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

Vacuum Technology Poster Session

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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