Vacuum Technology
Room: 303 - Session VT-TuM

Gas Dynamics, Modeling, and Pumping Systems
Moderator: Lily Wang, Los Alamos National Laboratory, Martin Wüest, INFICON Ltd., Liechtenstein

8:00am **VT-TuM1 A Fast Numerical Method for Determining the Pressure Distribution in Electrostatic Chucks**, ***Jack McInerney***, Lam Research Corp

The excellent cooling capabilities of the electrostatic chuck enable high power plasma etching of modern semiconductor devices. In order to maintain a uniform temperature across the silicon wafer, a thin layer of helium is inserted between the wafer and chuck. Some of this gas leaks out at the wafer edge, and the resulting flow of helium can lead to pressure drops that compromise the heat transfer uniformity of the chuck. Fluid dynamics modeling of the helium distribution is often used in the design phase to ensure uniform pressure under various scenarios.

Because of the small gaps and low pressures, the gas behind the wafer is in the transitional or molecular flow regime. Modeling electrostatic chuck designs then requires using very computationally expensive methods such as Direct Simulation Monte Carlo (DSMC). In this paper, a simplified modeling approach is developed that allows the pressure distribution to be modeled as a two-dimensional conductance problem. This is done by extending the conductance calculations used in one-dimensional vacuum piping networks. The accuracy of the method is compared to molecular flow modeling. The method is then used to model some chuck configurations.

8:20am **VT-TuM2 Numerical Simulation of a Jet Disrupter in an Electrospray RF Ion Funnel**, ***Eric Tridas***, *R. Schlaf*, University of South Florida, *M. Anthony*, Elion Systems

Electrospray ionization (ESI) is a versatile method for creating gas phase ions from solution while maintaining the native chemical functionality of the solute. Using this method, functional bio- and macromolecular thin films can be produced for use in biosensors, scaffolding for tissue generation, photovoltaics and other emerging fields of research. The Macromolecular Patterning System, designed and constructed at the University of South Florida (USF), utilizes ESI as a material source to create such films. The system is comprised of three differential pumping stages, each containing custom designed electrodes used to define the trajectory of the ions. The focus of this study is on the first of the three stages which contains a radio frequency (RF) ion funnel. Computational fluid dynamics (CFD) simulations of the air flow into this chamber were performed and coupled with simulations calculating the generated electric field. Using the ion trajectory simulation software SIMION, the flight paths of ions within this first chamber were calculated. Experiments were then performed to test the results of the simulations. A “randomization parameter” based on the turbulence kinetic energy of the CFD simulations was used to model the time-varying component of the flow velocity yielding a result that closely matched the system. Variation of electrode voltages in the physical apparatus yielded similar results to those obtained from the simulations. Most significantly, the overall trend and peak values of ion transmission were accurately predicted from the simulations.

8:40am **VT-TuM3 Gas Dynamics Modelling Efforts at CERN**, ***Roberto Kersevan***, CERN, Switzerland **INVITED**

The Vacuum Surfaces and Coatings (VSC) Group at CERN is involved in several large projects, either at CERN or in collaboration and/or support of other laboratories. The design of new vacuum chambers and components is taking a considerable amount of time of many physicist and engineers in the VSC. New accelerators are being designed, either for fabrication and installation in a short time or as part of the European strategy for future accelerators. Two extreme examples are: 1) The ELENA project (Extra-Low Energy Accelerator ring) a ~ 30 m circumference 100 keV anti-proton decelerator aimed at increasing the anti-proton production from the existing AD machine (Antiproton Decelerator ring). ELENA will require an average pressure better than 3E-12 Torr. ELENA is under design and construction now, with expected start of commissioning in 2016. On the other side of the spectrum are the TLEP and HE-LHC machines, which are part of the Future Circular Colliders lepton-lepton and hadron-hadron (FCC-ee, FCC-hh) versions of colliders aiming at greatly improving the production of Higgs and W/Z0 bosons, and top quarks (FCC-ee), and raising the center-of-mass energy in the 50+50 TeV range (FCC-hh). Such conceptual machines would require circumferences in an unprecedented 80~100+ km range. The FCC-ee versions would generate of the order of 50 MW of synchrotron radiation (SR) for 175+175 GeV electron-positron beams, and the FCC-hh would generate as well a considerable amount of SR in the 4~5 keV critical energy range, thanks to 16-20 tesla superconducting magnets. The already approved High-Luminosity upgrade of the LHC (HL-LHC) and this FCC program will require a thorough upgrade of the injector chain, composed of some accelerators which are today exceeding the 50 year mark. In parallel, there are accelerators like the HIE-ISOLDE upgrade of the ISOLDE machine, aimed at post-acceleration of radioactive ion-beams, and new-concept experiments like the AWAKE plasma-acceleration project. In order to tackle all these projects, the VSC group has decided to develop several numerical analysis tools, namely test-particle montecarlo (TPMC) codes and the electrical-network analogy (ENA) (implemented via the Ltspice freeware). This paper will briefly describe the various codes developed (Molflow+ for molecular flow, SYNRAD+ for SR, and McCRYO-T for radiative heat exchange) and the ENA approach. It will then show some examples of the application of these codes to CERN projects and also comparison and benchmarking with results published in the gas dynamics field and dedicated experiments carried out at CERN.

9:20am **VT-TuM5 Mixture Flow of Rarefied Gases through a Thin Orifice Over the Whole Range of Gas Rarefaction**, ***Felix Sharipov***, Federal University of Parana, Brazil

Rarefied gas flow through a thin orifice is well studied on the basis of the direct simulation Monte Carlo (DSMC) method, see e.g. Ref.[1,2]. In spite of the fact that in practice one deals with gaseous mixtures more often than with a single gas, the information about such kind of flows is still poor. That is why it is attractive to treat gaseous mixtures as a single gas with the molecular mass equal to its average values of the corresponding mixture. However, such an approach not always provides reliable results. The aim of the present work is a numerical modeling of mixture flows of rarefied gases through a thin orifice on the basis of the direct simulation Monte Carlo (DSMC) method. The mass flow rate and flow field are calculated over the whole range of the rarefaction parameter for various values of the pressure ratio and for several values of the mole fraction. A comparison of the present numerical results with those obtained for a single gas is performed. A recommendation of the applicability of single gas results to gaseous mixture is given.

References

1. F. Sharipov, Numerical simulation of rarefied gas flow through a thin orifice. J. Fluid Mech. Vol.518, pp. 35-60 (2004).

2. F. Sharipov and J.L. Strapasson, Ab initio simulation of rarefied gas flow through a thin orifice. accepted in Vacuum.

9:40am **VT-TuM6 Numerical Modeling of Particle Transport in Rarefied Flow**, ***Andreas Mack***, *Van der Donck*, *O. Kievit*, TNO Delft, the Netherlands

Within wafer handling devices, environments from ambient pressure to ultra-high vacuum are present. The wafers are moved by robots between the compartments which are separated by load locks. With closed load lock valves, the pressure is reduced by pumping-down such that the pressure level of the next compartment is roughly matched. Since the pumping speed is approximately constant, the pumping time to very low pressures would take long or require additional pumps such that usually the target pressure is only matched by two orders of magnitude. The final pressure is then achieved by opening the load lock valve such that the pressure in both compartments reach equilibrium. This process includes a strong expansion of the flow such that locally very high flow velocities can be reached up to supersonic speed. Since the flow is in the rarefied regime, the forces on surfaces such as the wafer are small but particles released during the wafer handling process can be dispersed downstream due to drag or gravitational forces. Since there is only sparse information available about the coupling between contaminating particles and the rarefied flow, the present paper focusses on the numerical modelling of particle transport in rarefied flow. A DSMC (Direct Simulation Monte Carlo) code is applied to typical domains of wafer handling such as load lock valves and coupled with a particle tracer. Both codes are available within the open source software package OpenFoam and have been validated in the relevant regimes by either generic numerical experiments or, where available, experimental or other numerical data. By this, particle contamination in low pressure environments can be investigated. On the one hand, possible particle contamination regions and active or passive measures to reduce particle contamination can be identified. On the other hand, the global dispersion behavior of different particle classes is investigated such that conclusions over the generic movement of particles within a low pressure environment can be drawn. By this, the dispersion of certain particles can be excluded due to geometrical or physical constraints which is valuable information for particle contamination measurement. Beside the modelling of particle transport for the generic valve opening between compartments the present paper includes also the venting-up of a representative load lock to ambient pressure whereas the results of pseudo-3d and a full 3D modelling are discussed with respect to flow topology and particle contamination.

Keywords: DSMC, rarefied flow, particle contamination, load lock

11:00am **VT-TuM10 Improving the Performances of Getter Pumps: Recent Developments in NEG Technology**, ***Fabrizio Siviero**, G. Bongiorno, L. Caruso, A. Gallitognotta, L. Viale, E. Maccallini, P. Manini*, SAES Getters, Italy **INVITED**

Non Evaporable Getter (NEG) pumps are commonly used when large pumping speeds for H2 and active gases (i.e., H_2O, O_2, CO, CO_2) are required. The NEG pumps are very small, lightweight, with reduced magnetic interference, cause no vibration, and consume negligible power. Thanks to these qualities NEG pumps are widespread in many UHV applications.

Nevertheless, some factors still limit an even wider diffusion of NEG pump technology, mainly related to the topics of particle release and gas evolution during activation. Indeed, as a precaution, NEG pumps are generally not used in application requiring particle-free environment. Only recently, measurements performed at a large accelerator facility have shown the compatibility of St172® alloy sintered getters in particle free environments, i.e RF cavities, after suitable treatments. Also, it is well known during getter activation hydrogen as well as other physisorbed species are desorbed causing pressure increase up to the 1e-6 mbar range. In some applications this is seen as a problem due, for example to constraints in pumping efficiently hydrogen away from long and narrow chambers.

These topics will be discussed based on recent outcomes of research activities carried out in SAES R&D labs to address these issues. New alloys, belonging to the ZAO® family, and new production processes have been developed, showing interesting characteristics. Among them we highlight intrinsically reduced particle release, lower hydrogen equilibrium isotherms and more efficient management of the gas load during activation. These properties are combined with a new pump design, even more compact and simpler to install than before, with the aim of providing an enlarged community of users with smarter solutions to their vacuum needs.

11:40am **VT-TuM12 Advanced High Speed Water Vapor Cryopumps: Enabling Today's Vacuum Processes**, ***Kevin Flynn**, C. Rebecchi*, Brooks Automation, Inc., Polycold **INVITED**

Effective and efficient pumping of water vapor in vacuum systems via cryopumps or cryotraps is critical to achieving required vacuum system performance for many processes. A brief over view of general cryopumping methods is presented along with an in depth review of water vapor cryopumping. Water is of special importance due to its difficulty to be pumped, its deleterious impact on coatings when it remains on the substrate, and its ability to form oxygen which reacts with and degrades thin film quality. In addition to the basic pumping function, the ability of a cryopump to rapidly cool and defrost or regenerate the cryosurface are important for enabling high chamber productivity. Required water vapor partial pressures vary widely among typical vacuum processes, ranging from 10-1 torr to below 10-9 torr. Similarly required pumping speeds range from thousands of liters per second to over 200,000 liters per second. The combination of these varying requirements drive different demands for cryopump cooling capacity and temperatures. A variety of different vacuum applications covering medium, high and ultra high vacuum applications, and including batch and inline processes, are reviewed along with considerations of cryosurface location relative to the chamber and process.

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