Thursday Afternoon, October 5, 2000

Vacuum Technology
Room 201 - Session VT-ThA
Pressure and Flow Measurements

Moderator: N. Peacock, HPS Division, MKS Instruments

2:00pm **VT-ThA1 A Practical Guide to the use of Bayard-Alpert Ionization Gauges*, J.H. Singleton,*** Consultant **INVITED**

The Bayard Alpert (BA) ionization gauge is the most common device used for the measurement of pressure in vacuum systems. There are however many potential problems in the use of the gauge and in the interpretation of the data that it provides. Perhaps the most basic problem is that the sensitivity of the gauge is substantially different for the common gases encountered in a vacuum system, including hydrogen, argon and nitrogen: if the gas composition is unknown, the absolute pressure cannot be determined. Nevertheless, in many systems, where the gas composition remains constant from day to day, the reading from a BA gauge can serve as a meaningful indicator of relative pressure. But if something goes wrong in the system, such as a water leak, the gauge alone can provide virtually no information as to the problem. This paper is primarily directed to the many other problems that can afflict a gauge; it is an attempt to give practical guidance on the use of a gauge, such as the appropriate connection to a system, and the operating techniques which can be used in order to obtain meaningful data. The topics addressed include gas pumping, by generation of ions, and by chemical interactions at the gauge filament; the change in gas composition by interaction at the gauge filament, and errors in pressure measurement including Barkhausen-Kurtz oscillations, electron stimulated desorption, and the x-ray effect. Factors which dictate the specific BA gauge selection, such as the method used for outgas, and the selection of the electron emitter, will also be discussed.

2:40pm **VT-ThA3 The Ultimate Resolution of Commercial Spinning Rotor Gauges*, J. Setina,*** Institute of Metals and Technology, Slovenia

The resolution of a spinning rotor gauge (SRG) depends primarily on the precision of measurement of the rotor deceleration rate and on the stability of the rotor residual drag. The ultimate resolution of the SRG can be achieved only when the ambient conditions allow stable residual drag. Our measurements of the residual drag were done in a sealed vacuum system with glass and stainless steel SRG thimbles and a small appendage ion pump. The system was placed in a thermostat together with the SRG suspension head. The suspension head was fixed to the laboratory wall virtually vibration free. The imprecision of the deceleration rate measurements is determined by the rotor frequency and the integration time. Old versions of SRG controllers were limited to the integration time of 30 seconds and the rotor operation frequency was preset to the narrow window of 405 to 415 Hz. Some new versions of controllers allow the extension of the integration time to 60 seconds and the operation of the rotor at frequencies up to 800 Hz. In the present study we varied the integration time and rotor frequency and observed the statistical distributions of sequential readings of the rotor residual drag. We found some instabilities of the gauge immediately after the re-acceleration of the rotor. Such instabilities were not reported previously and can affect the accuracy of pressure measurements. We also found that operation of the rotor at higher speeds increases the frequency dependence of the residual drag.

3:00pm **VT-ThA4 Extending the Upper Pressure Limits of Cold-Cathode Gauges*, B.R.F. Kendall,*** Elvac Laboratories*; E. Drubetsky,* Televac Division of the Fredericks Company

Processes occurring in magnetron-type discharges at normal and elevated pressures are compared. As pressures rise into the micron range, an increasing fraction of electron-molecule interactions occur at less than ionizing energies, and more of the ions collide with molecules on their way to the cathode. This results in fundamental changes in the discharge behavior. Discharge currents have been measured as a function of pressure and voltage up to 1 Torr for a number of magnetron and inverted magnetron electrode configurations. Additional experiments covered AC and pulsed operation. Practical aspects of high-pressure operation such as sputtering, electrode heating and the formation of polymer films are reviewed. The possibility of operating a double inverted magnetron at pressures approaching 1 Torr is discussed. Simple extended-range gauges of this type could replace complicated hybrid gauge combinations in some applications.

3:20pm **VT-ThA5 An Absolute Vacuum Gage Based on the Q Value of the Vibration of a Silicon Micro Cantilever*, Y. Kawamura,*** Fukuoka Institute of Technology, Japan

The Q value of a silicon micro cantilever has been measured in vacuum under the condition of ultra micro amplitude of the vibration. The maximum Q value of about 30000 was obtained in the vacuum of 1x10-6 torr. The measured Q value was in good agreement with the theoretical calculations based on the momentum exchanges between the cantilever and gas molecules. This system can be expected to be applied to a new type of absolute vacuum gage.

3:40pm **VT-ThA6 Performance of the Axial-symmetric Transmission Gauge Improved for the Measurement of Wide Pressure Range*, H. Akimichi,*** *N. Takahashi, T. Hayashi, Y. Tuzi,* ULVAC Japan, Ltd., Japan

The axial-symmetric transmission gauge (AT gauge) is originally developed for the pressure measurement in extreme high vacuum . The Bessel-Box type energy analyzer is placed between the ionizer and the ion collector with a secondary electron multiplier (SEM). The analyzer prevents the SEM from the effects of soft x-rays and electron stimulated desorption (ESD) ions produced in the ionizer. The lower limit of the pressure measurement was estimated to be about 10 @super -12@ Pa. The higher limit, however, was restricted to about 10 @super -6@ Pa due to the limit of pulse resolution of the SEM. In order to expand the pressure measurement up to high vacuum range (~ 10 @super -2@ Pa), the SEM was replaced by a Faraday cup type ion collector. The sensitivity factors of the gauge calibrated by the Conductance Modulation Method through the pressure range of 10 @super -10@ to 10 @super -6@ Pa were (6.7 ± 0.2) x 10 @super -3@ Pa @super -1@ for nitrogen and (2.3 ± 0.04) x 10 @super -3@ Pa @super -1@ for hydrogen, respectively. Comparison of the AT gauge to the extractor gauge (EG) and the spinning rotor gauge also gave the sensitivity factor of (5.8 ± 0.1) x 10 @super -3@ Pa @super -1@ for nitrogen in the pressure range of 10 @super -8@ to 10 @super -2@ Pa. When oxygen was introduced into the system with an AT gauge and a conventional EG, the nominal pressure readings of the EG showed higher values than those of the AT gauge. The difference increased with the increment of oxygen pressure and exposure, and decreased to zero by the bake-out of the system during the pumping process. The results show that the ESD ions, originated from the oxygen adsorbed on the grid surface of ionizer, are effectively separated from the gas phase ions by the energy analyzer in AT gauge.

4:00pm **VT-ThA7 Study of Thermal Transpiration of Capacitance Diaphragm Gauge by DSMC Method*, M. Hirata,*** *S. Nishizawa,* Electrotechnical Laboratory, Japan*; K. Watanabe,* CRC Corporation, Japan

Capacitance diaphragm gauge (CDG) is one of the most important vacuum gauges in low and middle vacuum ranges. Sensor head of a high precision CDG is kept for 45°C in order to minimize zero drift from room temperature fluctuation. The difference of temperature between the sensor head and the vacuum chamber gives a non-linear sensitivity of the gauge depending on the pressure less than 130 Pa due to thermal transpiration effect. Change in the sensitivity of about 4 % between molecular flow regime and viscous flow regime is significant for metrological use of the gauge. Empirical equation is widely used to explain the effect.@footnote 1@ In this study, by using a direct simulation Monte Carlo (DSMC) method @footnote 2@, pressure distribution in the connecting tube of the gauge was obtained under the pressure range from molecular flow regime to viscous flow regime (10@super -2@ - 10@super 2@ Pa) with taking account of temperature distribution along the connecting tube. Furthermore, the pressure dependence of sensitivity of CDG for several gases was derived from the pressure difference between the hot and cold ends. It was in good agreement with the pressure dependence of sensitivity obtained by static expansion system experimentally. The pressure distribution inside the connecting tube explains the mechanism of thermal transpiration phenomenon. This method can be also applied for complicated real system. @FootnoteText@ @footnote 1@ T.Takaishi and Y.Sensui, Trans.Faraday Soc. 59, 2503(1963). @footnote 2@ G.A.Bird, "Molecular Gas Dynamics and the Direct Simulation of Gas Flows", Clarendon, Oxford (1994).

4:20pm **VT-ThA8 Intelligent Flow Measurement and Control*, G.H. Leggett,*** *S.A. Tison, K. Tinsley,* Millipore Corporation

Vacuum processes typically use mass flow controllers for delivery of stable and known flow of gas to the process chamber. A variety of techniques are used for gas measurement and control, but the most prevalent is based on thermal transfer between a heated tube wall and the gas stream. This class of mass flow controller is referred to as a thermal mass flow controller.

These instruments have been in use for over 20 years and have evolved with time. Most recent versions are digital controllers which allow for digital setpoints and digital outputs. While advances have been made, MFCs are still custom manufactured for a particular gas and flow range, and their accuracies with process gases is typically no better than +/-5%. A new thermal based MFC has been developed which is capable of operating over extended ranges (500 to 1 flow ratios) and is able to achieve accuracies with process gases to within 1% of the MFC full scale. These accuracies are attained by using theoretical and empirical based techniques for relating the flow of the calibration gas to that of the process gas. Similar techniques are used for tuning of the MFC to ensure typical response times of one second. This paper describes the design, control techniques, calibration processes, and verification data for a thermal based mass flow controller with typical semiconductor process gases.

4:40pm **VT-ThA9 Summary of the Extreme High Vacuum and Surface Conditioning Workshop***, G.R. Myneni,* Jefferson Lab, US

Summary of the Extreme High Vacuum and Surface Conditioning Workshop The Vacuum Technology Division, the Mid-Atlantic Chapter of the AVS and the Jefferson Lab have sponsored a workshop on Extreme High Vacuum and Surface Conditioning at Jefferson Lab in June 2000. The main focus of the workshop was the limitations of various pumps in achieving XHV. The deliberations included kinetic pumps (turbo-molecular pumps), and capture pumps (ion pumps and cryopumps). Discussions on improvements in vacuum measurement techniques, extreme sensitivity helium leak detection practices, as well as the calibration of such advanced instrumentation systems were an integral part of the workshop. The various topics of interest that were covered in technical sessions include: applications of XHV technologies, a quantitative understanding of virtual leaks, means to eliminate or reduce the various gas sources in XHV systems, XHV materials, XHV vacuum system fabrication methods, XHV technology standards and development of low cost XHV systems. High lights of this workshop will be presented in this talk.

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