Vacuum Technology
Room 104C - Session VT-TuA
Accelerator and Large Vacuum Systems

Moderators: Marcy Stutzman, Thomas Jefferson National Accelerator Facility, Marcelo Ferreira, European Spallation Source-ESS, Sweden

2:20pm **VT-TuA1 Vacuum Design of the European Spallation Source Target Monolith System***, **Peter Ladd**,* European Spallation Source, Sweden **INVITED**

The European Spallation Source (ESS) is a multi-disciplinary research center based on the world's most powerful neutron source being built in Lund, Sweden . The facility design and construction includes the most powerful linear proton accelerator ever built, helium-cooled tungsten target wheel, state-of-the-art neutron instruments, a suite of laboratories, and a supercomputing data management and software development center . The LINAC will deliver 5 MW of power to the target at 2000 MeV. Ground breaking took place in September 2014 and construction is rapidly progressing towards first neutron on target scheduled for mid 2019 .

ESS is a long pulse superconducting linac that accelerates protons in 2.86 ms long pulse stream with a repetition rate of 14 Hz at a 4 % duty cycle providing an average beam power of 5 MW. The stream of protons is intercepted by a helium cooled tungsten target wheel where about 10% are converted to mass, through the nuclear reactions in the spallation process and the remaining 90% is deposited as heat within a distance of about 1m from the target wheel. The moderators and reflectors maximize the yield directing the flow of neutrons to a suite of neutron instruments through neutron guides.

The "Target `Monolith Vessel" (CPMV) is a vacuum vessel nominally 6m in diameter x 9m high fabricated of 304 stainless steel. The major equipment located within this vessel are the helium cooled target wheel, 42 actively cooled neutron beam port inserts that connect to the external neutron guides, actively cooled moderators and reflector plugs and water cooled radiation shielding blocks. The CPMV is designed to operate either under a helium atmosphere, normally at 1 bar pressure, or under high vacuum and is directly connected to the accelerator beam-line that operates under ultra high vacuum conditions. A proton beam window (PBW) physically separates the two environments when the monolith is under a helium atmosphere and in the vacuum mode the PBW is removed and the two vacuum environments are directly connected.

The paper presented reviews the various aspects of the Vacuum Design of the Target Monolith System including material selection, surface finishes and construction issues, equipment sizing and selection and the development of a Strategic Installation and Test Strategy in order to minimize project risk.

3:00pm **VT-TuA3 Achievements and Problems in the First Commissioning of SuperKEKB Vacuum System***, **Yusuke Suetsugu**, K. Shibata, T. Ishibashi, M. Shirai, S. Terui, K. Kanazawa, H. Hisamatsu,* KEK, Japan

The SuperKEKB is an electron-positron collider with asymmetric energies, that is, 7 GeV electrons and 4 GeV positrons, aiming the goal luminosity of $8x10^{35}$ $cm^{-2}s^{-1}$. Most of the vacuum components of the main rings (MR), especially in the positron ring, were newly fabricated to manage the high power of synchrotron radiation and the electron cloud effect (ECE), and to reduce the beam impedance, which are essential to keep the low-emittance beams stable in the operation with high beam currents. The construction of the new vacuum system had finished by the end of December 2015, and the beam commissioning started in February 2016. The maximum stored beam currents steadily increased from the beginning, and reached to 650 mA and 590 mA for the positron and electron rings, respectively, by the end of April. The average pressures at these beam currents were on the order of 10^{-6} Pa and 10^{-7} Pa for the positron and the electron ring, respectively. The vacuum scrubbing of the new beam pipes by the synchrotron radiation processed steadily. The pressure rises per unit beam current were on the order of 10^{-6} Pa A^{-1} and 10^{-7} Pa A^{-1} for the positron and electron ring, respectively. The high gas desorption in the positron ring was due to the electron stimulated gas desorption at aluminum parts in the ring. On the other hand, the reused beam pipes of the electron ring well memorized the surface condition of that in KEKB, which lead to the low gas desorption. The residual gas during the beam operation was continuously monitored using a quadrupole mass analyzer. The main components were hydrogen, methane, carbon monoxide and carbon dioxide. The electron numbers around the positron beam were also monitored at an arc section in relation to the electron cloud issues. The effect of antechambers and TiN coating on the suppression of electron cloud was confirmed. Newly developed vacuum components, such as the bellows chambers and gate valves with a comb-type RF-shield, and the MO-type flanges with little step inside, worked well as expected. One annoying problem was frequent pressure bursts accompanying beam aborts observed in the positron ring. Discharges at gaps or collision of the beam with dusts were suspected, but the investigation is still in progress. Here the major achievements and problems obtained in the first beam commissioning of the SuperKEKB MR vacuum system are presented.

4:20pm **VT-TuA7 Saving Megawatts in a Micron: Tailoring the Surfaces of Superconducting RF Cavities***, **Sam Posen**[*],* Fermi National Accelerator Laboratory **INVITED**

In particle accelerators, superconducting radiofrequency (SRF) cavities are specially-shaped chambers in which intense electromagnetic fields are built up through resonant excitation, in order to transfer energy to beams of charged particles as they pass through. Large AC currents are generated in the region in which magnetic fields penetrate into the superconductor—just hundreds of nanometers below the surface—dissipating power that must be absorbed in the liquid helium bath that cools the cavities. Because of the significant cost of removing heat at cryogenic temperatures, accelerator scientists take great care in tailoring the surfaces of these superconducting materials to minimize dissipation, as well as to maximize the accelerating electric field. This contribution will present an overview of modern techniques used in SRF surface preparation, including doping with nitrogen, high temperature deposition of tin, and plasma processing. These processes, which generate micron-scale modifications of the surface, will be outlined, and their substantial impact on the accelerator will be presented.

5:00pm **VT-TuA9 NEG Coating of Narrow-Gap Insertion Devices and Beam Pipes: Recent Achievements and Future Perspectives***, **Paolo Manini**, M. Puro, S. Raimondi, T. Porcelli, F. Siviero, E. Maccallini, G. Bongiorno,* SAES Getters S.p.A., Italy

Non-evaporable getter (NEG) coatings are nowadays successfully employed in several accelerator facilities, where stringent ultra-high vacuum (UHV) conditions should be met.

NEG coatings are able to provide high distributed pumping speeds for every getterable gas; in addition, the thermal outgassing and secondary electron yield of a NEG-coated beam pipe are considerably reduced, thus allowing the achievement of better results in terms of base pressure and, consequently, beam lifetime and luminosity.

The use of NEG coatings is especially suitable for narrow-gap beam pipes and insertion devices, which could not otherwise be pumped with the same effectiveness by a series of traditional UHV lump pumps. This aspect is particularly significant in view of next-generation machines, for which long and small-aperture tubes (*i.e.*, down to 4 mm) are envisaged in order to reach even higher luminosities and lower emittances.

Such stringent requirements should be carefully addressed, as a number of technical issues arise—both in terms of coating deposition and characterisation—when dealing with narrow-gap beam pipes of this kind.

SAES' recent achievements in this field are here presented, together with an overview of the ongoing R&D activities, whose aim is to demonstrate the feasibility and pumping effectiveness of narrow pipes under 10 mm of diameter. These include SEM morphological inspections, chemical composition analyses and thickness profiling made by EDX and, finally, measurements of the getter film's sorption capacity for CO. Future perspectives and issues—including the possibility to coat very long and narrow chambers and to perform transmission factor measurements on them—are also reviewed.

5:20pm **VT-TuA10 Realisation of a Vacuum System of an EUV Exposure System***, **Freek Molkenboer**, N.B. Koster, A.F. Deutz, B.A.H. Nijland, P.J. Kerkhof, P.M. Muilwijk, B.W. Oostdijck, J. Westerhout, C.L. Hollemans, E. te Sligte, W.F.W. Mulckhuyse, M. van Putten, A.M. Hoogstrate, P. van der Walle, J.R.H. Diesveld, A. Abutan,* TNO Technical Sciences, Netherlands

TNO is designing and building an Extreme Ultra-Violet (EUV) exposure facility, as presented last year. This system, called EUV Beam Line 2 (EBL2) will be capable of exposing a wide range of samples, including 6" EUV reticles.

The EBL2 system combines 6 major sub systems;

[*] **VTD Early Career Award**

An atmospheric and vacuum handler connected through a load lock, enabling both molecular and particle clean handling of the sample. Samples will be loaded on the atmospheric handler using SEMI standardised EUV dual pods.

The vacuum handler transports the samples to and from all the attached sub systems. The particle cleanliness of the EBL2 system shall ensure that the EUV reticles can re-enter into EUV lithography tools to assess the imaging impact of the exposure after handling and exposure.

The EUV radiation is generated with a Sn fuelled EUV source and focussed with two collectors, providing EUV irradiation on the sample. The two collectors are mounted in a differentially pumped vacuum system which ensures good vacuum quality in the exposure chamber while maintaining the increased pressure in the EUV source.

The exposure chamber is an ultra-clean vacuum chamber which enables exposure of the sample in an ultra-clean environment. The vacuum design also enables a controlled introduction of various contaminants and process gasses to facilitate the customer's request. The sample or EUV reticle is mounted on a clamp that can be moved in XYZ and rotated around X and Z. This movement is achieved with a large hexapod which is located in atmosphere. The vacuum barrier between the hexapod and the exposure chamber is a 1 meter long, CF250 mm edge welded bellow.

The last sub system is an X-ray Photoelectron Spectroscope (XPS) which is capable of analysing the full surface area of an EUV reticle, as well as performing angle resolved analysis on smaller samples in a specially designed sample holder that can be loaded in the exposure chamber for exposure to EUV.

This presentation will focus on the realisation of the vacuum system of the EBL2 system and will highlight the design choices made to meet the stringent vacuum and particle contamination requirements. Preliminary results of vacuum qualification of chambers will be shown together with progress in building the system.

EBL2 will be publicly accessible as a test facility for EUV lithography related research after qualification, which is expected to be finished end of Q1 2017.

5:40pm **VT-TuA11 Cleaning and Verification Strategies for UCV and UHV Components***, **Michael Flämmich,*** VACOM, Vakuum Komponenten & Messtechnik GmbH, Germany*; C. Worsch, S. Gottschall, R. Bauer, U. Bergner,* VACOM Vakuum Komponenten & Messtechnik GmbH, Germany **INVITED**

The requirement of high quality vacuum components for ultra clean vacuum (UCV) and ultra high vacuum (UHV) has become stronger over the last years, especially driven by industrial applications, research institutions and accelerator facilities. Besides the prerequisite of ultra clean surfaces, the outgassing properties from the bulk material are critical for in-situ baked UHV systems. For these applications stainless steel has been and still is the most commonly used raw material. The challenge of suppressing hydrogen outgassing from the bulk material has extensively been discussed in the past. Some approaches seem to be promising, but at the same time they are quite expensive and economically hardly viable. As an alternative to stainless steel, aluminum is regarded as a promising raw material due to some fundamental advantages, even though metal sealed CF components and chambers made from aluminum are hardly available and rarely used.

The present talk focusses on vacuum components and chambers for UCV and UHV applications made from both raw materials, stainless steel and aluminum. In this context, a viable cleaning strategy applying some state-of-the-art cleaning methods will be presented. In order to carefully characterize the extremely low outgassing of components for these vacuum sectors (UCV: non baked; UHV: in-situ baked), appropriate setups for outgassing rate measurements (throughput, accumulation, and pressure rise) will be discussed and respective experimental data will be shown. Measuring, verifying, controlling, and, at the end, knowing the outgassing rate of the produced components enables to explicitly specify, classify and guarantee the cleanliness and outgassing properties of UCV & UHV vacuum components.

As a further focus of the talk, metal-sealed CF vacuum components made from aluminium are introduced. In this context, adequate knife edge stability, complicated weldability and reliable outgassing properties have always been discussed as major challenges. It will be shown that these challenges have been solved lately and that Alu-CF components and chambers (AluVaC®) are today a serious alternative to the established components made from stainless steel.

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