Tuesday Morning, October 19, 2010

Vacuum Technology
Room: Laguna - Session VT+MS-TuM

Outgassing, Contamination Control, and Process Modeling
Moderator: M. Wuest, INFICON, Liechtenstein

8:00am **VT+MS-TuM1 Reduction of Hydrogen Content in Stainless Steel Vacuum Components**, ***L.L. Wang***, *R.Y. Weinberg, K.A. Lao*, Los Alamos National Laboratory

Hydrogen is dissolved in stainless steel during the initial phases of production and fabrication. At room temperature, the dissolved hydrogen slowly diffuses out of the stainless steel. For stainless steel vessels assembled from commercially available vacuum components, we consistently measured constant rates of gas pressure increase in these sealed stainless steel vessels after they had been evacuated to 1×10^{-7} torr. The pressure in a 97 cc stainless steel vessel can reach up to 0.8 torr in six months at room temperature. The gas accumulated in these vessels, previously vacuum baked at 150°C for 48 hours to remove adsorbed gas, was analyzed to be essentially hydrogen. To determine how effective high-temperature vacuum bake out is in reducing the hydrogen content in the stainless steel components, we undertook a study that involved vacuum bakeout of the components at 400°C for 10 days and analysis of the hydrogen contents of the components with and without the vacuum bakeout. The hydrogen concentrations were measured by a LECO analyzer. The results will be presented and compared with that predicted by the Fick's law of diffusion.

8:20am **VT+MS-TuM2 Hydrogen Outgassing in a Small Vacuum Chamber**, ***R.F. Berg***, National Institute of Standards and Technology

In a closed vacuum chamber, the problem of hydrogen outgassing from stainless steel increases with both the temperature and the chamber's surface-to-volume ratio. This talk will describe the outgassing in a chamber that is used to measure the vapor pressures of organic compounds in the range from 1 Pa to 100 kPa. The chamber, which is a small manifold built from stainless steel fittings and two capacitance diaphragm gauges, has a combination of challenges not usually present in a larger apparatus at room temperature. (1) Its volume of only 29 cm^3 created a relatively large surface-to-volume ratio. (2) Operating at temperatures as high as 200 °C greatly increased the outgassing rate. (3) The pressure gauges limited the maximum allowed bakeout temperature.

Closing the valve to the vacuum pump caused the pressure to increase nonlinearly with time. The initial rate slowed during several hours and usually became linear with time within one day. Intermittent pumping during one month at 200 °C showed that the linear rate decreased with an exponential time constant of approximately 11 days, which was consistent with the diffusion of hydrogen from the stainless steel fittings. Understanding this behavior is important because a pressure increase of 1 Pa/day (3×10^{-10} Pa m^3/s) can cause a significant error in the vapor pressure measurement. A model that accounts for the diffusion of hydrogen in the chamber wall and its nonlinear accumulation in the chamber volume will be compared to the pressure measurements.

8:40am **VT+MS-TuM3 Point-of-Use Abatement Devices and Exhaust Management Strategies**, ***M. Sherer***, Sherer Consulting Services, Inc. **INVITED**

Semiconductor processes emit various contaminants which require exhaust management and in some cases point-of-use (POU) abatement. It is important to understand process exhaust management strategies, and to select the best, lowest cost-of-ownership POU abatement devices. This presentation will discuss these topics and provide relevant technical information.

9:20am **VT+MS-TuM5 Novel Instrument Capable of Efficient Gas Exchange to Remove Gas-phase Contamination in Complex Volumes Without Purging or High Vacuum**, ***J. Brown***, *J. Hochrein, S. Thornberg*, Sandia National Laboratories

Countless systems used in research and in industry contain complex assemblies that are sealed in some type of enclosure, meant to isolate them from the harsh operating environment of the open atmosphere and to maintain a pristine internal atmosphere. Unfortunately, the internal atmosphere of any sealed component or system is, in the long-term, only as clean as the materials sealed within its enclosure. Over time, moisture or other volatile contaminants initially trapped in the materials can begin to evolve and accumulate with potentially detrimental effects on the functionality of the component. This problem can be extremely difficult to address, depending on the physical and mechanical constraints of the particular system. Recently, an instrument was developed at Sandia National Laboratories that can "clean" the internal atmosphere of a critical optical component that cannot be subjected to conventional conditioning methods (such as N_2/Ar purge, high-vacuum pumpdown, etc.). By using multiple pressurization and evacuation cycles tightly controlled within a narrow ±2 psig window, the instrument fully and efficiently exchanges the liters of moisture- and contamination-laden internal gas of the component with clean, dry N_2. This process is repeated as moisture from the internal materials diffuses back into the gas phase until, over time, the source of the moisture is depleted. This instrument has been successful in reducing the equilibrium gas-phase moisture levels in the optical component from the thousands of PPMv (parts per million by volume) to single-digit PPMv. This instrument, called the "Automated Pressure Cycler," will be discussed in detail.

10:40am **VT+MS-TuM9 Modeling, Design, Fabrication, and Characterization of a Pulsed Vacuum System**, ***Z.C. Leseman***, *J. Butner*, University of New Mexico

Systems utilizing low to medium vacuum levels are becoming increasing popular due to packaging of micro and nanoelectronic devices, exploration of surface phehomena, and gas-phase etching of materials. In this work, pulsed vacuum systems are modeled, designed, fabricated, and characterized. Modeling efforts focus on methods for calibration of volumes, pump-down / pressure-up times, and vacuum system configuration considerations. As a result of this systems of linear equations are developed and solved, as well as systems of coupled differential equations which are solved analytically and numerically (when necessary). As a result of this modeling effort a new method has emerged for vacuum processing at discrete pressures and discrete times. Experimental validation is presented in regards to specific applications: MEMS environmentally dependent stiction failure, vapor phase lubrication of MEMS, and XeF_2 vapor phase etching of Si.

11:00am **VT+MS-TuM10 Effects of Inlet Pipe Diameters on Pumping Performance of Turbomolecular Pump**, ***F.-C. Hsieh***, *D.R. Liu, F.-Z. Chen*, National Applied Research Laboratories, Taiwan

11:20am **VT+MS-TuM11 Optimal Configuration of a Radiometer Array for Low Pressure Applications**, ***B. Cornella***, *A. Ketsdever*, University of Colorado at Colorado Springs, *N. Gimelshein, S. Gimelshein*, University of Southern California

A thin vane with a temperature gradient immersed in a rarefied gas will experience a force which tends to move the vane from the hot to the cold side. The radiometric force, as it is called, is the force that drives the Crookes radiometer. Applications of radiometric forces have been limited to date to high-density microdevices, most notably the atomic force microscope. However, applications can also involve larger devices in the low pressure regime (same equivalent Knudsen number). For an example, radiometric forces can act as a propulsion system to compensate disturbing forces on a vehicle traveling high in the atmosphere. Recent studies have shed new light on the relative influence of bulk radiometer area versus edge on force production, indicating that these effects are on the same order of magnitude in the Knudsen regime where the force is maximized (Kn=0.05). An experimental study has been conducted to investigate the impact of vane separation distance for a multiple-vane radiometer. This study is a first step in maximizing the force per unit volume (or mass) by optimizing the area versus edge geometries. Furthermore, this study provides experimental validation for today's numerical models involving rarefied radiometric flows. To emulate a near space environment, a 39" diameter vacuum chamber was used to set a range of pressures for the experiment from 0.1 to 10 Pa (corresponding to Knudsen numbers of 1.3 to 0.01). The experiment measures the total force of a one by three array radiometer configuration and compares it to a single vane with the same active area. Each individual radiometer vane consisted of a 40 mm square Peltier thermoelectric cooler where the temperature difference across the two surfaces was actively maintained at approximately 25 K. The relative separation between the vanes was varied from 0% (single vane setup) to 100% of the size of the individual vane element and the maximum forces between these varying configurations compared. Preliminary experimental results suggest that the total force produced by the overall radiometer increases with gap distance. Numerical results suggest that the optimum separation distance for maximum force production is around 75% of the vane height.

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