Vacuum Technology
Room: 230B - Session VT-MoM

Vacuum Measurement, Calibration, and Primary Standards
Moderator: Bob Garcia, MKS Instruments, Joe Becker, Kurt J. Lesker Company

8:20am **VT-MoM1 History of Widely Used Vacuum Gauges and the Variations and Motivations That Occurred Along the Way: How Did We Get Where We Are?**, ***Paul Arnold***, MKS Instruments,Inc.,Granvillle-Phillips Product Center **INVITED**

A historical development of low vacuum, high vacuum and UHV gauging will be presented, covering the beginnings of capacitance diaphragm gauges, Pirani gauges including modernization in recent decades, triode gauges, Schulz-Phelps gauges, Bayard-Alpert hot cathode ionization gauges from their start to their modernization, various cold cathode discharge ionization gauges, and the spinning rotor gauge. The thread of design motivations that occurred over decades will be followed from not being able to measure the likely base pressures, to a drive for accuracy and stability over the full ranges of the gauges, to finally in recent decades, a priority for gauges to have lifetimes which better withstand the environments of processing chambers with aggressive gasses. The limitations of all these gauge technologies will be discussed. The history of methods for studying behavior of charged particles in electric fields before computer simulation, during its beginnings, and finally using the SIMION program, will be shown. Historical development of gauge calibration methods and standards will be presented, starting from mechanical methods, through bare-bones first principles methods, their evolution to more precise methods, and to finally some modern-day new physical standards for measuring pressure.

9:00am **VT-MoM3 MicroPirani MEMS Sensors for Vacuum Pressure Measurement - Looking Back and Ahead**, ***Caspar Christiansen***, *O. Wenzel*, MKS Granville-Phillips Division, Denmark

It has been almost two decades since the invention of the MicroPirani MEMS sensor and its first introduction to the realm of vacuum pressure measurement. Based on the principle of thermal conductivity the MicroPirani sensor is in many ways similar to the traditional Pirani sensor that has been used for many decades for vacuum pressure measurement. Though similar, the MicroPirani offers several advantages, when compared to the standard Pirani including: a wider measuring range (1*10^-5 torr to atmospheric pressure), better accuracy, better thermal stability, increased robustness and lifetime. Over the last few years our group has dedicated significant effort to the understanding of the interactions between the MicroPirani MEMS sensor and several process chemistries with the ultimate goal of improving accuracy and long-term stability. As an example of our most recent progress, a new coated version of the MicroPirani sensor will be presented to address potential issues relating to corrosive gases in some of the most demanding vacuum applications. The coating does not compromise the current performance of the MicroPirani but serves as a protective layer for all MEMS sensor components.

9:20am **VT-MoM4 Performance Assessment of Absolute Capacitance Manometers Used in Long-term Irradiation Studies**, ***Lily Wang***, *P.D. Honnell*, Los Alamos National Laboratory

Absolute capacitance manometers (MKS121A) are used in our experiments to measure gas release of materials resulted from long-term low-dose-rate radiation exposures. The experiments involve irradiating the samples in sealed metal vessels initially under vacuum (~10-6 torr). An absolute capacitance manometer is mounted on this sealed vessel to measure the pressure of gas being accumulated from the radiolytic decomposition of the material. Recently, a set of these long-term irradiation experiments was completed. The pressure gauges had been in continuous service for almost three years (987 days) in these experiments. Of the total service time, the gauges were exposed to the Cs-137 gamma radiation for 640 days. After decommissioning these samples, the gauges were checked with a recently calibrated pressure measurement station to assess their post-irradiation measurement performance. Additionally, two gauges that exhibited an unusual behavior of measuring decreasing pressure with time during the last ~350 days are being further tested for long-term stability with this active gas. This talk will present the results of the performance assessment and the long-term stability test and discuss the pressure measurement uncertainty in this type of experiments.

9:40am **VT-MoM5 Analysis of Pressure Measurement Techniques from 1 kPa to 130 kPa**, ***Jacob Ricker***, *J. Hendricks*, National Institute of Standards and Technology

The most frequently measured pressures are those in the barometric regime. These measurements are used for everything from altimetry to weather and significant resources have been spent in the past couple years improving barometric measurements. Recent improvements in devices covering this range have drastically reduced their uncertainties, making 0.01% or lower very common. However for vacuum measurement (100 kPa > P > 0.01 Pa), most often people use the capacitance diaphragm gauges (CDG) for their resolution and ability to reach the lower pressures. The capacitance gauges are very prone to drift making uncertainty of 0.25% an average expectation for performance for a high end device. However, by pairing a capacitance gauge to a barometric sensor to compare the values at 1 kPa, a CDG can be corrected to reduce the uncertainty to as low as 0.05%. This technique will be incorporated into the NIST Portable Vacuum Standard (PVS) reference instrument that can be provided for calibration of vacuum gauges at a customer's facility.

Key to this concept is the accuracy and uncertainty of the barometric sensor. NIST has been evaluating measurement methods by taking different high accuracy barometric gauges into the vacuum regime. We have shown that less than 0.05% is easily achievable at 1 kPa and might be even be achievable at 0.1 kPa. The results will be presented for different gauge types, measurement methods, and manufacturers. The talk will include discussions on accuracy, noise, and stability and an uncertainty estimation of using this technique.

10:00am **VT-MoM6 Comparisons between Capacitance Diaphragm Gauges with Different Types of Diaphragm Materials using Force-balanced Piston Gauge**, ***HanWook Song***, KRISS, Korea, Republic of Korea, *M. Salazar*, UST, Republic of Korea, *S.Y. Woo*, KRISS, Korea, Republic of Korea

Capacitance Diaphragm Gauge (CDG) has been one of the most accurate check or transfer standard ranging from low pressure to the high vacuum region. Nowadays, it would be practical to cover wide range of measurement in the least number of equipment possible. Knowledge on the equipment, in this case, transducer's performance establishes not only its use but the accuracies it can maintain. CDG's accuracies depend mostly on linearity, hysteresis and repeatability. In this paper, six (6) commercially available CDGs of two different diaphragm types, one with metal and the other with ceramic, were performance checked through comparison to a reference standard, a Force-balanced Piston Gauge (FPG), through repeated measurements ranging from 0.01 Torr to 100 Torr at different times over a month period. Performance of CDGs were observed at 10% of its full capacity to characterize its feasibility to measure at its lowest range (vacuum region), thus, its practicability to cover wide range of pressure measurement. Results showed that the maximum deviation from the standard of the CDGs with metal diaphragm is 2.24% and 1.52% and the CDGs with ceramic diaphragms 8.37% and 1.39% at low and high range respectively. Additionally, CDGs with metal diaphragm showed similar pattern of accuracy changes with pressure on both the low and high range. On the other hand, the CDGs with ceramic diaphragm showed conflicting pattern of accuracy changes with pressure on different ranges. In conclusion, no matter how the CDGs are behaving on certain ranges, these results can establish the accuracies of the CDGs tested and may further be supported by repeating same tests at a later time.

10:40am **VT-MoM8 Inverted Magnetron with Different Cathode Materials**, ***Martin Wüest***, *J. Marki*, INFICON Ltd., Liechtenstein

We have recently developed an inverted magnetron with an exchangeable ionization chamber. The standard version has cathode walls made of stainless steel. We investigated ionization chambers that are made of different cathode materials such as Ni or Ti. For these materials, differences in a long-term self-sputtering test in Ar gas as well as in the anode current vs pressure characteristic were found.

11:00am **VT-MoM9 Modern Day Challenges to Ionization Gauge Lifetimes**, ***Gerardo Alejandro Brucker***, *S.C. Heinbuch*, *T.R. Swinney*, MKS Granville-Phillips Division, Longmont

Ionization gauges were introduced into the vacuum market over half a century ago with the initial intent of extending pressure measurement ranges into the ultrahigh vacuum range. In more recent years, ionization gauges have been pushed into industrial applications with total pressures as high as 100 mTorr while operating in the presence of both reactive and corrosive gases. The harsh chemical and physical environments of industrial process chambers present very serious challenges to the lifetime of modern ionization gauges. Lifetime is defined as the time until the pressure gauge fails to either operate or produce measurements within its specified accuracy. Following the recent development of a new commercial cold cathode ionization gauge specifically designed to provide extended lifetime, our laboratory has been involved in root-cause analysis studies to understand gauge failures caused by the harshest process conditions. Our long term goal is to create a comprehensive knowledge-base of physicochemical interactions between processes and ionization gauges, provide best known vacuum measurement practices to the industry and develop longer lasting products that meet the demands of the modern vacuum market. In this presentation, we discuss a case study for a cold cathode gauge used in an ion implantation process that revealed some interesting and unexpected results. Most cold cathode gauge failure mechanisms reported in the vacuum technology literature have focused on sensitivity losses due to internal sputtering; however, we will illustrate an example in which a different phenomenon eventually led to gauge failure. It is evident to our group that discovery is far from over and that gauge lifetime challenges are continuously evolving.

11:40am **VT-MoM11 Photonic Realization of the Pascal: The Future of Pressure and Vacuum Metrology?**, ***Jay Hendricks***, *J.E. Ricker*, *A. Stone, F. Egan, E. Scace, F. Strouse*, National Institute of Standards and Technology

NIST is actively developing a new paradigm in the methodology of pressure and vacuum gauging and metrology. In a break with nearly 400 years of mercury based primary standards, we are now poised to develop a new standard that is based on the fundamental physics of light interacting with a gas. For the vacuum community, this represents a shift in how we think about the unit of the Pascal in that it will be directly related to the density of a gas, the temperature, the refractive index, and the Boltzmann constant. The photonic technique has now achieved important benchmarks in performance when compared to the existing primary standards based on mercury manometers: The photonic technique has a 20X smaller footprint, 100X faster sensing response time, 100X lower pressure range, and for an emerging technique has demonstrated impressive accuracy, reproducibility and hysteresis. Photonic sensing of the pascal has the potential to be further miniaturized, and has the key advantage that the light used for sensing the pressure can be transmitted over light-weight, high-speed fiber optic cables and networks.

Authors Index

Bold page numbers indicate the presenter