Vacuum Technology

Room: 618 - Session VT-WeA

Miniature, Portable and Space Vacuum Applications

Moderator: J.H. Hendricks, National Institute of Standards and Technology

1:40pm **VT-WeA1 Vacuum Pumping Requirements for Miniature Mass Spectrometers**, ***R. Ellefson***, Consultant

A trend in mass spectrometers (MS) for gas analysis is miniaturization to occupy less volume when attached to vacuum chambers and additionally to decrease weight and power consumption for portable and space probe instruments. This presentation identifies the pumping system requirements for different MS applications. When sample impurities like H_2, H_2O, CO, N_2, O_2 and CO_2 are being analyzed, a lower base pressure (e.g. $<10^{-8}$ Torr) is required for low background ion currents from MS outgassing resulting in a low detection limits for these species in the sample. For analyzing hydrocarbons and other species with masses greater than 44, a higher base pressure (e.g. 10^{-6} Torr) can be tolerated if the hydrocarbon background is kept low by initial cleaning and operating methods. Factors dictating the operating pressure of the MS and the resulting gas throughput are presented together with scaling rules for miniaturization. Given the pumping requirements, a high vacuum pump can be selected or adapted. A comparison is made of throughput and capture pumps for MS applications focusing on the end use of the MS as a process monitor or a field portable instrument. Examples from literature are given. Finally the pumping system for gas sampling and pressure reduction to the MS is addressed.

2:00pm **VT-WeA2 Miniature High Vacuum Pump for Mars Analytical Instruments**, ***R.J. Kline-Schoder***, *P.H. Sorensen*, Creare Incorporated **INVITED**

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 mass spectrometers, and miniaturized versions of other analytical instruments are under development. However, the vacuum systems required to support these sensors remain large, heavy, and power hungry. In particular, high vacuum systems of adequate performance continue to be too large for systems such as time-of-flight, quadrupole, and ion trap mass spectrometers that are intended to be man-portable or to be deployed on UAVs, balloons, or interplanetary probes. The 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 10 years, Creare has been developing the technologies required to design and build miniature high vacuum pumps. During this time, we have designed and built two small high vacuum pumps that have the following pumping characteristics: a compression ratio for air that is greater than 10^8; a pumping speed of about 5 L/sec; and 10 W power consumption for an exhaust pressure of 10 Torr. The smallest of these pumps has a mass of 130 g, a diameter of 1.3 in., and an overall length of 2.3 in (i.e. the size of a c-cell battery). The slightly larger pump has a mass of 500 g, a diameter of 2.0 in., and an overall length of 4.6 in (i.e. the size of a soda can). The larger version is being space qualified for use on a NASA Mars mission scheduled for launch in 2009. The challenges of designing and building miniature turbomolecular/molecular drag pumps include: design of pump geometry in regions where little data exist, the need for precision machining of components, and the electromagnetic and mechanical design of very high speed, efficient, miniature electric motors. Data will be presented that show the performance, over a wide temperature range, of a brassboard prototype of the pump NASA currently plans to deploy on the Mars Science Laboratory mission.

2:40pm **VT-WeA4 Development of MEMS for Space Applications**, ***P.W. Valek***, *D.J. McComas*, Southwest Research Institute **INVITED**

Space flight missions have critical requirements such as low mass, low power, and high reliability. The technology of Micro-Electro Mechanical Systems (MEMS) naturally has many properties that address these space flight requirements. MEMS devices are built using the same techniques that have been developed by the semiconductor industry so they share the same benefits that we have come to expect from modern electronics, i.e., reduced size, low mass, low cost, etc. While there has been significant research on how MEMS technology operates in the more “normal” environments encountered for consumer electronics and biological application, for the benefits of MEMS technology to be fully realized for space applications their operation in a vacuum needs to be understood. The relative importance of different physical mechanisms shifts when going from a macro-scale world to that of the micron scale. For example, surface tension and stiction are easily dealt with on the macro scale but become significant problems on the MEMS scale. We will discuss the challenges and opportunities that are present for MEMS technology when used in space or any vacuum environment. For example, MEMS oscillators operating in vacuum have Q-values many orders of magnitude larger than when operated at atmospheric pressures.[1] We will present results from our testing of MEMS devices in a vacuum environment and discuss the implications for further space instrumentation development.

[1] McComas et al., "Space applications of microelectromechancial systems: Southwest Research Institute vacuum microprobe facility and initial vacuum test results", Rev. Sci. Inst., Vol 74, 2003.

4:00pm **VT-WeA8 The Role of Vacuum-Based Processes in Developing High Performance Chemical Microsensors**, ***S. Semancik***, *D.C. Meier, J.K. Evju, M.J. Carrier, C.B. Montgomery*, National Institute of Standards and Technology, *K. Newcomb, C.L. Keast*, M.I.T. Lincoln Laboratory **INVITED**

There is a growing demand for solid state chemical microsensors that are capable of analyzing gas phase compositions encountered in a wide range of application areas, from process control to space exploration and health care. In certain cases these small sensing devices would be used instead of more expensive and cumbersome instrumentation, and in others they would enable chemical monitoring within dispersed multipoint networks which are not amenable to instrument-based measurements. While the necessary detection characteristics vary with application, the defense/homeland security sector provides what are arguably some of the most demanding performance requirements for such microsensors: rapid detection; sensitivities to hazards such as chemical warfare agents (CWAs) and toxic industrial chemicals (TICs) at nmol/mol (ppb) and even pmol/mol (ppt) concentrations; reliability and robustness to avoid false target readings in practical backgrounds; and, extended lifetimes. This presentation will focus on vacuum-based processing and vacuum-related phenomena that enable the fabrication and evaluation of MEMS-based, chemiresistive microsensor array devices being developed for detection of low level chemical hazards in air-based backgrounds (including interference compounds). Microarray device platforms (1000s of devices on 6 inch wafers) are fabricated at a silicon foundry through a multi-step processing schedule including nearly two dozen controlled vacuum procedures (e. g. - etching, CVD, PVD). The incorporation of nanostructured sensing materials onto the ~ 100 µm (microhotplate) array elements of our devices is achieved using a variety of methods, including thermally activated, self-lithographic CVD (at 3 Pa), and an ion etch pre-process (at ~ 10^{-5} Pa base pressure) has been shown to produce good sensing material contact to the microdevice electrodes, which is critical for attaining high sensitivity and reliable operation. In addition, vacuum phenomena come into play while evaluating the microarray sensors, since very low concentrations of target analytes (often with low vapor pressures) must be injected into air-based backgrounds and delivered to a device exposure point within our testing system. Technical aspects (enhanced analytical content for species recognition, redundant elements, etc.) that have allowed us to achieve sub-ppb CWA simulant detection with our microsensors will be discussed.

4:40pm **VT-WeA10 A Novel Electrostatic Ion Trap Mass Spectrometer**, *A.V. Ermakov*, ***B.J. Hinch***, Rutgers University

We have developed, built and tested several prototypes of a novel mass spectrometer which operates with an entirely new basic principle - i.e. using an electrostatic resonance ion trap. This mass spectrometer has an unlimited mass range, is capable of achieving higher sensitivity, and has much faster scan rates than the widely used (larger size and) more complicated quadrupole or magnetic sector mass spectrometers. In addition, the new mass spectrometer is very compact (less than 2" long), and requires very small power (in the mW range, excluding ionizer) as it uses only static potentials and a very small RF voltage (in the 100mV range). The high sensitivity of our mass spectrometer at low background pressure (below 10^{-8} torr) allows for the possible construction of an easily portable analytical instrument (handheld, if necessary.) A portable system could use only a battery powered comp act ion pump, and would not require (noisy, bulky, and energy consuming) mechanical pumps.

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