Vacuum Technology
Room 310 - Session VT-MoM

Looking Back: Fifty Years of Vacuum Science and Technology

Moderator: B.R.F. Kendall, Elvac Laboratories

8:40am **VT-MoM2 Fifty Years of Vacuum Science*, E.V. Kornelsen,*** Unaffiliated, Canada **INVITED**

A selection is presented of problems in the physics and chemistry of vacuum systems and devices which has attracted considerable research during the past 50 years. These include examples where the limiting gas sources are water vapor, hydrogen, or helium. Also considered are self-sustained crossed-field discharges and the interaction of molecules, electrons, ions, and photons with the "technical" surfaces found in most vacuum systems.@footnote 1@ @FootnoteText@ This manuscript was prepared by J.P.Hobson shortly before his death.

9:20am **VT-MoM4 The Measurement of Vacuum;1950-2003*, P.A. Redhead,*** National Research Council, Canada **INVITED**

The major developments in the measurement of vacuum since the Bayard-Alpert gauge was invented in 1950 are reviewed.These include a) improvements in understanding the processes limiting the lowest measurable pressure (both total and partial), b) development of new gauges, residual gas analysers,and optical methods to reduce these limitations, c) introduction of room temperature electron sources to replace thermionic cathodes,and d) development of the spinning rotor gauge as a secondary standard.

10:00am **VT-MoM6 Major Advances in Capture Pumps in the Last 50 Years*, K.M. Welch,*** Consultant **INVITED**

Capture pumps either temporarily or permanently remove and store gases from a vacuum system by pumping mechanisms including chemisorption, physisorption and particle implantation on pumping surfaces. All or only some of these pumping mechanisms might come into play depending on the type of capture pump. Momentum transfer pumps, having no inherent capacity limitation, whisk gases through their innards, compressing the gases for removal at a pump outlet. Because capture pumps retain pumped gases, they have inherent capacity limitations. Developments of capture pumps focused on improving both the capacity and throughput of these pumps. Some of the major advances in the development and use of capture pumps in the last fifty years are given. Specifically, comments are included on the developments of nonevaporable getters, sputter-ion pumps, titanium sublimation pumps and cryopumps during this period.

10:40am **VT-MoM8 Major Advances in Transfer Pumps; 1953-2003*, M.H. Hablanian,*** Varian Inc. **INVITED**

The major advances made in the design and operation of transfer pumps (i.e. vacuum pumps that transfer gas from a vacuum system to the atmosphere) during the lifetime of the American Vacuum Society (1953-2003) are reviewed. Included are vapor-jet, turbomolecular, and oil-free mechanical pumps. In addition to engineering development of pump designs, the basic understanding of pumping mechanisms of various pumps and their performance parameters has been greatly improved during this period.

11:20am **VT-MoM10 The Development of Ultrahigh and Extreme High Vacuum Technology for Physics Research@footnote 1@*, H.F. Dylla,*** Jefferson Lab **INVITED**

Over the last 50 years, increasingly large and more sophisticated devices have been designed and put into operation for the study of particle and nuclear physics, magnetic confinement of high temperature plasmas for thermonuclear fusion research, and gravity wave observatories based on laser interferometers. The evolution of these devices has generated many developments in ultrahigh and extreme high vacuum technology that were required for these devices to meet their operational goals. The technologies that were developed included unique ultrahigh vacuum vessel structures, ultrahigh vacuum compatible materials, surface conditioning techniques, specialized vacuum pumps and vacuum diagnostics. Associated with these technological developments are scientific advancements in the understanding of outgassing limits of UHV-compatible materials and particle-induced desorption effects. @FootnoteText@@footnote 1@ This work supported by the U.S. DOE Contract No. DE-AC05-84ER40150.

Vacuum Technology
Room 323 - Session VT-WeM

Dynamic Vacuum Systems
Moderator: L.A. Smart, Brookhaven National Laboratory

8:40am **VT-WeM2 Is Mass 19 in the Residual Gas of Very High Vacuum just F@super +@?**, ***C.R. Cole***, *R.A. Outlaw, R.L. Champion, B.C. Holloway,* The College of William and Mary

Typically, the mass spectral peak observed at 19 amu in residual gas analyzers at very high vacuum has been solely attributed to fluorine. Using Fourier Transform Mass Spectrometry (FTMS), the presence of the hydronium ion, H@sub 3@O@super +@,has been fully resolved from F@super +@ and shown to be quite prevalent. Analysis is presented that shows that there is ample time for the formation of the hydronium ion through ion-molecule interactions and a direct correlation to the partial pressure of H@sub 2@O. The formation time and its correspondence to ionization, trap and resonance sequences have been characterized, as well as the gas collision formation mechanisms. Additionally, the generation of hydronium was further confirmed with D@sub 2@O experiments. Formation of D@sub 3@O@super +@ in a conventional quadrupole mass spectrometer has also been observed. Gas phase formation mechanisms of hydronium and deuteronium and other formation avenues, such as ESD, are discussed.

9:00am **VT-WeM3 Quartz Capillary Gas Flow Meters**, ***R.F. Berg***, National Institute of Standards and Technology **INVITED**

The flow rate of a gas through a laminar flow impedance can be inferred from the pressures at the entrance and exit of the impedance. If the hydrodynamic model of the meter is well understood, one calibration allows such a meter to be used over a wide range of pressures and flow rates and for a wide variety of gases. The calibration is required to determine the impedance's effective geometry. This talk describes measurements on five gases with a laminar flow meter whose impedances were constructed from quartz capillary manufactured for gas chromatography. The meter is presently used as a transfer standard for flows from 1 to 1000 micromol/s (about 1 to 1000 sccm). Two additional uses are discussed. The first use relies on the circularity and uniformity of the capillary's cross-section. A determination of the average capillary radius by weighing (sensitive to radius^2) will be close to the effective radius for flow (sensitive to radius^4). This would allow the meter to be used as a primary flow standard. The second use is for gas flow measurements for primary vacuum standards. This requires extending the model to handle exit pressures less than 100 Pa.

10:00am **VT-WeM6 Development of a Low Cost Cylindrical Magnetron for Coating Long Vacuum Vessels***, *P. He, H.C. Hseuh, M. Mapes,* ***R. Todd***, *D. Weiss,* Brookhaven National Laboratory

The 2 MW US Spallation Neutron Source (SNS) includes a 248m accumulator ring that requires a 100 nm coating of TiN to reduce the secondary electron yield (SEY) of the vacuum chamber walls. Brookhaven National Laboratory (BNL) has developed a low cost cylindrical magnetron target capable of coating the wide variety of chamber geometries found in the SNS accumulator ring. Production chambers with lengths of 5m and diameters of 29cm have been successfully coated. This target is capable of reactive sputtering through the use of a gas introduction tube, and can easily be adapted for a wide variety of lengths. The magnetic field is such that primary electron trapping is longitudinally uniform, which results in excellent discharge characteristics. This method has also been used to successfully coat a Cu/TiN multilayer on production ceramic injection kicker pipes of SNS. Coating properties were analyzed with auger electron spectroscopy and scanning electron microscopy, and will be presented herein. Special emphasis will be given to the various coating configurations of production chambers and equipment used. *Work performed under Contract Number DE-AC05-00OR22725 with the auspicious of the U.S. Department of Energy.

10:20am **VT-WeM7 Advanced Closed Loop Control Method and Sensor for a Reactive Sputtering Drum Coater**, ***M.A. George***, *E.A. Craves,* Deposition Sciences, Inc.*; R. Shehab, K. Knox,* Ametek, Inc.

The reactive sputtering process is characterized by a hysteresis of reactive gas concentration and reactive gas flow.@footnote 1,2@ The precise control of the reactive sputtering process requires operating at a points on the hysteresis that ensures the desired high sputter flux and deposited thin film stoichiometry. The hysteresis is highly non-linear in these preferred operating regimes. The practical challenge of meeting this in the batch coating system requires a control system that can compensate for changes in reaction rate for various sputtered metals, system pumping speed changing with thermal variations and dynamic compensation of detrimental periodic cathode arcs. Closed loop control algorithms that rapidly bring the reactive sputtering system to the desired hysteresis steady state operating point are desired for multi-layer applications such as thin film interference filters that require many target starts (and stops). Conventional methods of starting the reactive sputtering process such as temporally ramping target power, voltage or current and target shutters are undesirable for precision thin film interference filters We will present control system hardware and closed loop control algorithms that permit the achievement of steady state operating points in less than 500 milliseconds on several different reactive sputtering drum coaters. The key feature of the hardware and control algorithms employed on these drum coaters is the determinism required for successful operation. We will discuss the reactive gas sensor and the algorithms employed for ensuring a temporally accurate signal of reactive gas concentration and the closed loop control method using this signal as an integral part of the loop. @FootnoteText@ @footnote 1@S. Schiller, U. Hesig, G. Beister, K. Steinfelder, J. Strumpfel, Chr. Kondorfer, and W. Sieber, Thin Solid Films, 118(1984), pp 255-270. @footnote 2@J. Affinito and R.R. Parsons, J. Vac. Sci. Technol. A, Vol. 2, No. 3, pp 1275-1284.

10:40am **VT-WeM8 The TRASCO-ADS Project Windowless Interface: Theoretical and Experimental Evaluation**, ***P. Michelato***, *D. Barni, D. Sertore,* INFN - Lab. LASA, Italy*; A. Colaiuda, P. Turroni,* ENEA Centro Ricerche di Bologna, Italy*; G. Bertacci,* ENEA Brasimone, Italy*; A. Bonucci, R. Giannantonio, M. Urbano,* SAES Getters, Italy*; L. Cinotti,* ANSALDO, Italy

TRASCO-ADS, the Italian acronym for Transmutation TRASmutazione) of nuclear Waste (SCOrie), is a national funded program in which INFN, ENEA and Italian industries work on the design of an accelerator-driven sub critical system (ADS) for nuclear waste transmutation. One of the most critical aspects of an ADS is the interface between the UHV environment of the accelerator and the pressurized system of the spallation target (400Â°C Pb-Bi eutectic or pure Pb at about 1 bar), due to thermomechanical issues and to radioprotection and safety constraints. Two interface concept designs have been evaluated. In a first case, a thin window physically separates the high pressure and the low pressure sides of the interface. In a second case (windowless), the linac and the spallation target are separated only by means of a suitable pumping system. This paper reports a description of the whole machine based on the windowless solution, an evaluation of the gas and vapour loads evolved from the hot interface region and the preliminary results drawn from numerical models developed to describe the flow of said vapours and gases inside the complex geometry of the interface. We here discuss about the experimental validation of the above models, carried out through suitably developed experimental devices. A first order design of the vacuum system is also proposed.

Vacuum Technology
Room Hall A-C - Session VT-WeP
Poster Session

VT-WeP1 Temperature Characteristics of a New Static Expansion Vacuum Standard, *J.C. Greenwood,* ***P. Carroll,*** National Physical Laboratory, UK

The uncertainty in the pressure generated in vacuum standards is often dominated by temperature contributions. In equilibrium, gradients across the system vessels make it difficult to assign a temperature to the gas contained inside. Gradients between vessels can also contribute to errors in the calculation of the generated pressure. To investigate the temperature characteristics of a new Static Expansion vacuum standard at NPL a series of measurements were made using an array of thermister thermometers located at over 100 distinct locations. This level of monitoring is not practical for normal operation, however, the temperature distribution for the system has been mapped so that probe locations for representative temperature measurements have been identified for normal operation. An indication of the worst case error is given together with the improvement in uncertainty for optimally located temperature probes.

VT-WeP2 Thermodynamic Effects on the Pumping Performance of a Dry Scroll Vacuum Pump, ***T. Sawada,*** *S. Kamada, W. Sugiyama, M. Yabuki,* Akita University, Japan*; M. Fujioka, M. Tsuchiya,* ANEST IWATA Corporation, Japan

The theory we proposed before gives the ultimate pressures closely consistent with the values from the actual machine at the rated speed, but gives smaller values than the actual machine does, for lower orbiting speed. This discrepancy increases as the orbiting speed decreases. The theory also seems to be incomplete for other gases than nitrogen, especially for a light gas like helium. It has been confirmed experimentally that this is caused by the difference in clearance between the theoretical analysis and the actual machine. The clearance is constant in the theoretical analysis regardless of the orbiting speed and the type of gases; however, the clearance in the actual machine changes with the temperature changes accompanying variations in orbiting speed and the differences in the thermophysical properties of gases. We propose a thermodynamic model expressing the temperature distributions on the orbiting and fixed scrolls. Since the heat generated in a suction side pockets is very small, it is considered that the heat generated by gas compression is carried adiabatically to around the shaft and then conducted to the orbiting scroll and the fixed scrolls. The temperature of the orbiting scroll rises higher than that of the fixed scrolls because the fixed scrolls are cooled more easily than the orbiting scroll. Then, we obtain the clearance change under the obtained temperature distribution and predict the ultimate pressure of the pump having the changed clearance. The predicted ultimate pressure agrees pretty well with the measured one throughout the experimented range of orbiting speed for all tested gases (nitrogen, argon and helium).

VT-WeP3 Novel Calibration Apparatus for Precise Barometer and Vacuum Gauge, ***S.Y. Woo,*** Korea Research Institute of Standards and Science, Korea*; S.H. Kang, I.M. Choi, Y.J. Lee,* Korea Research Institute of Standards and Science

In order to calibrate accurate absolute pressure gauges such as barometer and vacuum gauge, laser or ultrasonic mercury manometers have been used. However, complexity, harmfulness of mercury vapor, and cost of mercury manometers made it difficult to use in most calibration laboratories. As a substitute, a gas-operated pressure balance is used for calibration of such gauges. However, commercially available pressure balances cannot be suitable because consequent exposure of the piston and masses to the atmosphere raises the problem of contamination and the ingress of dust particles to the gap between the piston and cylinder. Moreover a lot of time is being spent in changing the mass combinations on the piston and breaking the vacuum each time when a different pressure point is required. To overcome these difficulties, we manufactured a novel weight-loading device for changing the masses in situ without breaking the vacuum. This device made it possible to add or remove weights easily in vacuum, thereby greatly reducing the time between measurements. Using this device, we could easily calibrate precise quartz resonance barometers from 940 hPa to 1050 hPa. Moreover we also found that with new calibration technique this device could be used very efficiently for the calibration of vacuum gauge in the range of 100 hPa full scale. In this paper, practical calibration results are presented for a precise barometer (Paroscientific, Model 760-16B) and a vacuum gauge (MKS, CDG 100 Torr).

VT-WeP4 Photon Stimulated Desorption Study for a NEG-Coated Insertion Device Vacuum Chamber for TLS, ***G.-Y. Hsiung,*** *J.-C. Lee,* National Synchrotron Radiation Research Center, Taiwan*; J.-R. Chen,* National Synchrotron Radiation Research Center and NTHU, Taiwan

An aluminum alloy vacuum chamber, 4.6 m in length, for a narrow gap insertion device at Taiwan Light Source (TLS) is coated with the Zr-Ti-V Non-Evaporable Getter (NEG) film on the inner surface. The chamber, after NEG-coating, was installed in the 19B(PSD) beam line at TLS for synchrotron radiation exposure measurement. The yield of photon stimulated desorption (PSD), measured by the throughput method, illustrates a lower value but slowly decayed curve at the earlier exposure beam dose. The desorbed gas species, measured by a quadrupole mass spectrometer, contain the CH@sub 4@, H@sub 2@, CO, CO@sub 2@, as well as Ar. The behavior of pumping and desorption from the NEG coated surface will be discussed.

VT-WeP5 The Effect of Environmental Humidity on Thermal Outgassing Rate, ***C.-K. Chan,*** *Y.-C. Ou, G.-Y. Hsiung, J.-R. Chen,* National Synchrotron Radiation Research Center, Taiwan

This work investigates how humidity of environment affects thermal outgassing rate of an A6063 aluminum alloy chamber. The throughput method was used to measure the thermal outgassing rate of a test chamber exposed to the air with different moistures. The aluminum chamber was then exposed to dehumidified-air under an airshower located at downstream of an oilless compressor. Experimental results indicate that by controlling the humidity around the chamber adequately, the thermal outgassing rate achieved without baking is comparable to that after in-situ bakeout.

VT-WeP6 Vacuum Pump Oil Tests at the National Synchrotron Light Source to Minimize Oil Waste@footnote 1@, ***C.L. Foerster,*** *J.-P. Hu, E. Haas,* Brookhaven National Laboratory

In order to reduce the large amount of oil waste produced during normal operation of the National Synchrotron Light Source (NSLS) at Brookhaven National Laboratory (BNL), an oil-testing project was established to determine if synthetic vacuum pump oil could be used effectively with longer oil change intervals. Due to the large number of oil-sealed rotary vane pumps that are used at the NSLS, a longer oil change interval would reduce maintenance costs as well as oil waste. Initially, two basic types of vacuum pump oils, mineral and synthetic, were selected for direct comparison. Three of the same size two-stage mechanical pumps were set up to run simultaneously with the same gas load. ConvectronR gauges, cold cathode gauges, and isolation valves were connected to a central vacuum chamber having a common inlet pressure control and a sampling valve for residual gas analysis. To simulate oil degradation produced by long-term mechanical pump operation, the system air load was manually controlled with an air bleed valve on the common vacuum chamber and was periodically adjusted to run at 500 mTorr. This easily tolerated pressure range for mechanical pumps was suggested by oil suppliers to expedite the oil viscosity change, acid buildup, and pump-wear debris production. Major advantages are that the testing time will be much quicker and that any back streaming of oil is minimized at this operating pressure. 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.@footnote 1@ Work performed under the auspices of the U.S. Department of Energy, under contract DE-AC02-98CH10886.

VT-WeP7 Plasma Sensors for Control of PVD Processes for Nanostructured Me-C:H Coatings@footnote 1@, ***C.C. Klepper,*** *E.P. Carlson, R.C. Hazelton, E.J. Yadlowsky,* HY-Tech Research Corporation*; M.A. Taher, B. Feng,* Caterpillar, Inc.*; B. Shi, W.J. Meng,* Louisiana State University

To improve the reproducibility of metal-containing amorphous hydrogenated carbon (Me-C:H) coatings deposited by physical vapor deposition (PVD) techniques such as reactive sputtering, various plasma probes are of interest as in-situ sensors integrated with a closed-loop deposition control system.@footnote 2,3@ In a series of Design-of-Experiment (DoE) test runs on an unbalanced magnetron sputtering setup, various plasma probes were tested for their sensitivity to process input factors and as candidates for a feed-back control system. These include

optical emission and absorption spectroscopy of metal atoms, conventional and electron emissive Langmuir probes (LP), and hydrogen atomic line emission (H@alpha@). Of particular interest are combinations of the outputs of these probes. For example, the H@alpha@, divided by the product of the electron density from the LP and the hydrogen partial pressure from a residual gas analyzer (RGA), can be used as a measure of the excitation temperature of the plasma. This factor scales differently from the electron temperature from the LP, which is representative of the cold component that dominates the electron energy distribution function in low-T plasmas. The plasma potential measured from the LP is also of interest, since it, together with the applied substrate bias, determines the energy of ionic species bombarding the substrate. This measurement is primarily sensitive to plasma composition, especially in the reactive phase. Details and interpretation of these dependences, as well as their importance in the design of the closed-loop control system, will be presented. @FootnoteText@@footnote 1@ Partial support for this project came from NIST ATP 70NANBH0H3048 through a subcontract with Caterpillar Inc.@footnote 2@ M. A. Taher, et al., contributed talk in this conference. @footnote 3@ B. Shi, W. J. Meng, Journal of Applied Physics, in press (2003).

VT-WeP10 Adsorption Force Control with Surface Roughness Modification for Smooth Sliding in a Vacuum, ***A. Kasahara***, *M. Goto, T. Oishi, M. Tosa,* National Institute for Materials Science, Japan

Vacuum friction measurement system based on Bowden-Leben type system has been successfully developed that can evaluate sliding friction force under changing load from 1.96N to 0.98mN and under changing atmospheric pressure from 1E+5 Pa to 1E-8 Pa. Friction measurement was carried out on typical vacuum materials as type 304 austenitic stainless steel sheets after such surface treatments as chemical polishing or electrochemical buffing. We have shown that the materials with surface roughness around 100nm can offer as smooth sliding in a vacuum as at an atmospheric pressure. This smooth sliding may arise from absorption gas as lubricant kept in hollows of surface nanoscopic asperities. We accordingly tried to estimate absorption force by decrease in sliding load with the friction measurement system to study the effect of surface roughness on adsorption force and the contribution to smooth sliding in a vacuum. We found existence of absorption force about 20mN on a sample with surface roughness about less than 600nm, at an atmospheric pressure. The sample with the surface roughness under 40nm also showed adsorption force below 0.98mN in a vacuum, while sample with the surface roughness around 100nm showed higher adsorption force over 0.98mN even in a vacuum. The surface roughness can also slow desorption rate of absorption gas layer and keep friction small in a vacuum. It is therefore concluded that the surface with 100nm roughness exhibiting similarly low friction in a vacuum as at an atmospheric pressure is ideal modified surface for trapping adsorbed gases strongly to act as vacuum lubricant. The surface roughness about 100nm will be a good candidate surface for smooth movement in a vacuum.

Vacuum Technology
Room 323 - Session VT-WeA

Outgassing and Large Vacuum Systems

Moderator: L. Westerberg, Uppsala University, Sweden

2:00pm **VT-WeA1 How to Control Hydrogen Outgassing from Gauges and Materials**, ***F. Watanabe***, Vaclab Inc., Japan **INVITED**

The most important point for XHV technology is control of hydrogen emitted from the bulk. If we generate XHV, which is denoted by a hydrogen equivalent pressure below P=10@super -10@(H@sub 2@)Pa in a vacuum chamber, from the equation P=Q/S at the ultimate pressure, the limiting level of total outgassing should be below Q=PS=~10@super -11@Pa(H@sub 2@)m@super 3@/s when the pumping speed is e.g. S=~0.1m@super 3@/s. Here, we need three technologies for XHV, a minimum amount of a chamber, a pump and a gauge, in order to check the generated vacuum. However, if there is a large hydrogen outgassing from any component, the ultimate pressure is limited by that total value. That is, Q@sub total@(material)= Q@sub c@(chamber)+Q@sub g@(gauge)+Q@sub p@(pump) In the case of the chamber, a surface area of A=~0.5m@super 2@ is typical for a laboratory, therefore, the hydrogen outgassing rate from the material should be below q=Q/A=~2×10@super -11@Pa(H@sub 2@)m/s. To meet this situation, we have obtained an outgassing of Q=~10@super -12@Pa(H@sub 2@)m@super 3@/s for a hot-cathode ionization gauge and the extremely low outgassing rate of q=~10@super -14@Pa(H@sub 2@)m/s in the material of a 0.2% beryllium copper alloy. Therefore, we can easily obtain XHV in a laboratory using a pump of only a few liters/second. At the session, the process of development up to the present will be reviewed with the following program: (1) the importance of low emissivity material, (2) the unavailability of cold emitters for a gauge, (3) the concept of the heated-grid gauge/RGA, (4) the importance of copper alloy materials, (5) a comparison of recently-published ultra-low hydrogen outgassing materials, and (6) my conclusion for hydrogen outgassing reduction.

2:40pm **VT-WeA3 Outgassing Characteristics of a TiN-coated SUS-316 Vacuum Chamber Developed for XHV**, ***M. Hirata***, *H. Akimichi, A. Kurokawa, S. Ichimura,* National Institute of Advanced Industrial Science and Technology (AIST), Japan*; H. Yamakawa,* ULVAC Technologies, Inc.

The control of outgas from a vacuum chamber is the key issue to achieve XHV condition, since any pump has a limited pumping speed usually determined by effective connection area of the pump to the chamber. We have developed a new chamber accordingly, aiming at reducing outgas from the chamber wall as low as possible, and studied outgassing characteristic of the chamber. The chamber is made of vacuum melted stainless steel (SUS 316L) to minimize hydrogen outgassing, and treated by electrolytical polishing followed by pre-baking in vacuum and TiN coating. The outgassing rate of the chamber was measured by a throughput method after each treatment. The results are 4x10@super -9@Pa m/s, 3x10@super -12@Pa m/s and 1x10@super -13@Pa m/s, respectively.@footnote 1@ However, the ultimate pressure of the chamber (1x10@super -9@Pa) evacuated by a pump (1000 L/s) was quite higher than the pressure of 2x10@super -13@Pa estimated from the lowest value of the rate and the chamber inner area. In order to clarify the difference, the rate of the TiN coated chamber was measured by pressure rise method using an ionization (extractor) gauge and a spinning rotor gauge for several months. The results were 3x10@super -10@Pa m/s by the ionization gauge and 2x10@super -13@ to 3x10@super -12@Pa m/s by the spinning rotor gauge, respectively. The lowest value measured by the spinning rotor gauge was roughly equal to the value obtained by throughput method. These results suggest that outgas from the ionization gauge could not be ignored, and that the measured pressure of 1x10@super -9@Pa could be mainly attributed to outgas from the ionization gauge. A new method for XHV pressure measurement is inevitable. @FootnoteText@@footnote 1@S.Ichimura et. al.: Vacuum 53 (1999) 291.

3:00pm **VT-WeA4 Residual Gas in the LIGO Beam Tubes: Science, Arts and Recipes**, ***R. Weiss***, Massachusetts Institute of Technology **INVITED**

The LIGO (Laser Interferometer Gravitational-wave Observatory) has remote sites at Hanford, Washington and Livingston Louisiana. At these sites laser beams traverse 4km long 1.2 meter diameter beamtubes in vacuum to make the gravitational wave detection. The vacuum requirements are pressures less than 10^-8 torr of hydrogen and smaller pressures for heavier and more polarizable gases. The talk will describe the science and techniques developed, including: outgassing models, outgassing measurements, optical properties, material preparation, surface cleaning, bakeout and leak detection.

3:40pm **VT-WeA6 RHIC Pressure Rise with High Intensity Beam***, *P. He,* ***H.C. Hseuh***, *L.A. Smart, D. Weiss, S.Y. Zhang,* Brookhaven National Laboratory

RHIC is a superconducting heavy ion collider with two rings of 3.8 km circumference designed for nuclear physics research. With increasing ion beam intensity during recent RHIC operations, pressure rises of several decades within a few seconds were observed at a few room temperature vacuum sections. There are two distinct types of pressure rises, one occurs at injection and the other during acceleration. The first type has been associated with electron multi-pacting, electron stimulated desorption and ion desorption. The second type is coupled with beam halo scraping and desorption, with desorption rates of up to 10e+7 molecules per incident ion. Improvements to the RHIC vacuum systems have been evaluated, and some implemented, including extensive in-situ bakes, additional UHV pumping with lumped pumps and NEG coating, electron detectors and beam tube solenoids. The effectiveness of these measures in reducing the beam induced pressure bumps and increasing the vacuum system reliability are discussed and summarized. *Work performed under Contract Number DE-AC02-98CH10886 with the auspicious of the U.S. Department of Energy.

4:00pm **VT-WeA7 The Effect of Purge Pressure on Desorbing Water Removal Rate**, ***L.D. Hinkle***, Falmouth Public Schools

The need for high purity gas supply for vacuum systems and related processing equipment has driven the requirements for the design and operation of components in gas delivery subsystems. Water has been widely regarded as a major contaminant species in such subsystems. For designs that follow generally accepted practices for construction, sealing, and layout, the primary cause of water contamination is associated with ambient atmospheric exposure during maintenance or repair. The subsequent removal of this adsorbed water, and in particular, how this process can be accelerated has been the subject of much interest. While the enhancement of molecular desorption through various methods has received considerable attention, the effective removal of water vapor after desorption is also worthy of attention. This is especially true when considering the typical geometry of gas distribution and delivery subsystems. It is shown that at typical purge pressures a water molecule desorbing from a surface is likely to be adsorbed again. Thus, desorption may be required multiple times for the molecule to be removed from the subsystem. However, if the purge flow is operated at modest vacuum, a desorbing molecule remains in the purge stream considerably longer and travels farther downstream before being re-adsorbed, thus improving the removal rate. The primary focus of this investigation is to understand the dependence of the rate of water removal on the pressure of an inert gas purge. In most cases, the implementation of lower pressure purge may be accomplished with little or no change to existing equipment. In addition to the obvious savings and convenience resulting from a time reduction, considerably less purge gas is consumed.

4:20pm **VT-WeA8 Vacuum Analysis and Improvement for the Jefferson Lab Photo-Electron Guns**, ***M.L. Stutzman***, *P.A. Adderley, G.R. Myneni, B.M. Poelker,* Thomas Jefferson National Accelerator Facility

The 100 keV photo-electron guns at Jefferson Lab have demanding vacuum requirements since the photo-cathode lifetime is decreased by residual gas ionization and photocathode ion back-bombardment. The gun vacuum in the vicinity of the cathode/anode gap is ~ 1x10@super -11@ Torr. Improved vacuum would enhance the operating lifetime of the photo-electron guns. Measurements on vacuum test stands have been undertaken to better understand the vacuum limitations of the Jefferson Lab photo-electron guns. The measurements include a comparison of vacuum chamber material outgassing rates, preliminary investigations into coatings to reduce outgassing rates, and NEG pump speed measurements under various activation conditions. The results of these studies will be presented together with recommendations for improving photo-electron gun vacuum. @FootnoteText@ This work was supported by U.S. Department of Energy Contract No. DE-AC05-84-ER40150.

4:40pm **VT-WeA9 Status of the SNS Accumulator Ring Vacuum Systems***, *P. He,* ***H.C. Hseuh***, *M. Mapes, L.A. Smart, R. Todd, D. Weiss,* Brookhaven National Laboratory

The 2 MW US Spallation Neutron Source (SNS) consists of a 1 GeV linac, a 248m accumulator ring, two beam transport lines, and a mercury target. Brookhaven is undertaking the design, construction and commissioning of

the accumulator ring and the beam transport lines for SNS. To this date, over 80% of the ring and transport line vacuum components have been fabricated and assembled. More than 50% of the ring vacuum chambers have been coated with TiN. The physics objective and the design of SNS will be briefly described. The status of the vacuum systems will be presented. Technical developments and challenges encountered, such as remote flange assemblies and conductive coating of large ceramic chambers, will be summarized. *Work performed under Contract Number DE-AC05-00OR22725 with the auspicious of the U.S. Department of Energy.

5:00pm **VT-WeA10 High Vacuum Applications of Silicon-Based Depositions on Stainless Steel**, ***D.A. Smith***, Restek Corporation; *B.R.F. Kendall,* Elvac Associates

Continuing tests of stainless steel components with a silicon-based deposition have shown progressively lower outgassing rates. Evolution of the coating process has led to significantly lower outgassing rates over a wide range of operating conditions when compared with untreated stainless steel and stainless steel surfaces cleaned via a combination of ultrasonic, heat and vacuum techniques. Experimentation was developed for comparing otherwise identical samples having various surface treatments and/or coating types. 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@super -7@ Torr to 1.2 x 10@super -10@ Torr. The coatings are resilient, inert and capable of withstanding temperatures above 400 degrees C. Other surface aspects have been evaluated, including electronic characteristics and anti-galling traits. As well as the obvious potential for reducing outgassing rates in vacuum chambers thereby allowing shorter pump-down times with smaller vacuum pump systems, these coatings have proved useful in minimizing errors due to thermal desorption in experimental metal-envelope ionization gauges operating down to the low 10@super -10@ Torr range.

Vacuum Technology
Room 323 - Session VT+MS-ThM

Reproducibility, Precision, and Accuracy of Vacuum and Process Measurements

Moderator: R. Dobrozemsky, Vienna University of Technology, Austria

8:20am **VT+MS-ThM1 Component Requirements for ALD Technology**, ***T.E. Seidel,*** Genus, Inc; *J. Mason, A. Londergan, S. Ramanathan,* Genus, Inc. **INVITED**

In the last several years Atomic Layer deposition (ALD) has emerged as a commercial technology. This technology is a variant of CVD, and therefore requires reactor and reactor related components for operation under well-controlled vacuum conditions. The requirements include fast gas switching, precisely controlled gas delivery systems with high performance Mass Flow Controller and / or Pressure Controllers, precise control of gas delivery line temperatures, heated walls and substrate susceptors, and quality down stream pumps to provide suitable flow and pressure capacity. Precursor usage and costs must be managed as well. Ancillary requirements include sensitive RGA's and fast response baratrons. There are gaps in he performance of components and the users requirements. As and example, today's fast gas switching valves have a lifetimes of the order of one to a few million cycles, but lifetimes of the order of 10 million cycle are needed. Substrate and gas line temperature control is critical. Additionally, because the precursors used in this technology are particularly reactive, the downstream pump components must be robust. This review provides a generic status and progress of the ALD field followed by generic requirements and requirement gaps for components used in ALD.

9:00am **VT+MS-ThM3 Towards Improved Control of PVD Processes for Nano-Structured Me-aC:H Coatings@footnote 1@**, ***M.A. Taher,*** *B. Feng, A.G. Shull,* Caterpillar Inc.*; B. Johs, G. Pribil,* J.A. Woollam Company Inc.*; C.C. Klepper, E.P. Carlson, R.C. Hazelton, E.J. Yadlowsky,* HY-Tech Research Corporation

The reliability and durability of machine components such as bearings and gears can be enhanced through the application of metal-containing amorphous carbon (Me-aC:H) coatings, deposited by physical vapor (PVD) techniques such as sputtering. Commercial sputtering systems used for tribological coatings often employ computerized recipe managers to attain a certain level of reproducibility in the coating process. In most cases, these recipe managers control the deposition process through an open loop, time stepping approach where deposition parameters are varied within a particular time frame, and the process is repeated consistently from batch to batch. This type of control generally provides a level of reproducibility that is acceptable in applications where the component benefits from the coating but does not depend on it for full functionality. However, in applications where the coating is integrated into the machine component design, creating a prime-reliance on the coating, higher levels of coating consistency are required. Such levels may involve the adoption of in-situ sensors integrated with a closed-loop deposition control system. To build such a successful control system, knowledge of the relationships between the input process factors, the sensed variables, and the critical coating characteristics is necessary. In this study, a set of in-situ sensors that included a residual gas analyzer, an optical emission spectrometer, an optical absorption spectrometer, a Langmuir probe and a spectroscopic ellipsometer were explored. Three Design-of-Experiment (DoE) test runs were conducted which explored the effects of the coating process input factors on the output sensor signals and the critical coating characteristics. Results of these experiments are presented and a closed-loop control strategy is discussed. @FootnoteText@ @footnote 1@This work was partially supported by the Department of Commerce through its NIST ATP program award number 70NANBH0H3048.

9:20am **VT+MS-ThM4 A Portable Reference Gas for InSitu Calibration of Residual Gas Analyzers**, ***R.E. Ellefson,*** *W.P. Schubert, L.C. Frees,* INFICON, Inc.

A new design for a portable source of reference gas with a fixed flow rate has been developed for producing a repeatable pressure in the ion source of a residual gas analyzer (RGA). The fixed flow rate of gas flowing through the fixed conductance of the isolation valve located between the process vacuum system and the RGA produces a repeatable pressure at the ion source of the RGA. The flow rate of 1x10@super -4@ Torr-l/s of Ar (and selected impurities) through the typical conductance of 10 l/s produces a reference pressure of 1x10@super -5@ Torr in the ion source. The ability to produce a repeatable pressure at the ion source on demand enables calibration of the mass scale, electron multiplier (EM) gain and measurement of absolute sensitivity. Data on sensitivity versus time is shown as an example of a quality assurance method for determining the stability of operation of an RGA and to determine when sensitivity or EM gain adjustment is necessary. The same reference gas source can be used for the calibration of closed ion source RGAs that have their own pumping system. The mechanical design minimizes the pressure burst at turn on and accomplishes viscous flow of the gas mixture. Data is presented on consumption rate, expected lifetime, shipping exemptions, temperature dependence of flow rate and species fractionation over lifetime. Methods for species abundance calibration in the RGA are also presented.

10:00am **VT+MS-ThM6 Specific Reference Calibration - A More Practical Approach to Vacuum Reproducibilty**, ***G.D. Lempert,*** Soreq N.R.C., Israel

Increasing demands for quality control, both in production as well as in R&D, have resulted the proliferation of instrument measurement calibration. However, despite the fact that vacuum measurement is often made with significantly larger uncertainties and errors than other physical or thermodynamic quantities, the calibration of vacuum measurement instrumentation, in particular in the high vacuum range, is generally ignored or neglected. Objective practical difficulties have been identified and defined which make vacuum measurement calibration problematic and very often not practically feasible. The requirements for vacuum measurement uncertainties for most practical vacuum systems have been assessed. In an effort to make reproducible vacuum measurement more accessible, a more practical approach to vacuum measurement calibration has been defined and developed. The approach incorporates a vacuum calibration system, whose specifications and design satisfy the accuracy requirements for all but the most demanding users of vacuum technology. Calibration results are presented which provide justification for the approach. In addition the new approach defines a concept of Specific Reference Calibration, SRC. SRC does not necessarily provide calibration of the users vacuum measurement instruments. However SRC does enable practically defining and attaining reproducible vacuum process conditions in the users vacuum system, with significant advantages over conventional calibration. The new approach is aimed to overcome the difficulties, which have inhibited the proliferation of vacuum measurement calibration up to this time, and to facilitate the attainment of reproducible vacuum conditions and processes.

10:20am **VT+MS-ThM7 Characterisation of a Fully Automated, Static Expansion Vacuum Standard at the National Physical Laboratory, UK**, ***J.C. Greenwood,*** *P. Carroll,* National Physical Laboratory, UK

A new, fully automatic, Static Expansion vacuum standard has recently been constructed to replace the existing manually operated system. The new instrument incorporates a number of design improvements which will be described. It is of all metal construction and operates from atmospheric pressure down into the UHV region. This paper discusses some of the procedures and measurements that have been performed to characterise the new standard. These include; mapping temperature distributions across and between the parts of the system; measuring the effects of inter-vessel valves on the pressure distribution; developing an improved measurement equation for the pressure generated in the standard, and comparison against existing vacuum standards that have been involved in recent international comparisons. We will show that calibration results taken from the new standard and the existing standards are equivalent.

10:40am **VT+MS-ThM8 A New Look at the Modulated Bayard-Alpert Gauge**, ***B.R.F. Kendall,*** Elvac Laboratories*; E. Drubetsky,* Televac Division of The Fredericks Company

There is an increasing need for accurate vacuum measurements below 10@super-9@ Torr. Ordinary Bayard-Alpert gauges may have large and unpredictable errors at these pressures because of x-ray and other unwanted effects. Several special gauges have been developed to overcome these problems. One of the most cost-effective is the Modulated Bayard-Alpert Gauge (MBAG), first described by P.A. Redhead in 1960 and subsequently investigated in detail in many other laboratories. These gauges were widely used in Europe for several decades. We have evaluated several different MBAGs, ranging from first-generation glass-envelope types to a new miniature metal-envelope version. Performance data are given for operation in various modulation modes. An advantage of these gauge tubes is that, if necessary, they can be used as conventional BA gauge tubes with existing controllers. Some versions can be electronically adjusted for uniform sensitivity. The design of demodulation circuitry is discussed. X-ray errors causing gauges to over-read by several hundred

percent at 10@super-10@ Torr can be essentially eliminated by using the modulation principle.

11:00am **VT+MS-ThM9 Dose Reproducibility in Axcelis GSD Implanters Using Stabil-Ion Gauge**, ***R.C. Johnson,*** INNOViON Foundry Ion Implantation Engineering

Long-term dose reproducibility and tool to tool dose matching in the Axcelis GSD end-station is critically dependent on process chamber pressure measurement and Pressure Compensation factor selection. Pressure Compensation factor (PCOMP) determination is well-established. Pressure measurement in the GSD end-station depends on accurate, repeatable gauge capability: incorrect pressure measurements directly lead to dose errors. For example, the dose equation using PCOMP tells us that for a modest PCOMP value of 30%, a chamber pressure measurement error of 2E-5 torr can result in a dose error up to 6% at normal process pressures. The original HCIG used for pressure measurement was not capable of meeting the requirements for good dose control since gauge to gauge differences were not controlled and gauge accuracy was only on the order of 30%. Axcelis introduced the Granville-Phillips 360 Stabil-Ion gauge to improve dose reproducibility through much improved gauge to gauge matching (+/-6%) and more accurate gauge output. This paper discusses the details of the care and feeding of the Stabil-Ion gauge system and it's impact on process dose and process trends.

11:20am **VT+MS-ThM10 How Stable are Spinning Rotor Gauges**, ***R.F. Chang,*** National Institute of Standards and Technology

The spinning rotor gauge is an excellent transfer standard in the pressure range of 0.0001 to 10 Pa (10@super -6@ to 0.1 torr) because of the remarkable stability exhibited by its accommodation coefficient. The stability comes from the fact that the accommodation coefficient depends mainly on the rotor surface properties of roughness and cleanliness, and does not change as long as these surface properties remain the same. Therefore, as common sense might dictate, one must avoid altering the rotor surface properties mechanically or chemically by not scratching the rotor surface or exposing it to corrosive agents. It is important that the accommodation coefficient remain constant when a spinning rotor gauge is moved from one laboratory to another such as in an inter-laboratory comparison or proficiency test. The level of confidence of the agreement between two laboratories is limited by how much the accommodation coefficient may have shifted in transit. For example, to transfer a spinning rotor gauge from one vacuum chamber to another, one must remove and reinstall the suspension head. During this procedure, the rotor comes into contact with the inner wall of the vacuum housing (thimble) and may be scratched. Sometimes the rotor is removed from the thimble for shipping, which requires additional handling of the rotor. By measuring the accommodation coefficient before and after various handling and cleaning procedures, we have quantified their effects on the accommodation coefficient. The results and impacts on gauge calibrations, including some surprises, will be presented and discussed.

11:40am **VT+MS-ThM11 Practical Procedures for the Frequency Corrections of the Spinning Rotor Gauge Residual Drag**, ***J. Setina,*** Institute of Metals and Technology, Slovenia

Spinning rotor gauge (SRG) uses a magnetically levitated steel ball as sensing element to measure low gas pressure, which is determined from the decay of the rotational speed of the rotor caused by the momentum transfer to the surrounding gas molecules. In addition we also have a small, gas pressure independent component to the measured SRG signal. This is called a residual drag (RD), and the main sources are eddy currents induced in the ball by asymmetries in the magnetic suspension field and eddy currents induced in surrounding metallic components by the rotating component of the ball's magnetic moment. In general, the RD depends on the ball rotational speed. The SRG operates the ball in a pre-selected frequency window, usually from 405 to 415 Hz, and the RD changes during the gas pressure measurement as the ball speed changes. The frequency dependence can be observed as saw-tooth variation of readings during continuous operation at constant pressure. For accurate measurements the frequency dependence of the RD has to be considered also. The commercial SRG controllers do not have the ability to take into account the frequency dependence of the RD and to make automatic on line corrections. The corrections have to be done separately by the user. We will describe our methods to determine the frequency dependence of the residual drag and procedures to perform the corrections to the pressure readings. The RD and its frequency dependence are unpredictable in magnitude for a given suspension of the rotor. Both can change considerably when the rotor is re-suspended. It is our experience that the frequency dependence remains reproducible during uninterrupted suspension, if vertical alignment or position of the suspension head stays well fixed. It is our experience also, that the behavior of the RD of the same ball is different in various suspension heads of different SRG controllers.

Vacuum Technology
Room 323 - Session VT-ThA

Industrial Vacuum Applications
Moderator: N.T. Peacock, MKS Instruments

2:00pm **VT-ThA1 The Role of Outgasssing, Outdiffusion and Desorption in Vacuum Coating**, ***D.M. Mattox,*** Management Plus Inc. **INVITED**

The role of vacuum technology in the vacuum coating industry has changed significantly in the last 30 years. Previously the objective of producing a vacuum was to attain the best possible vacuum in the shortest time possible. In recent years to this goal has been added the requirements of establishing specific partial pressures of inert and reactive gases and vapors, generating uniform plasma environments and controlling the gas flow and gas distribution in the processing system. The vacuum systems are of ten required to handle toxic and corrosive gases and to tolerate fine particles generated in the processing. The increasing use of polymer substrates and rolls of films (webs) has increased the demands imposed for handling outgassing and desorption during vacuum processing. This paper will describe some of the problems and solutions used not only to address the problems of outgassing and desorption but also to minimize the problems by proper system design and substrate treatments in the vacuum system.

2:40pm **VT-ThA3 Pumping Characteristics of Metal Films in a Vacuum Glass Vessel: Experimental and Theoretical Issues**, ***A. Bonucci,*** *C. Carretti, G. Longoni, R. Giannantonio, M. Urbano,* SAES Getters SpA, Italy

The evaluation of the pumping characteristics of metallic films deposited onto glass surfaces in a vacuum environment is a very important issue for several industrial and research applications. Many years ago, an optimized experimental setup was established to measure the pumping characteristics of barium films inside Cathode Ray Tubes (CRTs). However, some technological limitations, related both to the particular experimental configuration and to the materials used, prevented the possibility to extend this approach to a more general case, including adsorbing materials different from barium deposited onto surfaces having a geometry different from that of a CRT. The progress in vacuum technology makes today possible to use a large variety of components to assemble an experimental vacuum apparatus. Moreover, the availability of powerful computational tools allows to design the best experimental configuration for any specific purpose. In this work, a new approach to the study of the pumping characteristics of an adsorbing film in a vacuum is discussed. An improved experimental configuration is here first described and a mathematical method, based on the angular coefficients approach, able to suitably calculate the pressure distribution inside a vacuum vessel, is proposed. The agreement between the experimental and the theoretical results obtained in the simple case of a gettering surface deposited onto spherical glass bulbs having different dimensions is finally discussed.

3:00pm **VT-ThA4 Vacuum Thermal Insulation - Inventions for the Future**, ***V. Nemanic,*** Jozef Stefan Institute, Slovenia **INVITED**

The innovative application of vacuum in a gap between two bottles is attributed to Sir James Dewar in 1892. The underlying technical innovations followed through numerous patents that have often driven the remarkable progress in different fields. An examination of the past century of progress is indeed an exciting venture which manifests the state of the art of contemporary vacuum science and technology. The review of operational principles, main technical difficulties and future trends of developments are presented for: 1) cryogenic scientific instrumentation, where the insulating value of the single gap is improved by insertion of multiple reflectors. This was first done in the mid of the last century offering the lowest thermal flux in "super insulated" cylindrical vessels. Well proven solutions in this field seems to have an impact on potential storage of liquid hydrogen as it can become the automotive fuel of the future. 2) everyday thermos bottles became in last few years light and durable by replacing the glass wall with the thin stainless steel. This valuable change did not affect the price, but manifests better evacuation methods and application of new getters. 3) evacuated insulating flat elements with high insulating value are an efficient alternative for polymer foam panels. Longevity sets still very strict requirements for selection of highly porous filler material, as well as for envelope tightness and permeation rate. Anyhow, vacuum panels are already built in energy efficient home appliances and will soon spread in cargo containers and buildings. 4) transparent and translucent vacuum glazing were proposed for over a century in improving concepts in patents. Beside a still limited application in passive solar energy capture elements, the commercial vacuum window glazing, with point supported two sheets of glass, appeared in the last five years. Today performances may be thus optimistically envisioned for tomorrow.

3:40pm **VT-ThA6 A Comparison of Chamber Conductance Calculations Using CFD and a Thermal Radiation Analogy**, ***L.A. Gochberg,*** Novellus Systems

The design of semiconductor vacuum chambers often requires that overall chamber conductance be optimized. In high-density plasma (HDP) chemical vapor deposition (CVD) systems for dielectric deposition in STI applications, a high chamber conductance will promote lower chamber pressures over the wafer. These lower pressures can enhance the ability to perform high aspect ratio dielectric gapfill on the wafer. Flow modeling is routinely used in the design of such CVD systems, employing either Monte Carlo methods or Navier-Stokes solvers (CFD) using slip boundary conditions. In this work, a thermal radiation analogy to free molecular flow is used in place of a collisionless Monte Carlo computation for two different HDP-CVD chamber configurations. Modeling results show that with either the thermal radiation analogy approach, or the CFD approach, chambers with centrally-mounted pedestal chamber designs perform significantly better from a conductance/pressure perspective than do cantilever- mounted pedestal designs. Also, the thermal radiation analogy model approach allows complex 3D chambers to be modeled quickly with general-purpose, commercially available CFD codes. This CFD approach is preferable in industrial environments as opposed to using Monte Carlo methods, which require the use of a separate software modeling approach that is not available commercially, and is difficult to use for complex 3D geometries.

4:00pm **VT-ThA7 CFD Analysis of a 2D Model of a Gaede Drag Pump in Viscous and Slip Flow Regime**, ***S. Giors,*** Varian Vacuum Technology, Italy; *F. Subba,* Politecnico di Torino, Italy

Experimental analysis on a uniform and a tapered Gaede pumps were already performed in Varian in 2002 and the results presented at AVS 49th Intl. Symposium.@footnote 1@ The experimental results assessed both compression and pumping speed performances of those pumps and showed some weaknesses of the Couette-Poiseuille 1D model, developed a few years ago by Helmer and Levi to describe the Gaede stage behaviour and to be used as a design tool.@footnote 2@ A 2D model of the Gaede pump, based on Navier Stokes equations, is now developed and validated against experimental results. A commercial CFD code is used to simulate the pumping performance of a single stage Gaede pump (the uniform one in the experiment) in the viscous regime, for different operating conditions, with and without throughput, in order to assess both compression and pumping speed performances, as well as to improve the general understanding of the physics of Gaede pumps within the limitations of a 2D model. The possibility of extending the Navier Stokes model at low pressure, through slip flow boundary conditions is also explored, and the lower pressure limit found for the resulting model by comparison of the numerical results with the experiment. Validation against experimental results has shown some weakness of the pure 2D model, and ideas to include some 3D effects (e.g. the radial leak path) into the 2D model are proposed for future developments. @FootnoteText@@footnote 1@ S. Giors, R. Gotta, J.C. Helmer, "Experimental analysis of Tapered Gaede pumps", AVS 49th Intl. Symposium oral presentation, Denver CO, November 2002.@footnote 2@ J. C. Helmer, G. Levi, "Transition gas flow in drag pumps and capillary leaks", J. Vac. Sci. Technol. A 13(5), 2592-2599, Sep/Oct 1995.

4:20pm **VT-ThA8 Characteristics Evaluation Practice of Predictable Performance Monitoring for Low Vacuum Dry Pumps in the Semiconductor Production Line**, ***J.Y. Lim,*** Korea Research Institute of Standards and Science, Korea; *W.S. Cheung,* Korea Research Institute of Standards and Science; *J.H. Joo,* Sungwon Edwards Ltd., Korea; *Y.W. Kim,* Samsung Electronics Co. Ltd., Korea; *W.G. Sim,* Hannam University, Korea; *K.H. Chung,* Korea Research Institute of Standards and Science

The early prediction system of performance fluctuation for low vacuum dry pumps in the semiconductor process line has been issued since devastating malfunctions or characteristics degradations of dry pumps due to mainly chemical byproducts during the production processes have been occasionally reported in Samsung Electronics. This motivation drove implementing central monitoring system (CMS) to the production facilities. CMS, however, is not a single condition monitoring or a prediction analysis method, but an overall monitoring program with historical performance data only. To compromise with this issue, the real time, in-situ characteristics evaluation system for two Edwards iH600 dry pumps has

been established at the Ti/TiN chemical vapor deposition system in the Samsung Electronics production line #10, in which system pump malfunction or degradation mostly happens. The real time data in Samsung Electronics and the experimental reference data from the KRISS characteristics evaluation system@footnote 1@ have been thoroughly compared each other and analyzed to ascertain if there exist unusual degradation symptoms such as in pumping speed, power consumption, vibration, noise, etc. The integrated data at the actual process pressure range of about 1 to 10 mbar and experimental measurement rage of about 100 to 10@super -3@ mbar are time-synchronized with respect to the inlet pressure in a scientific manner of coincidence. In this recent work, we report the first significant results of the method of characteristics synchronization between the laboratory and process line in the way of the pump malfunction or degradation symptom to be clearly diagnosed and positively protected during the production process. @FootnoteText@@footnote 1@J.Y. Lim, S.H. Chung, W.S. Cheung, K.H. Chung, Y.H. Shin, S.S. Hong, W.G. Sim, Expanded Characteristics Evaluation for Low Vacuum Dry Pumps, AVS 49th International Symposium, November 4, 2002, Denver, CO, USA.

4:40pm **VT-ThA9 An Alternative-voltage Penning Cell for Low-voltage Vacuum Gauges and Other Applications***, S.A. Cherenshchykov,* National Science Centre "Kharkov Institute of Physics and Technology", Ukraine

A two-anode Penning cell with cold cathodes was researched. Due to additional source of a variable voltage used as power source, it becomes possible to ignite and to support the discharge at significantly lower voltage. This phenomenon was observed in a wide range of pressures (from 5 Pa up to 10@-6@ Pa). The reduction of Penning discharge voltage was up to 20 volts at the pressure value of 0.3 Pa and up to 300 volts when pressure was the lowest. The discharge current decreased together with pressure. The discharge current irreproducibility at the pressure of 10@-5@ Pa was not worse than 12 %. The current of existing discharge in magnetic field increased in many times under effect of additional variable voltage. It is supposed that efficiency of ionization of low-pressure gas will increase under affect of variable voltage. These discharge properties can make the basis for perfection of devices that use the Penning cell and other discharge magnetic cells (such as full and partial pressure gauges, leak detectors, ion pumps, ion sources and hot plasma sources). The new properties of the discharge can promote expansion of its application area, in particular, on sources of vacuum ultra-violet and soft x-ray radiation and polarized charged particles. The working model of the vacuometer was created based on such discharge. This vacuometer can unite all the advantages of magnetic discharge vacuometer and hot-cathode ionizing vacuometer. Besides it could be cheaper, is safer from the point of view of explosion possibility. Its power consumption and the heat dispersion on its gauge are almost hundred times lower. In addition, it can be smaller in volume and weight in comparison with analogues.

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