Vacuum Technology
Room: J1 - Session VT-WeA

Modeling and Accelerators
Moderator: M. Stutzman, Jefferson Lab

2:00pm **VT-WeA1 Slit Flow Simulation using Non-Linear BGK and ES-Models**, ***I.A. Graur***, *A. Polikarpov*, Provence University, France

The flow through a two-dimensional slit is simulated using non-linear model kinetic equations (BGK, ES-model) in the large Knudsen number range. The discrete velocity method is implemented to determine the flow parameters. Several different (finite and infinite) tank pressure ratios are considered and are compared with the results of DSMC simulations and some experimental data.

2:20pm **VT-WeA2 Background Reduction Strategies for Angular Profile Measurements of Gas Injected in Ultra-High Vacuum**, ***L.J. Isnard***, *R.M. Arès*, Université de Sherbrooke, Canada

Ultra-high vacuum (UHV) based deposition techniques, such as molecular beam epitaxy (MBE) and chemical beam epitaxy (CBE), have stringent requirements on layer thickness and composition uniformity. Concurrently, the source use efficiency is usually very low and needs to be improved while maintaining the same level of uniformity. There is therefore a need for a precise and reliable simulation platform to predict the angular distribution of gas molecules injected in vacuum through a nozzle of a given geometry. Several calculation techniques have already been proposed for MBE [1-6] and CBE [7].

However, the validity of such models needs to be established through a systematic experimental study that clearly isolates the contributions of each parameter. For this purpose, a test platform dedicated to the measurement of molecular beam angular profiles produced by a nozzle in UHV was designed and built. Its main features are discussed, especially regarding its ability to produce precise and reproducible data. For profiles being measured far away from the injector, the unwanted contribution from the molecules that reach the sensor after being scattered by the chamber walls (i.e. background level) is fairly large. In order to reduce it, several design strategies are considered and evaluated on the basis of the theory of rarefied gas dynamics. In particular, an innovative approach based on an angular selection tube is presented with a quantitative evaluation of its effect on the signal to background ratio. Finally a rule of thumb is proposed for the choice of the tube's dimensions allowing a maximum background reduction while keeping the impact on the signal as small as possible.

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2:40pm **VT-WeA3 Investigation of Vacuum Flows in Fusion Reactors**, ***S. Varoutis***, *V. Hauer*, *C. Day*, Forschungszentrum Karlsruhe (FZK), Germany

Vacuum flows are strongly connected to several subsidiary systems of fusion reactors. In particular, there are high vacuum pumping systems for evacuation and maintenance of the needed low pressure levels in the torus, in the cryostat and in the neutral beam injectors. Each vacuum system consists of networks of various channels with different lengths and cross sections. The flow in such channels varies from the free molecular regime up to the hydrodynamic limit. In the present work, an experimental setup for measuring the mass flow rate of gases is proposed. Its principle is based on the predefined conductance through the duct and the measurement of the corresponding pressure difference. Experimental data for channels with various lengths and cross sections are presented and compared with corresponding numerical results based on the linearized kinetic BGK equation and the direct simulation Monte Carlo method (DSMC). It is noted that in all cases a very good agreement between experimental and numerical approaches, is observed.

3:00pm **VT-WeA4 Accurate Measurements of Low Permeation Flows of Hydrogen**, ***V. Nemanic***, *B. Zajec*, *M. Zumer*, Jozef Stefan Institute, Slovenia

Permeation of hydrogen isotopes from the upstream pressure through a membrane into high vacuum at elevated temperatures is a challenging task for vacuum technology when very low flows must be determined. The detection limit and accuracy of results depend on several experimental details. Geometrical and mechanical constraints set an engineering issue since the ultimate tightness of seals at high temperature must be preserved. On the other hand, measurements of the steady permeation flux and its transients require high sensitivity and stability of the gauges. It is also essential that the background represents only a fraction of the signal. We present recent improvements applied on a permeation cell design that results in efficient background suppression. When implemented in an all-metal UHV system, low permeation fluxes down to 10^{-11} mbar L/(cm^2 s) could be measured. We also present an innovative technique to perform measurements at a low upstream pressure capable of detecting changes corresponding to a permeation flux as low as 10^{-14} mbar L/(cm^2 s). The interpretation of data is presented by the surface rate constants rather than by diffusivity and solubility since the permeation regime at low pressures is known to be limited by surface reactions. Better experimental capability is needed today in the hydrogen storage technology and also in the field of nuclear fusion reactors to study the efficiency of permeation barriers and to predict tritium retention in the walls.

4:00pm **VT-WeA7 Vacuum R&D at Cornell Towards to Cornell Electron Storage Ring Test Accelerator for ILC Damping Ring and the ERL-based Light Sources**, ***Y. Li***, Cornell University **INVITED**

Many research and development efforts in the vacuum technology front in supporting two major research programs at the Cornell Laboratory for Accelerator Based-Sciences and Education (CLASSE). Over the past 3 years, a prototype DC photo-cathode injector was designed and constructed at CLASSE, as a key initial step towards to the Energy Recover Linac (ERL) based light sources at Cornell. The prototype injector includes a DC photo-cathode electron gun, a 10-cell superconducting radio-frequency cavity cryo-module, electron beam transporting beamlines equipped with a suit of beam instrumentation and electron beam dumps. Among various challenges, achieve and maintain extreme high vacuum in the DC photo-cathode electron gun is essential to the success of the prototype injector project. In the past year, we have also successfully re-configured the Cornell Electron Storage Ring (CESR) vacuum system to convert it into a test accelerator (thus CesrTA), as a part of the Globe Design Efforts (GDE) of the International Liner Collider Damping Ring. One of the goals is to understand electron cloud growth in vacuum chambers with many in-vacuum instruments of unique low-profile design, and to explore various eletron cloud suppression methods, including coatings of interior surfaces of vacuum beampipes. In this talk, highlights of the vacuum R&D efforts related to the two research programs are discussed.

4:40pm **VT-WeA9 Amorphous Carbon Films for the Eradication of Electron Cloud Effects in Modern Particle Accelerators**, ***P. Chiggiato***, CERN, Switzerland

High-intensity and high-energy positively charged beams could engender high density electron clouds in vacuum chambers. As a result, several detrimental effects could arise, such as beam instability, pressure increase and, at cryogenic temperatures, excessive thermal load. Among the crucial factors, the secondary electron yield (SEY) of the beam pipe material plays an important role: only when it is higher than a well defined threshold, the electron cloud build-up is possible. As an example, a value of 1.3 has been calculated for the Large Hadron Collider (LHC) nominal beam. Coating the whole vacuum chamber with a low SEY material is an attractive solution to this accelerator performance limitation.

Low maximum SEY have been reported for Ti-Zr-V non-evaporable getter films following in-situ heating. However, heating is not always possible. To cope with this constraint, sputtered amorphous carbon thin films have been studied for the unbakeable vacuum system of the Super Proton Synchroton (SPS), namely the largest LHC injector. After exposure to air for a few hours, the produced coatings show maximum SEY of about 1. In general, the yield increases for a longer exposure to air, but it can be kept lower than the threshold providing the coating parameters are suitably selected. UHV compatibility has been also studied and the relationship between outgassing rate and coating parameters has been highlighted.

The encouraging results obtained for small samples and a few vacuum chambers installed in the SPS vacuum system have triggered a programme possibly leading to the implementation of a-C films in the whole SPS (about

7 Km which amount to roughly 600 vacuum chambers); such a large scale application will be presented and the production strategy depicted.

5:00pm **VT-WeA10 Update on Pressure Simulation of Vacuum System at NSLS-II Storage Ring**, ***M.J. Ferreira***, *H.C. Hseuh, J.-P. Hu*, Brookhaven National Laboratory

National Synchrotron Light Source II (NSLS-II) will be a 3-GeV, 792-meter circumference, 3rd generation synchrotron radiation facility, with ultra low emittance electron beams and extremely high brightness X-ray beams. The storage ring vacuum system has a simulated average operating pressure of less than 1x10-9 mbar. A summary of the updated vacuum system design will be presented, based on outcome from pressure simulation using window-version Monte-Carlo based MOLFLOW+ code. The versatile PC-compatible code provides increasing details in pressure distribution of residual gases in the vacuum system, particularly for those active species scattering at innards of high-power and small-gap insertion devices. Since low emittance for electron beam is expected to achieve when proposed damping wigglers are installed at storage ring, a fine segmentation of code input at such critical sections will be processed to evaluate details from calculated pressure profile.

*Work performed under auspices of the United States Department of Energy, under contract DE-AC02-98CH10886

5:20pm **VT-WeA11 Fabrication of NSLS-II Storage Ring Vacuum Chambers**, ***H.C. Hseuh***, *L. Doom, M.J. Ferreira, C. Longo, P. Settepani, K. Wilson*, Brookhaven National Laboratory

National Synchrotron Light Source II (NSLS-II), being constructed at Brookhaven, is a 3-GeV, 500 mA, 3rd generation synchrotron radiation facility with ultra low emittance electron beams. The storage ring vacuum system has a circumference of 792 m and consists of over 250 vacuum chambers ranging from 1 m to 6 m in length, and an average operating pressure of less than $1x10^{-9}$ mbar to minimize beam-residual gas interactions. Most vacuum chambers are made of aluminum and stainless steel, with different cross sections either fitted into the bending magnets or surrounded by multipole magnets. The layout of the storage ring vacuum systems will be presented. The detailed design of the vacuum chambers, the pumps and the photon absorbers will be described. The aluminum chambers are extruded, curved with 25 m radii in the case of the bending chambers, precision machined and welded to bi-metal Conflat flanges using robotic welding machines. The fabrication and evaluation of these aluminum chambers will be presented.

*Work performed under auspices of the United States Department of Energy, under contract DE-AC02-98CH10886

5:40pm **VT-WeA12 The Vacuum System of the 3 GeV Taiwan Photon Source**, ***J.R. Chen***, NSRRC and NTHU, Taiwan, *G.Y. Hsiung, C.C. Chang, C.L. Chen, C.K. Chan, H.P. Hsueh, C.M. Cheng, C.Y. Yang*, National Synchrotron Radiation Research Center, Taiwan

A design and prototype of the vacuum system of a low-emittance 3 GeV synchrotron light source, the Taiwan Photon Source (TPS, with a circumference of 518.4m), is described. The TPS vacuum system has low-outgas aluminum beam ducts, low impedance structure, oil-less pumping system and oil-less fabrication process. Little dust, a stable mechanical structure and high reliability components are also equipped in the vacuum system. A 14 m long prototype of the TPS vacuum system was fabricated. Two 4 m long bending-magnet chambers were made by the CNC machining process, lubricated with ethyl alcohol to protect the aluminum surface from oil contamination. Ozonated water cleaning process was applied to reduce the photo-desorption rate from the chamber surface. The design considerations, the critical factors in fabrication and the test results of the vacuum system prototype are presented.

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