Tuesday Afternoon Poster Sessions

Vacuum Technology
Room: Hall 3 - Session VT-TuP

Vacuum Technology Posters and Student-Built Vacuum Systems Poster Competition

VT-TuP1 New Developments at ISIS – The Worlds Leading Pulsed Neutron and Muon Source, ***S. Patel***, STFC Rutherford Lab, UK

Over the past 12 months there have been major advances at the above research facility operated by STFC, which is based at the Rutherford Appleton Laboratory, Oxford, England. In addition to the Second Target Station (TS2) becoming operational with a suite of seven new instruments, there have also been developments to improve the performance and reliability of existing instruments on Target Station One. Some of the key vacuum challenges faced during the last year will be outlined here, together with details of the challenges that lie ahead.

VT-TuP2 Vacuum Pressure Simulation for the Insertion Device Beamline at X-Ray Ring of NSLS, ***J.-P. Hu***, Brookhaven National Laboratory

Beamline 9 at the X-ray storage ring of the Brookhaven Lab's National Synchrotron Light Source has been upgraded from a conventional bending magnet beamline to an insertion device beamline, with installation of a mini gap undulator (MGU) between the two RF cavities at upstream of dipole magnet. The new water-cooled undulator, which is made of neodymium-iron-boron magnet and vanadium-permandur poles, was tested to generate a high-brightness coherent photon beam through the X-9 front-end to the experimental end-station enclosure, where sampling of nano materials will be conducted by small-angle X-ray scattering (SAXS). To meet required ultra-high vacuum (UHV) for beam transport under minimum scattering and aberration, the X-9 front-end was also upgraded, with installation of following provisions: fixed-aperture photon mask for beam filtering, high-density safety shutter for *bremsstrahlung* shielding, water-cooled collimator for ray focusing, windowless differential ion pump for shockwave throttling and spectrum broadening (2-20 keV), and pneumatically closed and sealed gate valve for the front-end vacuum and beamline vacuum separation. At downstream of the front-end gate valve, the 6-meter long X-9 is constructed of UHV-compatible SS spool pieces, welded bellows, optical chambers, fast shutter and angle valves. To maintain the intensity and quality of undulator beam for high-resolution sampling of nano materials, the conductance-limited beamline is equipped with multiple high-capacity ion pumps, respectively mounted at cryo-ready monochromator container (dual 300 l/s pumps), XZ-staged mirror tank (one 500 l/s) and exit-slit housing (one 300 l/s). For vacuum pressure minimization, the Monte-Carlo based Molflow code was used to simulate inline assemblies and pumping units encompassing the beam chamber, and the finite-difference based Vaccalc program was used to calculate pressure distribution along the beam trajectory, starting from the photon source MGU down to the beamline end valve next to the enclosure wall. Details of calculated pressure profile versus pumping setup will be presented. (Work performed under auspices of the United States Department of Energy, under contract DE-AC02-98CH10886)

VT-TuP4 A Vacuum Quality Monitor Sensor using an Integrated Total and Partial Pressure Measurement Design, ***B.G. Olsen***, *G.A. Brucker, J. Rathbone, S. Blouch, M. Schott, K. Van Antwerp*, Brooks Automation, Inc.

We have refined and built upon the work of A.V. Ermakov and B.J. Hinch from Rutgers University to further develop a novel electrostatic ion trap sensor that is based upon the principles of autoresonant ion-ejection and detection for use in low mass range mass spectrometry applications. In addition, we have developed a practical method of integrating a total pressure measurement capability into the same sensor envelope. This highly integrated Vacuum Quality Measurement (VQM) sensor is comprised of a hot-filament ion source, electrostatic ion-trap mass separator, Shulz-Phelps based pressure sensor, and an electron multiplier ion detector that is shared for both UHV total pressure and ratiometric partial pressure detection. The VQM ion-trap sensor is capable of a 1-100amu scan rate within 70ms and has been coupled with a total pressure and partial pressure measurement update rate of 100ms. A set of sensor electronics has been developed to control, drive and process complex sensory data, and output the processed data into a usable form within the cycle time of the measurement update rate. Finally, a novel dual-filament ionization source design was incorporated into VQM sensor design to allow fast and easy field replacement of filaments.

VT-TuP5 A Compact RHEED-TRAXS Chamber Modification Design for Real Time, In-Situ Stoichiometry Analysis during MBE, ***B. Sun***, *T.L. Goodrich, K.S. Ziemer*, Northeastern University

Real-time control of MBE film growth using Reflection High Energy Electron Diffraction (RHEED) oscillations allows precise layer-by-layer growth using real-time surface structure information. Many complex functional oxides of device importance, however, require tight stoichiometry control. RHEED- Total Reflection Angle X-ray Spectroscopy (RHEED-TRAXS) can provide real-time chemical information and thus has the potential to achieve real time stoichiometry control. When incident RHEED electrons with energy in the range of 12-20 keV graze the sample surface at approximately a 2° angle, characteristic x-rays which are representative of the film surface stoichiometry are emitted. By measuring the x-rays at or close to their total reflection angle, RHEED-TRAXS is reported to probe only the top 20Å of group V elements [1].

The goal of the RHEED-TRAXS chamber modification design is to incorporate a non-UHV compatible x-ray detector into the chamber, and ensure highly accurate detector positioning within 0.01° through a 4° angle range. For real time operation, a shielding strategy that is transparent to x-rays must be developed to protect the detector from fouling during MBE processing. As a high volume of x-rays are excited by the RHEED electrons, collimation is necessary to control the incoming x-ray flux and avoid detector overload.

Our system uses a Nor-Cal PMXY-600-400-2 ±1 inch X-Y stage to achieve 0° to 4.65° angular positioning of the detector. Differential pumping with a Leybold TURBOVAC 50 L/s turbo molecular pump is used to achieve UHV compatibility. Due to limited chamber space, off-the-shelf shielding options such as shutters would cut down the detector movement and thus reduce the maximum detection angle by 50%. To avoid this, we combined detector fouling protection and collimation by mounting the detector with a custom made half-nipple covered with a removable aperture cap which provides both collimation and beryllium foil shielding support. The ability to remove the aperture cap allows the Be foil to be replaced when needed and also allows the flexibility control net x-ray flux by changing the aperture size. The system has been used for real-time study of thin film deposition by MBE, and the results will be presented.

References:

1. Braun, W. and K.H. Ploog, Real-time surface composition and roughness analysis in MBE using RHEED-induced X-ray fluorescence. Journal of Crystal Growth, 2003. 251(1-4): p. 68-72.

VT-TuP6 Method of Measuring the Volume Flow Rate of Vacuum Pumps Using CFVN, ***W.S. Cheung***, *K.A. Park, S.W. Kang, S.S. Hong, J.Y. Lim*, KRISS, Republic of Korea

Critical flow Venturi nozzles (CFVN) have been widely used in most of national metrology institutes for the precision measurement and calibration of pressurised gas flow. They enable the relaisation of the critical flow speed equal to the speed of sound at the throat of the Venturi nozzle. The critical flow is exploited in this study not only to achieve the noble stability and repeatability of gas flow but also to minimize effects of the fluctuation of upstream and down stream pressures for the measurement of the volume flow rate of vacuum pumps. These singular properties of CFVN has not fully utilized to measure the pumping speed widely used in the vacuum-related academic and industrial sectors. On the onset of this work, it became apparent that the use of CFVN unfolds new findings for precision measurement of the volume flow rate.

One of the most technical challenges in measuring the volume flow rate was to design a set of Venturi nozzles that can cover the five decades of inlet pressures from 1 bar to 0.001 mbar. Preliminary tests were carried out to examine the practical range of upstream pressure Venturi nozzles can be used within the desired measurement uncertainty of 0.2 %. They revealed that Venturi nozzles were well calibrated in the three and half decades without loss of measurement uncertainty. This observation is very significant since two different sized nozzles are sufficient to cover the desired inlet pressure test range of vacuum pumps, specifically from 100 mbar to 0.001 mbar. This point has encouraged authors to develop a new CFVN-based measurement system targeted for the measurement of the volume flow rate of vacuum pumps. This paper will introduce the details of the developed measurement system, including the configuration of mechanical parts and measurement instruments. Test results obtained from the CFVN-based measurement system are compared to those from the conventional throughput method. The pros and cons of both measurement methods are also discussed. Finally, potential applications of developed CFVN-based volume flow rate measurement technologies for vacuum pumps are briefly pointed out for instance the MFC market for gas flow control and the on-site performance analyzer of dry vacuum pumps in the semiconductor and flat display production lines.

VT-TuP7 Vacuum System for a Low Temperature Dynamic Force Microscope, ***L. Tröger***, *M. Reichling*, University of Osnabrück, Germany

We present a complete ultra-high vacuum system designated for the operation of a home built dynamic scanning force microscope for use at cryogenic temperatures. The vacuum system was designed for maximum flexibility and consists of a measurement chamber with the cryostat and two separate chambers for sample transfer and preparation.

The cryostat was modified to implement leverage for the scan head for optimum thermal coupling and vibration decoupling by eddy current damping. Thermal anchors for all electrical supply lines were installed. An in vacuo reservoir for the glass fibre for the interferometric detection system of the force microscope ensures protection from vibrations and stores spare fibre for repair. The measurement chamber was designed for best handling and optimised use of space under several technical constraints. Due to the attached cryostat functioning as cryo-pump the chamber reaches lowest pressure regimes providing best conditions not only during experiments but also for storing force microscopy tips and samples in a magazine. The preparation chamber is based on several planes with distinct focus points for preparation instruments along the main axis. The load lock is conceived for maximum exchange efficiency enabling the transfer of up to eight tips or sample at a time. This is achieved by taking advantage of the rotational degree of freedom of the transfer rod that carries a revolving magazine.

VT-TuP9 Magnetron Sputter Coater Construction and Experiments, ***A. Mezzacappa***, Vassar College

Magnetron sputter coating is a method of physical vapor deposition which occurs in vacuum with an inert gas. Production of quality coatings necessitates a rigorous approach to vacuum science. Over the course of the 2008 – 2009 academic year with support from the University of Collaboration and private donors we constructed a sputter coater modeled on a General Atomics sputter coater. The vacuum vessel is eight inches in diameter and stands approximately two feet high. It has thirteen different ports ranging in size from one and one quarter inches to eight inches. The ports accommodate a turbo pump backed by a small diaphragm pump providing 30 liter per second pumping speed, vacuum gauging, Argon and Nitrogen in-gassing, electrical feed-throughs for biasing, viewing windows, and a double tip Langmuir probe on a linear bellows. The magnetron is a two inch US Gunn capable of height adjustment. It is water cooled and powered by a MDX Advanced Energy Power Supply. The sum total of these parts is a research quality machine with immediate applications for Vassar faculty and students. Since construction of the system, we have performed the following experiments: arc discharge, copper sputter coating, spectroscopy, and spatially resolved double tip Langmuir probe scans. We have determined plasma parameters such as electron density and electron temperature. Future experiments will include coating analysis using ultrafast acoustic thin film measurements techniques. In future years, the machine will become an advanced laboratory experiment maintained by Vassar College faculty for plasma physics education and research at Vassar College .

VT-TuP10 Design, Development and Assembly of a Modified PHI 5400 XPS System for XPS/UPS Surface Analysis, ***R. Davies***, *B. Gila, C. Abernathy*, University of Florida

A surface analysis system consisting of a vacuum chamber intended for 1-inch samples was redesigned and reconfigured to accommodate 3-inch samples due to laboratory equipment limitations and financial constraints. The surface analysis system is mainly comprised of a PHI 5400 XPS system with additional functionality provided by a SPECS UVS 10/35 UV source (UPS) and a PHI 77-067 sputter ion gun (surface analysis with depth profiling). Due to budgetary considerations, a previously used PHI 5400 XPS system was purchased. The redesign of the main vacuum chamber was necessitated by the requirement of joining this system with a 3-inch sample size Varian Gen II MBE system. The redesign of the vacuum chamber intended for surface studies involved utilizing the chamber in a horizontal orientation instead of the vertical orientation typically associated with XPS systems. Due to this reconfiguration, the vacuum chamber could both integrate with the current MBE system and accommodate 3-inch samples. The reconfiguration also introduced the need to design a sample manipulation system from square one. Working with Thermionics, a manipulation system was designed that provides for 3-inch sample transport along the x, y and z axis of the Cartesian coordinate system in addition to polar and azimuthal sample rotation. This manipulation system also includes a sample heater for surface adsorption studies up to 1200°C. The customization of the sample manipulation system provided numerous capabilities for surface analysis experimentation after being attached to the reconfigured vacuum chamber. In addition, a 56-inch long vacuum chamber, which acts as a buffer extension between the surface analysis system and both the MBE system and a vacuum briefcase, was designed and assembled. All of the vacuum plumbing necessary for the differential pumping of the sputter ion gun and UV source was designed to readily combine with the reconfigured main vacuum chamber and then assembled. A vacuum briefcase has been diagrammed to provide for sample transport from a Riber MBE 2300 system to the XPS/UPS surface analysis system under vacuum.

VT-TuP11 Reconstruction of a Veeco 776 Ion Beam Deposition System With Digital Sensing and Logging Modifications, ***J. Vanderford***, *A.P. Genis*, Northern Illinois University

The purpose of this project was to document the efforts of restoring a thirty-five year old Veeco 776 vacuum deposition system equipped with a 3 inch ion beam milli-tron which was destroyed in a laboratory fire. This was a system used for the deposition of Indium Tin Oxide (ITO) used for the fabrication of ITO / P-Silicon solar cells. The fire destroyed all electronics for powering the ion source, the gas delivery system for the ion source, vacuum measurement and valve control systems, the substrate chuck heat controller, and considerable damage to the vacuum pump stack and valves Due to the age of the system, direct replacement of these components were not available. The goal of this project was not only to rebuild the vacuum system but also to incorporate a data acquisition and logging system for monitoring and recording critical process parameters associated with the operation of the system in a real time graphic interface environment. The design and engineering which was required to complete this project, as well as the re-engineering of specialized components to achieve these goals will be presented.

VT-TuP12 Ultra-Clean Magnetron Sputtering System for Materials Research and Education, ***H. V Nampoori***, *G.J. Mankey*, University of Alabama

Construction and implementation of a multi-target magnetron sputtering system with substrate carousel is reported in this poster. The system has four magnetrons arranged on a circle and facing up, to enable deposition of multilayers for applications such as magnetic media, tunnel junctions and MRAM devices.

Up to twelve substrates can be loaded into the system on a rotating carousel. In addition, a lifter assembly can be used to move samples between positions on the carousel fitted with shadow masks. The bottom up sputtering is achieved in stainless-steel, bell-jar chamber with a rotary vane pump and Cryotorr 8 combination. With internal bake-out heaters using two 600 W halogen bulbs, a base pressure of 2 x 10^{-8} Torr is achieved. Argon pressure during sputtering is controlled using a MKS flow controller and Adaptorr butterfly valve with a Baratron gauge. Each magnetron has a shutter controlled by a Durant programmable timer. Substrate heating during deposition could be achieved using a 150 W halogen projector lamp located above each magnetron source. A quartz crystal microbalance thickness monitor can be used to determine the deposition rate for each gun. In addition, the carousel has integrated permanent magnets designed to grow magnetic thin films with induced uniaxial anisotropy.

This poster will describe the motivation and design of the system and present some preliminary results. The results will highlight the uniqueness of the system design for a manually-operated, simple and user-friendly machine.

This work was supported in part by the National Science Foundation MRSEC Grant DMR-0213985.

VT-TuP13 Outgassing Measurement of Ion and Getter Pumps at UHV Regime, ***G.Y. Hsiung***, *C.M. Cheng*, NSRRC, Taiwan, *J.R. Chen*, NSRRC and NTHU, Taiwan

The combination of ion pumps and getter pumps have been used for the advanced pumping at UHV regime of a pressure below 10 nPa. The effective pumping speed of ion and getter pumps is limited at UHV pressure due to the outgas of the materials inside the pumps such as H_2 and CO or that evolved from the surface reactions during or after pumping such as CH_4. Besides, the outgas of the noble gas such as He or Ar buried inside the cells of ion pumps as well as the Kr or Ar from the coated film of getter pumps is regarded as one of promising limit of pumping speed. The measurement of outgas of ion and getter pumps is performed by pressure build up method. The cleaning process for reduction of the outgas of the ion and getter pumps are evaluated.

VT-TuP14 Study of Secondary Electron Yield for KEKB Positron Ring, ***S. Kato***, *M. Nishiwaki*, KEK, Japan

In order to mitigate electron cloud instability in high-intensity positron and proton accelerators, material surface with a low secondary electron yield (SEY) for the beam ducts is highly desired. In-situ SEY measuring system in the straight section of the KEKB positron ring was reported where one can measure SEYs of sample coupons exposed to electron cloud during the KEKB operation. In this study we aim to develop a mobile UHV system for sample coupon transfer from an arc section of the positron ring to a load lock chamber of XPS at our laboratory in order to carry out SEY measurements and surface analyses without exposing coupons to the air. There are two sample ports with a size of 8x8 mm^2 at the side and the bottom of the positron beam duct for comparison. While both of samples are exposed to electron cloud caused by strong synchrotron light from a bending magnet of the ring, the light directly hits only the sample positioned at the side port. Sample coupons exposed to electron cloud can be transferred to UHV suitcases 1 and 2 through isolation gave valves installed between the beam duct and the suitcases. An amount of electron cloud is measured with the electron monitor. The UHV suitcase consists of a gate valve, linear and rotary motion drives to transfer the coupons, an ion pump with its power supply and drive batteries. The total weight is about 10kg. Two suitcases are almost identical. These suitcases are moved and connected to the second load lock chamber where the coupons up to 12 can be kept in UHV before the measurement. In this paper, the detail of the SEY measuring system is mentioned with its experimental results after a long time exposure of the coupons to the electron cloud during the KEKB operation.

VT-TuP15 Energy Consumption Characteristics of Low Vacuum Dry Pumps in Semiconductor Manufacturing, ***J.Y. Lim***, KRISS, Korea, *H.Y. CHoi*, LOTVacuum, Korea, *W.S. Cheung, J.H. Shin, S.B. Kang, Y.-H. Shin*, KRISS, Korea

Recent SEMATECH and SEMI studies showed that 50~60% of equipment power is used for vacuum pumps. Currently vacuum pump suppliers have responded by reducing power consumption and cooling water flow requirement in energy consumption at the component level. Actual process studies showed that for some processes, the energy consumption level did not change significantly during idle and processing operation modes. However, specified studies in experimental scale to characterize the energy consumption pattern have not been reported yet.

We have performed a simulation study to characterize energy consumption pattern in the idle and process modes.

The pressure range of about 0.1 to 50 mbar for 7 minutes was assigned to the simulated process mode, meanwhile the pressure of <0.1 mbar for 3 minutes to the idle mode. The integrated characteristics evaluation system for dry vacuum pumps has been utilized to gather the dry pump characteristics data for the simulation. The evaluation system exploits the constant volume flowmeter to measure the mass flow rate real-timely in standard level, and facilitates the evaluation of spatially averaged sound power levels using a reverberation chamber. Roots, claw, classical screw, and multi-stage type vacuum pumps supplied from the manufacturers have been evaluated using the evaluation system in terms of ultimate pressure, pumping speed, power consumption, vibration, sound power as well as nitrogen purge, cooling water rate from the single pump monitoring system in time-synchronized mode. This study includes the application of the SEMI S23-0705 standards – A Guide for Conservation of Energy, Utilities and Materials Used by Semiconductor Manufacturing Equipment.

The estimated power consumption per pump per year was ranged from 10 to 30 MWh and 15 to 50 MWh for 600 ~ 1200 m^3/h dry pumps in idle and processing modes, respectively. The utility energy consumption was also ranged from 5 to 10 MWh and 10 to 30 MWh, respectively. More specific energy consumption patterns with respect to the pressure are also presented. In this work we suggest that the correlation mechanism dependant on the actual process lines should be carefully analyzed and furthermore understood, for example, the relationship between cooling water flow rate and temperature variation during processes.

VT-TuP16 Development of a Pulse Motor Driven All Metal Valve for a Static Expansion System, ***K. Arai***, *T. Tomita, H. Akimichi, M. Hirata*, NMIJ/AIST, Japan

A static expansion system generates standard pressures for the calibration of a spinning rotor gauge and a capacitance diaphragm gauge. Valves are important parts for the system. All metal pneumatic valves are used for an automatic operation. However, the pneumatic valve closes so rapidly (<1 s) that the undesirable differential pressure between both sides of the valve is seemed to be induced by pushing gas. In order to clarify it, a test system consists of 45 m chamber and 3000ml chamber connected by the pneumatic valve was set up. The 13 Pa of differential pressure at the 100 kPa of line pressure was generated by closing the valve. The pressure decreased to 1.5 Pa by elongating the valve closing time, 150 s, by the control of the flow rate of the pneumatic line. However, the repeatability of the valve closing was not sufficient.

Pulse motor driven all metal valve was developed: (1) The motor drive part is attached to a commercial available valve, (2) A valve stem is driven by the pulse motor via a torque-limiter, springs, and a valve shaft, (3) The valve shaft position at closing the valve is always same by using the position sensor, (4) Springs are used to close the valve with the same torque, (5) To avoid the increase of the temperature of the valve body, the motor is operated only for the valve operation and 50 cm away from the body, (6) The torque-limiter is put between the motor and the shaft not to break the valve by the over torque.

The stem speed was controlled ranging from 0.1 to 0.008 mm/s (closing time: 25 ~ 300 s). The differential pressure could not be eliminated by slowing the stem speed. The smallest pressure was 1.4 Pa at the 100 kPa of the line pressure. Taking into account the pressure and the test chamber volume, 1.4 Pa is corresponding to the 0.0006 ml volume change of the valve. The mechanism of the undesirable differential pressure during the valve closing can be analyzed by measuring the detailed pressure change as a function of the time and the position of the stem.

VT-TuP17 A Novel Reactor Setup for Surface and Gas-Phase Diagnostics during Atomic and Molecular Layer Deposition, ***B. Jariwala***, *V. Rai, C.V. Ciobanu, S. Agarwal*, Colorado School of Mines

In this presentation, the authors will describe the design of a versatile reactor setup with multiple in situ diagnostics to study the surface reaction mechanisms during atomic and molecular layer deposition. The setup consists of two vacuum chambers: the first chamber is equipped with real-time attenuated total reflection Fourier-transform infrared (ATR-FTIR) spectroscopy and quadrupole mass spectrometry, while the second chamber is equipped with a quartz crystal microbalance. Both chambers are connected to multiple in-house-built bubblers to supply different precursors. In addition, each chamber is equipped with an inductively-coupled, radio-frequency plasma source that is in line of sight with the substrate for plasma-assisted atomic layer deposition (ALD). The precursor delivery into the chamber is controlled through solenoid valves operated via Labview. The infrared analysis chamber is ideal for observing the surface species and the gas phase products during each half-reaction cycle. However, due to the multiple diagnostics, which require several ports, the chamber volume is large resulting in long precursor exposure and purge cycles. On the other hand, the second process chamber is a hot-wall tubular reactor with a small volume, which allows shorter reaction cycles enabling the deposition of films that are several 10s of nm in thickness: these thicknesses are required to obtain enough sensitivity for ex situ IR and x-ray diffraction analysis. We will specifically present results for the thermal and plasma-assisted ALD of TiO_2 that will demonstrate the synergistic utilization of each diagnostic tool to unravel the specific surface reactions during film growth.

VT-TuP18 A Method of Transfering Parts Rapidly Into and Out of a High Vacuum Environment, ***E. Trillwood***, CEO Electron Beam Engineering

The novel device uses a piston and a cylinder, both with seals to penetrate the wall of a high vacuum processing chamber. The piston is hollowed out for a portion of its length and the component to be processed in the chamber is placed in this cavity, or breach. The piston, as it moves into the chamber, passes over a pre pumping station which is fitted with a two stage mechanical pump to pre evacuate the breach. Since the volume closely fits the component the evacuation time is usually one second or less. When the component enters the chamber "volume sharing" occurs and the resulting pressure rise is very small and rapid as the chamber high vacuum pumps the differential pressure between the breach and the chamber.

The seals are placed in such a manner as to isolate the atmosphere, the pre pumping and the chamber vacuums from each other at all times in the cycle.

On completion of the process the piston is withdrawn from the chamber and the breach returned to atmosphere.

Apart from the speed of operation the system has the advantage of being self valving and if a second breach or dummy piston is added to the opposite side of the chamber the forces on the piston due to atmospheric pressure are equalized and the force required to transfer the piston is greatly reduced.

This system has been used successfully in production Electron Beam Welding but has many other potential uses where ease and speed of loading and unloading relatively small parts into a vacuum chamber is requied.

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