Tuesday Morning, October 21, 2008

Vacuum Technology
Room: 205 - Session VT-TuM

Vacuum Pumping Technologies, Large Vacuum Systems, Vacuum Modeling

Moderator: M.L. Stutzman, Jefferson Lab

8:00am **VT-TuM1 Modeling a Turbomolecular Pump with Direct Simulation Monte Carlo (DSMC)**, ***M.E. Roos***, *R. Versluis, L. Thielen*, TNO, the Netherlands

Three flow regimes can be distinguished (ordered in decreasing pressure): the continuum regime, the transitional or rarefied regime and the molecular regime. Modeling of the continuum flow regime is covered by Computational Fluid Dynamics. The fluidum is regarded as a continuum and the discrete character of molecules is not taken into account. For the molecular regime network modeling can be applied. This is the equivalent of electric network modeling applied to flows. It has always been a problem to model the transitional regime. Transitional flow conditions appear in a wide range of applications where vacuum is applied or small dimensions prevail. Some examples: the design of precision instruments (newest generation lithography machines), physical and chemical vapour deposition processes (fabrication of solar cells or coating of metals) or space technology (plume from a rocket nozzle). TNO has developed in cooperation with the Delft University of Technology a tool to model the transitional regime. This tool is based on the Direct Simulation Monte Carlo (DSMC) method. In this model flow properties are determined by simulating the movement and collisions of molecules. A mixture of different gases can be modeled as well as chemical reactions between gases and on surfaces. The DSMC model is implemented in the parallelized numerical 3D flow solver CVD-X (developed in-house by TNO). The DSMC model is also valid in the molecular and continuum regime. The development of the model is an ongoing process. Recently the model has been extended to be able to simulate moving parts in the transition regime. In our method moving parts are implemented as special boundaries which are moving through the domain. A moving boundary has all properties of a normal stationary boundary (like temperature and accommmodation coefficient). In addition the exact time and position in space of the interaction between molecules and a moving boundary is determined throughout time. Multiple collisions of molecules in one time step with moving and non-moving surfaces are taken into account. This method makes it e.g. possible to model the spinning rotors of a turbomolecular pump and optimize the efficiency. We are performing DSMC simulations on a turbomolecular pump using this method. The results of these simulations and the validation with experimental data are presented.

8:20am **VT-TuM2 Evaluation of Metallic Films of TiZrV and Au used in Ultra-High Vacuum**, ***M.J. Ferreira***, *R.M. Seraphim*, Brazilian Synchrotron Light Laboratory - LNLS, *P.A.P. Nascente*, Federal University of Sao Carlos - UFSCAR, Brazil

The construction of ultra-high vacuum chambers (UHV) for particle accelerator demands pressure in the range of 10^{-8} Pa. It is particularly more difficult to obtain this vacuum level in chambers with a length to traverse section rate of 150:1. Among several methods used to obtain this condition, it stands out the internal coating with a metallic film capable of absorbing gases, called NEG (non-evaporable getter). Metallic films used in synchrotron accelerators cannot have gas molecules adsorbed on the surface and should be deposited on the internal surface of the chamber, making it a vacuum pump. Usually these materials are constituted by elements of great reactivity and solubility (such as Ti, Zr, and V) at room temperature, for oxygen and other gases typically found in UHV (H_2, CO, and CO_2), besides having considerable diffusibility at low temperature (< 700 K), the so-called activation temperature. The objective of this work is to prepare and evaluate films of TiZrV alloy and Au produced by magnetron sputtering. The film structure, morphology, and aging have been characterized in order to know how much of the gas absorption property at low temperature can be attributed to the chemical reactivity of the elements and to the structure formed by the deposition process. The morphological, structural, and chemical characterization was carried out by atomic force microscopy (AFM), high-resolution scanning electron microscopy (FEG-SEM), energy dispersive spectroscopy (EDS), X-ray diffraction (XRD), and photon stimulated desorption (PSD). The produced materials were compared with commercial TiZrV samples, and this comparison made clear that the desired characteristics are related to the nanometric structure of the films and that the structure is clearly sensitive to the heating treatments.

Acknowledgements: we would like to thank Vinicius L. Pimentel and Roosevel Droppa Jr. for their assistance on some of the experiments.

8:40am **VT-TuM3 Sorption Properties of Non Evaporable Getter Pumps for Selected Hydrocabons and Organic Compounds**, ***A. Conte***, SAES Getters S.p.A. Italy **INVITED**

Non Evaporable Getter (NEG) pumps are very clean, vibration-free, compact UHV pumps able to deliver large pumping speeds for all active gases, including water and hydrogen. Plenty of literature is available describing the sorption characteristics of NEG pumps toward the gases typically present in UHV system, e.g. hydrogen, carbon oxides, water, nitrogen and oxygen. Fewer papers can be found describing the behaviour of NEGs toward hydrocarbons. Most of the experimental data available in the literature are related to pumping of methane or relatively simple hydrocarbons like the lower alkanes. Very few data are available for more complex molecules. On the other hand, pumping of volatile and organic compounds is an issue in a variety of vacuum applications , especially those related to silicon and semiconductor materials processing, wafer in-line inspection, e-beam and Extreme Ultra Violet Lithography (EUVL). In the present study we report the results of specific tests aimed at measuring the pumping speed for some selected organic compounds, namely toluene, decane and methyl methacrylate (MMA). The study shows that NEG pumps can effectively sorb these large organic molecules with high speed and capacity even at room temperature. This opens up the possibility of using NEG pumps in combination with other typical UHV pumps in those systems were organic volatile compounds can be present to improve the ultimate vacuum and mitigate the carbon/oxygen contaminations.

9:20am **VT-TuM5 New Methods to Achieve XHV/UHV with Refrigerator Cooled Cryopumps**, *B. Rock*, ***D. Muller***, *M. Ahlers, T. Brown*, Oerlikon Leybold Vacuum

Cryopumps have a higher effective pumping speed compared to ion pumps or turbomolecular pumps, especially for the typical gasses which limit the ultimate pressures in UHV devices like water vapor or Hydrogen. In addition, they are absolutely hydrocarbon free. The ultimate pressure of commercial refrigerator cooled cryopumps is mostly limited by 2 factors: they cannot be baked completely and they cannot be operated while attached to a chamber during bakeout due to the high thermal load. This paper presents a simple modification of a standard cryopump including the ability to cool the radiation shield with LN2 during bakeout. Pressures below 1 X 10^{-12} mbar have been reached even in larger vacuum chambers. The possibilities to measure these pressures via the Extractor gauge are shown too.

9:40am **VT-TuM6 The KATRIN Experiment: Vacuum Performance of the Large Main Spectrometer Vessel**, ***J. Wolf***, Universität Karlsruhe, Germany

The scientific objective of the KArlsruhe TRItium Neutrino experiment (KATRIN) is to measure the electron neutrino mass from the β-decay of tritium with an unprecedented sensitivity of 200 meV/c^2. The kinetic energy of the decay electrons will be measured by an electrostatic spectrometer. Background considerations require a very good vacuum of 10^{-11} mbar or better in the large spectrometer vessel (volume 1240 m^3, surface: 690 m^2). A combination of NEG pumps (S = 10^6 l/s) and turbo-molecular pumps will provide the necessary pumping speed. In addition a very clean surface and low outgassing rates are mandatory. This talk reports on the manufacturing, vacuum performance before and after bake-out at 350°C.

10:40am **VT-TuM9 LHC Beam & Insulation Vacuum Systems**, ***J.M. Jimenez***, CERN, Switzerland **INVITED**

In May'08, the world largest vacuum system was fully commissioned and consolidated in the Large Hadron Collider (LHC), a CERN accelerator built near the City of Geneva in Switzerland. Its more than 100 km of vacuum systems are operating over a wide range of pressures and integrates an impressive variety of vacuum technologies. These vacuum systems are composed of 54 km of UHV vacuum for the circulating beams and two times 24 km of insulation vacuum around the cryogenic magnets and for the cryogenic helium transfer lines. 48 km out of the 54 km are operated at a cryogenic temperature (1.9 K). The remaining 6 km of beam vacuum containing the insertions is at ambient temperature and uses non-evaporable getter (NEG) coatings, a vacuum technology that was born and industrialized at CERN. The pumping is completed using 600 ion pumps to remove noble gases; 1000 gauges are used to monitor the pressures. The cryogenic insulation vacuum of the magnets, while technically less demanding, impresses by its 24 km in length and a diameter of 900 mm for a total volume of 640 m3. Once cooled at 1.9 K, the cryogenic pumping allows reaching pressure in the 10-6 mbar range. This talk will introduce the vacuum systems and the challenges of its design, manufacturing, installation, commissioning and consolidation phases.

11:20am **VT-TuM11 The Modeling of Large and Distributed Vacuum System**, ***A.D. Chew***, *M. Galtry, J. Luby*, Edwards, UK

As the size and complexity of vacuum systems increases the financial and technical challenges do so also. Accurate modeling allows system optimisation in advance of engineering efforts and negates the need for inefficient empirical iterations. This paper will describe a computational modeling technique which allows the modeling of vacuum systems incorporating any number of primary and secondary pumps and all other elements of a vacuum system. Real examples will be used to illustrate accuracy and efficacy.

11:40am **VT-TuM12 Introduction to Molflow+, a New GPU-Based Monte Carlo Code for Simulating Molecular Flows and for Calculating Angular Coefficients in the CUDA Environment**, ***R. Kersevan***, *J.L. Pons*, European Synchrotron Radiation Facility, France

Molflow+ is a new test-particle (TP) monte carlo (MC) code developed for the simulation of molecular flows. It is the natural evolution of the code Molflow which had been developed by one of the authors (R.K.) and used by many laboratories since 1991. Molflow+ implements modern computing trends, such as the use of the OpenGL graphical interface and C\C++ code, and takes advantage of recent developments in the field of graphical processing units (GPUs) which allow a substantial parallelization of the TP MC algorithm for a modest capital cost. The Compute Unified Device Architecture (CUDA) environment has been chosen for its ease of use and portability to different computing environments. A second version of the program will let a similar code run on computers which have no GPUs or non CUDA-compatible GPUs, and only single or multi-core CPUs. As for the original code Molflow, in Molflow+ the geometry of the vacuum component under study is described in terms of planar polygonal surfaces to which attributes such as transparency, sticking coefficient, desorption profiles and more are assigned. The geometry is defined either by using a built-in editor program or by importing files obtained by using a popular computer-assisted design program which generates a triangularization of the surfaces. A very large period random number generator has been implemented into the code, in order to minimize systematic statistical errors. It will be shown how Molflow+ can also be used to calculate the angular coefficients of arbitrarily complex geometries, which can then be used to perform vacuum calculations based on the resolution of matrix operations. It will also be shown how using the GPU yields a dramatic improvement of the processing speed, thus allowing the simulation of complex vacuum systems which could not hitherto be carried out unless powerful and expensive computing tools were used. The paper will outline the early stages of development of the code, its benchmarking against existing analytical as well as numerical results, and will hint at possible fields of application where the dramatic computational power of the GPU could make a difference as compared to CPU-only cases. It will also discuss possible future developments such as the inclusion of intramolecular collisions which could extend the domain of application to flow regimes other than molecular.

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