Vacuum Technology
Room Hall D - Session VT-TuP

VT Poster Session (and Student Poster Competition)

VT-TuP1 Smart Measurement and Diagnostics Module for Dry Vacuum Pumps*, **Wan-Sup Cheung**, K. Baik, J.Y. Lim,* KRISS, Republic of Korea

This paper addresses recent industrial demands for more reliable predictive maintenance and diagnostics for the failure protection of dry vacuum pumps operated in the semiconductor and flat display chemical processes. Korean leading companies are very expecting to improve the predictive maintenance and self-diagnostics capability sufficient to meet such higher demands for dry vacuum pumps. This project has started to satisfy Korean industrial demands. On the onset of this work, the first technical issue was to examine what kinds of state variables are measured from dry vacuum pumps. Most of them were found to be the static properties such as body and exhaust temperatures, N2-flow rate, motor supply currents of booster and dry pumps, exhaust pressure, etc. Most vacuum pump manufactures have reported that most of vacuum pump failures come from their rotating machinery parts such as rotors, bearings and/or gears. It became apparent that reliable self-diagnostics of vacuum pumps cannot be realized without vibration measurement of those rotating parts. A vacuum pump vibration measurement (VPVM) module has been developed to enable the measurement of three vibration harmonics of rotors, bearings and gears. Tested results of the VPVM module are shown to provide harmonic vibration measurements of rotors, bearings and gears. In addition to the vibration measurement capability of the VPVM module, another technical challenge was to collect the measurements of the state variables available from each vacuum pump via the digital communication interface. This work has attempted to integrate both the traditional state variables and the three harmonic vibration levels into an extended set of state variables required to realize more reliable predictive maintenance and diagnostics of dry vacuum pumps. To obtain the extended state variables, the VPVM module was developed to support three kinds of serial communication ports (RS232C/RS485, CAN and/or SPI) to an individual vacuum pump controller. Furthermore, the VPVM module was designed to provide a 128 MB backup flash ROM to record a time series of the extended state variables in real-time. These records of the extended state variables are used to implement the self-diagnostics and predictive maintenance algorithms of dry vacuum pumps developed and patented by KRISS.

VT-TuP2 Vacuum System of Positron Damping Ring for SuperKEKB*, **Kyo Shibata**, Y. Suetsugu, T. Ishibashi, M. Shirai, S. Terui, K. Kanazawa, H. Hisamatsu,* KEK, Japan

SuperKEKB, which is an upgrade of the KEKB B-factory (KEKB), is a next-generation high-luminosity electron-positron collider. Its design luminosity is 8.0×10^{35} $cm^{-2}s^{-1}$, which is about 40 times than the KEKB's record. To satisfy tight requirements on beam quality for positron injection, a new damping ring (DR) with a circumference of 135.5 m is constructed in the positron injection system. For beam quality improvement, the positron beam extracted from an injection linac with an energy of 1.1 GeV stays in the DR for 40 ms. Maximum stored current is 70.8 mA, and the number of bunches is 4.

The DR has two arc sections (~110 m) and two straight sections (~20 m). In the arc sections, walls on both sides of the beam pipes are irradiated with synchrotron radiation (SR, critical energy: ~1 keV). To deal with SR and photoelectrons, the beam pipes in the arc sections have antechambers on both sides of a beam channel. The antechamber is also effective in reduction of the beam impedance. The height of the beam channel in the arc sections is 24 mm and the width including the antechambers is 90 mm. To remove the heat by SR irradiation, a water cooling system is also required in the arc sections. In the straight section, on the other hand, an antechamber structure and a water cooling system are not necessary. The cross-section of the beam pipe is octagon with an inscribed circle diameter of 46 mm.

Required beam lifetime due to residual gas scattering is longer than 1000 sec and averaged pressure should be lower than 1×10^{-5} Pa. In the arc sections, pumping speed should be much larger than that in the straight sections because a major dynamic gas load during the beam operation is photon stimulated desorption by SR. Non-evaporable getter (NEG) pumps are mainly used with auxiliary ion pumps, and the average effective pumping speed in the arc sections is about 0.05 $m^3s^{-1}m^{-1}$ (CO) just after NEG activation. If the photon stimulated desorption coefficient drops to below 1×10^{-4} molecules photon^{-1} by the sufficient SR irradiation (i.e. scrubbing), the target pressure can be achieved even after the average pumping speed reduces by nearly half.

The material of the beam pipes is aluminum alloy. The number of the beam pipes is about 100, and almost all beam pipes are coated with titanium nitride films as a countermeasure against the electron cloud issue. Moreover, the beam pipes in the arc sections have the grooved surfaces on upper and lower sides of the beam channel to reduce the secondary electron yield structurally.

Installation work of the beam pipes will start on May of 2016, and the construction of the vacuum system will finish by the summer of 2017.

VT-TuP3 Testing Pump Speed & Thermal Loading of Titanium Arc-Gettered High Speed (~2,000 m^3/s for H_2) Cryoboxes*, **Ernesto Barraza-Valdez**,* Tri Alpha Energy

We have a need for very high pump speed for H_2 and D_2 with a finite capacity that can be periodically refreshed. Special pumps are being developed to achieve S_{H2} ~ 2,000 m^3/s and S_{D2} ~ 1,500 m^3/s with an inlet area of 10 m^2 that fits within our 15 m^3 vessel. The pumps are an array of LN2 (Liquid Nitrogen) cooled cryoboxes with multifaceted surfaces that are coated with titanium using cathodic-arc gettering. Since these are rather large cryoboxes, ~1m^2 inlet area each, the standard AVS test dome pump speed method is not practical in our case. This poster will present our own test methods, which are guided by and checked against simulated pump speeds using Molflow+. Additionally, experimental cooling and thermal stress tests will be presented on the cryoboxes and VCR fittings used to make the LN2 connections between pumps. This will be compared to our simulated cooling and thermal stress analysis.

VT-TuP4 Formation and Characterization of Hydrogenated Amorphous Silicon (a-Si:H) Thin Films Deposited by ECR-CVD with Different RF Powers*, **Hugo Alvarez**, A.R. Santos, J.G. Fo, F.H. Cioldin, J.A. Diniz,* Universidade Estadual de Campinas, Brazil

Hydrogenated amorphous silicon (a-Si:H) films have been deposited on Si substrates using electron cyclotron resonance (ECR) plasmas. ECR systems are downstream plasma reactors, which allow a separate control of ion energy and ion flux, and can operate at low pressures (1-50mTorr) and can allow reducing sharply ion surface sputtering. A 2.45GHz microwave ECR source generates the plasma at high power (up to 1000W). A 13.56MHz RF power source biases separately the sample chuck. The 2.45GHz ECR source and RF chuck power control the ion flux and ion energy, respectively, allowing low temperature (20^{0}C), low pressure (4mTorr) and low damage chemical vapor deposition (CVD). Due to high discharge power conditions in ECR plasmas, high dissociation degree of silane (SiH4), gas molecules can be obtained. SiH4 diluted in 98% of Ar allows low silane concentration in the ECR plasma that, with high degree of dissociation, can reduce the Si-H bond incorporation in the films deposited. Moreover, to optimize the composition and the microstructure of the deposited a-Si:H films, the H incorporation should be kept at less than 20%, depending on RF power source bias. In this work, to study the effects of RF chuck power in the H incorporation into films, different RF powers of 1, 3 and 5W were deposited on silicon substrates, with fixed parameters: ECR power of 500W, pressure of 4mTorr, substrate temperature of 20^{0}C, gas flows of SiH4 and Ar, 200 and 20 sccm and 20 minutes. The hydrogen incorporation in the films was determined by FTIR (Fourier Transformed Infrared). These films were annealed at 1000^{0}C, during 60s (Rapid Thermal Annealing (RTA) process). Thus, before and after the RTA annealing, for films deposited with RF powers between 1 and 5W: i) The crystalline level of each film, obtained by Raman spectroscopy, changed from totally amorphous film to amorphous and polycrystalline (19.4% - 32.4%) structures; ii) The images from optical microscopy were used to identify the presence of pin holes on the film surfaces. Using scan profiler system, it was extracted the depth (100µm - 2.2µm) and diameter (1800Å - 90 Å) of them. For that, it can be concluded that if the RF power values increases, the crystalline level increases and pin holes dimensions and densities decreases. Considering that the pin holes are generated due to H incorporation into the films, if RF chuck power is higher, the intensities due to Si-H bonds are reduced (extracted from FTIR analyses), indicating the low H concentration into the films. Thus, the a-Si:H films deposited by ECR-CVD that are part of the hybrid solar cells with a-Si:H-p+/c-Si-n++ structures are going to be presented at the conference.

VT-TuP7 Low-carbon Steel Chamber and Double Viton O-ring Sealing for Electron Microscope*, **In-Yong Park**, N.-K. Chung, B. Cho,* KRISS, Republic of Korea

Generally, EM(Electron Microscope) consists of an electron beam generation part, beam control part and a specimen chamber. Among them, in order to get a high imaging resolution, condition and function of electron gun are the most important. Firstly, vacuum level of electron gun chamber is maintained properly depends on the method of electron beam generation. Secondly, gun chamber should be shielded from stray magnetic field which influences the electron beam. Lastly, gun chamber had better have adjustable parts for precise alignment of gun position. In this work, we center around on a simple and cheap electron gun structure for EM. For the purpose of it, we adopt the low-carbon steel for gun chamber material and double Viton O-ring for gun chamber sealing, thereby succeeding in making adjustable gun system maintaining UHV(Ultra High Vacuum) condition.

Recently, *B. Cho* shows that Low-carbon steel (C≤0.2 wt. %) has a sufficiently low outgassing rate for constructing UHV chamber [1]. Low-carbon steel is a soft magnetic material that is relatively inexpensive and has a high magnetic permeability, so it block out the stray magnetic field. O-ring is usually used for motion vacuum part and also possible to align electron gun in high vacuum. Schottky emitter and cold field emitter are used for high resolution EM, however those require the UHV condition for preventing contamination of tip surface. For EM based on Schottky emitter, we designed the electron gun with low-carbon steel and double O-rings which support UHV condition by pumping out the permeated gases between double O-rings. We compared the performance of double Viton O-rings and double Kalrez O-rings experimentally after 150 ℃ baking process. The Viton material is better than Kalrez in our system and the vacuum pressure of electron gun arrived at ~10^{-8} Pa at room temperature. The vacuum pressure is maintained as UHV when the electron gun chamber surface is moved at the double O-ring surface. We applied the Viton double O-ring electron gun system to commercial EM replacing original electron gun to get EM images. We observed the evaporated gold nano-particles and got the magnification up to 200K. Also, we measured the electron beam current stabilities of extractor and probe beam. We demonstrated that Low-carbon steel and double Viton O-ring can be used for EM with Schottky emitter and show highly magnified images of gold nano-particles. We anticipated that these methods could replace the existing electron gun system of EM, thereby providing a simple structure and reducing the cost of production of EM.

[1] C. Park, T. Ha and B. Cho, J. Vac. Sci. Technol. A 34(2), (2016).

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