Vacuum Technology Division
Room 203B - Session VT-MoA

Pumping and Outgassing

Moderators: James Fedchak, National Institute of Standards and Technology, Giulia Lanza, SLAC National Accelerator Laboratory

1:20pm **VT-MoA-1 Gas Adsorption and Desorption Properties of 3D Printed Objects***, **Matt Hartings,*** American University*; J Scherschligt, J Fedchak, Z Ahmed,* National Institute of Standards and Technology **INVITED**

Additive manufacturing processes are enabling technologies, supporting advances in a number of applications where either controlled gas uptake and release or the maintenance of a good vacuum environment are critical. In each of these scenarios, a detailed understanding of how a 3D printed object interacts with gas molecules is necessary to advancing how these objects can be used in a technical setting. I will describe two 3D printed systems and their outgassing properties. In the first system, we have compared traditionally machined vacuum chambers, made of either steal or titanium, with their 3D printed counterparts. We have evaluated hydrogen outgassing at low pressures for each of these systems and analyze how the surface micro- and nano-scale structure affects these measurements. In doing so, we assess how different printing parameters can affect outgassing of the object of interest. In the second system, we have studied the gas uptake, retention, and controlled gas adsorption of polymer composites that contain metal organic framework (MOF) particles. MOFs are a relatively new class of materials that have been implicated in a number of gas storage and delivery applications. We have 3D printed objects with our polymer-MOF composite materials and have evaluated the dynamics with which they adsorb and desorb hydrogen and nitrogen. We have found that chemical interactions between the MOF and the polymer can help to support or diminish the capacity to effectively store gas. Our work in both of these areas has shown how additive manufacturing processes can help to further technological goals while delineating the work that remains to successfully incorporate 3D printing objects into commercial devices.

2:00pm **VT-MoA-3 Outgassing, Desorption, and Gas Uptake of 3D-Printed Materials***, **James Fedchak,*** NIST*; J Scherschligt, Z Ahmed,* National Institute of Standards and Technology*; M Hartings,* American University

We are investigating the outgassing, gas uptake, and gas desorption properties of novel 3D-printed composite materials, 3D-printed metals, and heat-treated metals. Materials we have investigated include 3D-printed titanium, stainless-steel, and composites of acrylonitrile butadiene styrene (ABS) melt-blended with metal-organic framework (MOF) materials. We have performed measurements of the outgassing into vacuum, the gas absorption of atmospheric gases such as H_2, N_2 and water at pressures greater than 50 kPa, and the desorption of the gases into vacuum. There are three motivations behind these investigations: first, we are interested in producing ultra-high vacuum (UHV) and extreme-high vacuum (XHV) pressures in small devices for quantum sensor and quantum science applications, such as our cold-atom vacuum sensor (CAVS). Second, we are interested in using novel new materials for gas sensing and, third, we are interested in using these composite materials for gas storage and separation. We will present our most interesting and recent results from these studies. For example, the ability of MOFs to store gas is now well-known, but our studies show that the MOFs retain their gas-absorption properties within the 3D-printed MOF-ABS composites.

2:20pm **VT-MoA-4 Performance Prediction Approaches for Liquid Ring Vacuum Pumps with Mercury as Working Fluid***, **Santiago Ochoa Guaman,** T Giegerich,* Karlsruhe Institute of Technology, Germany*; C Dahlke,* HERMETIC-Pumpen GmbH, Germany*; C Day,* Karlsruhe Institut of Technology (KIT), Germany

In the European fusion reactor (DEMO) development program, continuous working vacuum pumps are foreseen to pump the reactor. The pumps have to process large amounts of tritium, a radioactive and chemically very active gas. In a systems engineering approach, a pumping solution based on liquid ring pumps (LRPs) and diffusion pumps has been identified. Mercury is the only fluid perfectly tritium compatible and will be applied as working fluid.

LRPs exist for around 130 years and several mathematical approaches have been developed for its 1D modelling. Diagrams and tables also have been produce from experiments for fluid densities between 800 kg/m^3 to 1200 kg/m^3 but mostly for water as working fluid and with air as pumped gas. Modern 3D simulation tools have not been applied so far for analyzing these pumps. Thus, in order to design and analyze the operating behavior of LRPs with mercury as working fluid, it is necessary to design a special code for the prediction of the thermodynamic and operational behavior of LRPs operating with high density working fluids.

This great challenge is presented in this work, starting with the development of a simulation code based on three already existing methods. For its benchmarking against literature data, water as working fluid and air as pumped gas will be used. In a follow-up step, the code will be run considering mercury as working fluid. These results will be discussed against experimental results produced at the THESEUS vacuum pump test facility at KIT.

In the second part of this work, a two-phase three-dimensional CFD model will be performed using a more detailed pump geometry. Goal of this activity is to achieve a more accurate description of the pump performance without the use of empirical parameters. This requires extensive modelling and high computational effort. The status of this task will be presented in this paper and first results will be shown and benchmarked against experiments and the code.

2:40pm **VT-MoA-5 Particle Emission from Ion Pumps: Optimized Shielding without Severe Conductance Limitation***, **Mauro Audi,** C Paolini,* Agilent Technologies, Italy*; P Manassero,* Agilent Technologies

Charged particle emission from ion pumps is a potential major concern in sensitive applications such as Electron Microscopes , Particle Accelerators and Synchrotron Light Sources .

In fact , emitted positive ions and electrons can affect the performance of the machine or the resolution of the instrument.

Optical shield can be used to limit the number of emitted particles , but standard existing solutions have major conductance limitations as an unwanted side effect .

A test campaign on various shielding designs was carried out with a Faraday Cup powered at different bias voltage at the inlet of the ion pump , and the tests were repeated at different operating pressures and voltages .

Test results demonstrate that it is possible to reduce the number of charged particles by three orders of magnitude with minor conductance limitation and consequently maintaining a high fraction of the original ion pump pumping speed .

3:00pm **VT-MoA-6 Extension of the Range of Primary Vacuum Calibration Methods with the Use of Non-evaporable Getters***, **Sefer Avdiaj,*** University of Prishtina, Albania

In many vacuum devices there is a need for reliable vacuum measurement down to XHV range. Only few national metrology institutes (NMIs) around the world operate below 10^{-11} mbar. Recently the Institute of Metals and Technology has built an experimental calibration system with base pressure close to $1x10^{-12}$ mbar. It operates according to continuous (dynamic) gas expansion principle. XHV of has been achieved by using a non-evaporable getter pump (NEGP) cartridge in the calibration chamber. Getter is used to suppress the background from outgassing of the chamber walls. After activation of the NEGP only inert gases which are not pumped by the getter can be used for calibration because NEGP has high pumping speed for active gases and almost zero pumping speed for noble gases. In order to generate a known gas flow a calibrated conductance is used. It is operated in molecular regime, where the gas flow is proportional to the upstream pressure. Lower measurement limit of this flow-meter was extended down to $3x10^{-12}$ mbar l s^{-1}. This low gas flow was achieved by using another NEGP in the flow-meter. With this flow-meter it was generated the lowest calibration pressure of argon gas $8x10^{-13}$ mbar. Operation of XHV calibration system has been demonstrated by calibration of two extractor ionization gauges having a low-pressure limit $1x10^{-12}$ mbar.

3:40pm **VT-MoA-8 VTD Early Career Award Invited Talk: The Development of the Spacecraft Atmosphere Monitor***, **Steven Schowalter**[1]*,* Jet Propulsion Laboratory **INVITED**

In this talk I will focus on our team's recent development of the Spacecraft Atmosphere Monitor (SAM), a miniaturized Gas Chromatograph Mass Spectrometer slated to be commissioned as a Technology Demonstration Unit on the International Space Station in early 2019. The sensor system for this instrument consists of a quadrupole ion trap mass spectrometer coupled with a MEMS preconcentrator, gas chromatograph, and valve system. The SAM has been designed to monitor major constituents as well

[1] **VTD Early Career Award**

as trace organic contaminants in the atmospheres of crewed spacecraft. The requirements of spaceflight have placed stringent constraints on the instrument design which have led to a highly-intentionally designed vacuum system. The vacuum chamber is manufactured by a custom additive process and is equipped with novel differential pumping and gas inlet architecture. The design of this vacuum system will be detailed and preliminary data will be presented.

4:20pm **VT-MoA-10 Surface Modification to Reduce Species Retention and Outgassing Rate from Vacuum Components***, **Quirinius Grindstaff**, J Peak, C Miracle,* CNS, LLC

The base pressures of Ultra-High Vacuum (UHV) and Extreme-High Vacuum (EHV) at ultimately governed

by the outgassing of hydrogen and other species from the chamber walls. Furthermore, when a vacuum

system is pumped down from atmosphere, desorption of water is a time consuming hurdle to overcome

to reach higher vacuum. Desorption rates can be improved by material selection (such as aluminum over

stainless steel) or material treatment (high temperature vacuum anneal of components before

assembly). However, these approaches pose additional challenges over a standard 304L stainless steel

based system. In this paper we report on work to improve outgassing and modify the required energy

for desorption

To improve pump down rates (desorption based) and base pressure the performance of an

alumina coating on 304L SS is compared to untreated (as received) and vacuum annealed 304L SS. Ideal

coating thickness is also assessed. The test components were connected to a well-conditioned vacuum

system with a high resolution quadrupole mass spectrometer and a high compression turbo pump. The

outgassing rates and the energy required to degas absorbed molecules is reported. Pump down rates

are reported for each approach along with the specific gas species outgassing at room and elevated

temperature.

It was found that the alumina coatings did improve pump down times and reduced the presence

of hydrogen and water at the system's base pressure.

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