Vacuum Technology Division
Room 610 - Session VT-WeM

Vacuum Pumping Systems

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

8:20am **VT-WeM1 Affect on Pumping-Speed Measurements Due to Variations of Test Dome Design Based on Monte-Carlo Analysis**, ***S.B. Nesterov***, *Yu.K. Vassiliev,* Moscow Power Engineering Institute, Russia*; R.C. Longsworth,* IGC-APD Cryogenics, Inc.

Test domes for measuring pumping speed are defined in AVS Standard 4.1, Pneurop Standard PN5ASRCC/5 and the last draft of the new AVS Standard for Cryopumps. These test domes are similar. They try to provide a measure of the speed of a pump as if it is mounted in the center of a large, flat plate in a large chamber. In this case, the flow distribution is diffuse while in the test dome the flow pattern has a stronger axial component. The location of the pressure gauge is intended to compensate for the different flow pattern. Certain parameters in the design of the test domes are not rigidly specified -- including the shape for the top of the dome, the diameter of the gas feed tube for the single-dome method or the orifice for the two-gauge method. A Monte-Carlo Analysis has been carried out to analyze the differences in speed which will then be measured for different configurations for the top of the test dome, different gas feed-tube diameters and different diameters of the hole in the aperature plate. Variations in the range of 2% to 3% are calcualted. In addition, a comparison of pumping speed for an APD Cryogenics Marathon 8 Cryopump mounted in a test dome vs. being mounted on a flat plate in a large chamber is presented in order to illustrate the potential affect of the cryopump geometry.

8:40am **VT-WeM2 A Highly Simplified and Reliable Means of Regenerating Closed-Loop Gaseous Helium Cryopumps**, *D.W. Crone, J. Brady, M.O. Foreman,* Ebara Technologies Inc.*;* ***K.M. Welch,*** Consultant

A unique means of regenerating closed-loop, gaseous helium refrigerator cryopumps is reported. If one reverses the rotation of the expander motor of a Gifford-McMahon refrigerator, the thermodynamic cycle is reversed and heat rather than refrigeration is produced at the expander cooling stations. The heat input stemming from reversing the thermodynamic cycle may be used in a controlled manner to achieve a simple, safe and effective regeneration cycle of the cryopump. This reverse cycle regeneration process, and its effectiveness and reliability will be described.

9:00am **VT-WeM3 Review of Pumping by Thermal Molecular Pressure**, ***J.P. Hobson,*** National Vacuum Technologies Inc., Canada*; D.B. Salzman,* Polychip Inc. **INVITED**

Pumping energy is supplied by temperature changes only. A general feature of such pumps is that the upper pressure limit is reached when the mean free path becomes small relative to the physical dimensions of the pump in the region of the temperature transition. Thus the upper pressure limit of these pumps has been determined by the microfabrication technology of the day; they have operated at relatively low pressures, with low throughputs, and have not become main-line pumps. In recent years, however, MEMS (Micro-Electronic-Mechanical Systems) has introduced a whole new level of miniaturization to devices in general, including vacuum devices, and hence has raised the upper pressure limits, and thus the throughputs, of thermal molecular pumps to near atmospheric levels.@footnote 1@ The purpose of this paper is to review various physical manifestations of pumps using thermal molecular pressure, which have been realized over the years. Emphasis is placed on pumps which have actually been constructed and tested. The general pumping phenomenon has had various names: the Knudsen compressor, thermal transpiration, thermal creep, thermodynamic, thermomolecular, thermal molecular, and accommodation pumping. This multiplicity of names can cause some confusion and it is one of the objectives of this review to simplify this situation. We have chosen to title the paper "Review of Pumping by Thermal Molecular Pressure", following the terminology used by Knudsen.@footnote 2@ It is found that, broadly speaking, these pumps divide into two classes: (a) those using no explicit surface treatment; and (b) those using specially prepared surfaces. It is further found that pumps in class (a) have both an upper and lower bound in pressure, while pumps in class (b) have only an upper bound in pressure. A Table is assembled comparing experimental results of pumps which have actually been built and tested. However, scaling rules for multiple stage pumps, based on results obtained for single stage pumps are presented. Despite their diversity thermal molecular pumps all have the compelling advantage that there are no moving parts, nor any fluids, in the vacuum. @FootnoteText@ @footnote 1@ S.E.Vargo, E.P.Muntz, G.R.Shifflet, and W.C.Tang, J. Vac. Technol. A, (in press). Paper presented at the 45th International Symposium of the American Vacuum Society, Baltimore, 1998. @footnote 2@ M.Knudsen, "The Kinetic Theory of Gases", Methuen's Monographs on Physical Subjects, John Wiley and Sons Inc., New York, 1934.

9:40am **VT-WeM5 Inner Pressure Measurement of Turbo Molecular Pump**, ***H.-P. Cheng,*** *R.-Y. Jou, J.-C. Lin, F.-Z. Chen, Y.-W. Chang,* Precision Instrument Development Center, National Science Council, Taiwan, ROC

In the past decades, a lot of papers have been published to deal with the pumping mechanism of turbo molecular pump. These articles contain theoretical and experimental investigations. But there are only few of articles contain the experimental data can supply to the comparison with the theoretical models. Most of previous experimental works devoted on the measurement of pumping speed and compression ratio of one stage turbo blade structure or one whole pump. The foregoing review shows that no related work has been published to measure the pressure variation of inner pump from inlet to outlet ports. In this study, the inner pressure measurement of a new type turbo molecular pump is investigated. The pump is developed by the cooperation of Kashiyama Industries Ltd. and Precision Instrument Development Center with a desire to replace the mechanical booster pump. The experimental measurement is followed by the Japan standard JVIS-005. The flow meter method is adopted here. In order to measure the pressure variation from pump inlet to outlet, there are 9 holes with 6.5-mm inner diameter are drilled through the casing of pump along the axial direction. The distances of 9 holes from the plane of inlet port are 49.5, 79.5, 107, 127, 147, 167, 187, 207, and 227 mm. The metal gasket face seal fittings with inner diameter 3-mm are welded into the holes by TIG-Tungsten inert gas welding method. The vacuum gauges with the range of 1.E-4 to 10 torr are linked with metal gasket face seal fittings by the metal bellow tube. Six sets of inlet pressures with 1.E-4, 1.E-3, 1.E-2, 0.1, 0.5 and 1 torr are measured. The pressure variations along the axial direction are plotted versus normalized axial distance. The pressure tendency related to rotor shaped is discussed. Tendency of pressure variation of measurement and prediction is compared.

10:00am **VT-WeM6 Measurement of Axial Pressure Distribution on a Rotor of a Helical Grooved Molecular Drag Pump**, ***T. Sawada,*** *W. Sugiyama,* Akita University, Japan*; K. Takano,* Mitsui Zosen Ltd., Japan

The theory in regard to the pumping performance of a helical grooved molecular drag pump proposed by the authors has been employed successfully as a design and evaluation tool. However, some researchers presented results different from the authors' using direct simulation Monte Carlo method. Their method included the inlet effect and the secondary flow in grooves either of which was neglected in the authors' theory. This study was planned to examine the validity of the authors' theory precisely. A helical grooved cylindrical rotor was located concentrically in a smooth sleeve. In order to obtain the pressure distribution on the rotor, several taps were installed on the sleeve along axial direction. The taps led to one side of a differential pressure gauge via valves and the upstream side of the rotor was connected to the other side of the gauge. The pressure was measured by switching the valves in turn. The measurements show that (a) the pressure in the free molecule flow regime increases exponentially from the inlet to outlet, (b) the pressure increases almost linearly from the inlet to outlet in the slip and viscous flow regime, and (c) the inlet effect becomes remarkable in the turbulent flow regime. The validity of the theory has been proved from the free molecule to viscous flow regimes, but the theory needs modification so as to include the inlet effect in the turbulent flow regime.

10:20am **VT-WeM7 An MHD Plasma Vacuum Pump**, ***E.S. Ensberg,*** Microwave Plasma Products, Inc.

The demand for increased productivity in high vacuum plasma processing chambers calls for greater vacuum system throughput. Pump manufacturers have responded by refining turbomolecular and drag pump designs to raise speed and operating temperature limits. Plasma pumps, in a modular design with no moving parts, offer an alternative to rotating machinery for transport of large quantities of gas, especially light or inert gases. The concept depends on the Lorentz force j x B to generate a pressure gradient, directed from the inlet to the outlet of each of an array of channels. The transverse magnetic field B is provided by permanent magnets incorporated in the channel array. Microwave electric fields, parallel to B, form the plasma within the channel array. A steady electric field E, between stainless steel electrodes in each channel, drives the transverse current density j, such that j x B is always directed from the inlet to the outlet region of each channel. Measurements of compression ratios and of throughput per channel vs. pressure (in the range 0.001 to 1 Torr) in evolving laboratory models employing these concepts are reported, together with an approach to modelling transport of plasma and neutrals in the channels.

10:40am **VT-WeM8 Stable Sputter Ion Pump Design*, J.B. McGinn,*** FEI Company

Title: Stable Sputter Ion Pump Design Abstract: The cause of unstable leakage currents in diode sputter ion pumps (SIP) was investigated. The discharge current of diode SIP's of various designs was monitored through a testing protocol of alternate gas exposures. Discharge current instabilities were detected after gas exposures. Specific patterns of current instability were found characteristic to the gas exposure sequence and pump design parameters. Post-mortem examination revealed fields of dendritic protrusions on the cathode plates localized upon the highly ion bombarded cathode craters. Dendritic protrusion density was greatest in cathode craters adjacent to either virtual anode cells or standard cylindrical anode cells optimized for maximum current with close anode to cathode spacing. The dendritic protrusions were found to be responsible for field emission based unstable leakage currents. Various high stability diode SIP's were built and characterized. High stability was achieved through the implementation of the optimal combination of anode cell diameter, anode to cathode spacing, operating voltage and magnetic field as was found necessary to minimize the growth rate of dendritic protrusions. An ultra-high stability diode SIP was built and tested incorporating a muffin tin cathode shape in conjunction with the elimination of virtual anode cells. Single Penning cell optimization results are presented. J. B. McGinn FEI Company 7425 NW Evergreen Pkwy Hillsboro OR 97124 jbm(at)feico.com (503) 640-7580.

11:40am **VT-WeM11 Dry Vacuum Pumps for Semiconductor Processes - Guidelines for Primary Pump Selection*, P.A. Lessard,*** Varian, Inc.

Each of the many processes used for the production of ultra-large scale integrated (ULSI) devices or flat panel displays (FPD) has its own chemical and physical requirements. Many require a vacuum environment that may range from slightly below atmospheric to ultrahigh vacuum (UHV). Requirements for system cleanliness often dictate an oil-free pumping system. This paper discusses each of the process classes which require a dry primary vacuum pump - deposition (both physical and chemical), doping and material removal - and offers guidelines for the selection of the proper pump type. There are three classes of pump needed depending on the severity of the process - clean, moderate and harsh - with escalating complexity and cost for pumps made for the harsher environments. In addition to reviewing some of the latest developments in materials and vacuum design, particular attention is paid to operating experience with the very harshest processes - dielectric deposition and metal etch.

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