Monday Morning, October 19, 2015

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.

Vacuum Technology
Room: 230B - Session VT-MoA

Extreme High Vacuum
Moderator: Martin Wüest, INFICON Ltd., Liechtenstein, Jay Hendricks, NIST

2:20pm **VT-MoA1 An XHV Standard: Making Absolute Measurements in the UHV and XHV**, ***James A. Fedchak***, *J. Scherschligt, M.S. Sefa*, National Institute of Standards and Technology (NIST)
Ultra-high vacuum (UHV) and extreme-high vacuum (XHV) underpins much of the manufacturing and research found in today's high-tech products and advanced research programs. Several National Metrology Institutes have high-vacuum standards that allow the calibration of vacuum gauges and mass spectrometers down to 10^{-8} torr, but few have capabilities to perform absolute calibrations in the UHV and below. To date, most vacuum standards utilize the dynamic expansion technique. Low vacuum pressure is realized by scaling down a known high pressure to a low pressure region via an orifice with well-characterized dimensions . Although these standards are often described as being "primary", these standards are not, in fact, either primary or fundamental. Here, we describe NIST's efforts to build a UHV/XHV standard covering the pressure range from 10^{-8} torr to 10^{-12} torr. We will pose and propose and answer to the question: Is it possible to build an absolute vacuum sensor that is also a primary standard in the UHV and XHV?

2:40pm **VT-MoA2 Reducing the Ultimate Pressure of Turbo Pumps for XHV Applications**, ***Julia Scherschligt***, *J. Fedchak, M.S. Sefa*, NIST
Typically NEG or ion pumps are used to achieve XHV pressures, but these are unsuitable for our application because they're gas specific. Turbo pumps can pump all gases, but the ultimate pressure for a common turbo pump is dominated by outgassing and is in the range of about 10^{-10} torr. We investigate reducing the ultimate pressure of a turbo pump for XHV applications.

3:00pm **VT-MoA3 XHV Cryopump Performance and Limitations for the Jefferson Lab Polarized Electron Source**, ***Marcy Stutzman***, *P.A. Adderley, M. Poelker*, Thomas Jefferson National Accelerator Facility
Cryopumps are typically limited to pressures above 1x10^-10 Torr. This is partly due to the lower pump speeds for hydrogen and other light gasses that dominate systems approaching XHV. Additionally, the cryosorbers and adhesives in cryopumps are typically not compatible with the bakeouts of systems used to reduce water vapor pressure in XHV systems. A series of investigations will be described using a commercial XHV cryopump from Leybold, both alone and with the NEG and ion pumps typically used in the Jefferson Lab electron source. The benefits and limitations of using this cryopump for our applications will be examined.

3:20pm **VT-MoA4 A Comparison of Reduced Outgassing Rates for Air-Baked and Vacuum-Baked Stainless Steel Vacuum Chambers**, ***Makfir Sefa***, *J. Fedchak, J. Scherschligt*, National Institute of Standards and Technology (NIST)
Stainless steel is the most common metal used in the construction for ultrahigh vacuum (UHV) and extremely high vacuum (XHV) chambers. Hydrogen outgassing from the chamber walls is the predominant residual gas and it limits the lowest attainable pressure level in vacuum systems. There are several methods for reducing hydrogen outgassing rates from stainless steel chamber walls. High temperature (T > 400 °C) heat treatments are typically used to remove hydrogen from the bulk material and reduce outgassing. In this work, a comparison of reduced outgassing rates for high temperature air-baked and vacuum-baked stainless steel chambers is presented. We also will describe a simple apparatus that allowed us to directly compere outgassing rates from two different heat treatment methods.

4:00pm **VT-MoA6 Deposition of Non-Evaporative Getters (NEG) in Very Narrow Chambers**, ***Andre Anders***, *X. Zhou, Y. Yang, C. Swenson*, Lawrence Berkeley National Laboratory
Several next-generation accelerators require much narrower beam pipes than in the past in order to gain better control of beam position and shape. For example, diffraction-limited synchrotrons currently under construction or in the design phase call for vacuum chambers as narrow as 4 mm at certain sections. For such narrow chambers, the vacuum conductance is greatly reduced making it difficult to reach the ultrahigh vacuum requirements that are customarily required for accelerators. The solution seems clear: the beam pipes and other vacuum components have to be the pump. Non-evaporative getters (NEG) coatings are the straight-forward answer to these challenges. In this contribution we report about progress to coat very narrow vacuum chambers with NEG coatings using pulsed sputtering techniques at relatively high process gas pressures. We discuss deposition rates, film composition, various issues encountered and initial tests of pumping performance.

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Vacuum Technology
Room: 230B - Session VT-TuM

Vacuum Suitcases and Particulate Control
Moderator: James Fedchak, NIST, Marcelo Ferreira, European Spallation Source

8:00am **VT-TuM1 Applications for Mobile Vacuum Environments in Semiconductor Manufacturing**, ***Daniel Babbs***, Brooks Automation **INVITED**

The majority of processes found in semiconductor manufacturing occur within a vacuum environment. A vacuum environment provides a stable operating regime which permits precise process control which is highly repeatable. However, after a semiconductor wafer is processed it is removed from the vacuum environment, placed into an atmospheric transport container and subsequently delivered to the next process tool. Transitioning the semiconductor wafer between atmospheric and vacuum environments has been the traditional process method in the industry but recent advancements in device structures below the 22nm technology node are challenging the effectiveness of this method. Specifically, management of the semiconductor wafer exposure limits to oxygen and moisture at all times is now becoming standard practice to achieve desirable production yields.

The application of a mobile vacuum carrier to transport and store semiconductor wafers provides a contiguous vacuum environment between process platforms. The vacuum carrier utilizes a standard mechanical interface, or vacuum port, for docking to the process platform and is compatible with current factory automation systems. The vacuum port provides automatic loading/unloading of the vacuum carrier which includes dynamic pressure equalization between source and target environments. Typically, a vacuum carrier load/unload on the vacuum port is completed in <60 seconds on average. Preliminary experiments have demonstrated acceptable vacuum performance sustained in the carrier over prolonged durations (after 72 hours <3 Torr). Over the same period, exposure limits of oxygen and moisture within the vacuum carrier are within part-per-million ranges (66ppm and 349ppm, respectively). The reduction in exposure to environmental contaminants removes variability thus improving process quality and yield. In addition, a mobile vacuum environment can be used to connect discrete process platforms and create customized process flows without the semiconductor wafers ever leaving vacuum. This capability presents opportunities to develop new equipment architectures and unique semiconductor processes.

In summary, as device dimensions continue to shrink, wafer sensitivity to environmental contamination increases. This in turn drives the necessity for improved environmental control throughout the entire semiconductor process including transport and storage of the semiconductor wafers. For semiconductor manufacturers, the mobile vacuum environment provides the capability for endpoint-to-endpoint control of the wafer environment not only within critical process chambers but also while transferring them between process platforms.

8:40am **VT-TuM3 Experience of UHV Transportation of Critical Components**, ***Paolo Michelato***, Italian National Institute for Nuclear Physics (INFN), Italy **INVITED**

High quantum efficiency semiconductor photocathodes, as alkali telluride and antimonides, are used as high brightness electron sources in laser triggered radio frequency and high voltage guns. These materials are quite sensitive to gas contamination and UHV conditions must be guaranteed during preparation, storage and handling. Their photo emissive characteristics, as the quantum efficiency, are strongly affected by the exposition to reactive gases as oxygen, carbon dioxide and water vapor.

Photocathodes are commonly prepared and fully characterized in the preparation laboratory and then moved to the point of use, usually inside the tunnel of the accelerator facility. Different laboratories built custom designed UHV suitcases, which will be described and analyzed in this paper, for the transportation and manipulation of these sensitive materials.

INFN Milano – LASA produces, handles and transports Cesium Telluride photocathodes to different laboratories since 1990. Our suitcases are successfully used for transferring photocathode between production sites (INFN Milano, DESY-HH, Fermilab) to the accelerator facilities at DESY Hamburg (FLASH, XFEL), DESY Zeuthen, FERMILAB and LBNL. Up to now, seven suitcases transfer photocathodes between laboratories for preparation procedure, use in the gun, diagnostic and post-mortem investigation.

The transportation of other critical and delicate components might benefit from a similar suitcase design.

Generally, a sputter ion pump maintains the photocathodes in UHV during their transfer. This type of pump is heavy, and needs a HV power supply for continuous operation. These characteristics pose serious limitations for cathode air freight transportation due to present safety regulation. To overcome these limitations, we adopt a different strategy coupling a NEG pump with sputter ion pump. With this approach the NEG pump can preserve photocathode characteristics for a long time, even with the sputter ion pump switched off.

At present, we are testing a SAES Getters NEXTorr® pump that combines, in a synergic design, sintered NEG and sputter ion pump technologies. This would provide a more compact and lightweight system, with less residual magnetic fringe field, and an integrated pressure reading. The paper will discuss the results so far obtained, in terms of suitcase performances and reliability as well as photocathode properties preservation.

9:20am **VT-TuM5 Particle Behavior in Vacuum Systems: Protection Schemes for EUVL Critical Surfaces, Speed Controlled Particle Injection, Prevention of Particle Formation during Pump Down**, *D. Pui*, ***Shawn Chen***, University of Minnesota **INVITED**

Extreme Ultraviolet Lithography (EUVL) is a leading lithography technology for the next generation semiconductor chips. Photomasks, in a mask carrier or inside a vacuum scanner, need to be protected from nanoparticle contamination down to below 20 nm diameter, the minimum feature size expected from this technology. We have developed models and performed experiments in vacuum tools down to 20 mTorr. Nanoparticles between 60 nm and 250 nm were injected into the vacuum chamber with controlled speed and concentration to validate the analytical and numerical models. Also, methods and models were developed to evaluate nanoparticle generation, transport and deposition on photomasks in carriers. Various protection schemes have been developed and evaluated using these experimental and modeling tools. Inside the vacuum chamber, nanoparticles could be formed during rapid vacuum pump down and/or by conversion of outgassing materials by soft x-ray. The detection and control of these nanoparticle contaminants will also be addressed in this presentation.

11:40am **VT-TuM12 Differentially Pumped Interface to Transfer Environmentally Sensitive Materials Designed with Built-in figures of Merit**, ***Hugo Celio***, University of Texas at Austin

An interface designed to transfer air sensitive samples (e.g., battery materials) from an argon filled glove box (1 part-per-million of O_2 and H_20) into an ultra-high vacuum (UHV) chamber for surface analysis is described. This interface (referred as interface for pressure-to-vacuum environmental sample transfer or IP-VEST) is equipped with a differentially pumped load lock, a buffer chamber, a detachable vacuum suitcase (referred to as a capsule), pump chamber, and a set of pressure gauges. Differential pumping minimizes back-flow from the mechanical pump that backs the turbomolecular pump (TMP) of the pump chamber. In the glove box, where argon pressure is 800-900 Torr, samples are loaded into the capsule and remain under this pressure during their transport to the load lock of the IP-VEST. An automatic sequence of pneumatic valves control differential pumping gas flow from the capsule to the pump chamber during the transition from atmospheric pressure (viscous flow) to high vacuum (molecular flow). During this pressure transition, the IP-VEST is also designed to generate a pressure spike in the buffer chamber that is a six order in magnitude, crossing over from the molecular flow to the viscous flow, and returning to molecular flow. This pressure spike is tunable with respect to pressure and time, and it is used as reference peak, allowing a comparison between pump down curves acquired during different sample transfer events. This pressure spike, combined with pump down curve, is referred to as a viscous-to-molecular flow curve (or spiked flow curve). The high repeatability of the spiked flow curves allows a user to develop a method, e.g., figures of merit, to evaluate sample transfer reliability during the entire transfer process that includes gaseous contents of an argon filled glove box and pumping efficiency of the IP-VEST. As a comparison, spiked flow curves were measured after filling the capsule near standard pressure from two sources of argon gas: (1) A high pressure cylinder bottle and (2) a commercial glove box. Both argon sources have intrinsic levels of $_2$ and H_2O at 1 ppm. In addition, silicon and tin were separately exposed to these two sources of argon in order to evaluate the amount of oxidation of these materials due to intrinsic and extrinsic (e.g., leaks and back-flow) factors. These samples were transferred using the IP-VEST that is coupled to a port of a UHV chamber which is equipped with an X-ray photoelectron spectroscopy (XPS). XPS confirms that the IP-VEST does not contribute to the oxidation of these materials due to extrinsic factors.

Vacuum Technology
Room: 230B - Session VT-TuA

Gas Dynamics and Modeling, Pumping and Outgassing
Moderator: Marcy Stutzman, Jefferson Lab, Jacob Ricker, NIST

2:20pm **VT-TuA1 The Evolution of Cryopumps**, ***Sergei Syssoev***, Brooks Automation **INVITED**

Cryopumping is a widely used technique to produce vacuum in an enclosed space via removal of residual gases by cooling them to the point that they are condensed or adsorbed on an appropriate cryogenic surface. Depending upon the application and the gas species, cryopumps operate at different temperatures between 4K and 150K. To attain these temperatures, different thermodynamic cycles are employed ranging from helium liquefaction to mixed gas auto-cascaded systems. Of these various thermodynamic cycles the Gifford-McMahon (GM) cycle has emerged as the dominant cycle for economically delivering the appropriate cooling power at the appropriate temperatures required for cryopumping. Cryopumps based on GM cryocoolers have been commercially adapted to a variety of vacuum processes; notably semiconductor substrate processing equipment, flat panel display fabrication, thin film coatings, analytical instruments and space simulation systems. Built around a dual stage cryocooler, GM cryopumps consists of two internal cryocondensation regions (arrays) that operate at different temperatures. The warmer (first) stage is generally operated at temperatures between 65K and 100K, condensing mainly residual water vapor and other type I gases such as hydrocarbons, carbon dioxide etc. The colder (second) stage is kept at 8K to 20K, which allows condensing of type II gases (such as nitrogen, argon, oxygen) and adsorbing type III gases (hydrogen, helium, neon). To adapt a cryogenic pump to a specific application the geometry and temperatures of the condensing arrays can be modified or tuned to suit the user's application.

By far the dominant application of cryopumping is for the semiconductor fabrication processes of physical vapor deposition (PVD) and ion implantation. There are significant differences in the vacuum environments, namely the gas species and gas densities in which these two processes are conducted. Over time, the vacuum requirements of these processes have become more stringent as line widths decreased in keeping with Moore's Law. In response to the changing vacuum requirements for these processes, the designs of closed cycle cryopumps have evolved. The evolutionary performance improvements of GM cryopump that has taken place in the past few decades will be discussed in this work. Extensive developments have led to significant increase of storage capacity (up to factor 5), pumping speed, pressure dynamics, functionality and energy efficiency. The safety aspects of cryopumping of explosive gases such as oxygen (ozone) and hydrogen will also be discussed.

3:00pm **VT-TuA3 Simulation of a Large Linear Jet Mercury Diffusion Pump with the Test Particle Monte Carlo Method**, ***Xueli Luo***, *T. Giegerich, C. Day*, Karlsruhe Institute of Technology (KIT), Germany

In current nuclear fusion research, the cryopump in various designs has become the standard solution for pumping the plasma chamber. However, considerable amounts of accumulated tritium have been found the issues towards a fusion demonstration power plant (DEMO). A recent study has shown that the mercury diffusion pump has the potential to replace the cryopump, and KIT has been charged to develop a new linear mercury diffusion pump [1]. Obviously, a reliable simulation tool is essential in such a development.

The first mercury diffusion pump was invented by W. Gaede 100 years ago. In the fifties of last century, a large, linear mercury diffusion pump was built and tested in Livermore Research Laboratory [2]. In this paper, we will present the simulation of this pump by ProVac3D, which is a versatile Test Particle Monte Carlo simulation code developed by KIT [3-4]. Based on the fact that the profiles of the mercury jets are hardly changed by the gas load, the simulation was carried out in two steps. First, the background density of the mercury molecules established by the mercury jets was calculated. Secondly, the collision between the molecules of the gas load (N_2 at 15°C) and the mercury molecules had been considered. In order to achieve high simulation precision, ProVac3D had been parallelized, and 10^{12} test molecules were simulated at a supercomputer. The calculated pumping probability, which is the ratio of the number of particles absorbed at the pump bottom to the number of the total simulated particles, was compared with the ratio without collisions between the gas load and the mercury jets. In this way, the pumping effect of the mercury gas jet had been clearly revealed and compared with the experimental data. The agreement is good and this novel simulation approach with ProVac3D will be employed in the development of such a pump for DEMO. Further investigation to combine the Monte Carlo simulation of the gas load with the CFD calculation of the mercury jet is in plan.

References

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3:20pm **VT-TuA4 Monte-Carlo and Angular Coefficients Simulations of Complex Vacuum Systems Equipped with NEG Pumps**, ***Fabrizio Siviero***, *T. Porcelli, G. Bongiorno, M. Urbano, E. Maccallini, P. Manini*, SAES Getters, Italy

The use of analytical and numerical tools for the simulation of several physical quantities in complex vacuum systems is becoming a well-established practice. Applications range from large machines like particle accelerators to smaller systems, for example analytical instrumentation or special processing chambers. The computational approach is essential whenever an accurate estimation of pressure profiles or effective pumping speeds is needed for vacuum systems that do not present a very simple geometry. This is very often the case of real UHV systems, where NEG pumps are increasingly employed to improve the performances of the pumping system in terms of base pressure, size, weight or power consumption.

Two main approaches are currently used in the field, i.e. the test-particle Monte Carlo (TPMC) and the Angular Coefficients (AC) methods. At SAES labs both these methods are being used, the former by means of the MOLFLOW+ code, the latter with an interface developed internally in MATLAB and ANSYS environment. The simulation work has two main aims: first as a tool to support the development of NEG products, then more and more frequently to help customers in taking full advantage of the use of getter technology in their systems. Indeed, the use of NEG pumps in the vacuum layout may allow redesigning the complete system, for example enabling the improvement of other important parts in the design of the machine.

The case of NEG pumps simulation presents some peculiar features, since it is not always possible to model the pump as a simple absorbing surface, i.e. the flange inlet, but the complete device must be modelled. Thus it becomes important to properly set the characteristics of the pumping surface in terms of geometry and sticking probability. Some examples will be presented about:

i) the NEG characterization in terms of pumping speed for different gases;

ii) the design of new systems and the upgrade of existing facilities, where NEG pumps, including combination pumps (NEXTorr®) and custom solutions, are used to improve the vacuum level or solve practical issues related to the size and weight of the conventional pumping system.

Results show that vacuum modeling of NEG pumps is an helpful tool to system design and optimization.

4:20pm **VT-TuA7 Simulation of Steady-State and Impulse Pressure Profiles in Front-End of A1-Beamline at Cornell High Energy Synchrotron Source**, ***Yulin Li***, Cornell University

During summer 2014 accelerator shutdown, a pair of Cornell Compact Undulators (CCUs) was installed at Cornell Electron Storage Ring (CESR), together with a 3.5-long vacuum chamber with 5-mm vertical aperture. In a canted arrangement, these CCUs provide much brighter X-ray beams to 5 (out of 12) user stations at Cornell High Energy Synchrotron Source (CHESS). To take full advantage of the brighter sources, one of CHESS beamline, namely A1 beamline, was re-designed entirely and constructed with new vacuum chambers along ~25-m length. Similar to most 3rd generation light sources, the new CHESS A1 beamline deployed a windowless design without any vacuum barrier between CESR and A1 user station. However, the windowless design poses potential risks to CESR ultra-high vacuum (UHV) systems from potential vacuum excursions at the user station. Differential pumping and various protection interlocks are

incorporated in the A1 beamline to mitigate the risks. In this paper, vacuum responses to large gas loads in A1 beamline front-end section were simulated using a test-particle Monte-Carlo program, MolFlow^{+} [1]. The front-end sector of the A1 beamline is constructed of UHV-compatible components with all-metal seals, including an X-ray optics box, beam shutters, two collimators, and all-metal gate valves etc. Vacuum pumping consists of a large turbo-molecular pump (1300 l/s) at the mirror box, and 6 additional sputtering-ion pumps (SIPs) and non-evaporable getters (NEGs) with pumping speed ranging from 45 to 200 l/s. To simulate vacuum incidents, a very large gas load (0.1 torr×liter/sec) is introduced at the X-ray optics box. The vacuum pressure profiles are simulated along the front-end sector to assess the impact of the large gas load to CESR UHV system, for various pumping conditions. To evaluate the A1 front-end sector as a vacuum delay-line, time-dependent pressure profiles are also simulated with MolFlow^{+}. The simulation results indicate that CESR UHV system is immune from vacuum incidents at CHESS user stations and the A1 front-end sector acts as effective delay line.

This work is supported by the National Science Foundation, under Grant# DMR-1332208 and 0936384. Mr. Aaron Lyndaker of CHESS provided a 3D model of A1 front-end used in the simulations.

[1] MolFlow^{+} is available from CERN's web-site: http://test-molflow.web.cern.ch/

4:40pm **VT-TuA8 APS-Upgrade Storage Ring Vacuum System Design using SynRad/MolFlow+ with Photon Scattering**, ***Jason Carter***, Argonne National Laboratory

The SynRad/MolFlow+ vacuum simulation package from CERN has been used to evaluate a conceptual design of a storage ring vacuum system for the APS-Upgrade project. The design requirements call for a system that can reach sufficiently low pressures within a reasonable commissioning time in order to achieve required beam lifetimes. A SynRad/MolFlow+ simulation of the storage ring vacuum system pressures has been computed which includes photon scattering and predicts photon stimulated desorption outgassing rates from the irradiated vacuum surfaces. The vacuum system design incorporates two important analyses. Synchrotron radiation absorbers are located at critical lattice sites in order to both mitigate high heat loads and to localize the high predicted gas loads so that they can be efficiently removed with discrete pumps. In addition, the residual gas species are calculated to identify regions with high molecular gas concentrations. Vacuum pumping is then designed to mitigate the high mass gas loads and increase beam lifetimes.

5:00pm **VT-TuA9 Simulation and Measurement of Radioactive Radon in the KATRIN Main Spectrometer**, ***Joachim Wolf***, Karlsruhe Institut for Technology (KIT), Germany

The objective of the **Ka**rlsruhe **Tri**tium **N**eutrino experiment (KATRIN) at the Karlsruhe Institute of Technology (KIT) is the measurement of the electron neutrino mass. A central component is the Main Spectrometer (MS), where the energy of the β-electrons from tritium decay (18.6 keV) will be measured with high precision. It consists of a large ultra-high-vacuum vessel with a volume of 1240 m^3. The pumping system of the MS consists of turbo-molecular pumps, a large-scale getter pump (3000 m NEG strips, St707) and three cryo-baffles at LN_2 temperature, designed to maintain an ultimate pressure in the range of 10^{-11} mbar.

The NEG strips, as well as the stainless steel walls are known to emanate small amounts of radon atoms, increasing the intrinsic background rate, which would limit the sensitivity for the neutrino mass. The cryogenic copper baffles are expected to capture most of the radon, before it decays in the main volume. However, radon does no not stick to the cold surface indefinitely. There are two possibilities, it either desorbs after a limited residence time (depends on desorption enthalpy and baffle temperature), or it decays into polonium. In the first case, it can contribute again to the background rate.

This work reports on radon measurements with cold baffles at various temperatures and compares the results with Test-Particle Monte-Carlo (TPMC) simulations. The simulation was performed with a modified MOLFLOW+ code, where we added two new, time-dependent features, (i) a finite residence time for all adsorbing surfaces, and (ii) the half-life of the test particles. For the measurements we used two different radon isotopes with a half-life of 4 s and 56 s, respectively. By comparing measured rates with TPMC simulations for different residence times, we want to learn more about the surface conditions of the baffles (Cu, Cu_2O, H_2O) and the corresponding desorption enthalpies.

This work has been supported by the German BMBF (05A14VK2).

5:20pm **VT-TuA10 Degassing of the Kicker Magnet in J-PARC RCS via New *In Situ* Baking Method**, ***Junichiro Kamiya***, *N. Ogiwara, M. Kinsho*, Japan Atomic Energy Agency

The usual way to reduce outgassing from a device in vacuum is to heat up a whole vacuum chamber containing the device. However, the situation, where this method can be applied, is limited due to the heat expansion of the chamber. Especially in accelerators, where the vacuum chambers are connected with nearby beam pipes, this normal bake-out method may not be applied. If a heat source and heat shields are appropriately installed inside the chamber, heat flux is directed to the device. Therefore the device can be baked out without raising the temperature of the vacuum chamber.

One candidate for such bake-out method to be applied is kicker magnets in J-PARC 3GeV synchrotron (RCS), which are installed in large vacuum chambers. The kicker magnets are installed in vacuum to prevent the discharge by high voltage. The kicker magnet mainly consists of Ni-Zn ferrite cores, aluminium electrode plates. The total outgassing rate of the materials is large due to the large surface area. Therefore it is very important to develop a degassing method for the kicker magnets in the beam line because the vacuum quality may become poor after repeated exposures to air for the maintenances. The main outgassing component of those kicker magnet components is water vapour. Therefore the bake-out temperature should be above 100 °C, which is the typical desorption temperature of water vapour from the general surface. In the RCS beam line, 3 and 5 kicker magnets are located in vacuum chambers, whose length is 3 and 5 m, respectively. It is undesirable to use a normal baking method like baking the vacuum chamber of the kicker magnets because the large heat expansion of the vacuum chamber will break nearby equipment such as alumina ceramics pipes. By applying the bake-out method, which is mentioned at the beginning, only the kicker magnet is heated without raising the temperature of the vacuum chamber. In the first stage, we performed the operability assessment of the new degassing method by the calculation with a simple model and the principal experiments using the kicker magnet, which have the same structure as the production kicker magnets in RCS. As a result, the kicker components were heated up above 100 °C by a wide margin, while keeping the temperature rise of the vacuum chamber less than 20 °C. Next, we developed the design of the heater, which has a good maintainability. The small heater of graphite, which is installed through a maintenance port of the vacuum chamber, is designed. The ideal temperature distribution was obtained with this graphite heater. Furthermore, the outgassing of the graphite was suppressed by the heating process.

5:40pm **VT-TuA11 Uncertainty of UHV Flowmeter Standard Related to the Gas-Surface Interaction**, ***Felix Sharipov***, *Y.B. Barreto*, Universidade Federal do Parana, Brazil

Gas flows through orifices of various shapes are used in the primary metrology of vacuum in order to develop a primary standard of conductance [1]. Since the orifices are usually very think and the most part of gaseous molecules passes through the orifice without a collision with its surface, it is assumed the diffuse scattering for those particles which undergo collisions with the surface. However, many experiments, see e.g. [2], pointed out a significant deviation from the diffuse scattering especially for light gases like helium so that the conductance calculated on the basis of the diffuse scattering can be different from the real one and that leads to an additional uncertainty that is not included in the total uncertainty [1]. As was pointed out in Ref.[3], the diffuse-specular model of the gas surface interaction having just one adjustable parameter contradicts to some experimental data on the so-called thermomolecular pressure difference. At the same time, the Cercignani-Lampis (CL) model containing two adjustable parameters describes more physically the gas-surface interaction. The aim of the present work is to calculate the conductance of orifices used in the primary metrology based on the CL model using the accommodation coefficient extracted from various experimental data. A comparison of these data with those obtained for the diffuse scattering will give us the uncertainty related to the gas-surface interaction. Preliminary results show that the uncertainty is within 1%. Basing on these data, some recommendations to reduce the uncertainty will be given.

[1] L. Peksa et al., Vacuum. Vol.101, P.377 (2014)

[2] B.T. Porodnov et al., J. Fluid Mech. Vol.64, P.417 (1974)

[3] F. Sharipov and V. Seleznev, J. Phys. Chem. Ref. Data. Vol.27, P.657 (1998).

6:00pm **VT-TuA12 Investigation of the use of Viton as Certified Reference Material for Outgassing**, ***Janez Setina***, Institute of Metals and Technology(IMT), Slovenia

Goal of this study was to make samples with well known outgassing rate which can be used as a reference for calibration and validation of different outgassing measurement facilities.

Main criteria for selection of suitable material were (i) sufficient solubility of different gases in the material (ii) diffusion constant for different gasses in the range from 10^{-8} cm^2/s to 10^{-6} cm^2/s, and (iii) material shall be "clean" and compatible with high vacuum, which means it shall not release volatile organic compounds. Only materials which have sufficient repeatability and reversibility of gas absorption could be used as reference samples. Materials with desired properties can be found among polymers and we selected Viton (FPM-fluoropolymer) as a good candidate for outgassing reference samples. Use of Viton in high vacuum systems down to 10^{-7} Pa is well established.

We have prepared outgassing reference samples in the following way: pieces of Viton were placed in a gas loading cell and were evacuated on an ultrahigh vacuum system for sufficiently long period to get fully degassed state. Then the loading cell was filled with a pure gas or gas mixture at a pressure up to several 100 kPa and the samples were kept in the gas for several days to penetrate into material to a fully saturated state. Samples were removed out of the loading cell just before they were placed into the outgassing rate measurement apparatus.

A reference sample can be first loaded with a certain gas or gas mixture and measured by a "primary" outgassing measurement system (like the system in PTB-Germany which was developed in the frame of EMRP-IND12 project), yielding a certified reference value of the outgasing rate as a function of time. Then the same sample can be re-loaded with the same gas and under the same conditions and sent in the loading cell to a user in industry or another laboratory for the measurement in their system.

Certified reference samples can be used in round robin tests for the proficiency testing of systems in different laboratories. Distinctive feature of newly developed reference samples based on Viton material is that they can be reloaded many times and with many gases, and also with mixtures of gases at arbitrary concentration ratios. Gases which do not react chemically with Viton are expected to produce reproducible outgassing rates. This was confirmed in our tests with gases H_2, He, Ar, Kr, CH_4, N_2, O_2 and CO.

Support through the EMRP IND12 project is gratefully acknowledged. The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union.

Vacuum Technology
Room: Hall 3 - Session VT-TuP

Vacuum Technology Poster Session

VT-TuP1 Estimating Measurement Uncertainty of Pressure Calibration, ***Yu-Wei LIN***, *C.-P. Lin, C.N. Hsiao*, National Applied Research Laboratories, Taiwan, Republic of China

A vacuum gauges calibration system for wide-range pressure was developed, and the measurement uncertainty associated with the system. The design of the system took into consideration of influencing factors that include uniformity of gas distribution and the geometric location of the gauge to be calibrated. The system operates following the procedure stipulated in the comparison vacuum gauge calibration method. The calibration may range from 10^5 to 10^{-5} Pa . The system makes use of capacitor vacuum gauge, SRG and hot cathode thermion vacuum gauge to estimate the degree of uncertainty associated with the system. The data collected from the gauge calibration tests indicated that if the background pressure of the system had reached 10^{-7} Pa, the uncertainty associated with the system were as follows: less than 3.6 % in the pressure range of 10^{-5} to 10^{-2} Pa, less than 2.3 % in the pressure range of 10^{-2} to 10^5 Pa. The present research has demonstrated the high stability of the vacuum calibration system, and its capabilities of conducting calibration for vacuum gauge with great efficacy.

VT-TuP5 The ESS Vacuum Control System Concept, ***Hilko Spoelstra***, *M. Zaera-Sanz*, European Spallation Source, Sweden

The European Spallation Source (ESS) is a high current proton LINAC to be built in Lund, Sweden. The LINAC will deliver 5 MW of power to the target at 2000 MeV, with a nominal current of 74 Ma. Ground break took place in September 2014 and the construction of the accelerator tunnel and adjacent buildings progresses rapidly.

Although the different LINAC sections will be in-kind contributions from the several member countries, the accelerator vacuum control system and the machine protection system, will be mainly designed and build in-house which requires a tight collaboration between the Integrated Control System Division (ICS) and the Vacuum Team of the Accelerator Division (AD) of ESS.

The Vacuum control system is based on PLC (Programmable Logic Controller) technology and on EPICS (Experimental Physics and Industrial Control System) SCADA (Supervisory Control and Data Acquisition). Each accelerator section has one or more PLCs to control the different valves by acting on the analog and interlock signals from the gauge- and pump-controllers through a pre defined voting scheme. EPICS modules will be used as the interface between the operator screen and the vacuum controllers. Besides local interlocks for vacuum, machine protection interlocks shall be integrated in the control system for the protection of the LINAC. This integration will provide beam permission to the beam interlock system when all nominal conditions for vacuum are met.

A set of control and machine protection functions will define the vacuum controls system architecture and implementation. This contribution will discuss the design of the ESS proton LINAC vacuum control system, strictly complying with all identified control and protection functions.

VT-TuP6 Effect of Impeller Tip Clearance on the Degree of Vacuum of Self-Priming Pump, ***Youn-Jea Kim***, *H.J. Jeon, J.-H. Boo*, Sungkyunkwan University, Republic of Korea

Self-priming vacuum pump is hybrid-type pump of which the principles of axial-type screw vacuum pump and centrifugal pump are combined for better performance. It is operated by the rotation of inducer-impeller generating partial vacuum and centrifugal force. Due to its unique operating principle, self-priming vacuum pump is characterized for transferring fluid having viscosity and is able to be used in various industrial field treating multiphase fluids such as slurry. Tip clearance in self-priming vacuum pump is an important design factor affecting the performance of the pump, which is closely associated with the suction performance. In this study, the effect of impeller tip clearance on the degree of vacuum of self-priming pump was numerically investigated. Numerical analysis was conducted by ANSYS CFX ver. 16. The results for pressure and velocity distributions and H-Q curve were prepared with various values of tip clearance

VT-TuP7 Simulation of the Transporting of Sputtering Particles and Comparison of the Film Thickness Distributions between Simulations and Experiments, ***Kohei Kuroshima***, *M. Iguchi*, Osaka Vacuum, Ltd., Japan, *S. Sugimoto*, Osaka Vacuum, Ltd.Osaka Vacuum, Ltd., Japan

A Monte-Carlo simulation of the transporting of sputtering particles was performed, using Born-Mayer potential as the two-body potential. Film thickness distribution on the substrate was calculated and compared to experimental results obtained under the same conditions. Calculations and experiments were made for a variety of gas pressures and target-substrate (T-S) distances.

The film thickness distribution on the substrate is determined by the distribution of particle emissions from the target, gas pressure and T-S distance. Therefore, if we can control the distribution of particle emissions, the pressure and the T-S distance, we can control the film thickness distribution on the substrate. The distribution of the transparent film thickness will create the designed Moire pattern.

Our simulations serve as basic research on this control.

VT-TuP8 Finite Element Based Multiphysics Analysis of Photon Stimulated Desorption from Vacuum Chamber used in Electron Storage Ring, ***Kamlesh Suthar***, *B.K. Stillwell*, Argonne National Laboratory

We present preliminary study of the Photon Stimulated Desorption from aluminum vacuum chamber. Synchrotron radiation is generated in electron storage ring when the electron beam pass through magnetic field. In this paper, such synchrotron radiation is simulated on magnetic lattice of the storage beam. The temperature of the vacuum chamber increases due to absorption of photon beam simultaneously the molecular pressure also increases due to desorption of the adsorbed gases. This process of increasing in gases depends upon various physical phenomena, such as irradiation of photon beam due to interaction of electrons in applied magnetic field, secondary emission of electron from surface, heat transfer, and molecular flow of gases. Therefore, the solution of vacuum pressure inside the storage ring depends on various physics. This paper discusses preliminary results of analysis of vacuum pressure combining responsible physics.

Wednesday Morning, October 21, 2015

Vacuum Technology
Room: 230B - Session VT-WeM

Accelerator and Large Vacuum Systems
Moderator: Yulin Li, Cornell University, Lily Wang, Los Alamos National Laboratory

8:00am **VT-WeM1 MAXIV Vacuum System: From Design to Operation**, ***Eshraq Al-Dmour***, *M. Grabski, J. Ahlbäck, P. Fernandes Tavares, C. Pasquino*, Max IV Laboratory **INVITED**

MAXIV facility is under commissioning in Lund-Sweden. The facility consists of full energy Linac, two electron storage rings operating at 1.5 GeV and 3 GeV and a short pulse facility. The 3 GeV storage ring is 528 m in circumference, and has compact magnets design with small magnet apertures, as a result, the chambers inside diameter is also small (22 mm), so the conductance of the vacuum chambers is low and lumped pumps are ineffective. In order to provide the desired vacuum level (less than 1e-9 mbar) distributed pumping which has been realized by the use of non-evaporable getter (NEG) coating of the chamber walls was implemented. In addition, the vacuum chambers should absorb the heat from synchrotron radiation (SR) as an antechamber is difficult to realize, to solve this, the chambers are made from Silver bearing oxygen free (OFS) copper and the walls work as distributed absorbers where distributed cooling is used at the location where the SR hits the wall. The design, production, installation and conditioning of the vacuum system were a challenge, and therefore they are presented here.

8:40am **VT-WeM3 Construction Status of the SuperKEKB Vacuum System**, ***Yusuke Suetsugu***, *K. Kanazawa, K. Shibata, T. Ishibashi, H. Hisamatsu, M. Shirai, S. Terui*, KEK-High Energy Accelerator Research Organization

The SuperKEKB, the upgrade project of KEKB, is an electron-positron collider with asymmetric energies, that is, 7 GeV electrons and 4 GeV positrons. The goal luminosity is $8x10^{35}$ $cm^{-2}s^{-1}$, approximately 40 times higher than that achieved in the KEKB. The construction of the new vacuum system for the SuperKEKB has been in progress since 2010, as a key item of the upgrade. Most of the vacuum components, especially in the positron ring, are newly fabricated to manage the electron cloud effect (ECE), and to reduce beam impedance, which are essential to keep the low-emittance beams stable even for high beam currents. The design and the manufacturing of the major vacuum components, including beam pipes, bellows chambers, gate valves, vacuum pumps and so on, have been completed. Approximately 1240 new beam pipes were made of aluminum-alloy or pure copper depending on the intensity of the irradiated synchrotron radiation. They basically have two antechambers at both sides of a central beam channel. The main pump at arc sections of the ring is a strip-type NEG installed in one of the antechambers. Approximately 1130 NEG modules were prepared with various lengths of from 0.7 to 3 m consisting of three NEG strips. New bellows chambers and gate valves have basically a comb-type RF-shield and have the same cross sections to the connecting beam pipes. Countermeasures against the ECE, such as the coating of TiN film, the grooved surface, the clearing electrode and so on, were prepared for the beam pipes of the positron ring. All of aluminum-alloy beam pipe have TiN coating inside to reduce the secondary electron yield. Approximately 150 beam pipes for dipole-type magnets have grooved structure at top and bottom of the inner surface. Beam pipes for wiggler magnets have 116 clearing electrodes inside in total. The installation of these components into the KEKB tunnel has almost finished. The MO-type flanges, which have structurally little step inside, were adopted to the connection flanges between the beam pipes and the bellows chambers. The air-leak rate at the first fastening was less than 5 % out of more than 5000 times fastening in total during the pre-baking, the TiN coating and the connection in the tunnel. The final activation of NEG pumps in the tunnel has finished approximately 70 % of the ring until October. After the NEG activation, the average pressures decreased to on the order of 10^{-8} Pa, where the beam pipes were not baked in situ. The vacuum system will be ready in next January, 2016. The construction status SuperKEKB vacuum system, including various experiences during the construction stage, will be reported.

9:00am **VT-WeM4 Commissioning of the 3 GeV TPS Accelerator Vacuum System**, ***Gao-Yu Hsiung***, *Y.C. Yang, H.P. Hsueh, L.H. Wu, C.M. Cheng, C.K. Chan, J.R. Chen*, National Synchrotron Radiation Research Center, Taiwan, Republic of China

The Taiwan Photon Source (TPS), a 3 GeV synchrotron light source composed of a booster synchrotron and the electron storage ring concentrically installed in the same tunnel, has been completed the construction and the installation in July 2014. Then the commissioning of the booster has been started and reached to the goal of 3 GeV full-energy-injections on Dec.17. After tuning the beam parameters, the electron beam was stored at 1 mA beam current, extracting the first synchrotron light, and raised to 4.5 mA stored with few minutes beam life time on Dec. 31 2014. The beam-cleaning process for mitigating the significant photon-stimulated-desorption (PSD) outgas inside the storage ring is one of the major purposes of the commissioning. The pressure in the beam duct was kept under 1E-6 Pa that limited the increase of beam current and the consequent upper bound of the Bremsstrahlung radiation level through the beam-cleaning. After three-months commissioning that has achieved the accumulated beam dose of 30 Ampere-hours, the average pressure was reduced to ~ 1.2E-7 Pa at 100 mA of stored beam current with life time of ~ 6 hour. Besides the vacuum conditioning, the beam emittance of 1.6 nm-rad approached to the goal has been demonstrated. In this paper, the concept about the high efficient beam-cleaning process and the progress of the commissioning for the TPS will be described.

9:20am **VT-WeM5 Construction, Installation, and Commissioning of TPS Booster Vacuum System**, ***Hsin-Pai Hsueh***, *C.M. Cheng, S.N. Hsu, G.Y. Hsiung, J.R. Chen*, National Synchrotron Radiation Research Center, Taiwan, Republic of China

For better performance and more efficient operation of today's storage ring of electron synchrotron radiation facilities, it is essential to have a good booster vacuum system to start with. The ultrahigh vacuum system for the electron booster ring of the 3GeV Taiwan Photon Source accelerator has been constructed since 2010, and then installed and commissioned since 2014. TPS booster is a 496.8m long stainless steel vacuum system and currently the largest of its kind in the world. Although low impedance consideration is not critical in a booster vacuum system, the tight dimension and other demanding engineering tolerances do show their criticalness in the construction, installation, and commissioning phases. During construction, some of the original ideas have been modified due to these given tight tolerances. It is even more demanding as we found in the commissioning phase and a lot of actions have been taken to make commissioning process possible. The original design, the modifications in both the construction and commissioning phases will be described in this paper.

9:40am **VT-WeM6 Design of a 250 KV DC Electron Gun Operating at Cryogenic Temperature**, ***Xianghong Liu***, *I. Bazarov, B.M. Dunham, V.O. Kostroun, H. Lee*, Cornell University

A photocathode DC electron gun is being built in our laboratory for ultrafast electron diffraction experiments. It is designed to operate at voltages up to 250 KV, with a maximum electric field of 12 MV/m in the cathode – anode gap. An inverted ceramic insulator is used for the high voltage insulation, making the gun relatively compact. In order to reduce the mean transverse energy of the electrons emitted from the photocathode, and hence increase the coherent length of the electron beam at diffraction, the photocathode is operated at 20 K instead of room temperature. A stainless steel thin wall tube connects the cathode holder to the insulator; it minimizes the heat load through conduction while providing a rigid support for the cathode holder. The cathode holder is cooled by a cold head through a sapphire rod of 225 mm length. The sapphire rod provides both sufficient electrical insulation and excellent thermal conduction at the temperature of interest. A load-lock system is attached to the back of the gun chamber for loading the photocathode to the gun. Photocathodes are transported into and out of the system through a vacuum suitcase. The load-lock system also provides storage for multiple photocathodes. The decay of the quantum efficiency of the photocathode is dominated by the existence of residual gases in the gun chamber, and thus vacuum level of 1x10-11 Torr or better is required to prolong the lifetime of the photocathode. The chamber is pumped by NEG pumps and ion pumps. We'll describe details of the design and report initial test results.

11:00am **VT-WeM10 Introduction to Tri Alpha Energy's Fusion Concept, Vacuum Requirements and Performance of Our Current C2U Machine**, ***Alan Van Drie***, Tri Alpha Energy

Tri Alpha Energy (TAE) is researching a novel fusion concept of energetic ions magnetically trapped as large orbits in a Field Reverse Configuration plasma (FRC). C2 and C2U are the previous and current generation machines that have pushed and continue to push our understanding of FRC plasmas, energy levels, durations, control, and engineering required toward an energy generating machine. C2 was operated between 2008 and 2014, followed by its completed upgrade to C2U in early 2015. C2 and C2U are both linear vessels (~20m long, ~17m^3 volume, low 10^{-9} Torr pressures) with many attached sub systems such as 1.8 MW neutral beam sources (10 MW total injected power into the plasma) and a plethora of diagnostics. The talk will first give an overview to TAE's concepts and C2U, followed by a discussion of the physics that drive the vacuum requirements, such as wall recycling, ion-neutral losses, divertor gas loads and how we solved many of the technical vacuum challenges in order to meet our performance goals.

11:20am **VT-WeM11 Vacuum Architecture of an Extreme Ultra-Violet Exposure System**, ***Freek Molkenboer***, *N.B. Koster, A.F. Deutz, D.J. Naron*, TNO Technical Sciences, Netherlands

TNO is designing and building an Extreme Ultra-Violet (EUV) exposure system capable of exposing samples and 6" EUV masks with high EUV power and intensity. This system will be named EBL2.

EBL2 will be suited for characterizing and analysing phenomena such as carbon growth on EUV masks, oxidation of multilayer optics, as well as investigating the physics and effects of EUV-induced plasmas.

EBL2 contains an EUV Beam Line, in which samples/EUV masks can be exposed to EUV radiation in a flexible gas environment, with UHV background vacuum quality. Gases such as H_2, XCDA and H_2O can be added in a controlled fashion to create a customized environment for the exposure at hand.

Attached to this Beam Line is an XPS system, which can be reached from the Beam Line via an in-vacuum transfer system. This enables surface analysis of exposed samples/masks without breaking vacuum. Automatic mask handling with dual pods is foreseen so that exposed EUV mask will still be usable in EUV lithography tools to assess the imaging impact of the exposure.

Qualification of the setup is expected to start Q1 2016. After completion, this unique facility will be open for external customers and other research groups.

This presentation will focus on the vacuum architecture and design implementations of the EBL2 system to meet all the stringent vacuum requirements.

In-Situ Spectroscopy and Microscopy Focus Topic
Room: 211B - Session IS+SS+NS+BI+VT+MN+AS-WeA

In situ Imaging of Liquids using Microfluidics
Moderator: Xiao-Ying Yu, Pacific Northwest National Laboratory, Stephen Nonnenmann, University of Massachusetts - Amherst

2:20pm **IS+SS+NS+BI+VT+MN+AS-WeA1** ***In Situ*** **Multimodal Biological Imaging using Micro- and Nanofluidic Chambers**, ***James Evans***, *C. Smallwood*, Pacific Northwest National Laboratory **INVITED**

Biological organisms have evolved a number of spatially localized and highly orchestrated mechanisms for interacting with their environment. Since no single instrument is capable of probing the entire multidimensional landscape, it is not surprising that one of the grand challenges in biology remains the determination of how dynamics across these scales lead to observed phenotypes.

Therefore, there is a need for in-situ correlative multimodal and multiscale imaging to fully understand biological phenomena and how chemical or structural changes at the molecular level impact the whole organism. We have been advancing new methods for both cryogenic and in-situ correlative analysis of biological samples using electron, ion, optical and x-ray modalities. Central to this work is the development of new micro- and nanofluidic chambers that enable in-situ observations within precisely controlled liquid-flow environments. In this talk I will review the design of these new chambers, highlight current science applications and outline our future goals for adding additional functionality and expanding the versatility of the devices to other disciplines.

3:00pm **IS+SS+NS+BI+VT+MN+AS-WeA3 Glyoxal Aqueous Surface Chemistry by SALVI and Liquid ToF-SIMS**, ***Xiao Sui***, *Y. Zhou, Z. Zhu,* Pacific Northwest National Laboratory, *J. Chen,* Shandong University, China, *X.-Y. Yu*, Pacific Northwest National Laboratory

Glyoxal, a ubiquitous water-soluble gas-phase oxidation product in the atmosphere, is an important source of oxalic acid, a precursor to aqueous secondary organic aerosol (SOA) formation. Many recent laboratory experiments and field observations suggest that more complex chemical reactions can occur in the aqueous aerosol surface; however, direct probing of aqueous surface changes is a challenging task using surface sensitive techniques. The ability to map the molecular distribution of reactants, reaction intermediates, and products at the aqueous surface are highly important to investigate surface chemistry driven by photochemical aging. In this study, photochemical reactions of glyoxal and hydrogen peroxide (H_2O_2) were studied by a microfluidic reactor, System for Analysis at the Liquid Vacuum Interface (SALVI), coupled with Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS). Aqueous surfaces containing glyoxal and hydrogen peroxide were exposed to UV light at variable lengths of time and were immediately analyzed in the SALVI microchannel by in situ liquid ToF-SIMS. In addition, various control samples were conducted to ensure that our findings were reliable. Compared with previous results of bulk solutions using ESI-MS, our unique liquid surface molecular imaging approach provided observations of glyoxal hydrolysis (i.e., first and secondary products, dimers, trimers, and other oligomers) and oxidation products (i.e., glyoxylic acid, oxalic acid and formic acid) with sub-micrometer spatial resolution. We potentially provide a new perspective and solution to study aqueous surface chemistry as an important source of aqueous SOA formation of relevance to atmospheric chemistry known to the community.

3:20pm **IS+SS+NS+BI+VT+MN+AS-WeA4 Investigating** ***Shewanella*** **Oneidensis Biofilm Matrix in a Microchannel by** ***In Situ*** **Liquid ToF-SIMS**, ***Yuanzhao Ding***, Nanyang Technological University, Singapore, *X. Hua, Y. Zhou, J. Yu, X. Sui, J. Zhang, Z. Zhu,* Pacific Northwest National Laboratory, *B. Cao,* Nanyang Technological University, Singapore, *X.-Y. Yu*, Pacific Northwest National Laboratory

Biofilms consist of a group of micro-organisms attached onto surfaces or interfaces and embedded with a self-produced extracellular polymeric substance (EPS) in natural environments. The EPS matrix, like the "house of the cells", provides bacteria cells with a more stable environment and makes them physiologically different from planktonic cells. *Shewanella oneidensis* MR-1 is a metal-reducing bacterium, forming biofilms that can reduce toxic heavy metals. This capability makes *S. oneidensis* biofilms very attractive in environmental applications. To better understand the biofilm EPS matrix composition at the interface, in situ chemical imaging with higher spatial resolution and more molecular level chemical information is strongly needed. Traditionally, electron microscopy and fluorescence microscopy are common imaging tools in biofilm research. However, the bottlenecks in these imaging technologies face the limitations that it is difficult for them to provide chemical information of small molecules (e.g., molecule weight <200). In this study, we use an emerging technology liquid Time-of-Flight Secondary Ion Mass Spectrometry (ToF-SIMS) to observe *S. oneidensis* biofilm cultured in a vacuum compatible microchannel of the System for Analysis at the Liquid Vacuum Interface (SALVI) device. Chemical spatial distributions of small organic molecules that are considered to be the main building components of EPS in live biofilms are obtained. Principal component analysis is used to determine differences among biofilms sampled along the microchannel. This new approach overcomes previous limitations in live biofilm analysis and provides more chemical information of the EPS relevant to biofilm formation. Better understanding of the biofilm matrix will potentially fill in the knowledge gap in biofilm surface attachment and detachment processes and improve the engineering and design of *S. oneidensis* biofilms with high efficiencies in heavy metal reduction.

4:20pm **IS+SS+NS+BI+VT+MN+AS-WeA7 Ultrafast Proton and Electron Dynamics in Core-Level Ionized Aqueous Solution**, ***Bernd Winter***, Helmholtz-Zentrum Berlin für Materialien und Energie/Elektronenspeicherring BESSY II, Germany **INVITED**

Photo- and Auger electron spectroscopy from liquid water reveals a novel electronic de-excitation process of core-level ionized water in which a pair of two cations forms, either $H_2O^+ \cdot H_2O^+$ or $OH^+ \cdot H_3O^+$. These reactive species are the delocalized analogue to H_2O^{2+}, formed in a localized on-site Auger decay, and are expected to play a considerable role in water radiation chemistry. Both cationic pairs form upon autoionization of the initial ionized water molecule, and we are particularly interested in the situation where autoionization occurs from a structure that evolves from proton transfer, from the ionized water molecule to a neighbor molecule, within a few femtoseconds. The actual autoionization is either through intermolecular Coulombic decay (ICD) or Auger decay. Experimental identification of the proton dynamics is through isotope effects. A question that arises is whether such so-called proton-transfer mediated charge separation (PTM-CS) processes occur in other and similarly hydrogen-bonded solute molecules as well. This is indeed the case, and is illustrated here for ammonia and glycine in water, as well as for hydrogen peroxide in water, where characteristic differences are detected in the Auger-electron spectra from the light *versus* heavy species, *i.e.*, NH_3 in H_2O *versus* ND_3 in D_2O, glycine(H) in H_2O versus glycine(D) in D_2O, and H_2O_2 in H_2O versus D_2O_2 in D_2O. The important spectral feature here is the high-kinetic energy tail of the Auger spectrum, which has no gas-phase analogue, and hence reflects the participation of solvent water in the relaxation process. The probability of the proton dynamics, judged from the intensities of the electron signal and inferred from methods of quantum chemistry and molecular dynamics, is found to depend on hydrogen-bond strength and hence on the specific hydration configuration. Favorable configurations for hydrogen peroxide(aq) occur due to the molecule's flexible structure. In ammonia(aq) the PTM processes are found to be less probable than for water(aq), which is attributed to the planarization of the ammonia molecule upon core-level ionization. The effect is smaller for the neutral $-NH_2$(aq) group of glycine at basic pH, where intramolecular dynamics is less likely. Nature and chemical reactivity of the initial transient species and their role for radiation chemistry and for local reactions relevant for biological molecules in an aqueous environment are discussed for the different molecular hydrogen-bonded systems.

5:00pm **IS+SS+NS+BI+VT+MN+AS-WeA9 Water Dissociation in Metal Organic Frameworks with Coordinatively Unsaturated Metal Ions: MOF-74**, ***Kui Tan***, The University of Texas at Dallas, *S. Zuluaga,* Wake Forest University, *E. Fuentesf,* The University of Texas at Dallas, *H. Wang,* Rutgers University, *P. Canepa,* Wake Forest University, *J. Li,* Rutgers University, *T. Thonhauser,* Wake Forest University, *Y.J. Chabal*, The University of Texas at Dallas

Water dissociation represents one of the most important reactions in catalysis, essential to the surface and nano sciences. However, the dissociation mechanism on most oxide surfaces is not well understood due to the experimental challenges of preparing surface structures and characterizing reaction pathways. To remedy this problem, we propose the metal organic framework MOF-74 as an ideal model system to study water reactions. Its crystalline structure is well characterized; the metal oxide node mimics surfaces with exposed cations; and it degrades in water. Combining *in situ* IR spectroscopy and first-principles calculations, we explored the MOF-74/water interaction as a function of vapor pressure and

temperature. Here, we show that, while adsorption is reversible below the water condensation pressure (~19.7 Torr) at room temperature, a reaction takes place at ~150 ˚C even at low water vapor pressures. This important finding is unambiguously demonstrated by a clear spectroscopic signature for the direct reaction using D_2O, which is not present using H_2O due to strong phonon coupling. Specifically, a sharp absorption band appears at 970 cm^{-1} when D_2O is introduced at above 150 ˚C, which we attribute to an O-D bending vibration on the phenolate linker. Although H_2O undergoes a similar dissociation reaction, the corresponding O-H mode is too strongly coupled to MOF vibrations to detect. In contrast, the O-D mode falls in the phonon gap of the MOF and remains localized. First-principles calculations not only positively identify the O-D mode at 970 cm^{-1} but derive a pathway and kinetic barrier for the reaction and the final configuration: the D (H) atom is transferred to the oxygen of the linker phenolate group, producing the notable O-D absorption band at 970 cm^{-1},while the OD (or OH) binds to the open metal sites. Experimental data and theoretical modeling further shows that the reaction is facilitated by a cooperative effect of several H_2O molecules. This finding explains water dissociation in this case and provides insight into the long-lasting question of MOF-74 degradation. Overall, it adds to the understanding of molecular water interaction with cation-exposed surfaces to enable development of more efficient catalysts for water dissociation.

Ref: K. Tan, S. Zuluaga, Q. Gong, P. Canepa, H. Wang, J. Li, Y. J. Chabal and T. Thonhauser, *Chem. Mater.*, 2014, **26**, 6886-6895.

5:20pm **IS+SS+NS+BI+VT+MN+AS-WeA10 Competitive Co-Adsorption of CO_2 with H_2O, NH_3, SO_2, NO, NO_2, N_2, O_2, and CH_4 in M-MOF-74 (M= Mg, Co, Ni): The Role of Hydrogen Bonding**, *K. Tan,* The University of Texas at Dallas, ***Sebastian Zuluaga,*** Wake Forest University, *H. Wang,* Rutgers University, *Y. Gao,* The University of Texas at Dallas, *J. Li,* Rutgers University, *T. Thonhauser,* Wake Forest University, *Y.J. Chabal,* The University of Texas at Dallas

The importance of co-adsorption for applications of porous materials in gas separation has motivated fundamental studies, which have initially focused on the comparison of the binding energies of different gas molecules in the pores (i.e. energetics) and their overall transport. By examining the competitive co-adsorption of several small molecules in M-MOF-74 (M= Mg, Co, Ni) with *in-situ* infrared spectroscopy and *ab initio* simulations, we find that the binding energy at the most favorable (metal) site is not a sufficient indicator for prediction of molecular adsorption and stability in MOFs. Instead, the occupation of the open metal sites is governed by kinetics, whereby the interaction of the guest molecules with the MOF organic linkers controls the reaction barrier for molecular exchange. Specifically, the displacement of CO_2 adsorbed at the metal center by other molecules such as H_2O, NH_3, SO_2, NO, NO_2, N_2, O_2, and CH_4 is mainly observed for H_2O and NH_3, even though SO_2, NO, and NO_2, have higher binding energies (~70-90 kJ/mol) to metal sites than that of CO_2 (38 to 48 kJ/mol) andslightly higher than water (~60-80 kJ/mol). DFT simulations evaluate the barriers for H_2OàCO_2 and SO_2àCO_2 exchange to be ~ 13 and 20 kJ/mol, respectively, explaining the slow exchange of CO_2 by SO_2, compared to water. Furthermore, the calculations reveal that the kinetic barrier for this exchange is determined by the specifics of the interaction of the second guest molecule (e.g., H_2O or SO_2) with the MOF ligands. Hydrogen bonding of H_2O molecules with the nearby oxygen of the organic linker is found to facilitate the positioning of the H_2O oxygen atom towards the metal center, thus reducing the exchange barrier. In contrast, SO_2 molecules interact with the distant benzene site, away from the metal center, hindering the exchange process. Similar considerations apply to the other molecules, accounting for much easier CO_2 exchange for NH_3 than for NO, NO_2, CH_4, O_2, and N_2 molecules. In this work, critical parameters such as kinetic barrier and exchange pathway are first unveiled and provide insight into the mechanism of competitive co-adsorption, underscoring the need of combined studies, using spectroscopic methods and *ab initio* simulations to uncover the atomistic interactions of small molecules in MOFs that directly influence co-adsorption.

Ref: K. Tan, S. Zuluaga, Q. Gong, Y. Gao, N. Nijem, J. Li, T. Thonhauser and Y. J. Chabal, *Chem. Mater.*, 2015, **27**, 2203-2217.

6:00pm **IS+SS+NS+BI+VT+MN+AS-WeA12 *In Situ* STM Observation of Pd(110) Under the Hydrogen Pressure Between 10^{-6} Pa and 10^{-3} Pa**, ***Jun Yoshinobu,*** *H. Kikuchi, T. Koitaya, K. Mukai, S. Yoshiomoto*, University of Tokyo, Japan

Hydrogen adsorption and absorption on/in Pd and Pd alloys are vital processes for the hydrogen storage and hydrogen permeation materials. We investigated the Pd(110) surface under the hydrogen pressures between 10^{-6} Pa and 10^{-3} Pa at room temperature using in-situ atom-resolved scanning tunneling microscopy (STM). We observed missing-atom, missing-row and added-row structures and the number of atoms in these structures were quantitatively analyzed as a function of exposure time. Note that adatoms were not detected probably because they were mobile in the present experimental conditions. At 10^{-6} Pa, the numbers of missing-row and added-row atoms increased up to ~20 L (langmuir) and after that they were gradually reaching the saturation (steady-state). On the other hand, the number of missing-atoms decreased gradually from the initial stage. With increasing the hydrogen pressures the number of missing-row atoms and added-row atoms increased, and the whole surface was covered with these reconstructed structures after large exposures (>1000 L). It has been known that not only hydrogen adsorption but also hydrogen absorption occur in such conditions. Thus, the missing-row and added-row reconstructed structures are inevitable for hydrogen absorption on Pd(110).

Vacuum Technology
Room: 230B - Session VT-WeA

Vacuum Quality and Partial Pressure Analysis
Moderator: Steve Borichevsky, AMAT VSE, Ted Martinez, SLAC National Accelerator Laboratory

2:20pm **VT-WeA1 Plasma Cleaning of SEMs and Large Vacuum Systems**, ***Ronald Vane***, XEI Scientific Inc. **INVITED**

Vacuum-based processes can suffer harmful effects from the presence of adventitious hydrocarbons that result from various sources such as oils and solvents as well as work-pieces. The problem of carbon and hydrocarbon contamination in vacuum chambers of scanning electron microscopes (EM) and other ion beam instruments is well known. An effective tool at removing hydrocarbon contamination from electron microscope chambers is remote, or downstream, plasma cleaning. Electrically neutral radicals flow from the plasma source into the chamber so that carbon compounds are removed by chemical reactions.

Plasma cleaning of hydrocarbons for electron microscopes and vacuum chambers is a simple version of the more complex plasma etch and ashing technologies used in semiconductor production and other plasma processing. Its premise is straight forward: remove carbon compounds and do no damage to the instrument. Doing this requires a small plasma source that can be mounted on an instrument port. Desirable properties are 1) Use air as an oxygen source for oxygen chemical etch, 2) Avoid ion sputtering . 3) operate at low power to avoid heat and high sheath energy potential 4) Produce a narrow electron energy distribution. 5) operate over wide pressure range.

The Evactron® De-Contaminater from XEI Scientific is a hollow cathode RF plasma device that meets these criteria. First developed to operate at low vacuums produced by roughing pumps, it has been now been modified to work with high vacuum produced by turbo molecular pumps (TMP). Now Evactron cleaning can be initiated with a TMP at full speed and vacuum of < 10-7 Torr. The flow of gas through plasma raises the chamber pressure during cleaning but the TMP retains full speed. If the chamber pressure drops below 15mTorr (2 Pa) the mean free path becomes long enough that a pink flowing afterglow fills the chamber. The afterglow is the result of reduced recombination rates of radicals and metastables at the lower pressures. The flowing afterglow is a marker for the presence of the oxygen radicals that do the plasma cleaning. The cleaning volume and rates are greatly increased with flow afterglow cleaning.

The pink flowing afterglow from air plasma is caused by nitrogen metastables and contains many UV emission lines that can desorb water vapor and hydrocarbon vapors from surfaces in the chamber which speeds pump down after plasma cleaning. RGA mass spectrometry results have shown remarkable decreases of the partial pressures of all gasses in UHV chambers if flowing afterglow cleaning is done during pump down. If this effect can be used to avoid bake out of UHV systems, considerable time savings may be achieved.

3:00pm **VT-WeA3 Double Deflection and Enhanced Detection - The Use of a Novel Ion Optics for Metastable Rejection and Improved Detection in the Low ppb Range**, ***Jonathan Leslie***, MKS Instruments Spectra Products, UK **INVITED**

During electron ionisation in a Quadrupole Mass Spectrometer (QMS), metastable neutrals are produced in addition to positive ions. The ion source in current QMS Residual Gas Analysers (RGA) is coupled with “line of sight” into the mass analyser and detector. Conversion of the metastable neutral into an ion and electron can cause increased noise, especially at lower masses. The higher noise level can determine the limit of detection in the RGA. The baseline signal can vary with changes of bulk gas and/or pressure.

The use of ion optics with novel cylindrical geometries between the ion source and mass analyser, enables a focused beam of ions to be displaced onto a second parallel axis, then back to the original axis. The cylindrical

geometry provides good focusing resulting in no loss of signal, combined with a simple and robust mechanical design. The tuning is robust with a single low voltage lens setting.

The theory and performance of this elegant and innovative deflection system will be discussed, highlighting applications in which it offers a competitive advantage over current RGA designs.

4:20pm **VT-WeA7 The Deployment of a Commercial RGA to the International Space Station**, ***Matthew S. Kowitt***, Stanford Research Systems, *D. Hawk*, Orbital-ATK, *D.J. Rossetti*, Conceptual Analytics, *M.S. Woronowicz*, SGT Inc. **INVITED**

The International Space Station (ISS) uses ammonia as a medium for heat transport in its Active Thermal Control System. Over time, there have been intermittent component failures and leaks in the ammonia cooling loop. One specific challenge in dealing with an ammonia leak on the exterior of the ISS is determining the exact location from which ammonia is escaping before addressing the problem.

Together, researchers and engineers from SRS and NASA's Johnson Space Center and Goddard Space Flight Center, have adapted a commercial off-the-shelf (COTS) residual gas analyzer (RGA) for repackaging and operation outside the ISS as a core component in the ISS Robotic External Leak Locator, a technology demonstration payload currently scheduled for launch during 2015. The packaging and adaptation of the COTS RGA to the Leak Locator will be discussed. The collaborative process of adapting a commercial instrument for spaceflight will also be reviewed, including the build-up of the flight units. Measurements from a full-scale thermal vacuum test will also be presented demonstrating the absolute and directional sensitivity of the RGA.

5:00pm **VT-WeA9 Temperature-stable Quartz Oscillator Applicable to Pressure Gauges, Gas Sensing, Partial Pressure Measurement, and Plasma Diagnostics**, ***Atsushi Suzuki***, AIST, Japan

A quartz friction pressure gauge (Q-gauge) is advantageous because it can measure pressures in the range of 0.01 kPa to 100 kPa and because the size of a quartz oscillator is less than 1x1 cm^2. The underlying principle of Q-gauge use in pressure measurement is that the electric impedance (*Z*) of the quartz oscillator depends on the viscosity and gas density of the measured gas. When the total absolute pressure is known, then properties related to viscosity and molecular weight can be obtained from *Z*.

This is important because it enables changes in viscosity and molecular weight of the measured gas to be detected in addition to changes in pressure. Thus, many types of methods are made possible, such as hydrogen gas sensing, hydrogen concentration measurement, partial pressure measurements of binary gas mixtures such as ozone-oxygen and silane-hydrogen, and measurements of gas decomposition efficiency and composition changes induced by plasma.

However, the disadvantage of these measurements using a quartz oscillator is that the output *Z* from the quartz oscillator is affected by temperature. This temperature dependence must be corrected in particular for uses of hydrogen sensing outdoors and in other applications in which temperature changes.

In this presentation, a novel temperature-stable quartz oscillator (TSQO) will be introduced. The output from the TSQO used in this study was the electric-impedance converted voltage, which represents *Z*. First of all, it was shown that this output depended on the total pressure from 0.01 kPa to 100 kPa, indicating that this TSQO works well as a Q-gauge device. Fluctuation of the reading output at constant temperature was 0.06% of the total output.

Temperature stability was confirmed at atmospheric pressure and for temperatures varying from 15 °C to 50 °C. With this temperature change, the change of the TSQO output was less than 0.2% of the reading output. Because the output fluctuation of a conventional quartz oscillator across the temperature range above is normally about 2.0% of the reading output, it was shown that temperature stability was attained by the TSQO. The measured degree of output fluctuation for this TSQO is acceptable for hydrogen sensing because it is smaller than the 0.2% change induced by contamination of hydrogen concentration and less than one-fourth of the fluctuation introduced by low-level explosions of hydrogen in air (4%), which is the necessary minimum detection level. Therefore, it can be concluded that this TSQO is practically useful for various measurements that involve hydrogen sensing anywhere that temperature fluctuates.

This work was supported by ISPS KAKENHI Grant Number 24560070.

5:20pm **VT-WeA10 An Ultra-high Vacuum Processing System for Constructing Small Format Photodetectors**, *D.R. Walters, R.J. Wagner,* ***John Noonan***, *L. Xia, J. Xie, J. Wang, H. Zhao, M. Virgo*, Argonne National Laboratory

The Large Area Picosecond Photodetector was envisioned to be a frugal design for use in upcoming water-based Cherenkov photodetectors for the detection of neutrinos. This project's goal is to develop a glass enveloped 20 cm photodetector but to understand the issues of constructing such a detector a smaller 6 cm format was chosen to be the vehicle for parts and process development. An ultra-high vacuum system was designed and constructed for handling the sub-assemblies. This multi-chamber system is integrated so that the scrubbing, photocathode deposition, and hermetic sealing all occur within a single environment. The design of this system has process stations in adjacent chambers so that the sub-assemblies can be easily moved using magnetic linear manipulators. The vacuum performance of the system will be presented along with results on the efficiency of the photocathode, >15%, the clean-up of the scrubbing, and a brief overview of the indium vacuum seal.

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