Tuesday Morning, November 1, 2005

Vacuum Technology
Room 200 - Session VT-TuM

Total and Partial Pressure Gauging

Moderator: T. Gessert, National Renewable Energy Laboratory

8:40am **VT-TuM2 New Ignition Devices for Cold-Cathode Gauges*, B.R.F. Kendall,*** Elvac Laboratories*; E. Drubetsky,* Televac Division of The Fredericks Company

The discharge in a cold-cathode gauge does not start immediately when power is applied. In the absence of special starting devices the delay may be quite long, with large variations between successive starts. Average values typically range from seconds at 10@super -6@ Torr to hours or even days at 10@super -11@ Torr. For this reason, gauges which require frequent starting at very low pressures have sometimes been fitted with either radioactive or thermionic emitters to ensure relatively quick and predictable starting. Although effective, these solutions can cause other problems. Many laboratories are now reluctant to handle even weak radioactive sources, while the disturbance to the background pressure caused by some thermionic emitters can be significant. In an attempt to resolve these difficulties, we have tested diamond-like film emitters and electron generator arrays, both of which offer suitable fluxes of cold electrons for gauge starting. We have also made a detailed study of the physical processes occurring during gauge starting with thermionic electron sources. This has led to a very compact low-power emitter which greatly reduces thermal desorption during the starting process. The test gauges were double inverted magnetrons operating at pressures down to the 10@super -11@ Torr range.

9:00am **VT-TuM3 Selecting Vacuum Instrumentation for Your Applications*, C.R. Tilford,*** Independent Consultant **INVITED**

Vacuum users today are offered a wide variety of commercially-available vacuum instrumentation. But selecting adequate or best instruments for a particular application can sometimes be a daunting task since the only well defined parameter may be the cost. This talk will provide information to help users select instruments that will best meet their needs. This will include a brief description of thermal conductivity gauges, capacitance diaphragm gauges, micromachined electromechanical pressure gauges, ionization gauges and residual gas analyzers, and a discussion of the relative advantages and disadvantages of each type. Beyond this, experimental procedures will be described that can be carried out in the user's laboratory to determine important characteristics of specific instruments and, in some cases, make adjustments to optimize performance.

9:40am **VT-TuM5 Results of Performance Dependencies of Bayard-Alpert type Hot Cathode Ionization Gauges Upon Operational Parameters of Their Controllers*, P.C. Arnold,*** Helix Technology Corporation

An evaluation has been performed of the precision required to provide indicated pressure repeatability time-to-time and reproducibility controller-to-controller, with respect to the operational parameters of ionization gauge controllers. Gauge sensitivity of Bayard-Alpert type hot cathode ionization gauges has been studied and the dependence upon parameters of operation has been measured and will be displayed graphically. These measurements will allow a user to compare the precision of the userâ?Ts gauge controller to the needs of accurate pressure indication. The independent parameters varied were anode potential and cathode potential, with either cathode end at the cathode bias potential and with the cathode heating voltage applied at either cathode end, while the other variables of operation were held fixed. The fixed parameters were various electron emission currents, various nitrogen pressures, and several gauges. Another issue in ionization gauge operation is measurement of the base pressure of a vacuum chamber by a gauge attached to that chamber which is a continual problem in practical applications. Test data will be shown demonstrating that the magnitude of electron emission can significantly affect the indicated pumpdown rate observed for the chamber, or can significantly affect the steady state value of the indicated base pressure for a practical chamber in the UHV range.

10:20am **VT-TuM7 Residual Gas Analyzers as Total Pressure Gauges**, M. Maskell,*** Old Dominion University*; P. Adderley,* Jefferson Lab*; G.A. Brucker,* Stanford Research Systems*; C. Day,* Forschungszentrum, Karlsruhe*; G.R. Myneni,* Jefferson Lab

Residual Gas Analyzers (RGAs) provide many benefits over other types of gauges that measure total pressure only. RGAs give information about the specific composition of the residual gas in a vacuum system, and can be used for leak detection and diagnosis of other problems in a vacuum system. When the partial pressure capabilities of an RGA are needed, it is economically advantageous to be able to use the RGA as the systemâ?Ts total pressure gauge, rather than installing a total pressure gauge in addition to the RGA. The problem with using RGAs as total pressure gauges is that their sensitivity is affected by the mass of the gas they are detecting. These effects may be small for individual species of gas, but when the errors are added together in calculating the total pressure from the sum of the partial pressures, the total pressure measurement can become much less accurate than for gauges that measure total pressure only. This study is intended to find correction factors that can be applied to different gas species to make the RGA as accurate as any total pressure gauge. In this study, we use four Stanford Research Systems 100 AMU RGAs, an Ionivac IM-520 extractor gauge, an Ulvac AxTRAN gauge, and an MKS SRG SH-700 Spinning Rotor Gauge (SRG). First the SRG transfer standard is used to calibrate the extractor and AxTRAN gauges, by introducing various gases into the system, by direct comparison method. Then the RGA sensitivities for individual gas species are determined by comparing the partial pressure reading of the RGA with the extractor and AxTRAN gauge readings. Finally, a preselected gas mixture is introduced into the system, and the change in pressure reading on the extractor and AxTRAN are compared to the total pressure of the RGA with appropriate corrections to the various peaks of the RGA output. *This work was supported by U.S. Department of Energy Contract No. DE-AC05-84ER40150 and KATRIN International Collaboration at FZK in Germany.

10:40am **VT-TuM8 Calibration Systems Used for Calibrating Space Physics In-situ Particle Sensors*, M. Wüest,*** Astroglobo, Switzerland

Any measurement device needs to be calibrated to ensure that the signal output is in some known relation to the input. This is especially true for particle sensors sent into space. Those instruments can usually not be retrieved for recalibration in case questions about the validity of the measurements occur. Also, these in-situ space instruments are sometimes flown to locations where no other instrument has been before (e.g. Pluto). We will describe typical calibration systems for particle instruments for spacecraft such as plasma sensors, mass spectrometers, energetic neutral atom imagers or solid-state detector telescopes spanning the energy range from 0 eV to 10 MeV. We will touch upon selection for beam sources and beam monitors.

11:00am **VT-TuM9 Progress Towards User Oriented Vacuum Pressure Measurement*, M. Wuest,*** *R. Stocker,* INFICON Ltd., Liechtenstein

Since the beginning of vacuum measurements in the days of Torricelli, Pascal and von Guericke we have made a lot of progress in vacuum measurement. Measurement of total pressure in vacuum systems is characterized by an extremely large measurement range (> 14 decades) and the use of rather intransparent measurement principles such as heat conductivity of the gas, gas friction or ionization of the gas. This makes the measurement of the total pressure for the innocent user quite tricky as environmental parameters such as gas species, temperature, contamination or operating parameters must be considered. What efforts have been made in the past and what can be done in the future to provide the common user with simple to operate, accurate and reliable pressure gauges?

Vacuum Technology
Room 200 - Session VT-TuA

Calibration: Pressure and Flow Metrology
Moderator: P.J. Abbott, NIST

2:00pm **VT-TuA1 A New Determination of the Volume Ratio of the NPLI Static Expansion System**, ***P. Mohan,*** National Physical Laboratory, India

Recently we have acquired high accuracy resonant silicon gauges of two different ranges, one 130 kPa full scale and the other 1 kPa full scale, for measurement of the initial and final pressures. These gauges have been utilized in a cumulative expansion process for the measurement of the volume ratio of the NPLI Static Expansion System which is nominally 2820. With these new gauges, and with the use of calibrated Platinum Resistance Thermometers mounted inside the vacuum chambers, it has been possible to measure the volume ratio with a relative expanded uncertainty (k=2) of 0.0015. The standard thus characterized has been used to calibrate SRGs at a number of pressures in the range 0.1 Pa to 1 Pa in steps of 0.1 Pa. The Gauge Constant at each of these pressures, defined as equal to the ratio of the indicated pressure to the true pressure is then plotted against the true pressure. The resulting straight line plot has a negative slope and its intercept equals the gauge coefficient. The two SRGs, NPL-0 and NPL-2 thus calibrated are used (i) as a device for measuring the pressure rise in the flowmeter of the NPLI orifice flow system and (ii) as a secondary standard for the calibration of the user gauges.

2:20pm **VT-TuA2 Precise Volume Measurement of Bellows with its Length for a Constant Pressure Flowmeter**, ***K. Arai,*** *H. Akimichi, M. Hirata,* AIST, Japan

A constant pressure flowmeter has been used to generate very low gas flow from 10@super -5@ to 10@super -10@ Pa m@super 3@ s@super -1@ as a reference standard to calibrate standard leaks. The rate of the flow is obtained by a volume change in a time while the pressure is kept constant. There are several methods to change the volume of the flowmeter. Bellows directly elongated and shortened by a pulse-driven linear actuator was used for precise measurements of the displacement and low outgassing due to the all-metal structure. In this study, the volume change in the bellows was measured as a function of its length by Boyle's law. The flowmeter was isolated from pumps and gas sources. The ratio of the volume change to the initial volume was obtained from the ratio of the pressures before and after shortening the bellows. The absolute value of the volume change was obtained from the difference of the pressure ratio by introducing a well-known volume (ball bearings). Pressure measurements were performed by capacitance diaphragm gauges (CDGs). The repeatability of the pressure ratio measurements was 3x10@super -5@, which was comparable to the chamber temperature fluctuation of 30 mK. The deformation of the bellows was caused by a pressure difference between inside and outside of the bellows. The pressure difference was kept under 2500 Pa by controlling the outside pressure. The remaining deformation was compensated by the value of the pressure difference. The volume change in the bellows by shorting it by 25.00 mm was 32.24 ml. The uncertainty of the measurement was 0.07% after consideration of the temperature fluctuation, the difference from the ideal gas and the thermal transpiration effect of the gauge. The volume changed with its length quadratically, as estimated from the structure of bellows.

2:40pm **VT-TuA3 High-accuracy Vacuum Calibration System**, ***S. Tison,*** *S. Lu, S. Sukumaran,* Mykrolis Corporation

Many industrial vacuum processes require high-accuracy vacuum measurements to enable process capabilities critical to the device attributes or performance. Semiconductor device manufacture, flat panel displays, optical coatings, and vacuum metalurgy are a few examples where vacuum measurements are critical to product performance. While these measurements are critical, there is a lack of high accuracy industrial calibration systems that can support these needs; particularly at pressures below 100 Pa. A new vacuum calibration system has been developed for calibrating vacuum gages in the range of 1 Pa to 100 kPa with uncertainties ranging from +/-0.02% to +/-0.2% of reading. The paper describes this system which utilizes high stabilty transfer standards in conjunction with pressure expansion techniques to achieve reliable high-accuracy vacuum gage calibration and characterization. The data indicates that automated high accuracy vacuum measurements can be made with a single vacuum system utilizing transfer standards in conjunction with a "primary type" pressure expansion technique which relies on the known ratio of two calibrated volumes to achieve accuracies previously unachievable solely by utilizing vacuum transfer standards.

3:00pm **VT-TuA4 Development of a New High-Stability Transfer Standard Based on Resonant Silicon Gauges for the Range 0.1 kPa - 130 kPa**, ***J.H. Hendricks,*** *A.P. Miiller,* NIST

The National Institute of Standards and Technology (NIST) has developed a new transfer standard capable of absolute-mode and differential-mode operation in the range 0.1 kPa to 130 kPa. The transfer standard is based on Resonant Silicon Gauges (RSGs) of the same type used to provide superior calibration stability in recent CCM Key Comparisons of absolute and differential pressure standards,@footnote1,2@ which covered pressures up to 1 kPa. The new NIST transfer standard consists of two 10-kPa RSGs, two 130-kPa RSGs, and an ion pump to provide a reference vacuum when making absolute pressure measurements. The pairs of RSGs provide redundancy but, more importantly, they enable Youden analyses to be applied to the data to identify systematic differences between pressure standards. The RSG transfer standard package has demonstrated good short term zero stability and pressure resolution over the 0.1 kPa to 130 kPa range, and has demonstrated long term instability of a few ppm at 130 kPa, increasing to 0.01% at 0.1 kPa. In terms of long term stability, the new NIST transfer standard package is nominally commensurate with piston gauges at pressures down to 10 kPa, and extends measurement capability down to 0.1 kPa. Although its intended use is for intra-laboratory comparisons of primary standards at NIST, this transfer standard may also find applications in international comparisons of pressure standards. @FootnoteText@ @footnote 1@ Miiller, A. P., Bergoglio, M., Bignell, N., Fen, K. M. K., Hong, S. S., Jousten, K., Mohan, P., Redgrave, F. J., and Sardi, M., Final report on key comparison CCM.P-K4 of absolute pressure standards from 1 Pa to 1000 Pa, Metrologia, 2002, 39, Tech. Suppl., 07001.@footnote 2@Miiller, A. P., Cignolo, G., Fitzgerald, M. P., and Perkin, M. P., Final report on key comparison CCM.P-K5 of differential pressure standards from 1 Pa to 1000 Pa, Metrologia, 2002, 39, Tech. Suppl., 07002.

3:20pm **VT-TuA5 New Calibration Apparatus for 1, 10, 100 Torr Capacitance Diaphragm Gauges**, ***S.Y. Woo,*** *I.M. Choi,* Korea Research Institute of Standards and Science, Korea

Capacitance diaphragm gauges are electromechanical pressure sensors in which the displacement of a stretched thin metal diaphragm is detected by a capacitance measurement. They have gained widespread international popularity not only as high accuracy transfer standards but also as reliable replacements for many other vacuum gauges used in process industries. In order to calibrate such accurate vacuum gauges, laser or ultrasonic mercury manometers have been used. However, complexity, health concerns of mercury vapor, and cost of these manometers made it difficult to use in most calibration laboratories. As a substitute, a gas-operated pressure balance can be used with some modifications. In this article, we introduce a new apparatus for the calibration of the precise vacuum gauges. This device has a unique mass handling structure that allows masses to be changed in-situ without breaking the vacuum. It covers three pressure ranges of 1 Torr, 10 Torr, and 100 Torr. Using this apparatus, the characteristics of three commercial vacuum gauges (MKS, Model 626) were studied.

3:40pm **VT-TuA6 Real Time Calibration of Leak Detection Sensitivity**, ***X. Chen,*** *T.B. Huang, L.B. Xiao, L.Z. Cha,* Tsinghua University, China

The most important characteristic for leak detection is the smallest leak rate that an instrument, method, or system is capable of detecting under specified conditions. It is used to call the smallest detectable leak rate the leak detection sensitivity. One permeation type reference leak with a fixed leak rate is commonly used to calibrate the leak detector and the method has been standardized. It is no doubt that is basic and important to guarantee the instrument in optimized condition. However, the real level of the leak detection sensitivity depends on not only the test instrument, but also the system and methods. The detection limit will be higher or lower if the partial flow pump or accumulation method is used. Sensitivity calibration is necessary to distinguish between leak detector and leak detection. The demand for quantitative leak tests has increased sharply in recent times because the information is more important for the quality control. Real time calibration of the leak detection sensitivity can be achieved by comparing the tested leak rate with a fixed reference leak rate, a series of such reference leak rates or a variable reference leak rate. The last one is optimal for calibration since it provides the reference leak rate in the similar range of the tested leakage rate under the real situation. An adjustable reference leak rate system is put forward with wide dynamic

range from 10 @super -7@ to 10 @super -14@Pa.m @super 3@ /s by changing the inlet helium pressure and concentration of a platinum wire-glass reference leak with molecular flow characteristics. The real time calibration for the leak detection has been realized quantitatively not only for the instrument, including the ultra sensitive MSLD system, but also for the methods and system, even for the ultra sensitive leak detection. The detected leak rate under the real situation can be quantitatively calibrated which attracts more and more attention but has not been standardized until now.

Vacuum Technology
Room Exhibit Hall C&D - Session VT-TuP

Vacuum Technology Poster Session

VT-TuP1 Vacuum Measurement by Carbon Nanotube Field Emission, ***I.M. Choi***, *S.Y. Woo,* KRISS (Korea Research Institute of Standards and Science), Korea

A new vacuum measurement technology using carbon nanotube(CNT) field emission effect has been designed and manufactured. The fabricated pressure sensor is a triode type similar with a conventional ionization gauge, but has planar structure similar with a Field Emission Display. Due to the excellent field emission characteristics of CNT, it is possible to make a cost effective cold cathode type ion gauge. The triode type CNT sensors have been manufactured by screen-printing method and by thermal CVD growth method. The glass grid with Cr deposited by E-Beam put on the cathode with the gap of 200 mm between two electrodes was manufactured. By the voltage applied to the grid, the electrons emitted from the carbon nanotubes ionize gas molecules in the chamber and the ionized molecules are gathered to the collector. On this occasion, two modes are available to detect the gas density in the chamber; one is electron emission mode, the other is ionization mode. In the electron emission mode, the collector voltage is controlled a little higher than the grid voltage. On the other hand, the collector voltages are controlled lower than the grid voltage to obtain a large ionization ratio in the ionization mode. The current ratio shows increase characteristic according to the pressure in each mode. The ionization characteristics are dependent on the gas and the voltage applied to the grid and the collector. In this paper, the various metrological characteristics of the home made pressure sensor utilizing carbon nanotubes will be shown.

VT-TuP2 Monte Carlo Simulation of Transmission Probability of Gas on Thin Orifice Considering Specular Reflection, ***M. Shiro***, National Institute of Advanced Industrial Science and Technology (AIST), Japan; *M. Hirata, H. Akimichi,* AIST, Japan

To estimate the conductance of an orifice, the influence of its thickness on the transmission probability of gas molecules should be considered. In general, the probability is calculated assuming that molecules hitting inner wall of the orifice reflect with cosine law. However, a specular reflection of gas molecules on the wall should be also considered on the calculation judging from that the accommodation coefficient of a spinning rotor gauge depends on gas species. In such case, it is difficult to calculate the probability analytically. In this study, the probability considering the specular reflection was calculated by the Monte Carlo simulation. The results are as follows, 1) the probability increases with the ratio of the specular reflection. 2) This increment is significant in thick orifice. Even if the thickness is small, it is necessary to consider the effect of the specular reflection. If the specular reflection elements are1%, 3% and 10%, this effect increases the probability 0.1% by the increase of the ratio L/r of thickness L to radius r of the orifice greater than 0.2, 0.07 and 0.02, respectively. In case of thin orifice, the probability can be expressed in a simple equation of the L/r and the ratio of specular reflection. The great portion of molecules passes through the orifice directly. Molecules reflecting in specular on the inner wall of the orifice pass through the orifice. 50% of remaining molecules hitting the wall also pass through the orifice. The deviation of this equation from the result of the simulation is less than 0.1% in the range of L/r<0.2, even if 10% of gas molecules reflected in specular.

VT-TuP4 Selection of State Variables for Diagnosing Dry Vacuum Pumps, ***J.Y. Lim***, *W.S. Cheung,* Korea Research Institute of Standards and Science; *K.-H. Chung,* Korea Research Institute of Standards and Science, Korea

Detection of degradation and failure-related symptoms of dry vacuum pumps has been currently hot-issued in the semi-conductor and display process lines since the loss time and costs due to abnormal malfunction are astronomically rising. The baseline for the detection is direct monitoring of all state variables from target pumps such as currents, exhaust pressure, vibration, sound pressure, purge gas, temperature, etc. However, the analyzed results show that the state variables are very closely correlated each other, and their factorization may be required for the symptom detection. Also, confusion for the selection has been frequently arisen since vacuum pumps of the same type and of about the same size offered by different manufacturers frequently have minor or even large differences in their mechanical structures. To achieve the process and pump state monitoring ability, gas-type independent vacuum gauges have been installed at the very near pump inlet to monitor the inlet pressure variation with respect to the process time. Five 600 m3/h dry vacuum pumps of the same type have been selected, and tested in the laboratory as well as the actual process line for analyzing state variables. The resultant variability coefficient of the inlet pressure was less than 3.5% above 0.05 mbar corresponding to the actual process pressure range. In the case of the power consumption, the coefficient was above 10%. This very meaningful information provides us with the inlet pressure as the most significant state variable for the detection of degradation and failure-related symptom in the pump type or size independent manner.

VT-TuP5 Active Algorithms for State-Variable Monitoring of Dry Vacuum Pumps, ***W.S. Cheung***, *J.Y. Lim, C.U. Cheong,* Korea Research Institute of Standards and Science; *K.-H. Chung,* Korea Research Institute of Standards and Science, Korea

Demands on capacity and reliability of dry vacuum pumps in modern semiconductor manufacturing processes have been constantly increasing. It is the reason that the costs for failed wafer batches and lost production times are higher and higher as the size of the production wafer is larger and larger. To tackle vacuum pump-related demands in the semiconductor production lines, Korean IC makers have recently put much efforts to establish the predictive maintenance and failure protection of vacuum pumps. For instance, Samsung has decided to buy no vacuum pump without the monitoring system for the pre-failure protection and predictive maintenance. This research team has surveyed what state variables are monitor in the Korean production lines and the current state-of-art of pump monitoring systems available from pump suppliers. This paper will introduce the surveyed results and will suggest what state variables a pump monitoring system should measure. Active ways of monitoring the change of selected state variables are proposed to assess the degradation of running pumps. To examine the effectiveness of the proposed methods, several field test results are demonstrated. Attempts of those field tests have allowed this research to see what limits current pump monitoring systems have. One of significant limits was the incompatibility to the SEMI equipment modeling and communication standards. The current monitoring systems were found to be too far from either SECS-II/GEM standards or the current e-Diagnostics guideline. Finally, this paper suggests a guideline for the vacuum pump manufacturers to meet for the integration of vacuum pumps into the computer-based management system.

VT-TuP7 Effect of a Depth of a V-shaped Groove of Substrate Keeping Adsorption Layer on Sliding in a Vacuum, ***A. Kasahara***, *M. Goto, M. Tosa,* National Institute for Materials Science, Japan

We found that materials with a surface roughness around 100nm can offer as smooth sliding in a vacuum as at atmospheric pressure, and have also studied relation between direction of sliding probe and generated friction force. Results showed a decrease in friction force under optimum combination conditions that surface roughness of substrate was smaller than that of probe with surface roughness about 100nm and also showed that V-shaped groves line patterns of substrate and sliding probe cross each other at right angles. It is considered that smooth sliding might arise from absorption gas layer of the V-shape groove kept strongly. We therefore prepared V-shaped grooves with different heights for type 304 austenitic stainless steel sheets and studied a form of adsorption gas layer on the V-shaped groove of substrates to understand the effect of the grove on adsorption layer acting as a vacuum lubricant. Structure of the V-shaped groove such as height, open-angle and shape were analyzed by an atomic force microscopy (AFM) at an atmosphere. Cross-section of form adsorption layer on the V-shaped groove was then calculated by difference in pull-off distance from force curve diagrams obtained with AFM. Cross-section form of adsorption layer and the structure of the V-shaped groove were drastically changed by the structure depth. The structure of the V-shaped groove at a depth less than 120nm seemed to be satisfied with condition that absorption layer was trapped strongly. It is therefore concluded that the V-shaped groove at a depth about 100nm is ideal modified surface for satisfy adsorbed gases that can act as good vacuum lubricant because of exhibiting as low friction in a vacuum as friction at an atmospheric pressure.

VT-TuP8 Pumping Characteristics of Activated Alumina for Ortho- and Para-Hydrogen Molecules, ***T. Okano***, *K. Niki, K. Yoshida, T. Ito, K. Fukutani,* University of Tokyo, Japan

Hydrogen is the most dominant gas species in ultrahigh vacuum. With respect to the nuclear spin state of hydrogen molecules, the triplet nuclear

spin states are called ortho hydrogen (o-H@sub 2@) and the singlet ones are called para hydrogen (p-H@sub 2@). Since the spontaneous transition between a triplet and a singlet nuclear spin state is very small in gas phase, they are considered to be two distinct molecular species. In the present study, we studied on the behavior of o-H@sub 2@ and p-H@sub 2@ in a vacuum chamber. The apparatus consisted of a stainless steal chamber equipped with a mechanical compressor type cryohead. The lowest attainable temperature of the cryohead was 6 K. A small vessel (diameter: 10 mm, depth: 2 mm) was attached on the end of the cryohead and was filled with granules of activated alumina. The state-selective measurement of o-H@sub 2@ and p-H@sub 2@ was made by (2+1) resonant-enhanced multiphoton ionization (REMPI) method. Due to the requirement of antisymmetry of the total wave function of hydrogen molecules, even rotational state J is only allowed for o-H@sub 2@ and odd J-state for o-H@sub 2@. The J-state selective measurement by REMPI made it possible to detect o-H@sub 2@ and p-H@sub 2@ with very high sensitivity. The REMPI laser pulses with a wavelength of 201nm and an energy of 0.4 mJ/pulse is focused at the center of a radiation shield surrounding the activated alumina vessel. The ionized H2 is detected by a microchannnel plate attached to the radiation shield. After admitting hydrogen up to 2x10@super â?"4@ Pa, we started to cool down the temperature of the activated alumina. The densities of o-H@sub 2@ and p-H@sub 2@ in the chamber decreased rapidly at a temperature of 29 K and 25 K, respectively. This deference in the pump-down behavior was ascribed to the deference in the activation energy of desorption of ortho and para H@sub 2@.

VT-TuP10 A Summary and Status of the SNS Ring Vacuum Systems *, *H. Hseuh,* Brookhaven National Laboratory; ***M. Mapes,*** Brookhaven National Laboratory, usa; *I. Smart, D. Weiss, J. Rank, R. Todd,* Brookhaven National Laboratory

The Spallation Neutron Source (SNS) ring is designed to accumulate high intensity protons. The vacuum system consists of the High Energy Beam Transport (HEBT) line, Accumulator Ring and the Ring to Target Beam Transport (RTBT) line. The accumulator ring has a circumference of 248m with 4 arcs and 4 straight sections while the RTBT and HEBT have a total length of 350m of beam transport line. Ultrahigh vacuum of 10-9 Torr is required in the accumulator ring to minimize beam-residual gas ionization. To reduce the secondary electron yield (SEY) and the associated electron cloud instability, the ring vacuum chambers are coated with Titanium-Nitride (TiN). In order to reduce radiation exposure quick disconnect chain clamp flanges are used in some areas where radiation levels are expected to be high. This paper describes the design, fabrication, assembly, and vacuum processing of the ring and beam transport vacuum systems as well as the associated vacuum instrumentation. *Work performed under the auspices of the U.S. Department of Energy.

VT-TuP11 Improvement of Materials Surface Properties by RF Glow Discharge Treatment, ***T.B. Huang***, *X. Chen, X.Q. Tian,* Tsinghua University, P.R. China; *L.Z. Cha,* Tsinghua University, P.R. China, China

Glow discharge treatment is not only an effective means to remove the absorbed gases and impurity, but also an important tool to improve the materials surface properties in vacuum and electronic applications. Anyway, it can shorten the pump-down time when the system or devices are not permitted to carry out high temperature baking. Especially, the production of the longeval ultra-high vacuum environment is difficult in small volume so that it is a desirable means of glow discharge treatment. In the electronic applications, the rough surface is not desirable due to unexpected discharge occurring. Then, it is necessary to use some surface treating means, such as glow discharge treatment, which could make materials surface smooth in a certain scale. For some insulator, RF discharge is a good solution. However, special ultra high vacuum and electronic applications enlarge the difficulties of glow discharge treatment process. For meeting the complicated demands, its influence on materials surface properties is necessary to investigate. The RF glow discharge treatment experiments have been carried out for improving the materials surface properties in vacuum and electronic applications. The surface morphology and outgassing rate were studied under different glow discharge treatment. The key process parameters were the cleaning power, pressure, time, and so on. It could be known by experiments that the roughness of materials surface varied due to glow discharge treating process. The experimental results revealed that the outgassing rates of different gases decrease due to glow discharge treatment. The clean and smooth surface in nanometer scale for materials was obtained after the glow discharge treatment. The evacuating properties for materials became better due to the glow discharge treatment. Different bombardment ions were applied in the experiments, and the outgassing trend induced by ion bombardment was discussed in this paper.

VT-TuP12 Electron Stimulated Desorption of Hydrogen Physisorbed on a Cold Cupper Surface, ***S.-S. Hong,*** Korea Research Institute of Standards and Science, Republic of Korea; *M. Shoaib,* Pakistan Vacuum Society; *Y.-H. Shin,* Korea Research Institute of Standards and Science; *K.-H. Chung,* Korea Research Institute of Standards and Science, Korea; *I. Arakawa,* Gakushuin University, Japan

Study of hydrogen is indispensable in vacuum technology for extreme high vacuum (XHV). XHV can only be achieved by minimizing the hydrogen outgassing from the materials used in vacuum system. Outgassing phenomena can be classified into four categories by the combination between the source (chemisorbed or physisorbed species) and the process (thermal or electronic desorption). We have been investigating the electron stimulated desorption at the cold surface on which hydrogen is physisorbed in order to clarify the fundamental process of outgassing from a cryopump which is exposed to charged particles or radiation. An experimental system was constructed in the Korea Research Institute of Standards and Science (KRISS). The system consists of a UHV chamber, two turbomolecular pumps and a dry pump, a residual gas analyzer, an electron gun and a micro channel plate for ion detection. The time of flight spectrum of the desorbed ions is obtained using a multi channel scaler. ESD yields of the H+ ion were systematically measured as a function of H2 pressure upon the cold surface and the amount of adsorption of H2.

VT-TuP13 High Temperature Outgassing Tests on Materials Used in the DIII-D Tokamak, ***K.L. Holtrop***, *M.J. Hansink,* General Atomics

This paper is a continuation of previous work on determining the outgassing characteristics of materials used in the DIII-D magnetic fusion tokamak.@footnote 1@ In order to achieve high performance plasma discharges in the DIII-D tokamak, impurity levels must be carefully controlled. Among the techniques used to control impurities are routine bakes of the vacuum vessel to an average temperature of 350°C. Materials used in DIII-D must not release any impurities at this temperature that could be transferred to the first wall materials and contaminate plasma discharges. To better study the behavior of materials proposed for use in DIII-D at elevated temperatures the initial outgassing test chamber was modified to include independent heating control of the sample and a simple load-lock chamber. The goal was to determine not only the total outgassing rate of the material under test but to also determine the gas species composition and to obtain a quantitative estimate of the removal rate of each species by the use of a residual gas analyzer. Initial results for aluminum anodized using three different processes, stainless steel plated with black oxide and black chrome, and a commercially available fiber optic feedthrough will be presented. This work was supported by the US Department of Energy under DE-FC02-04ER54698. @FootnoteText@ @footnote 1@K. Holtrop, J. Vac. Sci. Technol. A 17, 2064 (1999).

VT-TuP14 Photon Stimulated Desorption (PSD) and Secondary Electron Measurements of a Titanium Nitride Coated Copper Beam Chamber for the KEKB Collider@footnote 1@, ***C.L. Foerster,*** Brookhaven National Laboratory, US; *C. Lanni,* Brookhaven National Laboratory; *K. Kanazawa,* High Energy Accelerator Research Organization, Japan

KEKB is an asymmetrical collider operated by the High Energy Accelerator Research Organization (KEK) in Ibaraki, Japan. The collider utilizes two UHV ring chambers, one for a 3.5 GeV positron beam and the other for an 8 GeV electron beam, to study B-mesons. An electron cloud instability occurs at high currents which limits high current operation and reduces beam luminosity. To study a possible solution, which would reduce or eliminate the electron cloud, the inner surface of a one (1) meter long sample KEKB copper beam chamber was titanium nitride coated and studied on beamline U9a at the National Synchrotron Light Source (NSLS). The sample chamber has a circular cross section of 94mm inner diameter. The sample was installed in the U9a beam line and exposed to approximately 2.3X10@super+23@ photons directly from the source at a critical energy of 595 eV, striking the sample at an incident angle of 100mrad. Next, the TiN surface of the sample chamber was Argon Glow Discharge conditioned with approximately 2X10@super+18@ ions per square centimeter. After the conditioning the photon exposure was re-started and the measurements continued. The major PSD yields for hydrogen, carbon monoxide, carbon dioxide, methane, water vapor and photo-electron production are reported as a function of accumulated photon flux and sample preparation. The results are compared with previous PSD measurements on NSLS beam lines and those of other laboratories published for copper and TiN coated

copper. @FootnoteText@ @footnote 1@ Work performed under auspices of the U.S. Department of Energy, under contract DE-AC02-98CH10886.

VT-TuP15 Results of Vacuum Pump Oil Testing to Minimize Oil Waste After More Than Two Years of Evaluation at the National Synchrotron Light Source, *C.L. Foerster,* Brookhaven National Laboratory, US; ***E-P. Hu***, *E. Haas,* Brookhaven National Laboratory

This oil-testing project was established two and a half years ago to determine if synthetic vacuum pump oil could be used effectively to reduce some of oil waste produced during normal operation of the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL). More than two hundred oil-sealed rotary vane pumps are currently used at the NSLS facility, such that a longer oil change interval would greatly reduce maintenance costs as well as oil waste. Prior to this project the mechanical vacuum pump oil waste was approximately 75 gallons per year. Two basic types of vacuum pump oils, mineral and synthetic, are being tested for a direct comparison. Three two-stage mechanical pumps were set up and run simultaneously. Convectron gauges, cold cathode gauges, and isolation valves were connected to a central vacuum chamber with a common inlet pressure control and an RGA sampling valve. To simulate long-term mechanical pump operation, the system gas load was controlled at an inlet pressure of 500 mTorr using an air bleed valve. Vacuum pump oil suppliers to expedite the oil viscosity change, acid buildup, and pump-wear debris production suggested the inlet pressure. At this inlet pressure any oil back streaming is minimized. After two and a half years of running there have been no significant changes in either of the oil types. The detailed test data for the resulting oil properties, oil degradation, visual comparison, vacuum conditions, and pump characteristics will be presented for comparison of the pump oils used at NSLS and for estimation of the resulting oil waste reduction. @FootnoteText@ @footnote 1@ Work performed under the auspices of the U.S. Department of Energy, under contract DE-AC02-98CH10886.

Vacuum Technology
Room 201 - Session VT-WeM

Gas Flow and Pump Technology

Moderator: R. Langley, Oak Ridge Science Consultant

8:20am **VT-WeM1 Pressure Dependence of Laminar-Turbulent Transition in Gases**, ***L.D. Hinkle***, Falmouth Public Schools; *A. Muriel,* World Laboratory, CERN; *S.A. Novopashin,* Institute of Thermophysics, Russia **INVITED**

The transition between the laminar and turbulent flow regimes is traditionally addressed using the continuum formulation of the Navier-Stokes equation and dimensionless parameters such as the Reynolds number. However, a detailed understanding of the transition mechanisms has remained elusive. Theoretical approaches based on molecular and quantum mechanical models have been proposed but have yet to be thoroughly tested experimentally. In an effort to test a quantum-based model, specific apparatus and experiments have been designed to evaluate particular features of the laminar-turbulent transition. The experiments and analysis examine the transitions by producing a hysteresis plot as displayed on a flow versus differential pressure graph. This has been done for the transitions occurring in a tube with a divergent entrance. The hysteresis plots generated in these tests show several notable features and quantitative trends. The primary focus of this paper is on the observed absolute pressure dependence of the transition behavior. Whereas the continuum-based model does not predict a pressure dependence of the laminar-turbulent transition, a relatively simple quantum-based model indicates a particular pressure effect on the transition to turbulent flow.

9:00am **VT-WeM3 The Nanogate as a Nanoscale Variable Flow Leak Element**, *J.R. White,* ***P.J. Abbott***, *M.J. Tarlov,* NIST; *A.H. Slocum,* Massachusetts Institute of Technology

We present a variable flow leak artifact based on an ultra-high precision MEMS-based valve called a "Nanogate." Many critical industrial processes rely on generating and delivering accurate and precise flows of gas. Examples include leak testing of nuclear containment vessels, gas delivery in semiconductor processing, quantifying the emission of ozone-depleting chlorofluorocarbons, food processing and packaging, and testing of medical implants such as pacemakers. The flows of gas required for these applications span a very broad range, from as low as 10@super-14@ moles per second to higher than 10@super-6@ moles per second, and generally require several instruments to cover it; among these are mass flow controllers, metal capillary leak elements, and permeation leak elements. In contrast, the Nanogate can generate extremely low gas flows over several orders of magnitude, for any gas of interest, and offers the advantage of precise control of the flow rate due to the Nanogate's ability to change its opening in controlled two angstrom steps. Testing of the device with helium, carbon dioxide, and methane has shown good agreement with theory. Calibration results with several gases using the NIST low gas flow standard will be discussed.

9:20am **VT-WeM4 Thermal Fluid Dynamic Model of a Holweck Vacuum Pump Operating in the Viscous and Transition Regimes**, ***S. Giors***, Varian Vacuum Technologies, Italy; *E. Colombo, F. Inzoli,* Politecnico di Milano, Italy; *F. Subba, R. Zanino,* Politecnico di Torino, Italy

Holweck drag pumps are used as high-pressure stages in hybrid turbomolecular pumps, where they operate in the transition and the viscous regime. In these regimes, thermal problems related to the viscous heating of the rotor become a major issue in the design of the pump. The fluid dynamic study of the Holweck pump was carried out by Boulon et. al.,@footnote 1@ using a three-dimensional no-slip Navier-Stokes model. They show a good agreement with the experimental data in the viscous regime, and they suggest the need of slip-flow boundary conditions to improve the accuracy for Kn > 0.01. The benefits of slip-flow boundary conditions for Kn > 0.01 are also confirmed by Giors et. al.,@footnote 2@ for a Gaede drag pump. In this work the emphasis is on the application of slip-flow boundary conditions to a single-stage Holweck pump model, and on the heat exchange phenomena occurring between rotor and stator. A three-dimensional thermal fluid dynamic model of the pumping grooves is developed, based on the Navier-Stokes equations, with viscous slip and thermal jump boundary conditions. Taking advantage of the high Biot number, a lumped-parameter heat conduction model of the solid parts of the pump is justified and coupled to the three-dimensional fluid dynamic model. A commercial CFD code is used to solve the conjugate heat transfer problem in the viscous and transition regimes and to predict the pressure profile along the grooves, together with the friction power and the rotor temperature. The numerical results are compared with the available experimental data and critically analysed. @FootnoteText@ @footnote 1@ O. Boulon, R. Mathes, Flow modeling of a Holweck pump stage in the viscous regime, Vacuum 60, 73-83 (2001).@footnote 2@ S. Giors, F. Subba, R. Zanino, Navier-Stokes modelling of a Gaede pump stage in the viscous and transitional flow regimes using slip-flow boundary conditions, J. Vac. Sci. Technol. A, 23(2), 336-346 (2005).

9:40am **VT-WeM5 Selective Water Vapor Cryopumping Through Argon**, *A.P. Kryukov,* Moscow Power Engineering Institute, Russia; ***O. Podcherniaev***, Helix Polycold Systems, Russia; *P.H. Hall,* Polycold Systems; *D.J. Plumley* , Helix Polycold Systems, Russia, USA; *V.Yu. Levashov, I.N. Shishkova,* Moscow Power Engineering Institute, Russia

A selective cryopumping process for water vapor control takes place in vacuum systems for web coating or plasma operations; such as sputter deposition, etching, etc. Excessive water vapor content will affect quality of the processes and final products. These vacuum systems typically operate at pressures corresponding to transitional or viscous flow regimes, and water vapor cryopumping is highly limited by diffusion of water vapor molecules through a non-condensable process gas (argon, air). An analytical model was created to describe water vapor condensing process through a non-condensable gas diffusion barrier. The model accounts for the collisions of different molecules by means of Boltzmann kinetic equations for two-component rarefied gas. It was assumed that water vapor content is about three orders of magnitude lower than that of the non-condensable gas (argon). Cryopumping process was analyzed for two simplified cases when water vapor source and cryosurface are: parallel plates and coaxial cylinders. The calculations were conducted for different water vapor outgassing rates and argon pressures ranging from 0.5*10@super -3@to 20.0*10@super -3@ torr. At certain parameters a strongly non-linear distribution of water vapor pressure and density vs. distance between source and cryosurface was obtained. At high argon pressures an increase of water vapor pressure was observed nearby an outgassing surface. The results were used for calculation of water vapor cryopumping rates.

10:00am **VT-WeM6 The Effect of Heat Radiation on the Pumping Performance of Cryopump**, ***H.-P. Cheng***, *Y.-H. Shen, C.-W. Sun,* National Taipei University of Technology, R.O.C.

In this study, the quartz lamp was placed at the center top of the vacuum chamber of the G-M Cryopump. Measurements of the throughput, pumping speed, and the temperature of the cryopanel surface inside the Cryopump based on different energy levels of the quartz lamp were taken, in order to discuss the effect of quartz lamp energy on the pumping performance after transmitted to the inside of the Cryopump by means of heat radiation. The test system was built based on the standard suggested by Welch, the tested Cryopump was ULVAC-10PU. Before the transmission of heat by the quartz lamp, the measured pumping speed for nitrogen was 1,573~2,423 Liter/sec when the chamber pressure was controlled at 2.0E-03~1.3E-01Pa, and the throughput were 1.71~171.52 SCCM. The first-stage cryopanel surface temperatures were 66.52~85.27K, second-stage cryopanel surface temperatures were 9.93~12.73K. After transmitting heat energy of 5, 10, 15, 20W by the quartz lamp, the pumping performance of the Cryopump deteriorated, the temperatures of first- and second- stage cryopanel surfaces increased, while the increase of first-stage cryopanel surface temperature was more significant. When nitrogen was used as the testing gas, the increase of temperature inside the Cryopump was most significant when the energy of the quartz lamp was 20W. When the chamber pressure was 2.0E-03~1.3E-01 Pa, the throughput in the chamber was 1.61~145.65 SCCM, the pumping speed dropped to 1,476~2,058 Liter/sec, the temperatures of first- and second- stage cryopanel surfaces increased from 103.03K and 12.03K to 126.03K and 14.9K, respectively. Based on the above data, when the heat radiation of quartz lamp was 20W, the temperatures of first- and second- stage cryopanel surfaces were reaching the upper limit of the standard suggested by Welch, thus, it is not recommended to increase the quartz lamp energy.

10:20am **VT-WeM7 A Comparison of Various Standards Proposed for the Measurement of the Speed of Sputter-ion Pumps**, ***S.P. Clough***, Gamma Vacuum, LLC

A detailed comparison is made of the recommended procedures and equipment for measuring the speeds of sputter-ion pumps as proffered by: i) the ISO in DRAFT INTERNATIONAL STANDARD ISO/DIS 3556-1,2 (1992); ii) the DEUTSCHE NORM Acceptance specification for sputter-ion pumps DIN

28 429 (1985); and, iii) the AVS Recommended procedure for measuring pumping speed, no number (1987). The purpose of this work is to: highlight the concurrences and disparities between the "standards", ii) suggest reasonable criterion relating to procedures and equipment; and, iii) propose a more global template for such measurements.

10:40am **VT-WeM8 The Hydrogen Pumping Speed of Sputter-Ion Pumps**, ***K.M. Welch***, Kimo M. Welch, Consultants; *S.P. Clough,* Gamma Vacuum

It is difficult to find consistent quantitative data for the hydrogen speed of a conventional diode sputter-ion pump. The reported numbers range from 80% to greater than 200% of the speed of the sputter-ion pump for nitrogen. Reported numbers are in part obscured by conductance considerations when comparing speeds for the two gases. For example, results of speed measurements on smaller pumps, with restricted input conductances, might yield higher relative hydrogen speeds than that observed with larger pumps. Also, relative speed measurements are further obscured by pump conditioning prior to the measurements. This paper first reviews the existing literature on reported hydrogen speeds of sputter-ion pumps for a variety of cathode materials. Thereafter, results are reported on comparative speed measurements for the two gases in tests on a larger pump. These data permit calculations of the actual intrinsic speeds of a unit-cell sputter-ion pump for the two gases., and therefore more reasonably predict expected speeds of multi-celled sputter-ion pumps.

11:00am **VT-WeM9 New High Capacity Getter for Large Vacuum Devices**, ***H. Londer***, Alvatec Alkali Vacuum Technologies GmbH, Austria; *P. Adderley,* Jefferson Lab; *G. Bartlok,* MAGNA STEYR Fahrzeugtechnik AG & Co KG, Austria; *W. Knapp, D. Schleussner,* Otto-von-Guericke-Universitaet Magdeburg, Germany

Current Non evaporable getters (NEGs) are important for the improvement of vacuum by the help of metallic surface sorption of residual gas molecules. High porosity alloys or powder mixtures of Zr, Ti, Al, V, Fe and other metals are the base material for this kind of gas sorbents. The development of vacuum technologies creates new challenges for the field of getter materials. The main sorption parameters of the current NEGs, namely, pumping speed and sorption capacity, have reached certain level limits. Chemically active metals are the basis of NEGs of a new generation. The appearance of new materials with high sorption capacity at room temperature is a long-felt need. It is obvious, that chemically active metals and alloys with reactivity higher, than that of transition metals, can become this kind of materials. The potential of active metals as the strongest gas sorbents is very high. The improved getter materials allow a faster pumping speed and a significant higher sticking rate on the chemically active surface. The sorption capacity can be increased by up to 10@super 4@ times due to the active surface (during the life-time of a device the whole volume of the getter material reacts). Our directions are active metals with controlled insulation or protection. The main structural forms of the new getter concepts are spherical powders, granules and porous multi layers. The full sorption performance takes already place at room temperature, the activation temperature can be adjusted between room temperature and 650 degree C. The paper presents measurement- and analytical data of the sorption behaviour, like pumping speed, sorption capacity etc., of different residual gases, like H2, N2, O2, CO2, etc.. The comparison of the data with the existing getter technology shows several advantages and new fields of possible applications.

11:20am **VT-WeM10 Achieving Ultra High Vacuum By Backing Cascaded Turbo Pumps with NEG or Ion Pumps***, ***P. Adderley***, Jefferson Lab; *C. Day,* Forschungszentrum, Karlsruhe; *G.R. Myneni,* Jefferson Lab

The scientific community requires contamination free pumping systems to achieve low ultimate pressures in order to maintain low working pressures in a process or given application. Even though the turbo molecular pumps are able to achieve pressures in the ~5.e-11 Torr range, there are several disadvantages including back streaming, vibrations, oil-laden bearings of the traditional backing pumps. In this paper we present alternative backing methods, which will eliminate the above problems. In addition we will report the achievement of UHV pressures with cascaded conventional turbo pumps backed by ion, traditional NEG or the new active NEG pumps. *This work was supported by U.S. Department of Energy Contract No. DE-AC05-84ER40150 and KATRIN International Collaboration at FZK in Germany.

11:40am **VT-WeM11 A Micromachined Vapor-Jet Vacuum Pump with an Integrated Pirani Pressure Sensor**, ***M. Doms***, *J. Müller,* Hamburg University of Technology, Germany

A MEMS vapor-jet pump is presented which is based on the well-known principle of vapor-jet and diffusion pumps. A high velocity gas- or vapor-jet is used for vacuum generation. The microfabricated pump consists of two planar Laval nozzles (20-40 µm nozzle width) and water cooled sidewalls. Presently an external supply of the working fluid is used (nitrogen gas, water vapor). As no mechanically moving parts are required, the pump system offers an advanced long-term stability. A detailed mathematical and physical description of the micro vapor-jet pump has been described elsewhere.@footnote 1@ Based on simulation results, various systems with different geometries have been designed, fabricated and characterized. Starting from atmospheric pressure, a high pumping speed of more than 2.8 ml/min and an absolute pressure of 495 mbar were generated with this new type of micropump. Lower pressure regimes will be accessible with a full integration of all components (internal working fluid evaporation, condensation and recirculation) and by the use of more appropriate working fluids and multiple nozzle stages. Different concepts for the working fluid recirculation based on porous silicon and active or passive pump mechanisms which are currently investigated will be presented. The size of the complete pump system will not exceed 15 x 15 x 2 mm. Microfabricated pressure sensors based on the Pirani principle have been integrated into the micropump to monitor and control its function. Due to its novel geometry and fabrication process the operating range of the sensors can easily be adapted to different pressure ranges without any change of the layout. An integrated full bride layout is used for temperature compensation. The characteristics of the sensors correspond well with theory and fully satisfy the specifications. @FootnoteText@ @footnote 1@M. Doms, J. Müller, A Micromachined Vapor-Jet Pump, Sens. Act. A, Vol. 119 No 2, Mai 2005, p. 462-467.

Vacuum Technology
Room 201 - Session VT-WeA

Hydrogen, Outgassing, and Vacuum Systems

Moderator: L. Westerberg, Uppsala University, Sweden

2:00pm **VT-WeA1 System Modeling and Proof of Performance for Large Vacuum Systems**, ***J.P. Luby,*** BOC Edwards

Vacuum system modeling is the foundation of vacuum system component selection and provides the user tangible performance prediction. This paper examines vacuum system modeling and vacuum equipment selection for large vacuum systems and introduces the requirements and challenges of proving the performance of a large vacuum system. With rigorous applications engineering, performance modeling and component testing it is possible to provide a detailed performance statement to the user in the early stages of vacuum system design and build.

2:20pm **VT-WeA2 The ISAC Targets Vacuum System**, *I. Sekachev,* TRIUMF, Canadian Research Laboratory, Canada; ***D. Yosifov,*** TRIUMF, Canadian Research Laboratory

ISAC (Isotope Separator and ACcelerator) facility at TRIUMF has been in full operation since 1999. The ISAC East and West targets use the proton beam from the cyclotron to produce various radioactive isotope species in the target, which are then ionized and extracted. The ions are then passed through the mass separator and the selected ions are distributed to the low energy experiments or injected into an RFQ accelerator. The accompanying radioactive contamination from the production of radioactive ions requires the vacuum system to be quite complex. The main target vacuum space consists of two semi-separate (primary and secondary) volumes pumped by 1000L/s turbomolecular pumps. The primary volume uses four pumps while the secondary volume uses two pumps. The nominal vacuum in both volumes is about 1.0E-6 Torr. The pressure is monitored by two cold cathode ion gauges and two hot filament ion gauges. Both cold cathode gauges are used to interlock the system during the bake out of the target and beam production. Three exhaust gas storage tanks (decay tanks) are used for handling radioactive gasses and controlled release of the gasses to the atmosphere. The two ALCATEL hermetic rotary vane pumps are used as backing pumps. The gas specie insensitive membrane gauges are used for monitoring the storage tank pressures. This paper describes the details of the ISAC target vacuum system as well as some procedures related to the handling of the radioactive gasses produced by the targets.

2:40pm **VT-WeA3 Pumping Speed Measurement of TiZrV Coated Pipes**, ***A. Bonucci,*** *A. Conte,* SAES Getters S.p.A., Italy

In the last few years the interest of the particle accelerators community towards ZrTiV non evaporable getter (NEG) coatings of vacuum chambers has been continuously increasing. With the increase of the interest, also the number of characterizations of this coating from several final users is increasing. One of the key characterizations is the measure of the actual pumping speed of the NEG coating. The typical method used to measure the pumping speed of a getter is described in the ASTM F798-82. Normally, it has been applied onto a discrete sample coated during the process. This approach is not suitable with NEG coated vacuum pipes. An improved experimental configuration for sorption tests is here first described. The method is based on the ratio measurement of pressures at the inlet and the outlet of a coated pipe. A calibration curve permits to evaluate sticking probability of the coated surface from the pressure ratio. A mono-dimensional model is often used in order to obtain the calibration relationship; for high sticking probability this approach is not more suitable. We will show that a three dimensional mathematical model, based on the angular coefficients approach, is needed to calculate the gas distribution inside a vacuum vessel and the relationship between the pressure ratio and the specific pumping speed of the coated surface.

3:00pm **VT-WeA4 Beam Induced Dynamic Pressure Rise in RHIC**, ***H. Hseuh,*** *S.Y. Zhang,* Brookhaven National Laboratory

Relativistic Heavy Ion Collider (RHIC) consists of two storage rings of 3.8 km in circumference for high energy and nuclear physics research. With increasing ion beam intensity during recent RHIC operations, rapid pressure rises of several decades were observed at most warm sections and at a few cold (4.5K) sections. The pressure rises are associated with electron multi-pacting, electron stimulated desorption and beam ion induced desorption; and have been one of the major luminosity limiting factors. This dynamic pressure rises will be explained based on the observations at RHIC and the existing understandings. Some remedies to reduce the pressure rises, such as in-situ baking, NEG coating and solenoids, have been implemented over the last few years and their effectiveness will be illustrated. *Work performed under Contract No. DE-AC02-98CH1-886 with the auspices of the US Department of Energy.

3:20pm **VT-WeA5 Hydrogen in Vacuum Systems: An Overview**, ***R.A. Outlaw,*** College of William and Mary **INVITED**

Ubiquitous hydrogen plays a dominant role as the primary residual gas in low to ultrahigh vacuum, either in the form of water (unbaked systems) and/or in the form of molecular hydrogen (baked systems). Because of the very small size of the atom, hydrogen resides in interstitial sites, point, line, 2d and 3d defects in the bulk of virtually all materials and is the primary source of outgassing. At the vacuum interface, hydrogen is also located in the form of metal hydroxides. The effective outgassing rate for a given vacuum material is a function of the hydrogen surface concentration which, in turn, is a function of the density of the aforementioned sites and defects. System processing significantly affects the magnitude of the hydrogen concentration and can vary by many orders of magnitude. It is, therefore, quite difficult to analytically characterize the molecular dynamics in UHV systems without accurate knowledge of the existing concentration. In this review, the relevant parameters connected with the location and transport of hydrogen (primarily for stainless steel, but also for aluminum and other selected system materials) is presented. Gas phase variations are correlated with the surface complex chemical composition, thickness and concentration of defects. Surface diagnostics, such as AES, XPS, TDS and TOF-SIMS were employed to determine the sources of hydrogen, desorption mechanisms and the magnitude of outgassing into the vacuum space. Hydrogen solubilities and diffusivities are also presented. System processing, such as, thermal bake, glow discharge cleaning, molecular scrubbing and other outgassing reduction methods are compared. The magnitude of hydrogen outgassing is correlated with the extent of system processing.

4:00pm **VT-WeA7 Hydrogen in Vacuum Systems**, ***B. Hjörvarsson,*** Uppsala University, Sweden **INVITED**

Hydrogen is found as an impurity in all materials. The only relevant question in that context is how much there is and which influence it has. In this contribution I will discuss the possibility of influencing the hydrogen content and diffusion rate in materials. Special emphasis will be on what can be learned from modern thin film growth and how thin film techniques can be used to improve materials design and performance. Examples from magnetism, elasticity and outgassing will be highlighted in this context.

4:40pm **VT-WeA9 Explosive Nature of Hydrogen in a Partial Pressure Vacuum**, ***T.M. Jones,*** *W.R. Jones,* Solar Atmospheres Inc.

The explosive nature of hydrogen is well reported at atmospheric conditions. However, the explosive properties of hydrogen in a sub-atmospheric pressure are not well known. Hydrogen has desirable characteristics for many processes but using hydrogen in an atmosphere that is primed for an explosion must have several safeguards and an understanding of its explosive limits, vacuum or otherwise. A laboratory vessel was constructed to withstand hydrogen explosions to test these principals. Topics of discussion will include mixtures of hydrogen and air in partial pressure vacuum, and determination of the explosive ranges. Sources of ignition will be discussed and how the ignition source and location can affect the explosive characteristics. Other topics of discussion will be what types of safeguards could be used, more specifically an oxygen probe, and how these safeguards can be employed to prevent a catastrophic explosion.

5:00pm **VT-WeA10 Low Outgassing of Silicon-Based Coatings on Stainless Steel Surfaces for Vacuum Applications**, ***D.A. Smith,*** *M.E. Higgins,* Restek Corporation; *B.R.F. Kendall,* Elvac Associates

Comparative tests of stainless steel vacuum chambers and components with and without silicon-based passivation coatings showed exceedingly low rates of gas evolution from the coated surfaces. A variety of approaches have been used to illustrate the low outgassing qualities of vacuum systems and vacuum components modified with an amorphous silicon deposition layer. For example, the samples are heated and cooled in turn while the outgassing rates are recorded at temperatures up to 250 degrees C. Base pressures ranged from 10-7 Torr to 2.5 x 10-10 Torr. In other experimentation, the outgassing characteristics of systems in the 10-5 to 10-7 Torr vacuum range are compared. The coatings are resilient, inert and capable of withstanding temperatures above 400 degrees C. As well as

their obvious potential for reducing outgassing rates in vacuum chambers thereby allowing shorter pump-down times with smaller vacuum pump systems, they have proved useful in minimizing errors due to thermal desorption in experimental metal-envelope ionization gauges operating down to the low 10-10 Torr range.

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