Vacuum Technology Division
Room 9 - Session VT-ThA

Surface Science for Accelerators

Moderators: Jay Hendricks, National Institute of Science and Technology, Alan Van Drie, Tri Alpha Energy, Inc.

2:20pm **VT-ThA-1 Adsorption/Desorption from Amorphous Carbon Coating at Cryogenic Temperatures***, **Anne-Laure Lamure**, V Baglin, P Chiggiato, B Henrist,* CERN, Switzerland **INVITED**

The CERN Large Hadron Collider (LHC) is the world's biggest particle storage ring. Particles circulate in a 27km pipe, under vacuum. One of the main vacuum limitations is the electron cloud.

Photoelectrons are produced when the synchrotron radiation from the proton beam hits the wall. They are then accelerated toward the beam, gain energy and extract new electrons by secondary electron emission. The avalanche phenomenon which is observed is called multipacting.

Electron cloud is deleterious as it interacts with the beam, induces gas desorption and produces additional heat load on the cryogenic system of the magnets.

In order to mitigate the multipacting effect for the upgraded LHC (HL-LHC), amorphous carbon, with a low secondary electron yield, will be coated in some cryogenic magnets.

In this context, it is important to know the behaviour of the usual residual gas (H2, CO, CH4, CO2) on amorphous carbon coating held at cryogenic temperature, in order to know how to operate the vacuum in the accelerator. The quantity of gas that can be stored on the surfaces and the binding energy of adsorption are two highly interesting information.

The results of two types of experiments will be presented. Adsorption isotherms give the vapor pressure depending on the coverage of gas on the surface. Isotherms of H_2 at 4.2K and of CO and CH_4 at 77K have been measured.

Thermal Desorption Spectroscopy, that allow to determine the average binding energy between the gas and the surface, have been carried out for the four gases, for different initial coverages.

It has been measured that amorphous carbon is a porous material which can store more gas at cryogenic temperature than usual technical surfaces such as copper or stainless steel. The consequences for the accelerator will be discussed. A model to compute the pressure rise in the vacuum pipe, depending on the temperature variation and on the initial coverage, is under development.

3:00pm **VT-ThA-3 Heavy ion-induced Desorption and its Impact on Next Generation Accelerators***, **Markus Bender**, H Kollmus,* GSI Helmholtzzentrum für Schwerionenforschung GmbH, Germany*; E Mahner,* CERN, Switzerland **INVITED**

Dynamic pressure increases in vacuum systems of particle accelerators have been observed since almost 50 years. Since the turn of the millennium, the dynamic vacuum turned out to be an intensity limitation in particle accelerators, e.g. in the Low Energy Antiproton Ring (LEAR) at CERN or the heavy ion synchrotron SIS18 at GSI. Here, charge exchanged lost beam ions stimulate the release of gas from the chamber walls and the subsequent pressure increase leads to increased beam-loss. Hence the effect is self-amplifying and can lead to severe deterioration of the vacuum to the point of complete beam-loss. Consequently heavy ion-induced desorption is an issue for next-generation heavy ion accelerators such as the FAIR facility or Spiral2 with highest beam intensities.

To come up against this dynamic vacuum effect, several measures have been conducted. In particular the physics behind the ion-induced release of gas was investigated. For that purpose, several samples have been irradiated with ion beams of different parameters and the resulting desorption yields have been measured. A broad range from some 10 to several 10,000 released gas molecules per incident ion was observed. From the gathered results a clear picture of the underlying process of ion-induced desorption was drawn. It could be shown that the desorbed gas is originating mainly from the surface or surface-close regions of the target. But in contrast to earlier ideas, sputtering of the oxide layer on metals was not identified as the source for the desorbed gas. Latest experiments prove that pre-treatment of critical components is most important to minimize the desorption yield and therefore, especially thermal annealing was investigated in detail.

Besides experimental findings a model calculation was developed that is able to describe and compare desorption yields of different collision systems. The calculation is based on the inelastic thermal spike model and describes ion-induced desorption as enhanced thermal desorption due to a transient overheated spot around the ion impact.

Presently we are able to propose materials, coatings, and treatment procedures for best performance in particle accelerator vacuum systems.

4:00pm **VT-ThA-6 Outgassing Behavior of Different Oxide Ceramic Materials***, **Katharina Battes**, C Day, V Hauer,* Karlsruhe Institute of Technology (KIT), Germany

In general, ceramics show interesting mechanical, thermal and electrical properties and are supposed to have relatively low outgassing rates. Therefore, in vacuum applications they are often used for feedthroughs for example. However, quantitative numbers on outgassing of most of the ceramic materials are hard to find in literature.

For this reason the outgassing of different ceramic materials was studied at the Outgassing Measurement Apparatus (OMA), which uses the difference method. First, oxide ceramics like alumina, magnesia, silica, and MACOR®, which consists of silica and other oxide ceramics, were measured. All measurements were performed at room temperature, 100 °C and 200 °C to investigate the temperature behavior of outgassing. Additionally, the outgassing species were determined by a quadrupole mass spectrometer.

The paper shows quite low outgassing rates for most of the examined ceramics. After 100 h at room temperature an outgassing rate of about $2\cdot10^{-8}$ $(Pa\cdot m^3)/(s\cdot m^2)$ is achieved for alumina for example. The mass spectra show similar residual gas spectra as seen for metals. Thus, these materials can be used in ultra-high vacuum applications.

4:40pm **VT-ThA-8 APS-Upgrade Storage Ring Vacuum System Sector Mockup and Vacuum R&D Activities***, **Jason Carter**,* Argonne National Laboratory

As the APS Upgrade project continues in its preliminary design phase the APS-U storage ring vacuum system plans continue to mature while ongoing R&D activities and analysis are validating and strengthening the design. The storage ring magnets and structural support designs constrain the system to have narrow aperture vacuum chamber dimensions and limit allowable UHV pumping elements and locations. Monte-Carlo vacuum system analysis has indicated that the pressures and performance should meet requirements during and after accelerator commissioning. The margin of error for analysis must be better understood so a number of ongoing R&D efforts are helping to better predict and improve the performance.

A 28 meter length full sector vacuum system mockup will be installed in Fall 2017 and will include prototype vacuum chambers and all pumping elements. A sector mockup vacuum test plan will be presented which examines pumping speeds, outgassing rates, and the pumping conductance. NEG coating performance will be key to APS-U vacuum success and prototypes and further analysis are helping evaluate current coating plans and the option of adding more coatings. Finally, R&D proposals are progressing to measure photon stimulated desorption from APS-U style chamber designs.

5:00pm **VT-ThA-9 Numerical Tools for Particle Accelerator Vacuum Systems***, **Giulia Lanza**,* SLAC National Accelerator Laboratory

A number of different gas density simulation programs have been applied in the design of the SLAC National Accelerator Laboratory's LCLS-II accelerator's vacuum system. Starting from these basic programs, this talk gives an overview of the available numerical methods for the analysis and design of a linear accelerator vacuum system.

Programs like Pressure5, LTspice, Vaccalc, Molflow+ and others are described and compared. Their optimal domain of applicability, the pros and cons are discussed.

5:20pm **VT-ThA-10 Developing Particle Control Infrastructure for the ESS High Beta Project at STFC Daresbury Laboratory***, **Mark Pendleton**,* STFC Daresbury Laboratory, UK

As part of a UK In-Kind contribution to the European Spallation Source (ESS), STFC-Daresbury laboratory has agreed to procure, fabricate, test and deliver 84 + 4(5-cell) high-beta superconducting 704.41 MHz dressed cavities according to ESS requirements.

As part of the test phase and re-work at STFC the cavities will have to be processed and connected in a particulate controlled environment.

This paper will describe the developments of the Main Cleanroom facility which will be utilised for the workflow of the High Beta Cavity to undertake a High Pressure rinse cycle. It will also cover the Cryostat Insert stands and the design of the Modular cleanroom solutions that will be utilised to connect the cavity under ISO 4 conditions to the new Vertical Test Cryostat Insert developed at STFC.

5:40pm **VT-ThA-11 Functional Coatings for Gauges and Components***, B Andreaus, C Strietzel,* ***Martin Wüest****,* INFICON Ltd., Liechtenstein*; C Guerra-Nuñez, M Ruoho, I Utke, J Michler, X Mäder, M Polyakov,* Empa, Swiss Federal Laboratories for Materials Science and Technology, Switzerland

Process industry is constantly changing. New manufacturing processes using new chemistries are developed. Yet, quality and cost pressure demand that processes are highly reliable, repeatable and need fewer maintenance interruptions. For vacuum sensors this means that they need to have a longer life in process before they need to be exchanged due to sensor degradation caused by process corrosion. To cope with this, we have investigated ways to protect the vacuum sensors from process related influences. Coatings are a good way to protect a surface from corrosion while leaving the underlying structural part without change. Coatings can be adapted to the changing customer needs. We will present results from experiments we have done with gauges and components using different protective layers.

6:00pm **VT-ThA-12 60 Years of Ion Pumps: From the Invention to the Latest Developments***,* ***Mauro Audi****,* Agilent Technologies, Italy

Since their invention in 1957 at Varian Associates as a pumping device for electron tubes at relatively high pressures , Ion Pumps have continuously moved towards lower pressures , and nowadays they are the pumps of choice for most of UHV applications in both research and industrial field

This includes a large a variety of high and ultra high vacuum systems , from Particle Accelerators to Synchrotron Light Sources and Gravitational Wave Detectors , from Scanning Electron Microscope to Surface Analysis and Medical Equipment

Application requirements have changed dramatically in these 60 years in terms of starting and operating pressures , pumping performances , ability of pressure reading , cleanliness , particle emissions , safety , resistance to radiation .

The latest developments on Ion Pump Technology are presented , including :

- a new combination of magnetic field and cell dimensions to realize the first ion pump with the maximum pumping speed in the low pressure range

- a new vacuum firing process to minimize the outgassing and reduce particles

- an anode design that minimizes the field emission and the leakage current , and additional shields that minimize charged particle emissions

-a controller design that allows starting Ion Pumps with a very limited power and can vary voltage supplied to the ion pump in order to optimize both the pumping performances and the pressure reading ,

- a combination of ion pumps with NEG pumps in order to reach the lowest ultimate pressure

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