Vacuum Technology
Room 201 - Session VT-WeM
Gas Flow and Pump Technology

Moderator: R. Langley, Oak Ridge Science Consultant

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Author Index

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