Vacuum Technology
Room 2000 - Session VT-TuM

Vacuum Generation and Measurement

Moderator: J.H. Hendricks, NIST

8:00am **VT-TuM1 Turbo Pump Developments for Radioactive Environment in High Energy Physics Applications**, ***D. Baratto***, *M. Audi,* Varian Inc. VTT, Italy

This paper presents a novel development of a new 2000 l/s turbo-molecular pump that is resistent to radioactive environments such as those found in High Energy Physics applications including Tokamaks. A previous prototype has been successfully tested on the JET Tokamak UK. In order to withstand the severe application at JET, the new pump is designed with tritium flow compatibility, resistance to radiation, magnetic and high voltage environments. The new pump has several advantages for these applications over standard configured turbo-molecular pumps that cannot withstand radioactive environments. The pump has been designed with radiation resistance up to 10E+8rad, compatibility with high magnetic fields, and a 10E-9mbarl/s range leak specification that restricts the flow of radioactive gas out of the pump. The pump has an active breaking system that stops the pump without an external venting port in a shorter time than natural deceleration. The pump is equipped with a separate control and drive electronics unit that can be rack mounted behind the biological shield, outside of the radioative area in which the pump is mounted. The controller has galvanic isolation that allows it to operate at high potential. Materials selection was a significant challenge during the design phase of the new pump. Ceramic bearings of the pump permanently lubricated with radiation resistant polyphenyl-ester grease are a specific feature of compatibility with a magnetic device operating in a radioactive environment. Further radiation compatibility was achieved by replacing all elastomeric o-rings with full metal sealing. PEEK sheathed cables and glass ceramic connectors have been used: these materials are radiation resistant, non-magnetic and UHV compatible in terms of leak rate. The performances of the pump are presented. The pump proves to be an effective solution for many high-energy experiments and applications as nuclear fusion, particle acceleretors and synchrotron light sources.

8:20am **VT-TuM2 Use of Getter-Catalyst Thin Films for Enhancing Ion Pump Vacuum Performances**, ***M. Mura***, *C. Paolini,* Varian Vacuum Technologies, Italy

Extreme High Vacuum can be achieved only by combined pumping systems: on the basis of this scenario, the idea is to reach this pressure range with a unitary system, easy to use and with long lifetime, based on an ion pump specially designed for this purpose and provided with an additional internal NEG-Catalyst thin film coating. The conceived pump is designed with a new anode geometry and a magnetic circuit optimized in order to reduce boundary effects, moreover its shape is tailored for internal NEG+Pd coating produced by means of magnetron sputtering. Since the main drawback in the use of NEG films is their limited lifetime due to the progressive accumulation of contaminants (e.g. nitrogen, oxygen, etc.), with consequent reduction of adsorption performances, the idea is to protect the NEG, depositing on it an overlayer of a noble metal, such as palladium, which acts as a catalyst for the adsorption of hydrogen and allows its diffusion towards the NEG. In this way it is possible to pump large amounts of hydrogen, also in presence of not negligible pressures of other gases, with a very high sticking factor. The consequent loss of pumping for other getterable gases (with the exception of CO) is not an issue in the UHV pressure range, where hydrogen is typically the main residual gas, since the ion pump works fine to pump them all. The sorption of both hydrogen and CO is fully thermally reversible, resulting in a theoretically endless lifetime of the film. The performances of the combined pump, in terms of base pressure and hydrogen pumping speed, will be presented through the evidence of the experimental data collected.

8:40am **VT-TuM3 Strategies for Safe Hydrogen Pumping with Mechanical Vacuum Pumps**, ***J.P. Luby***, BOC Edwards

Vacuum pumping hydrogen gas carries significant risk of explosion. This paper examines strategies for minimizing explosion risks when pumping hydrogen gas in the laminar flow range with mechanical vacuum pump systems. Topics addressed include pumping hydrogen concentrations above, below and within explosion limits with various vacuum pump mechanisms and vacuum system configurations. Methodologies are presented to minimize explosion risk which may be applied to a wide variety of flammable applications. Vacuum system performance considerations when pumping low viscosity gases such as hydrogen are also discussed.

9:40am **VT-TuM6 The Effect of Sampling System Surfaces on Gas Species Measured by RGA Analysis**, ***R.E. Ellefson***, Consultant

Steady-state flow of gas through a vacuum process after some initial transient time produces a stable composition indicated by gas analysis. But commonly during vacuum processing, rapid changes in gas composition regularly occur; sampling such processes and analyzing the gas with a residual gas analyzer (RGA) can show a long time constant for gas species that have a strong interaction with the walls. A well known case is sampling gases with water vapor as a component of the gas. When onset of the sampling flow occurs, water vapor is adsorbed by the sampling system walls from the flowing gas and the water vapor partial pressure arriving at the RGA is lower than the process value. As flow continues, the wall is saturated and in equilibrium with the flowing gas so that a more accurate value is measured for water vapor. When the process gas is pumped away or water vapor level decreases, an exponential tailing of the water vapor signal occurs as the walls degas. This paper addresses the details of this transient adsorption-desorption process in gas sampling tubes related to changing species concentrations by modeling the gas-surface interaction. Some insights from the model for species equilibration time include the role of species adsorption energy, Î"H, with the surface material, the effect of concentration of the absorbing species in the gas and total pressure of the flowing gas on equilibration time and finally the temperature dependence of the equilibration time. An additional surface effect in RGA usage is the change in surface potential with changing adsorbed or surface reacted gases on ion source and rod surfaces and the filament. Changes in sensitivity can occur when gas is changed from a reducing or neutral gas to an oxidizing gas. This sensitivity change is slowly reversible by returning gas flow to a reducing or neutral gas. Examples of this effect and methods to minimize the effect are presented.

10:40am **VT-TuM9 Limiting Processes in Vacuum Measurement**, ***P. Looney***, Brookhaven National Laboratory **INVITED**

The Bayard-Alpert (BA) ionization gauge is the most widely used gauge for vacuum pressure measurement above 10-7 Pa. Its use is ubiquitous, although it does have several significant limitations - even at modest pressures. For pressures below 10-7 Pa, several critical processes which are both physical and chemical in origin, limit pressure measurement using BA gauges. Many variations have been designed to minimize limiting factors, with varying degrees of success. In this talk, I will overview the approaches to vacuum gauging and gauge designs for pressure measurement in the UHV and XHV regimes, with a focus on the limiting mechanisms, gauge interactions with residual gases, and the strategies that have been proposed to overcome them.

11:20am **VT-TuM11 Enhancement of Accuracy and Interchangeability of Multi-Sensor Gauges by Use of Individualized Calibration Parameters Stored on the Sensor Assembly Itself**, ***P.C. Arnold***, Brooks Automation, Inc.

Hot cathode ion gauge controllers that make use of gauge calibration information stored in memory in the gauge controller have been available for well over ten years. In recent years, high-temperature bakeout of hot-cathode ionization gauges has greatly diminished in common use, especially in commercial vacuum processing systems. For this reason, there are now many applications in which it is practical to store gauge calibration information in a memory chip attached to the transducer, rather than in a memory located in the controller. The attendant advantage in locating the memory on the transducer is that it permits maintaining a desired level of accuracy in the pressure measurement when one transducer is replaced by another or one electronics package is replaced by another. For those combination gauges containing hot cathode ionization sensors, heat-loss sensors, and piezo-resistive diaphragm sensors, calibration encompasses pressures ranging from high vacuum to atmosphere. A system for performing calibration of a multi-sensor gauge over such a wide pressure range is described, as well as the method of maintaining the reference gauges used in this system. Results are evaluated from testing of a multi-sensor gauge design in which calibration memory resides on the sensor assembly for several situations: (1) repeatability over time of pressure indication for the electronics and multi-sensor assembly as a system, (2) reproducibility of pressure indication when different sensor assemblies were used with the same electronic control unit, and (3) reproducibility of the pressure indication when different electronic control units were used with the same sensor assembly.

12:00pm **VT-TuM13 The Deviation and the Long-Term Variation of the Sensitivity Factor of an Axial Symmetric Transmission Gauge**, ***N. Takahashi,*** ULVAC Inc. Japan, Japan*; Y. Tuzi,* ULVAC Inc. Japan*; I. Arakawa,* Gakushuin University, Japan

We have reported the basic characteristics of two types of axial symmetric transmission gauge (AT gauge). The original AT gauge@footnote 1@ was aimed solely at the measurement in extreme high vacuum (XHV) by the pulse counting of ions using a secondary electron multiplier (SEM). In the commercial type gauge (AxTRAN, Ulvac Inc.),@footnote 2@ which is for practical use in the wider pressure range between 10@super -11@Pa and 10@super -3@Pa, the SEM ion detector was replaced with a Faraday cup type ion collector to extend the upper limit of the operating pressure and to improve the drift of a sensitivity caused by SEM. In both types, the soft x-ray effect and the electron stimulated desorption effect, which disturbs the XHV pressure measurement, are reduced by the Bessel-box type energy analyzer placed between an ionizer and the ion detector. In the present paper, two fundamental characteristics of the commercial type AT gauge are reported: the sensor-head deviation and the long-term variation of the sensitivity factor. The sensitivity factors for nitrogen of 50 sensor-heads of AT gauges were measured by the direct comparison with the spinning rotor gauge. These sensitivity factors were compared with those of 30 sensors of the extractor gauges and the BA gauges. The standard deviations for the three types of gauges are almost the same. The long-term variation of the sensitivity factors of two AT gauges for nitrogen has been examined for several years. The factor of one gauge decreased by 10% gradually in first 1.5 year in the examination. In the following 3 years, the variation of the sensitivity factor was less than 2%. The variation for the other one was relatively small. This different behavior of the sensitivity factor between two gauges is likely caused by the difference of the pre-treatment of the Y@sub 2@O@sub 3@ coated Ir filament before assembly. @FootnoteText@ @footnote 1@ H. Akimichi, et al., JVST A15 (1997) 753.@footnote 2@ N. Takahasi, et al., JVST A23 (2005) 554.

Vacuum Technology
Room 2000 - Session VT-TuA

Extreme High Vacuum and Vacuum Metrology

Moderator: N.T. Peacock, MKS Instruments, Inc.

2:00pm **VT-TuA1 Extreme High Vacuum (XHV): The Need, Production and Measurement**, ***M.L. Stutzman***, *P.A. Adderley, M. Poelker,* Thomas Jefferson National Accelerator Facility **INVITED**

Extreme High Vacuum is defined to be pressures below 1x10@super -10@ Pa. The technology required to achieve XHV at room temperature involves careful consideration of vacuum chamber materials and preparation, pumping, and pressure measurement. Many vacuum applications find UHV pressure (1x10@super -7@ to 1x10@super -10@ Pa) adequate for their purposes and research focuses on rapid pumpdown times or control of specific process gasses. However, for applications such as particle storage rings and high current photoelectron guns, operational lifetime is inversely proportional to the total pressure, with XHV pressures beneficial or essential for operation. Literature regarding the materials, preparation and fabrication processes required to achieve XHV, and XHV pressure measurement will be discussed. The focus will be on work performed at JLab for photoelectron gun applications including high average current RF and DC high voltage electron guns.

2:40pm **VT-TuA3 1450 m@super 3@ at 10@super -9@ Pa: One of the KATRIN Challenges**, ***Chr. Day***, *R. Gumbsheimer, W. Herz,* Forschungszentrum Karlsruhe, Germany

The KATRIN project is a challenging experiment to measure the mass of the electron neutrino directly with a sensitivity of 0.2 eV. It is a next generation tritium beta-decay experiment scaling up the size and precision of previous experiments by an order of magnitude as well as the intensity of the tritium beta source. Ultrafine spectrometric analysis of the energy distribution of the decay electrons at their very endpoint of 18.57 keV is the key to derive the neutrino mass. This is provided by a high-resolution spectrometer of unique size (10 m in diameter, 22 m in length). To avoid any negative influence from residual gas, the spectrometer vessel is designed to UHV/XHV conditions (an ultimate total pressure of below 10@super -9@ Pa and a wall outgassing rate below 10@super -13@ Pam@super 3@/scm@super 2@). The paper shortly describes the experimental idea behind KATRIN. The emphasis will then be given to the pumping concept for how to achieve the target parameters and to the manufacturing of the spectrometer tank. Critical issues will also be discussed (surface treatment, welding, transportation). Finally, a description of the current status and an outlook on the overall KATRIN schedule completes the paper.

3:00pm **VT-TuA4 XHV Experience at Daresbury Laboratory**, *K.J. Middleman,* ***J.D. Herbert***, CCLRC Daresbury Laboratory, UK

The Energy Recovery Linac Prototype (ERLP) is a new accelerator being built at Daresbury Laboratory in the UK. The project is a research facility to develop the technology required to build a 4th Generation Light Source (4GLS). The vacuum science group of ASTeC* is responsible for the design of the vacuum systems for the ERLP machine and their subsequent commissioning. The ERLP project is the first at Daresbury to require XHV and as such has presented a number of challenges to the design team. This paper will outline the requirements for XHV for the ERLP and detail some of the challenges that have been faced. Some details of bakeout, particle control, measurement limitations and leak detection will be presented. @FootnoteText@ *Accelerator Science and Technology Centre of CCLRC

3:20pm **VT-TuA5 Development of a New NIST Calibration Service Using the Comparison Method for Vacuum Gauges Spanning the Range 0.65 Pa to 130 kPa**, ***J.H. Hendricks***, *P.J. Abbott, J.E. Ricker, J.H. Chow,* NIST

A new calibration service based on a secondary pressure transfer standard spanning the pressure range from 0.65 Pa to 130 kPa (5 millitorr to 975 torr) is being developed at NIST. Vacuum gauges in this range are presently calibrated using the NIST Ultrasonic Interferometer Manometers (UIMs). However, many customers desire direct traceability to NIST but cannot justify the cost of the NIST UIM calibrations. These customers are typically using less accurate gauges, such as Thermal Conductivity Gauges@footnote 1,2@ (TCGs), or the newer combination type gauges that have 2 sensors combined with electronics that average or select which sensor is being utilized depending on the pressure being sensed. This new system under development is being designed to add a lower cost Comparison Method Vacuum Gauge Service that is currently not available to NIST customers. This service will follow a similar model of other calibration services where a lower cost, and less accurate service is offered to customers who do not require the lowest uncertainty possible. The comparison method utilizes a high accuracy transfer standard package that consists of a 133 Pa (1 torr) Capacitance Diaphragm Gauge (CDG), a 13.3 kPa (10 torr) CDG and a 130 kPa (975 torr) Resonance Silicon Gauge (RSG) all encased in a temperature controlled enclosure that is periodically calibrated against the NIST 160 kPa UIM and 140 Pa Oil UIM Primary Pressure Standards. The transfer standard package, and ultimately the Comparison Method Vacuum Gauge Service, is designed to have expanded uncertainties as low as 0.05 % from 1.33 kPa to 130 kPa (10 torr to 975 torr) and 0.3 % from 1.33 Pa to 1.33 kPa (0.01 torr to 10 torr).

3:40pm **VT-TuA6 A Comparison of the High Vacuum Standards of the National Physical Laboratory of India and the National Institute of Standards and Technology, USA at 0.05 Pa using the Spinning Rotor Gauge**, *P. Mohan,* National Physical Laboratory, India; ***P.J. Abbott***, National Institute of Standards and Technology

High vacuum (10@super-1@ to 10@super-4@ Pa) standards are maintained by many of the world's National Metrology Institutes (NMI). For purposes of trade equity as well as scientific integrity, it is important that NMI's compare their standards and determine a degree of equivalence within a well documented uncertainty. Comparing high vacuum standards presents a special challenge, as the transfer standards available for use in this range measure pressure indirectly and tend to have much larger uncertainties than the transfer standards used for comparing medium and low vacuum standards.@footnote 1@ The spinning rotor gauge (SRG) has excellent stability and its calibration has been found to be independent of pressure in the high vacuum regime. For these reasons, two SRG's were used to compare the high vacuum standards of the National Physical Laboratory of India (NPLI) and the National Institute of Standards and Technology, USA (NIST) at a pressure of 0.05 Pa. NPLI served as the pilot lab for the comparison. To minimize the possible effects of rough handling during shipping, the rotors were carefully packed and hand-carried between India and the United States and back to India. At each laboratory, multiple measurements of the accommodation coefficients of two rotors were made using the respective high vacuum standards of NPLI and NIST. A discussion of these standards along with the results of the comparison will be presented. @FootnoteText@ @footnote 1@Final report on key comparison CCM.P-K5 of differential pressure standards from 1 Pa to 1000 Pa A P Miiller, G Cignolo, M P Fitzgerald and M P Perkin Metrologia 39 No 1A (Technical Supplement 2002) 07002 .

4:20pm **VT-TuA8 A Linear Pressure Drop Gas Flow Calibrator**, ***P.D. Levine***, Zero K Designs

Gas flow calibration is typically accomplished by measuring the rate at which volume is displaced by gas flowing at constant pressure. An alternative methodology is described below which uses the measurement of pressure drop at constant volume to define volumetric flow rates. The pressure of a gas leaking from a fixed volume through a small conductance decays exponentially. The time constant for the decay is directly proportional to the size of the fixed volume and inversely proportional to the conductance. Thus, for measurement intervals short compared to the exponential time constant, the pressure and consequentially the rate of gas flow from the volume falls linearly to first order. This greatly simplifies the calculation of flow rate. The calibrator design provides for various configurations of volume, conductance and gas pressure to generate a wide range of linear pressure drops in time intervals sufficient for collecting meaningful data. Measuring the pressure drop differentially, as well as absolutely, affords a high level of resolution and precision. A flow meter based on this concept has already been proven effective for an orifice flow vacuum calibration system.@footnote 1@ This paper describes a scaling up of that flow meter design to provide known gas flow rates approaching those generated by piston provers, with the possibility for even further extension. Details of the design and the overall calibration methodology are described. Sources of uncertainty are identified and the inherent advantages and practical limitations are discussed. @FootnoteText@ @footnote 1@P.D. Levine, J.R. Sweda "A Precision Gas Flowmeter For Vacuum Calibration", J. Vac. Sci. and Technol. A 15(3) May/June 1997; pp 747-752.

5:00pm **VT-TuA10 A Memory of Jim Lafferty**,

James "Jim" M. Lafferty, a long time member of the society died on March 26 in Florida. During his time at General Electric, vacuum technology was central to the research he performed and directed. Having made a major

contribution to AVS, including President 1968-1969, Jim Lafferty was elected as President of the International Union for Vacuum Science, Technique, and Applications (IUVSTA), serving with great distinction from 1980 to 1983.

Vacuum Technology
Room 3rd Floor Lobby - Session VT-TuP

Vacuum Technology Poster Session

VT-TuP1 Vacuum Pump Oil Testing to Minimize Oil Waste at the National Synchrotron Light Source*, C.L. Foerster, **E.-P. Hu**, E. Haas,* Brookhaven National Laboratory

An oil-testing project was established three 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 storage rings and beam lines in 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 constantly adjusted at an inlet pressure of 500 mTorr using an air bleed valve. This inlet pressure was suggested by the suppliers of vacuum pump oil to expedite the oil viscosity change, acid buildup, and pump-wear debris production under minimal risk of oil backstreaming in the test pump. After three and a half years of continuous running there have been no significant changes in either of the oil types. Detailed test data for the resulting oil properties, oil degradation, visual comparison, vacuum conditions, and pump characteristics will be presented for evaluation of the pump oils used at NSLS and for estimation of the resulting oil waste reduction.@FootnoteText@*This research is supported by the U.S. DOE under the contract DE-AC02-98CH10886.

VT-TuP2 A Diagnostic Technique for Particulate Deposits in the Pipes within the CVD System*, **J.Y. Yun**,* Korea Research Institute of Standards and Science, S. Korea*; J.H. Lee, D.K. Moon,* Konkuk University, Korea*; S.W. Kang,* Korea Research Institute of Standards and Science, South Korea*; D.-J. Seong, Y.H. Shin,* Korea Research Institute of Standards and Science

In order to investigate the pipe clogging due to the particulate deposits in the CVD system, the various tests were conducted using the ultrasonic sensor and the vibration sensor system. At first, the pipe was examined with the ultrasonic sensor where the peak amplitude was observed to decrease as the particulate deposits increased. This is only applicable to the early stage where the particulate deposits are absorbing the ultrasonic energy. However, this trend would only last for a short period of time. The ultrasonic diagnostics would not be effective anymore when such samples are placed in a vacuum for two weeks. In this case, no particulate deposits were identified through the re-examination. This is attributed to particulate deposits drying off from the wall after some time, hindering particulate deposits from absorbing the ultrasonic energy and reflecting the ultrasonic wave back instead. As a result, this method will fail because it will not be able to differentiate the measurement from the reference sample. On the other hand, the vibration diagnostics system was able to show distinct differences depending on the amount of particulate deposits. The amount of particulate deposits could be detected by closely observing that the clean pipe achieves a high-level frequency with the impulse given by the vibration generator, while this frequency greatly reduces as the particulate deposits inside the pipes increase. It is believed that the vibration method can be applied to examine the pipes regardless of the conditions whether or not the particulate deposits are attached to the inner wall of pipes. This research also suggests that this method could be further investigated for effective application in monitoring the semi-conductor production line.

VT-TuP4 Specification Study of the Two Different Types Quadrupole Mass Spectrometer in Different Configurations and Operating Parameters*, **S.S. Hong**,* Korea Research Institute of Standards and Science (KRISS), Rep. of Korea*; I. Tanvir,* Pakistan Vacuum Society*; S.W. Kang,* Korea Research Institute of Standards and Science (KRISS), South Korea*; Y.H. Shin,* Korea Research Institute of Standards and Science (KRISS)

Quadrupole mass spectrometers (QMS) are used in many vacuum systems for leak checking and general monitoring of backgroung gases. The QMS performs mainly three functions: it ionizes a gas, it seperates the resulting molecular ions as a function of the mass-to-charge ratios and it detects the ions.@footnote 1@ Partial pressures as measurement of concentration of individual molecule species have been increasing interest in many semiconductor and display manufacturing applications. The Korean Research Institute of Standard and Science (KRISS) has newly developed a QMS calibration system for the investigation of all the QMSs performances. It consist of a vacuum chamber which is divided by orifice conductance, ultra-high pumping system, vacuum gauging instruments, and gas mixture chambers. And the system is also equipped with bake-out heater. Extractor ionization gauges and spinning rotor gauges have been used as accurate total pressure measurements. QMS sensitivity is the measurement response as a ratio of the change in spectrum peak height to corresponding change in total pressure due the change in partial pressure of a particular species. We will present the sensitivities dependences of the different types of two QMSs according to the operating parameter such as ion source, ion energy and ion detector. We will also present the ion current in combination some ionization energies to investigate behaviors of the either instrument's configuration, peak resolution and peak maximum behaviours, the response of number of cycle and etc. @FootnoteText@@footnote 1@D. J. Mitchell, 0J. Vac. Sci. Technol. A 3 (3) May/June, 527 (1993).

VT-TuP6 A Two-Stage Flow Divider System for the Test and Calibration of Vacuum Gauges*, **H. Yoshida**, K. Arai, H. Akimichi, M. Hirata,* AIST, Japan

Rapid generation of a stable vacuum pressure is necessary to evaluate characteristics of vacuum gauges. A two-stage flow divider system was developed to generate the stable vacuum pressure in high and ultra-high vacuum. This system mainly consisted of three parts, chamber 1, 2 and 3, which were connected in series using capillary A and capillary B. Chamber 2 for the gauge test was evacuated by a turbo molecular pump thorough orifice with the conductance of about 80 l/s. Chamber 1 is also evacuated by a turbo molecular pump, of which effective pumping speed is about 10 l/s, to reduce the gas flow rate from chamber 0 to chamber 2. The pressure P@sub 2@ in chamber 2 could be generated preciously by adjusting the pressure P@sub 0@ in chamber 0 using a pressure controller. P@sub 2@ was determined by P@sub 0@, the conductance of capillary A and B, and the effective pumping speed in chamber 1 and chamber 2. As P@sub 0@ was changed from 3.0x10@super 2@ Pa to 1.6x10@super 5@ Pa, P@sub 2@ was generated from 2.4x10@super -7@ Pa to 5.7x10@super -3@ Pa. P@sub 2@ reached stable within a few seconds and the fluctuation for 2.5 minutes was from 0.01% to 0.2%, which mainly depended on that of P@sub 0@. In addition, it was confirmed that the gas flow through capillary B was molecular flow because the pressure ratio of P@sub 2@ to P@sub 1@ was constant. Therefore, P@sub 2@ in lower pressure could be quantitatively determined from P@sub 1@ by using the P@sub 2@/P@sub 1@ ratio. This system is useful to evaluate characteristics of vacuum gauges. For example, it was found that the indication of ionization gauge was unstable for 600 s from the pressure setting.

VT-TuP7 ROR(t) Method in Vacuum Diagnostic*, **J. Zhou**, H. Gao, D. Paul,* Applied Materials Inc.

Rate of rise (ROR) in pressure is a key indicator used to diagnose vacuum issues in semiconductor industry. Normally, the final value of measurement will be compared with a preset pass/fail specification. A more useful approach is to evaluate the dynamic moving-average, and the value of this method is presented in this paper. In comparison to the go/no-go data provided by the final vacuum reading, the graph of vacuum over time can provide information on vacuum chamber performance: for example, if it had a leak or an outgassing problem. Thus, this approach minimizes downtime by avoiding unnecessary retests and parts replacement in troubleshooting. In this work, data was collected from more than 100 high vacuum chambers, and three basic types of ROR(t) curves were identified. Also, a controlled-leak experiment was performed to verify the correlation between the ROR(t) curves and chamber status in leak or outgassing. When a controlled leak was added to a leak-tight baseline chamber, the leak not only increased the chamber pressure, but also altered the shape and smoothness of the ROR(t) curve. When the leak was removed, the curve returned to the original shape and smoothness after a certain delay time. The ROR(t) curve signature reflected an evolution process of all gases loaded within the test chamber, which was sensed by the transducer (ion gauge). In a vacuum leak condition, the diffusion process during ROR will experience interference from the normally point-source leak, and this indicator may be especially useful in high volume manufacturing. The possibility of an automatic vacuum diagnostic employing the ROR(t) method will also be discussed.

VT-TuP8 Viscosity Measurement of Ozone-oxygen Gas Mixture with a Quartz-Friction Sensor, ***A. Kurokawa***, *Y. Kobayashi,* AIST, Japan

We would report on the viscosity of ozone-oxygen gas mixture. To measure the viscosity we developed a quartz-friction sensor method which was based on the principle that the resonance impedance of the vibrating crystal oscillator depends on the viscosity of the surrounding gas. This is an essential technique because the highly concentrated ozone gas is very reactive and easy to decompose by light absorption and heating. With the following procedure we evaluated the viscosity of the gas. The crystal oscillator was vibrated at its characteristic frequency which was around 32 kHz. The oscillator was set in the flow of ozone-oxygen gas mixture, and its impedance was monitored. During the measurement the gas pressure was measured by a capacitance manometer to cancel the pressure dependence of the impedance of the oscillator. We used the approximation that the variation of the impedance related to the viscosity of the gas. The impedance variation was defined with the impedance origin obtained at the vacuum pressure. The approximation curve was derived by the fitting to viscosity-known gases such as argon, nitrogen, oxygen, and consequently the measurement of impedance variation could give the viscosity. The highly-concentrated ozone gas was supplied from the ozone-gas generator in which 5 vol% ozone gas generated by electric discharge was condensed by selective absorption on cooled silica gel. All of the gas piping for ozone-gas had been electrochemically polished and well stabilized to minimize the decomposition of the ozone gas on the wall surface. Finally we derived the viscosity of the mixed gas with 20 vol% ozone in the 10 kPa to 100 kPa range of the gas pressure and that with 70 vol% in the 1 kPa to 10 kPa range.

VT-TuP9 Comparisons of Vacuum Standards Among NMIJ, NIST, IMGC and KRISS in Medium Vacuum, ***H. Akimichi***, *M. Hirata,* NMIJ AIST, Japan*; P.J. Abbott,* National Institute of Standards and Technology*; M. Bergoglio, A. Calcatelli,* IMGC, Italy*; S.S. Hong,* KRISS, Korea, Rep. of Korea

Comparison of vacuum standards was carried out among the National Metrology Institute of Japan (NMIJ), the National Institute of Standards and Technology (NIST), the Instituo di Metrlogia "G. Colonnetti" (IMGC) and the Korea Research Institute of Standards and Science (KRISS) from March 2004 to September 2005. Pressure range was from 0.01 to 1 Pa. Test gas was nitrogen. Spinning rotor gauges were used as transfer standard. After the calibration of the gauge by a static expansion system at NMIJ, rotors of the gauge were removed from their thimbles and packed in clean aluminum foil or clean dust free paper. They were transported to another NMI by hand and calibrated by their primary system, a dynamic system at NIST, a dynamic system and a static system at IMGC and a dynamic system at KRISS. Rotors were driven by electro units and coil heads at each NMIs. After the calibration, rotors were packed again and brought back to NMIJ by hand for re-calibration. Comparisons were done among the effective accommodation coefficient of rotors obtained by calibration at each NMI. While relatively large differences in the coefficient up to 2% (depending rotors) were observed compared with uncertainty at each NMIs, the difference was mainly caused by the change in the coefficient of the rotor during their packing and/or transportation. Mean value of coefficients of 2-6 rotors showed good agreement within 0.5% reasonably estimated from uncertainty of each NMIs. This result shows that the primary standards of NMIs seem to be equivalent to each other. It is important to clarify the way to carry the gauge without change in its accommodation coefficient.

VT-TuP10 Influences of Handling Procedures on the Accommodation Coefficient of a Spinning Rotor Gauge, ***M. Hirata***, *E. Komatsu, H. Akimichi,* NMIJ AIST, Japan

A spinning rotor gauge is widely used as a reference standard and as a transfer standard. Stability of the effective accommodation coefficient of the rotor in the gauge is very important for these applications. The value of the coefficient is very stable in operation mode. Though the gauge was turned switch to on and off several times, the relative value of two gauges was constant within 0.05 % - 0.1 % corresponding to the limit by drift and fluctuation of their offset. But significant change in the value is some times observed by transportation. For example, change in the value up to 2% was observed during the comparison of vacuum standard among NMIJ, NIST, IMGC and KRISS. In this study, we examined the influence of handling procedures on the value. In the case that the sensing head was mounted and demounted from the thimble, the value changes about 0.3 % - 0.5 % occasionally. By the washing of the rotor by alcohol and water, the value changes about 2 % - 3 %. Scrubbing the rotor inside the thimble by moving a magnet externally caused about 1 % change in it. Putting the rotor out of and into the thimble also caused about 1 % change in it some times. Even if the rotor was handled with spring-loaded device, in which the rotor is moved and fixed by a spring, used for the comparison of vacuum standards in Europe countries, it changes also about 0.3 % - 0.5 % occasionally. These results show that it is depend on the surface condition of the rotor and scrubbing the rotor inside the thimble causes also unexpected change in it. Finally stability within 0.1% in it was obtained by the transportation of the rotor together with the thimble and the sensing head.

VT-TuP11 Measurement of the Photon Stimulated Desorption for the Aluminum Chambers with Ti-Zr-V NEG-coating, ***G.Y. Hsiung***, *C.Y. Yang, C.M. Cheng, C.L. Chen, C.K. Chan,* NSRRC, Taiwan*; J.R. Chen,* NSRRC and NTHU, Taiwan

Several NEG-coated aluminum chambers have been considered for the injection section of the 1.5 GeV Taiwan Light Source (TLS) for improving the effective pumping speed. The performances of the NEG chambers including the pumping capabilities, the outgassing behaviors, the electron yield, the dusts, the reliabilities after activations and the long term photon exposures by synchrotron radiation, etc. will be inspected prior to the installation. The tests for the NEG chambers are performed at the 19B1 white light beam line of TLS, 2.14 keV of the critical photon energy, for the photon exposure experiments. A residual gas analyzer has been installed for measuring the outgassing rate and the yield of the photon stimulated desorption (PSD) for the chambers coated with the NEG film of Ti-Zr-V at 0.5 ~ 1 micron in thickness. Activations of the NEG film at both 180 °C for 24 hours and 200 °C for 2 hours have been made for the test. The behaviors of the outgas including the hydrogen, methane, krypton, and carbon monoxide, desorbed during the activations and PSD exposures are interesting throughout the experiments. The measured yields of PSD are lower than 1.0E-4 molecules/photon and reduced to 100 times lower after the exposure with > 100 Ah of the accumulated beam dose. The residual gases are mostly the hydrogen rather than methane or others. More measurements on the desorption of methane and krypton, the photoelectron yield, the dust, for the Al NEG-chambers are inspected and the results will be discussed.

VT-TuP12 Viscosity of Hydrogen-Methane Mixed Gas, ***Y. Kobayashi***, *A. Kurokawa,* National Institute of Advanced Industrial Science and Technology, Japan*; M. Hirata,* Shibaura Institute of Technology, Japan

In order to reduce CO@sub 2@ emission, EU started in May, 2004, an experimental approach named "Naturalhy Project" to transport hydrogen by mixing with existing high pressure natural gas pipelines. Naturalhy means a mixture of hydrogen and natural gas. Properties of Hydrogen-Methane mixed gas should be investigated much more because Hydrogen-Methane mixed gas is predicted to be an energy carrier to replace methane in the near future. Thus, our result would be useful for those who are developing pumps, compressors, or Mass Flow Controllers (MFC) for the next generation energy systems. This paper is considered to be the first report on the viscosity measurement of Hydrogen-Methane mixed gas. To measure the viscosity, the authors conducted two methods for comparison. The first method is the ordinary way that measures pressure drop in laminar pipe flow. The authors prepared a chemically polished, ultra clean and smooth tube and carefully measured pressure drop between upstream and downstream using a capacitance manometer. The second method measures drag acting on the quartz friction gauge in a gas atmosphere. The quartz friction gauge is sensitive to pressure, temperature and viscosity. To achieve proper conditions, the experiments are held in ultra clean tubes that have reached a constant and uniform temperature in a bath. The impedance, which correlates with drag acting on the quartz friction gauge, is measured for each gas. The authors computed viscosity of the gas from this drag by solving the Navier-Stokes equation. This study concluded as follows: (1) The authors give viscosity of Hydrogen-Methane mixed gas for system designers. (2) The authors verify the use of the quartz friction gauge as a viscosity measurement system.

VT-TuP13 Outgassing Rates of Stainless Steel Pipes Treated with 400°C Air Bake, ***X. Liu***, *K.W. Smolenski, Y. Li, C.K. Sinclair,* Cornell University

Creating an extreme-high vacuum environment is essential to the operational lifetime of the photo-cathode in the high voltage DC electron gun of the Cornell Energy Recovery Linac project. The key is to achieve an ultra-low hydrogen outgassing rate (OR) of the chamber material. Studies have reported dramatic decreases in hydrogen OR for stainless steels (SST) after a 400°C air bake. In this paper, we report the results of 400°C air bakeout of 304L SST tubes. The tested SST tubes are 6" in diameter and 40" long, with 8" ConFlat flanges welded to both ends. The tubes were cut from long tubes of the same production lot to assure consistent material properties and history. All bakeouts were carried out in a specially built oven to provide uniform temperature. The SST ORs were measured by two

methods. A spinning rotor gauge was used for a rate-of-rise method by valving out the tube from active pumps and gauges. For a throughput measurement, the tube was connected to a measurement chamber (MC) through a small orifice. The MC is pumped by an ion pump through a second orifice, to give a known pumping speed, and is equipped with a cold cathode ion gauge and a residual gas analyzer. The two methods agree very well. For each sample SST tube, ORs were measured after 150°C and 250°C vacuum bakeout both before and after a 400°C air bake. We have observed as much as a factor of three of reduction in the SST ORs, with a lowest measured OR of 3x10@super -13@ Torr l s@super -1@ cm@super -2@. This reduction in SST OR is significant, though much smaller than other reported values. Evidence also shows that bakeout history has a strong effect; higher bakeout temperature may result in higher outgassing rate.

VT-TuP14 The Small Quadrupole Mass Spectrometer for the Pressure Range Over 0.1Pa, ***Y. Matsumoto,*** ULVAC Inc. Japan, Japan*; K. Yamamuro,* ULVAC Inc. Japan*; N. Takahashi,* ULVAC Inc. Japan, Japan*; N. Mizutani, T. Nakajima,* ULVAC Inc. Japan

The quadrupole mass spectrometer (QMS) is usually used for the partial pressure measurement and the residual gas analysis of vacuum systems. However, the usual QMS, which quadrupole mass filter electrode length is about 100mm, is not available for partial pressure measurements over 10@super -2@Pa such as sputtering process etc., because of the sensitivity drop with pressure increase. This is caused by the loss of ions that arrive at an ion detector by ion-to-molecules scattering. The differential pumping system with a small orifice for gas introduction is usually used in such processes in order to maintain the pressure in the QMS less than its maximum operation pressure. But this system is relatively large and expensive. Another way to use the QMS in high pressure is down sizing of it. This presentation reports the development of the small QMS and its basic characteristics. The length and the field radius of the mass filter are 25mm and 1.8mm, respectively. The mass filter is operated with radio frequency of 7MHz. The filament and the grid of the ionizer is made of Y@sub 2@O@sub 3@ coated Ir wire and photo-etched Mo mesh, respectively. The ionizer includes an ion collector for the total pressure measurement. The ion detector for the partial pressure measurement is a Faraday cup type or a small secondary electron multiplier (SEM). The electron acceleration potential for ionization and electron emission current are 40V and 0.4mA, respectively. The sensitivity of this QMS for nitrogen was about 1x10@super -7@A/Pa with a Faraday cup type ion detector. The liner relation between ion current at mass-to-charge ratio of 28 and nitrogen pressure was obtained up to 0.1Pa. Proper correction of the sensitivity would make it possible to extend the operating pressure to 1Pa. The mass resolution, which is determined as peak width at 10% of the peak height, was less than 1 for all mass range from 1 to 50.

VT-TuP15 New Sublimation Reactor for Epitaxial Growth of II-VI Films, ***L.J. Rascon,*** *L.C. Romo, S. Rogers, S. Quinones, J. McClure,* University of Texas at El Paso*; D. Zubia,* University of Texas at El Paso, US

Close Spaced Sublimation (CSS) is a well established technique for deposition of polycrystalline CdTe thin films for solar cell applications. However, due to the very high growth rates at usual operating conditions, the technique has not been used for high quality films for advanced electronic applications. Our group has recently discovered operating conditions that yield smooth epitaxial CdTe thin films. This presentation will discuss a new CSS reactor designed at University of Texas El Paso which permits deposition of up to three different materials in layers as thin as a few tens of angstroms. Layers can be repeated as often as needed and with varying thicknesses if desired to build up a final device structure. The new reactor is able to deposit unary, binary and ternary semiconductor alloys and was conceived as a low cost alternative to high quality epitaxial crystal deposition techniques such as the costly molecular beam epitaxy (MBE). This poster presents the conceptual and physical design as well as the construction and operation of the new CSS reactor. The system performs depositions on a vertical arrangement in a vacuum of 5x10@sub -1@ Torr. Furthermore, it employs two servomotors. The first, to control the substrate to source distance, and the second, to position the substrate directly on top of one of the three sources. Hydrogen, helium and oxygen can flow during deposition to create different environments. A PID-loop controlled throttle valve manages the pressure to any set point regardless of the gas inflow. Moreover, the temperature of the three sources and the substrate are independently administered by three button heaters and a flat plate heater, respectively. Finally the complete deposition process is controlled by a computer program made in LabVIEW. Preliminary results of epitaxial CdTe films grown in the CSS reactor using very small temperature gradients will be presented.

VT-TuP16 A Study of New-Type System for Vacuum Gauges Calibration, ***Y.-W. Lin,*** *C.-P. Lin, C.N. Hsiao,* Instrument Technology Research Center, National Applied Research Laboratories, Taiwan

The purpose of this article is to analyse the stability of new-type system for vacuum gauges calibration. Design and operating procedures of the system mainly uses direct comparative method to calibrate vacuum gauges ranging from 10@super 3@ to 10@super -6@ Torr. The review of system is depended on capacitance gauge, ionization gauge and spinning rotor viscosity gauge, and estimated uncertainty is calculated with different pressure. Observational data show that chamber evacuates down to 10@super -8@ torr, the uncertainty of system varies from 0.6% at the high vacuum, to 1*10@super -5@ Torr at midrange, and 1*10@super -2@ Torr at the rough vacuum. From these pieces of result, the system can effectively use for calibration of vacuum gauges besides ultra-high vacuum.

VT-TuP17 Design of the EBIS Vacuum System, ***M. Mapes,*** Brookhaven National Lab, usa*; E. Beebe, A. Pikin, J. Alessi, J. Ritter, L. Smart,* Brookhaven National Lab

At Brookhaven National Labratory the Electron Beam Ion Source (EBIS) is presently being designed. The EBIS will be a new heavy ion pre-injector for the Realativistic Heavy Ion Collider (RHIC). The new pre-injector has the potential for significant future intensity increases and can produce heavy ion beams of all species including uranium. The background pressure in the ionization region of the EBIS should be low enough that it does not produce a significant number of ions from background gas. The pressure in the regions of the electron gun and electron collector can be higher than in the ionization region provided there is efficient vacuum separation between the sections. For injection the ions must be accelerated to 100KV by pulsing the EBIS platform. All associated equipment including the vacuum equipment on the platform will be at a 100KV potential. The vacuum system design and the vacuum controls for the EBIS platform and transport system will be discussed as well as the interface with the Booster Ring which has a pressure 10-11 Torr. @FootnoteText@ Work performed under the auspicious of U.S. Department of Energy.

VT-TuP18 Vacuum System of ISAC RFQ at TRIUMF, *I. Sekachev,* ***D. Yosifov,*** TRIUMF, Canadian National Laboratory

RFQ (Radio Frequency Quadruple) accelerator of ISAC (Isotope Separator and ACcelerator) at Triumf has been in full operation since 1999. The RFQ accelerator is a split ring 4-rod structure, 8m long with a bore radius of 7.5 mm operating at 35.36 MHz placed into diagonally split rectangular vacuum tank with dimensions of 1 x 1 x 8 m. The tank's main seal consists of two circumferential Viton O-rings with differential pumping of the space between them. There are six 1000 L/s turbo pumps operating continuously to keep the vacuum in the tank at about 5.0E-7 Torr, measured by two hot filament ion gauges. The gauges are also used for interlocks. This paper describes the details of the vacuum system of RFQ and its operation.

Vacuum Technology
Room 2000a - Session VT+AS-WeM

Outgassing, Materials Coatings for Reduction of Outgassing

Moderator: L. Westerberg, Uppsala University, Sweden

10:40am **VT+AS-WeM9 Outgassing of Construction Materials for Vacuum Chambers and Coatings for Reduction of Outgassing**, ***J. Setina,*** Institute of Metals and Technology, Slovenia **INVITED**

In vacuum systems we have to deal with continuous gas desorption from the chamber walls and inflow from the technological process. Working pressure in a vacuum system is a counterbalance of total gas flow rate and available pumping speed. Vacuum technological processes are very diverse and span more than 15 decades of pressure: from coarse vacuum to extremely high vacuum (XHV). To properly design a vacuum chamber, the vacuum engineer needs, reliable data on outgassing of constructional materials for the working conditions. Extensive data can be found in the literature, but there is considerable scatter in the data due to differences in sample quality, preparation technique, cleaning procedure and measurement method. Different methods for measuring outgassing will be discussed. Vacuum gauges can also influence the result as they can outgass, pump or significantly change the gas composition by promoting chemical reactions on hot filaments. Therefore, the measurement setup has to be considered and evaluated carefully to determine the uncertainty of the results. In ultrahigh vacuum (UHV) systems the dominant gas is hydrogen that is dissolved in the material used in its construction and continuously diffuses towards the chamber walls and desorbs into the vacuum. To achieve UHV, outgassing has to be reduced to the lowest practical values. Established methods are pre-treatment of materials (vacuum firing, air bake) and in-situ baking of the vacuum chamber. For XHV systems, such treatments are often not sufficient and passive barrier coatings to reduce gas diffusion have been reported in the literature. Published results for coatings on stainless steel or aluminum such as TiN, BN and SiO2 are not consistent. Hydrogen suppression depends on film thickness and density and also on pre-treatment of the coating substrate. These conditions were not the same in the published works and important experimental details are often missing.

11:20am **VT+AS-WeM11 Reducing SS 304/316 Hydrogen Outgas to 2E-15 torr liter/cm@super 2@ s**, ***Y.T. Sasaki,*** Quantum Mechanics Corp.

Significant reduction in the outgassing rate of 300-series stainless steel is routinely attained through combination of electropolishing and vacuum baking. Preferential removal of Ni, Fe, and Mn from the surface of stainless steel by electropolishing creates virtual chromium coating without trapping impurities under the surface. It also reduces the atomic surface area by more than an order of magnitude. When the material is vacuum-fired to remove interstitial hydrogen, the resultant stainless steel exhibits an outgas rate of ca. 2E-15 torr liter/cm@super 2@ s, as well as drastically reduced adsorption, absorption and catalytic behaviors.

11:40am **VT+AS-WeM12 Summary of the 45th IUVSTA Workshop on NEG Coatings for Particle Accelerators and Vacuum Systems***, ***H.C. Hseuh,*** Brookhaven National Laboratory*; K.J. Middleman, O.B. Malyshev,* CCLRC Daresbury Laboratory, UK*; P. Manini,* SAES Getters S.p.A., Italy

The 45th IUVSTA Workshop on NEG coatings for Particle Accelerators and Vacuum Systems was organized by the Accelerator Science and Technology Center (CCLRC Daresbury Laboratory, UK) and the Italian Vacuum Association. This workshop was held in Catania, Italy from April 5-8, 2006. The TiZrV NEG coating was introduced as a new technology for vacuum applications at the end of 1990s. The interest to this new technology has grown over the past 6 years since the first NEG coated vacuum chamber was installed at the ESRF (France). With conventional vacuum technology, an outgassing surface and a pump (lumped or distributed) are two different elements of a vacuum system. In comparison to this new NEG technology most surfaces of the vacuum chamber are coated with a TiZrV alloy which after activation desorbs much less than conventional materials such as stainless steel, copper and aluminium. The NEG coating also has pumping properties which results in a much low residual gas pressure. Due to a need for exchanging information between different research groups involved in the accelerator community as well as UHV pump manufacturers a dedicated workshop was set up to discuss NEG coatings. This paper summarises the main topics and discussions from the NEG workshop, those being, materials alternatives to TiZrV, production of the coating, characterisation (material science, electronic, photo-electronic and vacuum properties), problems associated with the study of NEG coatings and a final discussion on what further studies are needed for a successful vacuum system design. @FootnoteText@ Presenting author email address: hseuh@bnl.gov *Work performed under the auspicious of U.S. Department of Energy for the presenting author; and the corresponding funding agencies for co-authors.

12:00pm **VT+AS-WeM13 Delicacy in the Activation and Measurement of Non-Evaporable Getter (NEG) Films**, ***K.J. Middleman,*** *O.B. Malyshev,* CCLRC Daresbury Laboratory, UK*; R. Valizadeh,* Manchester Metropolitan University, UK

In recent years a new innovation to improve the performance of the "vacuum vessel" has been the development of a vacuum chamber with a Non-Evaporable Getter (NEG) coating magnetron sputtered onto the inner walls.@footnote 1-3@ This technique was intensively developed at CERN and is now widely used in a number of electron accelerators@footnote 4@ for narrow gap insertion device vessels where conductance limitations restrict the pumping speed available and cause a pressure rise resulting in increased gas brehmstralung. This new technique is still in its infancy and there are a number of issues which are still not yet fully understood. A number of unanswered questions remain for accelerators with regard to NEG coatings including how they can be optimised to exhibit low photon, electron and ion stimulated desorption yields and reduce secondary electron emission. The benefits of NEG coated vacuum chambers for accelerator vacuum systems led to a fundamental study of NEG coating research in the UK between ASTeC and MMU. This paper looks at the delicacy of producing NEG coated chambers and how the method of activation and regeneration of such coatings can have a significant impact on the end result. Identical NEG films were sputtered onto both planar and tubular samples with significant differences observed between the two in terms of both pumping capacity and sticking coefficients. Critical issues such as the ratio of NEG coated to uncoated surface will also be presented. @FootnoteText@ @footnote 1@C. Benvenuti, J.P. Bojon, P. Chiggiato and G. Losch, Vacuum, 44, 507 (1993)@footnote 2@ C. Benvenuti and F. Francia, J. Vac. Sci. Technol. A 6 (4), 2528 (1988)@footnote 3@ C. Benvenuti and F. Francia, J. Vac. Sci. Technol. A 8 (5), 3864 (1990@footnote 4@ R.Kersevan. "Performance of a narrow-gap, NEG-coated, extruded aluminium vacuum chamber at the ESRF." Proc. of EPAC-2000, Vienna, Austia, p. 2291.

Vacuum Technology
Room 2000 - Session VT-WeM

Electron, Photon and Ion-beam Induced Desorption and Their Effects on the Dynamics of Accelerators

Moderator: L. Westerberg, Uppsala University, Sweden

8:00am **VT-WeM1 New Understanding of Ion-Beam Induced Gas Desorption***, ***A.W. Molvik,*** *M. Kireeff Covo,* Lawrence Livermore National Laboratory*; F.M. Bieniosek, P.A. Seidl,* Lawrence Berkeley National Laboratory **INVITED**

Heavy-ion accelerator rings are frequently limited by gas-pressure rise, whereas proton rings are generally limited by electron clouds. We have shown that the desorption caused by high-energy ions is driven by the electronic component of ion slowing in matter, known as electronic sputtering to distinguish it from conventional or physical sputtering that is driven by nuclear scattering of ions in matter. A large body of literature exists on electronic sputtering, but does not include sputtering from metals that are clean except for one to a few monolayers of gas. We measured desorption by 70-1000 KeV potassium ions, for which the dominant ion energy loss transitions from nuclear stopping at 70 keV to electronic stopping above 250 keV. We found that gas desorption scaled with the electronic component, (dE/dx)@super n@ where 1<n<2 power. Gas desorption by electronic sputtering is closely related to electron emission from ion impact, a process that scales linearly with dE/dx, but desorption can be two orders of magnitude greater. Desorption from nominally clean stainless steel scales slowly with the ion angle of incidence, unlike other electronic-sputtering studies for which desorption scales linearly or faster with 1/cos(@theta@). Mitigation measures vary with ion energy: roughened surfaces significantly reduce desorption by low energy ions, but increase it for grazing-incidence energetic ions whose range encompasses multiple hills. @FootnoteText@ *This work performed under the auspices of the U.S. DOE by Univ. of California, Lawrence Livermore and Lawrence

Berkeley National Laboratories under contracts No. W-7405-Eng-48 and DE-AC02-05CH11231.

8:40am **VT-WeM3 Ion-Induced Desorption Yields for U@super 73+@ and Ar@super 10+@ Ions at 15-100 MeV/u**, *H. Kollmus, M. Bender, M.C. Bellachioma,* GSI, Germany*; E. Mahner,* CERN, Switzerland*; A. Kraemer,* GSI, Germany*; L. Westerberg,* ***E. Hedlund,*** Uppsala University, Sweden*; O.B. Malyshev,* CCLRC Daresbury Laboratory, UK*; H. Reich-Sprenger,* GSI, Germany

During operation of the heavy ion accelerators at CERN, GSI and BNL large pressure rises, up to several orders of magnitude, due to ion beam-loss induced desorption have been observed. In order to get a better understanding of these phenomena at intermediate energies we have measured desorption yields, @eta@, (released molecules per incident ion) for 15, 40 and 100 MeV/u U@super 73+@ beam on samples of 316LN stainless steel, 6028 aluminum and OFE copper. In a second experiment we used 40, 80 and 100 MeV/u Ar@super 10+@ beam on a 316LN stainless steel sample. The experiment was done in a UHV setup at GSI in Darmstadt, Germany. From the desorption yields, calculated from the measured pressure rises, as a function of energy loss, dE/dx, we deduced power laws in the order n=2-4. This is compared with theoretical power-law models for sputtering.

9:00am **VT-WeM4 Electron and Ion Desorption Studies at RHIC**, ***S.Y. Zhang****, H.C. Hseuh, P. Thieberger,* Brookhaven National Laboratory

The electron cloud, beam induced pressure rise and experimental background are limiting factors of RHIC heavy ion and polarized proton luminosities. Electron and ion desorptions with the normal and shallow angle incidents are relevant in machine improvement. In this talk, the effects of electron and ion desorptions on steel, NEG and saturated NEG surface in machine operation, beam study, and test stand will be reported.

9:20am **VT-WeM5 Ion-Induced Gas Desorption Modeling in High Vacuum Systems***, ***M. Kireeff Covo****,* UCB and LLNL*; A.W. Molvik, A. Friedman,* LLNL*; J.-L. Vay, F.M. Bieniosek, D. Baca, P.A. Seidl,* LBNL*; J. Vujic,* UCB

Ion beam interaction with walls desorbs gas and electrons. The gas can move to the beam path and be ionized. In a positively-charged particle beam the produced ions are expelled by the space-charge beam potential and the electrons are trapped inside a potential well. This ubiquitous effect grows at higher fill factors (ratio of the beam to the tube radius) and degrades the quality of the beam. In order to simulate it, we measured the gas desorption yield of stainless steel using the Gas-Electron Source Diagnostic in two distinct high vacuum facilities (High Current Experiment at LBNL and the 500 kV Ion Source Test Stand at LLNL). The desorption process is result from the interaction of the surface gas layer with ion-induced electrons. The experimental results will be discussed and compared with a theoretical model. @FootnoteText@ *This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48, and by Lawrence Berkeley National Laboratory under Contract DE-AC03-76F00098.

9:40am **VT-WeM6 Photon Stimulated Desorption from Aluminum and Electroplated Copper Chambers**, ***J. Gómez-Goñi****,* Universidad Politécnica de Madrid, Spain

Photon stimulated desorption (PSD) from aluminum and copper electroplated vacuum chambers have been obtained using synchrotron radiation of critical energies ranging from 12.4 to 280 eV. We first compared different cleaning methods on electroplated copper, including bakeout, pre bakeout (bakeout in situ, venting and pumping) and glow discharge with argon and 10% oxygen. As expected, in situ bakeout gave the best results, followed by glow discharge, which was quite effective removing desorbed gases. After this experiment, we compared two chambers manufactured with different copper electroplating methods measuring initial yields differing by factors between 1 and 3. During dose accumulation, the cleaning effect was more clearly seen in one of them, especially for hydrogen. Initial desorption yields were also measured for an aluminum chamber, before and after bakeout. We obtained that initial yields were almost linear with critical energy in this range. The difference between baked and unbaked aluminum was mainly due to water yield which was greatly reduced after bakeout. For aluminum we obtained that photoelectron production yield was linear with critical energy and specific pressure rise was also linear with photoelectron yield. Combining both facts we obtained that photoelectron stimulated yields were independent of critical energy for both baked and unbaked aluminum. This relation suggested a process where photoelectrons are responsible for the desorption of molecules.

Vacuum Technology
Room 2000 - Session VT-WeA

Space-based Vacuum Applications and Instrumentation; Panel Discussion on Vacuum Science and Technology

Moderator: P.J. Abbott, National Institute of Standards and Technology

2:00pm **VT-WeA1 Experimental Investigation of the Near-Earth Space*, M. Wüest,*** INFICON GmbH, Switzerland **INVITED**

Since the days of the first launch of an orbiting satellite containing scientific instrumentation in January 1958 the space environment in the vicinity of Earth has been studied in more and more detail. Substantial improvements have been made to the space-based instrumentation since then. In the area of low energy particle instruments they have evolved from the simple cylindrical electrostatic analyzer to complicated time-of-flight mass spectrometers. I will trace the evolution of the space physics instrumentation in terms of measuring capability and how this contributed to a better understanding of near-Earth space.

2:40pm **VT-WeA3 Bayard-Alpert Gauges for Space Research: Techniques and Results*, J.H. Clemmons,*** The Aerospace Corporation

Two variants on a common spaceborne ionization gauge design are discussed. The miniature, commercially-available sensors used to minimize the required spacecraft resources are described. Several special features of the controller are demanded by scientific use in space, including high-precision, high-rate sampling, DC filament regulation, and space compatibility, are presented and discussed. The variant used for suborbital flights, which employs 1 kHz sampling and an accommodation chamber designed to have a response function between that of a planar aperture and a pitot tube, as well as results from several flights, are presented. The variant used for orbital flights, which features a more traditional accommodation chamber with a planar aperture and high-reliability electronics, as well as results taken from about one year of data collection, are presented. A special mode of the instruments, designed to provide crude composition information, is also discussed and evaluated.

3:00pm **VT-WeA4 Ground Simulation Studies of Commercially Available Coatings and Adhesives for Low Earth Orbit Space Environment Applications*, A. Laikhtman,*** *R. Verker, Y. Noter, E. Grossman, I. Gouzman,* Soreq NRC, Israel

This work is dedicated to comparative ground simulation studies of two representative groups of materials: (i) black paints and (ii) adhesive coatings. Some of them are already in use in orbiting spacecrafts, mainly in optical systems, while others are considered for such applications. The paints and coatings discussed here are silicone-based or inorganic, alumina-based. Outgassing properties of the discussed materials were first evaluated by a standard outgassing test according to ASTM E595. These measurements do not provide, however, any information about the kinetics of the outgassing processes. The kinetic parameters characterizing outgassing of materials are of great importance, since they are used to evaluate the contamination and the associated degradation of optical space systems. Silicone-based materials are known to be a threat as a source of contamination, while inorganic coatings may be highly porous and, therefore, may aggregate molecular fragments from their environment followed by desorption of these fragments and contamination of neighboring parts. The experimental procedure was based on in situ monitoring of the contaminants by a quartz crystal microbalance (QCM) in a modified ASTM E595 system. It involved the following stages: (a) holding the sample at high temperature while keeping the QCM at low temperature; (b) cooling the sample and keeping it at room temperature without changing the QCM temperature, in order to isolate the contaminants re-emission process; and (c) increasing the QCM temperature to study the effect of temperature on the re-emission kinetics. In addition, chemical identification of the residual contaminants was performed by FTIR and UV spectroscopic measurements. Considerable differences in the outgassing kinetic parameters and contamination potentials were observed between the discussed materials. An analytical model was developed to derive the outgassing and re-emission kinetic parameters from the experimental data.

3:20pm **VT-WeA5 Report from the Mars Chapter*, M.H. Hecht,*** Jet Propulsion Laboratory, California Institute of Technology **INVITED**

This august organization represents generations of vacuum lore acquired for the sole purpose of preventing 100,000 Pa of a predominantly oxygen/nitrogen mixture laced with rare gases from fouling up important scientific experiments and lucrative fabrication processes. With this problem largely solved, our attention has fastened on the experiments and processes themselves, as well as their products, which now form the subject of most of our symposia. But for those of us in the Mars exploration business, constrained to pitifully small mass and power budgets and faced with excluding only 1,000 Pa of predominantly carbon dioxide, a new set of solutions to the original problem becomes attractive. The native atmosphere is thin enough for some experiments that would prefer vacuum on Earth, such as x-ray analysis or scanned probe microscopy, but is more severe than Earth with respect to others, such as those sensitive to triboelectricity. Getters are sufficient for some applications, including mass spectroscopy. This talk will cover some of the basic characteristics of working in the martian atmosphere (thermal properties, for example), and will review the adaptation of analytical instruments to that environment.

4:00pm **VT-WeA7 Evacuation Equipment and Techniques for Space Simulation Chambers*, J.P. Luby, R. Amos,*** BOC Edwards

Vacuum chambers used for space simulation often require large vacuum pumping systems or multiple, smaller vacuum pumping systems to accomplish evacuation in a reasonable time frame. Appreciable high vacuum pumping speed is required to complete evacuation and maintain vacuum at desired levels. There are numerous technical and economic challenges, as well as special design criteria that should be considered when selecting equipment and implementing techniques for large chamber evacuation. In this paper, selection criteria for rough vacuum and high vacuum equipment is reviewed with a focus on system sizing, system configuration, vacuum system operation and maintenance.

Vacuum Technology
Room 2000 - Session VT-ThM

Special History Session - Franklin and the Future

Moderator: T.E. Madey, Rutgers University

8:00am **VT-ThM1 Benjamin Franklin and the Meaning of Public Science, *J.E. Chaplin,*** Harvard University **INVITED**

Where did Benjamin Franklin do his science? The famous American Founder is closely associated with his political career, meaning his public life. Compared to that public life, Franklin's science has seemed to be an odd, private hobby, which he managed to do somehow (and somewhere) alongside his work in politics. But Franklin's scientific and political efforts were interconnected. In fact, he performed much of his science in public places. To be sure, he did some of his scientific investigations in private, at home. (He used his house as an experimental space for his work on heat and rigged up the house itself as a piece of electrical apparatus.) But in Franklin's Philadelphia, the best space for science was a public one: the Pennsylvania State House, now Independence Hall. Franklin had helped to found a learned society, the Library Company of Philadelphia, which for some time used rooms in the State House's west wing. There, the company had hosted a series of scientific lectures, including demonstrations with an air pump, which created an experimental vacuum; there, as well, Franklin and his collaborators did most of their famous electrical experiments. The open area outside the State House proved useful for astronomical observations and for the launch of the first balloon in the United States. The public space for science also functioned as a place for politics. A platform built for observations of the 1769 Transit of Venus was the very spot on which, seven years later, the Declaration of Independence had its first public reading. This lecture will explain why Franklin and his contemporaries expected their science to fit comfortably into public life--and public space. What kind of science was it?

8:40am **VT-ThM3 Monolayers Films: From Franklin's OIl-Drop Experiments to Self-Assembled Monolayer Structures, *G.L. Richmond,*** University of Oregon **INVITED**

Although we often view the explosive growth in studies of molecular self assembly and monolayer films on surfaces as a relatively recent phenomena, in fact, reports dating from Roman times note the value of the spreading of oil on the surface of water in calming the seas. But arguably the beginning of the field as a scientific discipline dates back to the experiments of Benjamin Franklin who reported to the Royal Society in 1774 that placing as little as one teaspoon of oil on the surface calmed the ripples on a small area that quickly extended to have an acre. This presentation will provide an overview of how this area of science has evolved from these early times where oil was used to calm the raging seas, to the present day where studies of self assembled monolayers structures and their application to a variety of technological, biological and environmental processes are all the rage.

9:20am **VT-ThM5 The Science and Technology of Electrophotography, *L.B. Schein,*** Independent Consultant **INVITED**

Electrophotography, one of the most prevalent applications of electrostatics, is the technology used in copiers and laser printers. In this review, the basis of the technology will be discussed, from the basic six steps to the underlying physics of the process. Discussions will include the physics of surface charging of insulators based on Paschen breakdown, the static electrification of insulating particles (sometimes called triboelectricity) and current challenges in color electrophotography, all of which evolved from Franklin's early experiments in electrostatics.

10:00am **VT-ThM7 From Lightning to Lighting: Physics and Technology Discharged from Franklin's Kite Experiment, *R.T. McGrath,*** The Ohio State University **INVITED**

In April 1749, Benjamin Franklin first sketched his experiments for demonstrating the "sameness of electrical matter" (heretofore generated using rubbed glass rods) "with that of lightning." By summer of 1752, the successful execution in France of the high tower, iron rod, sentry box experiment proposed by Franklin made him an international celebrity, while in Philadelphia the delayed completion of the Christ Church steeple led an impatient Franklin to devise and execute his "whimsical" and famous electrical kite experiment. Forsaking patents for the common good, Franklin's approach to technology transfer was to broadly publish his theories and experimental results, with lightning rods first installed on buildings in Philadelphia in the summer of 1752 and then disseminating throughout Europe and the then United States, quickly thereafter. Along the way, Franklin devised the one-fluid theory of electrical flow, designating that flow as positive and thereby condemning subsequent generations of freshman physics students to confusion about the direction of current flow, but also introducing such seminal concepts as conservation of charge and electrical action at a distance. From these rich ideas, each grounded in meticulously devised and executed demonstration experiments, flowed forth 250 years of subsequent theory, experimentation and understanding of electricity and discharge physics. Today, many of the indispensable conveniences of modern life, such as micro-discharges within our plasma televisions; discharges driving our domestic fluorescent lighting; reactive chemistry discharges used to manufacture our laptops, ipods and cell phones; and mega-amp tokamak discharges striving to provide us with fusion power; all derive their roots from that curious fellow with a kite from Philadelphia.

10:40am **VT-ThM9 Progress and Prospects in the Generation of High Voltage*, *H.F. Dylla,*** Jefferson Lab **INVITED**

In 1738, in the tradition of Robert Boyle, Benjamin Franklin's Library Company of Philadelphia -- a learned society founded by Franklin partly in imitation of the Royal Society -- obtained an air pump for study of vacua. In 1747, the organization obtained an electrostatic machine. By advancing the scientific understanding of electricity, Franklin helped light the way to countless not-then-foreseen modern applications of high voltage, from cathode-ray and photomultiplier tubes to huge systems for electrical power distribution. Because Franklin subscribed to the particle theory of matter, he would no doubt be fascinated by the particle accelerator, today's linkage of vacuum technology and high voltage for elucidating matter's particle structure. This talk will trace that linkage from Franklin's time to the International Linear Collider, which is now being designed to comprise two facing linear accelerators, each 20 kilometers long, that will hurl beams of electrons and positrons toward each other at nearly the speed of light -- and at energies planned eventually to reach the teravolt scale. * This work supported by US DOE Contract No. DE-AC05-84ER40150

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