Operation Experiences of the SRRC 1.3 GeV Electron Storage Ring Vacuum System

G.Y. Hsiung, D.J. Wang, J.G. Shyy, J.R. Huang, H.S. Tzeng, S.N. Hsu,
S.Y. Perng, K.M. Hsiao, W.D. Wey, J.R. Chen* and Y.C. Liu**

Synchrotron Radiation Research Center
No.1 R&D Road VI, Hsinchu Science-Based Industrial Park
Hsinchu, Taiwan 30077, R.O.C.

Abstract

The SRRC 1.3 GeV electron storage ring vacuum system was made of aluminum alloys. This system has the features of oil-free pumping configuration and low dust contaminated environmental installation. The system has been operated for nearly one year. The photon induced desorption (PID) phenomenon was observed clearly and the desorption coefficient of PID was reduced by more than three orders of magnitude after an accumulated beam dose of $\geq$ 140 Ah. The operation experiences of the SRRC vacuum system will be described.

1. INTRODUCTION

In the SRRC 1.3 GeV electron storage ring, a third generation synchrotron light source, design of the high brightness and low emittance synchrotron radiation from both the insertion devices and the bending magnets were considered.[1] The vacuum system is divided into two families of chambers, the straight section (S-) chambers and the bending magnet (B-) chambers. Stringent considerations, e.g. materials of chambers, estimation of desorption rate, pressure distribution and the pumping configurations were taken into account in the design stage. Due to many advantages in the fabrication of the storage ring vacuum system, the aluminum alloys were selected to fabricate the vacuum chambers.[2,3] In order to prevent from the oil contamination, several oil-less methods were proceeded.[4] The commissioning of the vacuum system is operated carefully and smoothly in the first year running. The investigation of the photon induced desorption (PID) phenomenon and the operation experience will be discussed.

2. VACUUM SYSTEM

Several oil-less processes were adopted in fabricating the storage ring vacuum system. The numerical controlled (NC) milling B-chambers were machining in ethanol environment and then degreased with freon before welding. The S-chambers were cleaned by chemical cleaning process after extrusion method. The distributed ion pumps (DIP) were vacuum fired to > 500 °C at a pressure of 10^{-6} Torr in a vacuum oven and then proceeded the pump tests before installation in the B-chamber. All of the standard vacuum parts including the all metal sector gate valves, ionization gauges, quadrupole mass spectrometers, non-evaporable getter (NEG) pumps etc. were baked to the ultrahigh vacuum (UHV) and degassed or activated prior to the installation. In addition to the oil-less pretreatments, the completely oil-free pumping system is adopted.

The dust trapping problem in a large accelerator affects the beam qualities is verified.[5] The dusts were easily generated during the installation of the UHV system and heavy loaded operation for the ion pumps. All installation were under clean room or clean booths. The ion pumps were not allowed to operate before baking to the UHV regime. It is helpful to remove the large quantity of desorbed outgas by assistant pumping of turbomolecular pumps (TMP) in the first year's commissioning.[6]

3. CONTROL SYSTEM

A vacuum control panel for the electron storage ring is set up for the safety interlock protection of the vacuum system. The status of pumps, gauges and valves were displayed in the panel. The vacuum equipments were controlled by a programmable logic control (PLC) unit which communicates with the control panel. The sector gate valves can be tripped off as soon as the significant pressure rise above the upper trip level, preset at 1×10^{-6} Torr, is found. The pressure read-out of the ionization gauges are recorded via the intellegent local control (ILC) system to the VAX workstation. Moreover, a local terminal station is set up to monitor the temperature of the vacuum chambers and the flow rate of the cooling water system. The alarm signals were sent to the main control room to warn the system operator.

4. COMMISSIONING OF VACUUM SYSTEM

4.1 Photon Induced Desorption

The commissioning of the storage ring was divided into two stages with a bakeout of the whole vacuum system in between.[6] The electron beam was accumulated to > 10 mA since August 1993, after bakout to $< 5 \times 10^{-10}$ Torr. The accumulated electron beam dose of > 140 Ah has been achieved after 10 months' operation.

* also at Inst. of Nuclear Sci., National Tsing-Hua Univ., Hsinchu.
**also at Dept. of Physics, National Tsing-Hua Univ., Hsinchu.

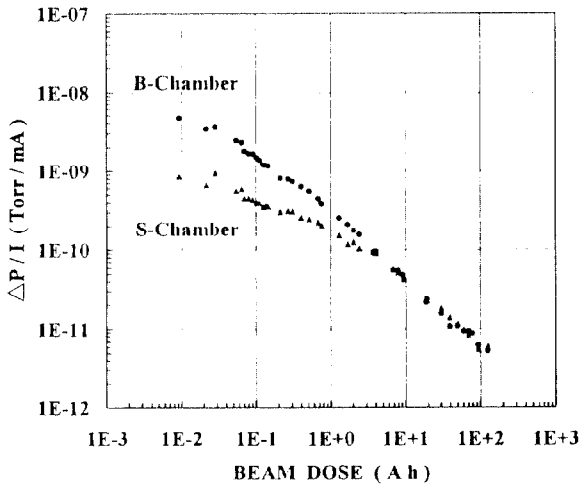

Figure 1. The pressure rise per electron beam current as function of the accumulated beam dose.

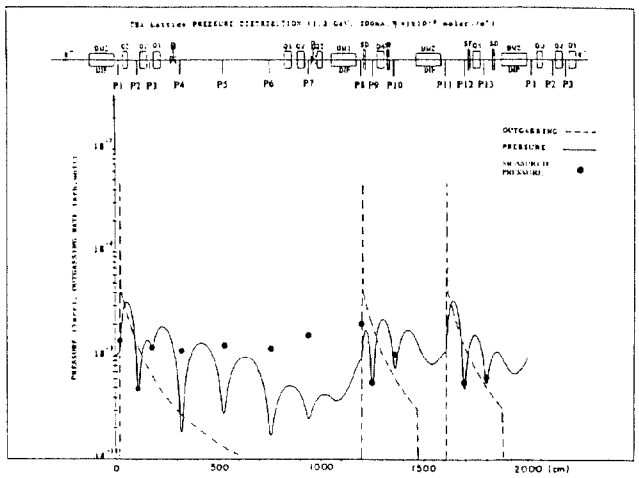

Figure 2. Comparison between the calculated (solid curve) and measured (dots) results of pressure distribution.

Thirty six sets of the ionization gauges were deployed to measure the pressure of the storage ring. Significant pressure rise due to the PID phenomenon was found in the early commissioning stage. Figure 1 shows the curves of the pressure rise per electron beam current ($\triangle P/I$), measured at the S-chamber and the B-chamber, as function of the accumulated beam dose. The transformations from $\triangle P/I$ to the desorption coefficient at B-chamber (η_B) and at S-chamber (η_S), respectively, are:[6]

$$\eta_B = 1.6\times10^5 (\triangle P/I)_B \quad \text{(molec./photon)} \qquad (1)$$

$$\eta_S = 5.5\times10^5 (\triangle P/I)_S \quad \text{(molec./photon)} \qquad (2)$$

The reasons to explain the difference between the two curves combine various factors: the spanned photon flux density, the incident angle of irradiation, history of the surface treatment on the inner wall of vacuum chambers and the effective pumping speed and so on. Feature of the diffusion model reveals on the curve of S-chamber exceeds that of B-chamber. It might be due to the grazing incident irradiation on the S-chamber wall that the diffusion from the surface layer is enhanced for S-chamber.

The desorbed gas species were measured by the quodrupole mass spectrometers near B-chambers. The residual gases include H_2 (93%), CO (4.4%), CO_2 (1.2%), CH_4 (0.5%) and H_2O (0.5%). The low concentration of the carbonate molecules shows low contaminated surface condition.

4.2 Pressure Distribution

A simulation program was established to estimate the distribution of both the surface outgassing rate and pressure in the storage ring.[7] The measured pressure with the simulated results at a beam current of 200 mA and a desorption coefficient of 1×10^{-5} are shown in figure 2.

The pressures near the B-chamber regions were consistent with the simulated result except those of S-chamber were higher than the predicted values. From the equation (1) and (2),

$$(\triangle P/I)_S \sim 3.44 \times (\triangle P/I)_B . \qquad (3)$$

Besides, the new design of the welding filler absorbers located at several leading places of the S-chambers to shadow the bellows, gate valves or other uncooled vacuum chambers from exposure of synchrotron radiation that modifies the distribution of PID. The effective pumping speeds of the ion pumps were not satisfied as the specified values which limits the pumping efficiency of the outgas.[6]

A typical pressure distributions of the stored electron beam current under 0 mA, 200 mA and 400 mA are shown in figure 3. The increments of each pressures are about the same in every local area in the case of 200 mA raising to 400 mA. The result is consistent with the trend of $\triangle P/I$ curves.

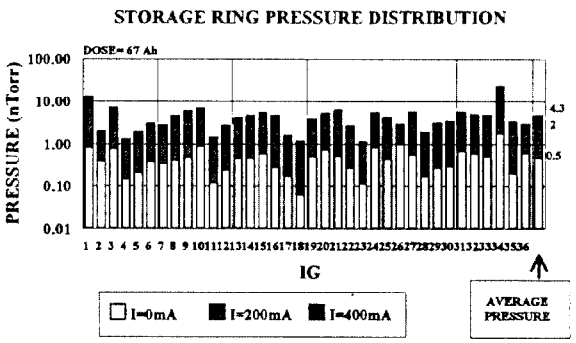

Figure 3. The pressure distribution of the electron storage ring at various electron beam currents.

5. SUMMARY

The operation and the commissioning experiences of the SRRC 1.3 GeV electron storage ring vacuum system are described. The accumulated electron beam dose of > 140 Ah has been achieved after 10 months' operation. The pressure rise per electron beam current has reduced to three orders of magnitudes and reached to $< 5 \times 10^{-12}$ Torr/mA. The residual gases due to the photon induced desorption (PID) were mainly H_2 (93%) followed by CO (4.4%) and other gases (totally < 3%). The low carbonate molecules prove the low contaminated surfaces of the vacuum chambers. This achievement thanks to oil-less machining, cleaning processes and the complete set of oil-free vacuum pumping system. The so called beam-self cleaning effect can be specified from the decay phenomenon of the ($\triangle$P/ I) curves. It is found the difference between the ($\triangle$ P/ I) curves of B-chamber and S-chamber. The phenomenon is worthy of further investigation.

6. ACKNOWLEDGMENT

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