Vacuum Technology
Room: 202 C - Session VT-MoA

Dynamic Vacuum Processes and Outgassing
Moderator: J.A. Fedchak, National Institute of Standards and Technology (NIST)

2:40pm **VT-MoA3 Modeling and Simulation of Fast Flows in the Vacuum Regime**, ***S. Pantazis***, Physikalisch-Technische Bundesanstalt (PTB), Germany **INVITED**

It is well known that the Navier-Stokes-Fourier formulation may provide inaccurate solutions for low pressure gas flows. On the other hand, the numerical solution of the Boltzmann equation poses up to date great challenges in problems of engineering interest. Several modeling techniques have been developed to provide results in corresponding ranges of the vacuum regime. Among them is the Direct Simulation Monte Carlo (DSMC) method, which is usually the method of choice for the simulation of fast flows due to its simplicity and the fact that it can accurately reproduce solutions of the Boltzmann equation in the whole range of the Knudsen number. Problems arise when the density levels increase, as the computational effort may reach prohibitively high levels. For the simulation of such flows, a method able to deal with locally rarefied flows may be required if the problem is not susceptible to modeling simplifications without significant sacrifices in accuracy. Hybrid particle-continuum algorithms are often used as viable alternatives for this purpose. The flow domain is decomposed in different regions based on appropriate criteria, such as the local Knudsen number, and treated either by a continuum or a particle method. However, such methods are less frequently encountered in problems of unsteady nature due to modeling difficulties.

An efficient implementation of a hybrid simulation algorithm is presented. The characteristics of such algorithms, such as the coupling at the interface between the two methods, as well as computational features, such as parallel computing capabilities and arbitrary geometry handling, are explained. The main differences with other works in the literature are highlighted. The validation is performed through comparison with simplified but relevant cases of fast flows in the vacuum regime, such as shock tube and orifice flow, and the benefits of the approach as opposed to pure DSMC are commented. Furthermore, a challenging application of the code on a practical problem is discussed. A dynamic vacuum expansion calibration facility is studied, constructed in PTB to study the response time of vacuum gauges to rapid pressure changes, such as in the control of load locks in industrial applications. The pressure may change from 100 kPa to 100 Pa in less than 1 s by expansion to a vessel with a larger volume through a fast opening gate DN40 valve. Experiments have been performed with capacitance diaphragm gauges with improved electronics, leading to an update time of 0.7 ms. The modeling approximations are explained and measurements are compared with simulation results.

3:40pm **VT-MoA6 Capacitance Diaphragm Gauges with Sub-Millisecond Measuring Rate**, ***Ch. Berg***, *M. Wuest, F. Mullis, H. Hanselmann*, INFICON Ltd, Liechtenstein

Capacitance Diaphragm Gauges (CDG) are used in many pressure control applications in industry. In a typical application the CDG pressure signal is used in the butterfly valve controller to regulate the pressure in a vacuum chamber. The control loop performance is often limited by the measuring rate of the vacuum gauge. Currently the fastest commercially available CDG has a time constant of about 8 ms, while most CDGs have rates between 20 and 30 ms. In this talk we will present a CDG that can deliver a new pressure value in less than 1 ms.

4:00pm **VT-MoA7 Measuring Static Outgassing Pressures at Elevated Temperatures**, ***L. Wang***, Los Alamos National Laboratory

In our material thermal aging studies, we need to accurately measure pressure of gas evolved from the material at elevated temperatures to reliably measure the quantity of total gas released. MKS 121A absolute capacitance manometer was selected for this in-situ pressure measurement because its electronic components are contained in a separated housing that can be located outside of the heating chamber. In this configuration, the sensor and the connecting cable can operate at an elevated temperature up to 150°C. To determine the performance of this type of gauges, pressure measurements were conducted with seven MKS 121A sensors of three different ranges (10, 100, and 1000 torr) in an oven at 25, 55, 80, and 145°C, and the measurements were compared with two reference pressure gauges (MKS 690A) located outside of the oven. The performance test results, the temperature effects on zero drift and pressure error, and the pressure measurement results of a static outgassing run with three materials at 145°C will be presented and discussed.

4:20pm **VT-MoA8 Gas Permeation Measurements on Low Temperature Cofired Ceramics**, ***R.S. Goeke***, *S.X. Dai, R.K. Grubbs*, Sandia National Laboratories

Commercial low temperature cofired ceramic (LTCC) technology is established in microelectronics and microsystems packaging, multichip and radio frequency (RF) modules, and sensors. The ability to combine structural considerations with embedded traces and components using laminated glass-ceramic tapes has created solutions to unconventional packaging requirements of micro-electro-mechanical systems (MEMS) devices. Many MEMS devices such as resonators are very sensitive to pressure and require packaging in a vacuum environment. Attaining and maintaining desirable pressure levels in sealed vacuum packages requires knowledge of the permeation characteristics of the vacuum envelope and the sealing materials.

An experimental system to measure the time dependent gas permeation through LTCC at temperatures from room temperature to 500°C has been developed. This system utilizes a membrane technique in which a gas is allowed to permeate through a test sample, held at a constant temperature, into a high vacuum chamber where it is detected using a mass spectrometer. The gas permeation value is determined from the steady state gas flux through the sample. The gas diffusivity and solubility in the material were calculated using data from the time dependent approach to the steady state condition. The gas-solid permeation data for helium and hydrogen through DuPont 951 and 9K7 LTCC will be presented and compared to the permeation through other common vacuum envelope materials such as glasses and high-purity alumina ceramics. Application of the permeation data to the prediction of vacuum levels inside hermetic LTCC packaged devices will be discussed. This data can further be utilized in designs to create LTCC packages that meet specific pressure/time operating requirements.

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