Vacuum Technology
Room: Laguna - Session VT+MN-MoM

MEMS Sensors, Vacuum Gauges, Measurements and Pumps
Moderator: J. Fedchak, National Institute of Standards and Technology

8:20am **VT+MN-MoM1 Practical Issues and Applications for Vacuum and Hermetic Microsystems Packaging**, *L. Fang, D. Chu,* ***K. Ewsuk***, Sandia National Laboratories **INVITED**

Microsystems packaging involves physically placing and electrically interconnecting a microelectronic device in a package that protects it from and interfaces it with the outside world. When the device requires a hermetic or controlled microenvironment, it is typically sealed within a cavity in the package. Sealing involves placing and attaching a lid, typically by welding, brazing, or soldering. Materials selection (e.g., the epoxy die attach), and process control (e.g., the epoxy curing temperature and time) are critical for reproducible and reliable microsystems packaging. This paper will review some hermetic and controlled microenvironment packaging at Sandia Labs, and will discuss materials, processes, and equipment used to package environmentally sensitive microelectronics (e.g., MEMS and sensors).

9:00am **VT+MN-MoM3 New NIST Comparison Method Calibration Service for Vacuum Gauges Based on MEMS Pressure Sensors**, ***J.H. Hendricks***, *D.A. Olson*, NIST

A new calibration service based on a secondary pressure transfer standard spanning the pressure range from 0.65 Pa to 130 kPa (5 mTorr to 975 Torr) has been developed at NIST. Until now, vacuum gauges in this range could only be calibrated using the NIST Ultrasonic Interferometer Manometers (UIMs). However, many customers desire direct traceability to NIST but cannot justify the cost of the NIST UIM calibrations. The new service follows a similar model of other calibration services where a lower cost, and less accurate service is offered to customers who do not require the lowest uncertainty possible but still desire direct NIST tracibility. The comparison method utilizes a high accuracy transfer standard package that consists of a 133 Pa (1 Torr) Capacitance Diaphragm Gauge (CDG), a 13.3 kPa (10 Torr) CDG and a 130 kPa (975 torr) MEMS type Resonance Silicon Gauge (RSG) all encased in a temperature controlled enclosure that is periodically calibrated against the NIST 160 kPa UIM and 140 Pa oil UIM primary pressure standards. Due to the superior calibration stability of the MEMS based RSG, the transfer standard package, and ultimately the comparison method vacuum gauge service, provides expanded uncertainties as low as 0.05 % from 1.33 kPa to 130 kPa (10 Torr to 975 Torr) and 0.3 % from 1.33 Pa to 1.33 kPa (0.01 Torr to 10 Torr).

9:20am **VT+MN-MoM4 Pirani for Industrial Processes**, *B. Andreaus, R. Enderes,* ***M. Wuest***, INFICON Ltd, Liechtenstein

In modern Pirani heat transfer gauges a filament is usually kept at a constant temperature and the necessary heating power is measured as a function of pressure.

Pirani gauges operated in coating and etching applications suffer from degradation due to process contamination or corrosion. Eventually, the Pirani may fail because the filament is etched away, its resistance and/or its emissivity have changed. Standard procedure for those processes is to use a corrosion resistant filament material adapted to the process in question, e.g. Nickel. Yet the choice of suitable filament material is limited as it needs to be manufactured as very thin coils, be electrically conducting, have a high and well-defined temperature coefficient for the resistance and be chemically inert. For some of the latest manufacturing processes in semiconductor industry none of the available filament materials is sufficiently resistant against corrosion.

We will present here a different approach in that we present first data on a coated Pirani sensor. The coating allows for a much broader field of application as electrical and mechanical requirements of the filament are separated from its chemical properties. Chemical stability is solely due to the coating, all other requirements, unaffected by the coating, can be met using a standard filament material.

9:40am **VT+MN-MoM5 Nitrogen Incorporated Ultrananocrystalline Diamond as a Robust Cold Cathode Material for Miniature Mass Spectrometry Application in Space Exploration**, ***X. Wang***, University of Puerto Rico; Argonne National Laboratory, *S. Getty*, NASA Goddard Space Flight Center, *A.V. Sumant, O.H. Auciello*, Argonne National Laboratory, *D. Glavin, P. Mahaffy*, NASA Goddard Space Flight Center

Ultrananocrystalline diamond (UNCD) thin films have been investigated for over a decade for application to electron field emission devices since they offer very low threshold voltage (1-3 V/µm) and reasonably stable field emission with time. Due to the small grain size (2-5 nm) and unique atomically abrupt grain boundary structure containing mixed sp^2/sp^3 carbon bonding, it has been postulated that field emission occurs mainly at the grain boundary due to the high field enhancement effect at the grain boundary and stable field emission has been observed independent of surface geometry or film thickness. In addition to low power consumption and potential for miniaturization, robust field emission materials are compelling for applications as long life electron sources for mass spectrometers for space exploration where electron sources are exposed to harsh environments. A miniaturized mass spectrometer under development for *in situ* chemical analysis on the moon and other planetary surfaces requires a robust, long-lived electron source, to generate ions from gaseous sample using electron impact ionization. To this end, we have explored the field emission properties and lifetime testing of nitrogen-incorporated ultrananocrystalline diamond (N-UNCD). The N-UNCD films were synthesized in a microwave plasma chemical vapor deposition system by introducing nitrogen in the Ar/CH_4 gas chemistry. Characterization of the N-UNCD films were carried out by using visible and UV Raman spectroscopy confirming characteristic signature of a good quality N-UNCD film. We will present results revealing that UNCD films with nitrogen incorporation during growth yield stable/high field-induced electron emission in high vacuum for up to 1000 hours.

This work was done with support from the NASA Astrobiology Science and Technology Instrument Development Program, under Grant Number 07-ASTID07-0020, and the NASA Goddard Space Flight Center Internal Research and Development Program. Use of the Center for Nanoscale Materials was supported by the U. S. Department of Energy, Office of Science, Office of Basic Energy Sciences, under Contract No. DE-AC02-06CH11357.

10:40am **VT+MN-MoM8 The Pumping Synergies of Integrated NEG and SIP Pumps for UHV Applications**, ***A. Bonucci***, *A. Conte, L. Caruso, L. Viale, P. Manini*, SAES Getters S.p.A., Italy

A variety of vacuum systems, such as particle accelerators, synchrotrons, surface science chambers or laboratory equipments, do require the achievement of very high or even extremely high vacuum conditions(UHV-XHV). To this purpose, Ion pumps and Non Evaporable Getter (NEG) technologies are widely applied, since they complement each other effectively. Ion pumps remove ungetterable species like noble gases and methane, while the NEG provides a constant and large pumping speed for all the other gases, in a very compact volume.

So far ion and NEG pumps have been mostly used as separate units mounted in separate part of the vacuum system. In this paper, we investigate how overall pumping performances are influenced by the mounting geometry of the two pumps. In particular we will show that a remarkable synergic effect arises when the two pumps are integrated into one unit having optimized design, known as NEG^+.

This configuration allows to minimize the detrimental effect given by outgassed species released by the SIP [1,2]This increases the real pumping speed of the SIP, generally masked in the UHV range by gas desorption from SIP internal surfaces. This effect is particularly noticeable for ungetterable gases like Argon and Methane.

The resulting pumping speed of the NEG^+ is therefore larger than the sum of the pumping speed of the two separated pumps.

Reducing the degassing effect also increases the overall pumping efficiency at the lower pressure.

In fact, the presence of oxides and nitride compounds onto the cathode surface are known to slow down the diffusion of hydrogen and helium into the cathode[3], which is mainly an ion implantation driven process.

In the present paper we discuss some of these effects as well as the synergies arising from the NEG+ integrated design. A specific focus will be given to argon [4] and methane, which are important gases to consider in a variety of application including electron microscopy and electron/ion optics.

[[1]] K.M.Welch, D.J.Pate and J.Todd, “Pumping of helium and hydrogen by sputter-ion pumps. II. Hydrogen pumping”, J.Vac.Sci.Technol.A 12(3), May/Jun 1994

[2]A Calcatelli et als. “Study of outgassing of sputter-ion pump materials treated with three different cleaning procedures”, Vacuum vol. 47 n. 6-8, 1996

[3]M. Audi and M. De Simon, “The influence of heavier gases in pumping helium and hydrogen in a an ion pump”, J. Vac. Sci. Technol. A 6 (3), May/Jun 1988

[4]D. Andrew, D.R. Sethna and G.F. Weston, “Inert-Gas pumping in a magnetron pump”, proc. 4th AVS, (1968)

11:00am **VT+MN-MoM9 NEG+: A Novel Route to Compact, High Performance Pumping in UHV-XHV Vacuum Systems**, ***P. Manini****, A. Bonucci, A. Conte, L. Viale, L. Caruso*, SAES Getters S.p.A., Italy

The need to miniaturize and reduce the footprint of vacuum systems is growing in a variety of industrial and R&D applications, encompassing scanning and transmission microscopes, vacuum chambers for surface science, material preparation or portable analyzers.

This is posing serious challenges to the UHV pumping groups in term of design, space constraints and weight. Even in large vacuum systems, like synchrotrons and particle accelerators, fitting the vacuum pumps is becoming increasingly difficult, due to the presence of magnets, power stations, a variety of diagnostic tools and instrumentation, as well as service and experimental devices. Non Evaporable Getter (NEG) pumps are very compact and light, vibration-free devices, able to deliver extremely high pumping speed per unit volume with minimal power requirement. One of the main drawbacks of NEG pumps is their inability to pump noble gases and methane. In the present paper the design of a novel combination pump, called NEG^+, is introduced. In the NEG^+, the getter cartridge acts as the main pumping element, leaving to an ancillary and small sputter ion pump the task of removing noble gases and methane, which are not pumped by the NEG. Pumping of all the gases as well as the ability to provide a pressure reading, so helpful in a variety of applications, is therefore possible in one single and compact unit. The design of the NEG^+ is optimized to ensure a high integration between the getter element and the ion pump. This provides large pumping speed in a very compact volume as well as interesting synergies in the pumping of gases at the UHV level. The design and general properties of this new pump, including pumping tests and example of applications will be reported.

11:20am **VT+MN-MoM10 Direct Simulation Monte Carlo Modeling of Miniature Vacuum Pumps**, ***B.J. Davis****, R.W. Hill, P.H. Sorensen, R.J. Kline-Schoder*, Creare Incorporated

NASA and other organizations have pressing needs for miniaturized high vacuum systems. Recent advances in sensor technology at NASA and commercial laboratories have led to the development of highly miniaturized time-of-flight, quadrupole, and ion trap mass spectrometers. However, high vacuum systems of adequate performance continue to be too large, heavy, and power hungry for man-portable mass spectrometers or spectrometers deployed on UAVs, balloons, or interplanetary probes. Terrestrial, man-portable applications impacted by this problem include military and homeland defense systems for detecting hazardous materials as well as portable leak detectors for commercial use.

For over 10 years, Creare has been developing the technologies required to design and build miniature high vacuum pumps. We have designed and built pumps that are as small as a D-cell battery, reach an ultimate pressure of 10e-7 torr, have a flow rate in excess of 5 L/s, and spin at 200,000 RPM. As mass spectrometers are reduced in size, the vacuum system requirements can be relaxed. As a consequence, Creare is developing an extremely low-cost and rugged high vacuum system whose performance is optimized for miniature mass spectrometers. The vacuum system is based on an innovative molecular drag pump designed to match the requirements of portable analytical instruments.

To support our miniature vacuum pump design efforts, Creare has developed statistical models of molecular drag pumps (MDP) in the free molecular flow regime. In this method, individual molecular trajectories through a simplified three-dimensional representation of the pump are calculated. The initial positions and velocities of the particles as they enter the pump are randomly generated, with statistics consistent with the gas states at the inlet and outlet of the pump. The free-molecular statistical simulation can be used to determine the probability that a molecule entering the pump at the inlet (outlet) exits through the outlet (inlet). In the free-molecular regime, these probabilities are sufficient to determine the pump’s capabilities for compression, flow rate, etc.

We will describe the modeling methods, the verification of the models using previously published data, and the results of special experiments performed to verify that the models can be used to support new miniature pump designs.

11:40am **VT+MN-MoM11 Improvements in the Performance of Turbomolecular Pumps Beyond the Molecular Range**, ***A. Chew****, B. Brewster, I. Olsen, S. Ormrod*, Edwards Ltd, UK

A new range of turbomolecular pumps, nEXT, has been developed. This incorporates a new damping mechanism and pumping stage options. A new Siegbahn drag stage in combination with a regenerative mechanism are described in their combination with pure turbomolecular stages. Consequent increased backing pressures, high compression ratios and the facilitisation of a boost port being used to back other turbos will be described.

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