Vacuum Technology
Room 323 - Session VT+MS-ThM

Reproducibility, Precision, and Accuracy of Vacuum and Process Measurements

Moderator: R. Dobrozemsky, Vienna University of Technology, Austria

8:20am **VT+MS-ThM1 Component Requirements for ALD Technology***, **T.E. Seidel,*** Genus, Inc*; J. Mason, A. Londergan, S. Ramanathan,* Genus, Inc. **INVITED**

In the last several years Atomic Layer deposition (ALD) has emerged as a commercial technology. This technology is a variant of CVD, and therefore requires reactor and reactor related components for operation under well-controlled vacuum conditions. The requirements include fast gas switching, precisely controlled gas delivery systems with high performance Mass Flow Controller and / or Pressure Controllers, precise control of gas delivery line temperatures, heated walls and substrate susceptors, and quality down stream pumps to provide suitable flow and pressure capacity. Precursor usage and costs must be managed as well. Ancillary requirements include sensitive RGA's and fast response baratrons. There are gaps in he performance of components and the users requirements. As and example, today's fast gas switching valves have a lifetimes of the order of one to a few million cycles, but lifetimes of the order of 10 million cycle are needed. Substrate and gas line temperature control is critical. Additionally, because the precursors used in this technology are particularly reactive, the downstream pump components must be robust. This review provides a generic status and progress of the ALD field followed by generic requirements and requirement gaps for components used in ALD.

9:00am **VT+MS-ThM3 Towards Improved Control of PVD Processes for Nano-Structured Me-aC:H Coatings@footnote 1@***, **M.A. Taher**, B. Feng, A.G. Shull,* Caterpillar Inc.*; B. Johs, G. Pribil,* J.A. Woollam Company Inc.*; C.C. Klepper, E.P. Carlson, R.C. Hazelton, E.J. Yadlowsky,* HY-Tech Research Corporation

The reliability and durability of machine components such as bearings and gears can be enhanced through the application of metal-containing amorphous carbon (Me-aC:H) coatings, deposited by physical vapor (PVD) techniques such as sputtering. Commercial sputtering systems used for tribological coatings often employ computerized recipe managers to attain a certain level of reproducibility in the coating process. In most cases, these recipe managers control the deposition process through an open loop, time stepping approach where deposition parameters are varied within a particular time frame, and the process is repeated consistently from batch to batch. This type of control generally provides a level of reproducibility that is acceptable in applications where the component benefits from the coating but does not depend on it for full functionality. However, in applications where the coating is integrated into the machine component design, creating a prime-reliance on the coating, higher levels of coating consistency are required. Such levels may involve the adoption of in-situ sensors integrated with a closed-loop deposition control system. To build such a successful control system, knowledge of the relationships between the input process factors, the sensed variables, and the critical coating characteristics is necessary. In this study, a set of in-situ sensors that included a residual gas analyzer, an optical emission spectrometer, an optical absorption spectrometer, a Langmuir probe and a spectroscopic ellipsometer were explored. Three Design-of-Experiment (DoE) test runs were conducted which explored the effects of the coating process input factors on the output sensor signals and the critical coating characteristics. Results of these experiments are presented and a closed-loop control strategy is discussed. @FootnoteText@ @footnote 1@This work was partially supported by the Department of Commerce through its NIST ATP program award number 70NANBH0H3048.

9:20am **VT+MS-ThM4 A Portable Reference Gas for InSitu Calibration of Residual Gas Analyzers***, **R.E. Ellefson**, W.P. Schubert, L.C. Frees,* INFICON, Inc.

A new design for a portable source of reference gas with a fixed flow rate has been developed for producing a repeatable pressure in the ion source of a residual gas analyzer (RGA). The fixed flow rate of gas flowing through the fixed conductance of the isolation valve located between the process vacuum system and the RGA produces a repeatable pressure at the ion source of the RGA. The flow rate of 1x10@super -4@ Torr-l/s of Ar (and selected impurities) through the typical conductance of 10 l/s produces a reference pressure of 1x10@super -5@ Torr in the ion source. The ability to produce a repeatable pressure at the ion source on demand enables calibration of the mass scale, electron multiplier (EM) gain and measurement of absolute sensitivity. Data on sensitivity versus time is shown as an example of a quality assurance method for determining the stability of operation of an RGA and to determine when sensitivity or EM gain adjustment is necessary. The same reference gas source can be used for the calibration of closed ion source RGAs that have their own pumping system. The mechanical design minimizes the pressure burst at turn on and accomplishes viscous flow of the gas mixture. Data is presented on consumption rate, expected lifetime, shipping exemptions, temperature dependence of flow rate and species fractionation over lifetime. Methods for species abundance calibration in the RGA are also presented.

10:00am **VT+MS-ThM6 Specific Reference Calibration - A More Practical Approach to Vacuum Reproducibilty***, **G.D. Lempert**,* Soreq N.R.C., Israel

Increasing demands for quality control, both in production as well as in R&D, have resulted the proliferation of instrument measurement calibration. However, despite the fact that vacuum measurement is often made with significantly larger uncertainties and errors than other physical or thermodynamic quantities, the calibration of vacuum measurement instrumentation, in particular in the high vacuum range, is generally ignored or neglected. Objective practical difficulties have been identified and defined which make vacuum measurement calibration problematic and very often not practically feasible. The requirements for vacuum measurement uncertainties for most practical vacuum systems have been assessed. In an effort to make reproducible vacuum measurement more accessible, a more practical approach to vacuum measurement calibration has been defined and developed. The approach incorporates a vacuum calibration system, whose specifications and design satisfy the accuracy requirements for all but the most demanding users of vacuum technology. Calibration results are presented which provide justification for the approach. In addition the new approach defines a concept of Specific Reference Calibration, SRC. SRC does not necessarily provide calibration of the users vacuum measurement instruments. However SRC does enable practically defining and attaining reproducible vacuum process conditions in the users vacuum system, with significant advantages over conventional calibration. The new approach is aimed to overcome the difficulties, which have inhibited the proliferation of vacuum measurement calibration up to this time, and to facilitate the attainment of reproducible vacuum conditions and processes.

10:20am **VT+MS-ThM7 Characterisation of a Fully Automated, Static Expansion Vacuum Standard at the National Physical Laboratory, UK***, **J.C. Greenwood**, P. Carroll,* National Physical Laboratory, UK

A new, fully automatic, Static Expansion vacuum standard has recently been constructed to replace the existing manually operated system. The new instrument incorporates a number of design improvements which will be described. It is of all metal construction and operates from atmospheric pressure down into the UHV region. This paper discusses some of the procedures and measurements that have been performed to characterise the new standard. These include; mapping temperature distributions across and between the parts of the system; measuring the effects of inter-vessel valves on the pressure distribution; developing an improved measurement equation for the pressure generated in the standard, and comparison against existing vacuum standards that have been involved in recent international comparisons. We will show that calibration results taken from the new standard and the existing standards are equivalent.

10:40am **VT+MS-ThM8 A New Look at the Modulated Bayard-Alpert Gauge***, **B.R.F. Kendall**,* Elvac Laboratories*; E. Drubetsky,* Televac Division of The Fredericks Company

There is an increasing need for accurate vacuum measurements below 10@super-9@ Torr. Ordinary Bayard-Alpert gauges may have large and unpredictable errors at these pressures because of x-ray and other unwanted effects. Several special gauges have been developed to overcome these problems. One of the most cost-effective is the Modulated Bayard-Alpert Gauge (MBAG), first described by P.A. Redhead in 1960 and subsequently investigated in detail in many other laboratories. These gauges were widely used in Europe for several decades. We have evaluated several different MBAGs, ranging from first-generation glass-envelope types to a new miniature metal-envelope version. Performance data are given for operation in various modulation modes. An advantage of these gauge tubes is that, if necessary, they can be used as conventional BA gauge tubes with existing controllers. Some versions can be electronically adjusted for uniform sensitivity. The design of demodulation circuitry is discussed. X-ray errors causing gauges to over-read by several hundred percent at 10@super-10@ Torr can be essentially eliminated by using the modulation principle.

11:00am **VT+MS-ThM9 Dose Reproducibility in Axcelis GSD Implanters Using Stabil-Ion Gauge*, R.C. Johnson,*** INNOViON Foundry Ion Implantation Engineering

Long-term dose reproducibility and tool to tool dose matching in the Axcelis GSD end-station is critically dependent on process chamber pressure measurement and Pressure Compensation factor selection. Pressure Compensation factor (PCOMP) determination is well-established. Pressure measurement in the GSD end-station depends on accurate, repeatable gauge capability: incorrect pressure measurements directly lead to dose errors. For example, the dose equation using PCOMP tells us that for a modest PCOMP value of 30%, a chamber pressure measurement error of 2E-5 torr can result in a dose error up to 6% at normal process pressures. The original HCIG used for pressure measurement was not capable of meeting the requirements for good dose control since gauge to gauge differences were not controlled and gauge accuracy was only on the order of 30%. Axcelis introduced the Granville-Phillips 360 Stabil-Ion gauge to improve dose reproducibility through much improved gauge to gauge matching (+/-6%) and more accurate gauge output. This paper discusses the details of the care and feeding of the Stabil-Ion gauge system and it's impact on process dose and process trends.

11:20am **VT+MS-ThM10 How Stable are Spinning Rotor Gauges*, R.F. Chang,*** National Institute of Standards and Technology

The spinning rotor gauge is an excellent transfer standard in the pressure range of 0.0001 to 10 Pa (10@super -6@ to 0.1 torr) because of the remarkable stability exhibited by its accommodation coefficient. The stability comes from the fact that the accommodation coefficient depends mainly on the rotor surface properties of roughness and cleanliness, and does not change as long as these surface properties remain the same. Therefore, as common sense might dictate, one must avoid altering the rotor surface properties mechanically or chemically by not scratching the rotor surface or exposing it to corrosive agents. It is important that the accommodation coefficient remain constant when a spinning rotor gauge is moved from one laboratory to another such as in an inter-laboratory comparison or proficiency test. The level of confidence of the agreement between two laboratories is limited by how much the accommodation coefficient may have shifted in transit. For example, to transfer a spinning rotor gauge from one vacuum chamber to another, one must remove and reinstall the suspension head. During this procedure, the rotor comes into contact with the inner wall of the vacuum housing (thimble) and may be scratched. Sometimes the rotor is removed from the thimble for shipping, which requires additional handling of the rotor. By measuring the accommodation coefficient before and after various handling and cleaning procedures, we have quantified their effects on the accommodation coefficient. The results and impacts on gauge calibrations, including some surprises, will be presented and discussed.

11:40am **VT+MS-ThM11 Practical Procedures for the Frequency Corrections of the Spinning Rotor Gauge Residual Drag*, J. Setina,*** Institute of Metals and Technology, Slovenia

Spinning rotor gauge (SRG) uses a magnetically levitated steel ball as sensing element to measure low gas pressure, which is determined from the decay of the rotational speed of the rotor caused by the momentum transfer to the surrounding gas molecules. In addition we also have a small, gas pressure independent component to the measured SRG signal. This is called a residual drag (RD), and the main sources are eddy currents induced in the ball by asymmetries in the magnetic suspension field and eddy currents induced in surrounding metallic components by the rotating component of the ball's magnetic moment. In general, the RD depends on the ball rotational speed. The SRG operates the ball in a pre-selected frequency window, usually from 405 to 415 Hz, and the RD changes during the gas pressure measurement as the ball speed changes. The frequency dependence can be observed as saw-tooth variation of readings during continuous operation at constant pressure. For accurate measurements the frequency dependence of the RD has to be considered also. The commercial SRG controllers do not have the ability to take into account the frequency dependence of the RD and to make automatic on line corrections. The corrections have to be done separately by the user. We will describe our methods to determine the frequency dependence of the residual drag and procedures to perform the corrections to the pressure readings. The RD and its frequency dependence are unpredictable in magnitude for a given suspension of the rotor. Both can change considerably when the rotor is re-suspended. It is our experience that the frequency dependence remains reproducible during uninterrupted suspension, if vertical alignment or position of the suspension head stays well fixed. It is our experience also, that the behavior of the RD of the same ball is different in various suspension heads of different SRG controllers.

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