pa to 100 Pa). Refinements to both the device design and optical readout system will allow field-deployable, chip-scale sensors with range extending below $10^{-4}$ Pa.

9:40am **VT-MoM-5 Novel Diaphragm Vacuum Gauge: Q'zGauge (QZG)***, **Masatoshi Ono**, S. Goto, H. Motoyama, H. Hojoh,* Vacuum Products Co., Japan **INVITED**

Among practical gauges, only diaphragm gauges give the pressure independent of gas species. Highly accurate (error of 0.2 %) capacitance diaphragm gauges (CDG) are used for process control of semiconductor fabrication, for example. The gauges have several problems, such as (a) Limited pressure range of two decades, (b) Possible measurement error of about 3% in molecular flow region due to thermal transpiration effect, (c) Startup time of a few hours, and (d) Necessity of stable room environment.

For overcoming these problems, we developed an accurate diaphragm gauge for wider pressure range, by using twin diaphragms and a quartz crystal oscillator, and named Q'zGauge (QZG). The head of the gauge, alike a drum in shape, consisted of a hollow metal barrel with a Inconel diaphragm welded at each end. The diaphragms, of 12 mm in diameter and 100 µm in thickness, were bridged at their centers with the oscillator, called "dual tuning fork resonator" , which showed large frequency change for longitudinal stress caused by deflection of the diaphragms. The inside of the head was kept at high vacuum. The resonant frequency was about 40 kHz without stress, and changed about 6% for the stress corresponding to pressure of 100 kPa which gave 3.5 µm of deflection of the diaphragms.

Through optimized design, taking into account of the temperature characteristics of the oscillator and gage head material, the sensitivity of the gauge, the ratio of change in pressure reading to that of the frequency, was almost constant, but shows slight temperature dependence. This dependence was measured with a thermistor attached to the head and used in the pressure calculation which made it possible to give an accurate pressure without a constant temperature oven.

The uncertainty of reading was 0.001 Pa for pressure range of 100 kPa to 0.1 Pa. This range was equivalent to that of more than two CDGs gauges.

Problems:

(a) Pressure range of QZG was more than four decade,

(b) and (c) problems peculiar to a constant temperature oven were unrelated to QZG.

(d) Influence of AC circuits of the controller in the ambient temperature and humidity was negligibly small on QZG's resonant frequency.

These performances of QZG were realized mainly by extremely high Q of the oscillator.

The deflection of the diaphragm was far smaller than the plastic deformation. This fact eliminated necessity of a cut off valve for protecting the damages of the diaphragms. This valve was essential to CDGs with maximum pressure of less than 10 kPa.

The similar tuning fork quartz oscillators have been used widely for wrist watches. This fact also made us expect reliable long life of Q'z Gauges.

10:40am **VT-MoM-8 A Demonstration of the Portable Cold Atom Vacuum Standard as a Pressure Sensor***, **Stephen Eckel**, D. Barker, J. Fedchak, J. Scherschligt,* NIST

We will demonstrate, live, the use of the portable cold atom vacuum standard as a pressure sensor. Cold atom vacuum standards use the loss rate of cold atoms from a conservative trap to measure the vacuum pressure. Because the collision cross section between a cold atom and a background gas particle can be calculated from first principles, such gauges are also primary standards. We will describe and show how these pressure readings are taken, including the preparation of the cold atom cloud, readout, and the conversion between loss rate and pressure. We will also describe the known specifications of this cold-atom-based vacuum gauge, including its range of operation, readout time, and overall precision.Our live demonstration will hopefully convince a skeptical audience of the ability of the portable cold atom vacuum standard to supplant ionization gauges for pressure sensing in the ultra-high vacuum.

11:00am **VT-MoM-9 Update on Construction of the Vacuum Fixed Length Optical Cavity Pressure Standard***, **Jacob Ricker**, K. Douglass, J. Hendricks,* 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 best primary standards in the world. NIST is currently constructing the next generation FLOC which will aim to have a resolution of below 5e-8 Torr. This FLOC will help span the gap in quantum traceable pressure standards between the Cold Atom Vacuum Standard and the existing FLOC performance.

Critical to our goals is construction of a high reflectance/narrow linewidth optical cavity. This presentation will update on the construction and fabrication of components for this next generation FLOC. Additionally, we will discuss the temperature control systems and temperature stability as it directly relates to our ultimate performance. Lastly, the goals and next steps to this project will be outlined.

11:20am **VT-MoM-10 Mfig a Mass Filtered Ion Gauge***, **Freek Molkenboer**, H. Bekman, T. Mechielsen, D. Elstgeest, Y. Westland, J. Emmelkamp, M. Haye, H. Lensen,* TNO Science and Industry, the Netherlands

In 2008, TNO introduced a sensor capable of detecting heavy hydrocarbons in vacuum systems at extremely low concentrations. In 2019, TNO embarked on the development of the third generation of this sensor, known as the Mass Filtering Ion Gauge (MFIG). To optimize the MFIG sensor's design, COMSOL modeling was utilized. The modeling allowed for the precise optimization of specific elements' geometric layout and size within the sensor, making it unique in its performance capabilities.

Through this approach, a highly sensitive sensor has been developed that is capable of measuring volatile organic compounds (VOC) contamination in high vacuum systems. The sensor operates in both transient and continuous regimes, outperforming state-of-the-art RGA technology in detecting a wide range of contamination. Additionally, the MFIG sensor exhibits the ability to detect ultra-short bursts of VOC contamination. These unique selling points offer distinct advantages that are valuable to industries where VOC contamination is a critical concern. Ultimately, this advanced sensor technology has the potential to increase yield and productivity in such sensitive fields.

To validate the performance claims of the MFIG sensor, extensive testing was conducted in laboratory environments both internally at TNO and by external companies, as part of the European ECSEL MADEin4 program which facilitated the development of this third generation sensor.

During the presentation, a detailed overview of the MFIG sensor's general concept will be provided, followed by a presentation of the experimental results obtained from the testing process.

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