OPERATION EXPERIENCES FOR THE 1.5 GEV TLS ULTRA-HIGH VACUUM SYSTEM

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Abstract

The ultra-high vacuum (UHV) system for the electron storage ring of the Taiwan Light Source (TLS) has been operated for ten years since 1993, at a full injected energy of 1.3 GeV and an upgrading to 1.5 GeV since 2000. The aluminum alloys vacuum chambers for the storage ring and the insertion devices perform high reliability and high vacuum qualities. The average pressure per beam current has been reduced to 1.0×10^{-10} Pa/mA after the integrated beam dose of > 7000 Ah having been achieved. However, some failures on the vacuum components occurred due to the synchrotron radiation hitting that include melt-down of the O-ring in the gate valve, and of the photon aperture; break of the ceramic insulators, the ceramic chamber and so on. In addition, the break on the electrical feedthrough of some ionization pumps due to sparking from the high voltage connectors some times happened. The impacts of those failure parts on the storage ring, the solutions for the troubleshooting, and the experiences of the operation for the electron storage ring UHV system will be discussed.

ALUMINUM ALLOYS BEAM DUCTS

The beam ducts for the TLS electron storage ring are made by the aluminium alloys (Al). The Al bending chambers are oil-less machined by the computer numerical control (CNC) method, to control the machining precisions, spayed with the pure alcohol to protect the fresh surface from the ambient oil contamination.[1] The Al straight chambers are extruded and cleaned the surface with the strong pickling nitric acid that etches the oxide layers and produces a fresh surface.[2] All the Al chambers after oil-less machining or the chemical cleaning are stored in the dust and humidity controlled clean room for proceeding the TIG welding. The beam ducts for the Undulators are manufactured like straight chambers, but final CNC machining on outside surfaces to a flatness of +/- 0.2 mm are performed after TIG welding. Figure 1(a) and 1(b) show the photographs of a half bending chamber and the sample pieces of various straight and Undulator chambers, respectively.

COMMISSIONING AND OPERATIONS

The new beam ducts exposed to the synchrotron light generate high pressure rise due to photon stimulated desorption (PSD) mechanism at earlier commissioning stage. A life time of 8 hours at beam current of 200 mA had been obtained after a ~ 5 months of beam cleaning after a beam dose of > 60 Ah been accumulated [3]. The beam dose of 1 Ah is equivalent to a linear photon flux of 1.72×10^{23} photons/m at 1.3 GeV of electron beam energy. The commissioning and operation will be described as follows.

(a)

(b)

Figure 1: Photographs for (a) Bending chamber; (b) sample pieces of straight and Undulator chambers.

Fast Commissioning

During the commissioning, the oil-free turbo-molecular pumps (TMP) were used for evacuating the desorbed gas molecules out of the chambers. The non-evaporable getter (NEG) pumps were activated during the vacuum baking for the chambers. The efficiency of the NEG is not high during the beam cleaning stage. The sputtering ionization pumps (IP) were not switched on before the pressure be reduced to 1.3×10^{-6} Pa. After one year's commissioning with beam dose up to 220 Ah, the average pressure rise due to PSD reduced to < 7×10^{-10} Pa/mA. The coefficient of PSD was 3×10^{-6} molecules/photon near straight chambers, and 6×10^{-7} molecules/photon near bending chambers [4].

Routine Operations

In the past ten years, the beam ducts at the long straight sections had been replaced by the beam ducts for the insertion devices, 3 Undulators and the 2 Wigglers. The quantity of the front ends increases from 3 sets to 18 sets. The storage ring has been exposed to the atmosphere in dry nitrogen gas several times due to the replacement of the new chambers, new absorbers, and new spare parts, etc., that caused the increase of the pressure. Figure 2 shows the averaged pressure per beam current recorded from 1996 to 2003. In figure 2, installation of vacuum chambers for EPU5.6 and U5 is shown as (a); U9 chamber is shown as (b); SWLS wiggler is shown as (c). The bumps of higher pressure near (a) and (b) are not due to installation of undulators, but the new front ends. However, the pressure rise after installation the SWLS chamber is much higher due to large outgassing rate from the SWLS beam duct and the downstream absorbers.[5]

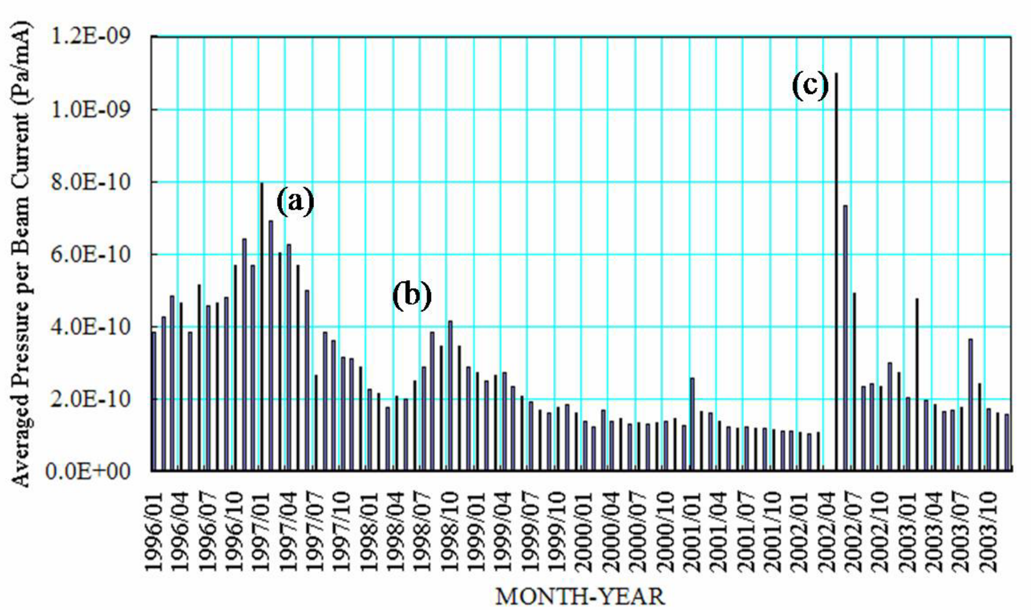

Figure 2: Averaged pressure per beam current recorded from 1996 to 2003. The time for installation the new chambers for the (a) EPU5.6 and U5 undulators, (b) U9 undulators, and (c) SWLS wiggler.

The vacuum system of the electron storage ring has been reached to an averaged pressure of 1×10^{-10} Pa/mA after integrating a beam dose of 5000 Ah, as shown in figure 3 (a). A peak of higher pressure indicated (b) in fig. 3 is due to outgas from SWLS operation. The lifetime at 200 mA is ~ 15 h without SWLS and is shortened to ~ 10 h with SWLS, at the beam dose of 5000 Ah.

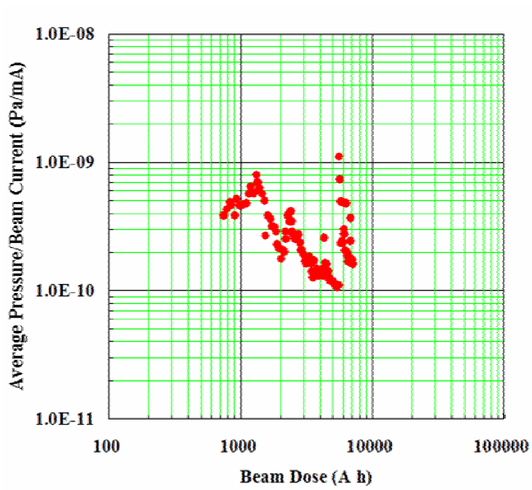

Figure 3: Averaged pressure per beam current versus beam dose, (a) and (b) indicates the pressure rises before and after the installation of SWLS.

FAILURE OF VACUUM PARTS

The failure of the vacuum parts that has happened to the storage ring to be described contains the problems caused by (1) synchrotron radiation heating; (2) high temperature baking; and (3) radiation damage.

Synchrotron Radiation Heating Problems

A photon aperture (PA), horizontally installed in a front end, was melted down due to insufficient cooling water supply, as a photograph shown in figure 4. When the supplied cooling water for the PA had been stuck, the cooling water for the Cu aperture was not sufficient. It caused the PA deformed due to thermal expansion. The more deformation on the upper part of PA, the closer the part moved to the center of photon beam. The higher heat load subjected to the deformed part that made the deformation worse. Finally the Cu was melted. The problem was solved by connecting the flow rate meters to the interlock system and the beam dump system.

Figure 4: Photograph of a Cu photon aperture that has been melt on upper side of the aperture.

The ceramic insulation pieces were broken due to directly hitting by the upstreaming SWLS synchrotron light.[5] Figure 5 shows the broken ceramic pieces inside a kicker chamber downstream the SWLS. There is no pre-absorber in front of the ceramic chamber to shield the insulators from wide-span synchrotron light from SWLS. A pre-absorber has been welded on the water cooled taper of SWLS later to shield the ceramic chamber.

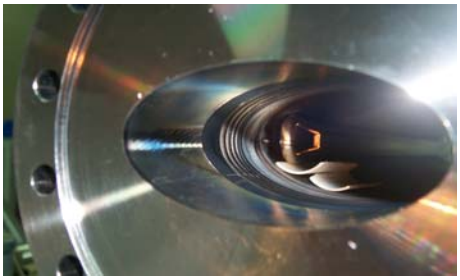

Figure 5: Photograph of the broken ceramic pieces inside a kicker chamber downstream the SWLS

High Temperature Baking Problems

An unsuitable baking for an O-ring sealed gate valve to a temperature of 300ºC was occurred at once of baking a bending chamber in the storage ring [6]. The overheated O-ring stuck on the flange when opening the valve, and then directly hit by the synchrotron radiation and melted. A residual gas analyzer (RGA) located at the bending chamber illustrated a mass spectrum, shown in figure 6, that some of the massive gas species, e.g. CxFy, be clearly observed. The problem has been solved by replacing all of the O-ring sealed valves by the all metal valves for the storage ring vacuum system.

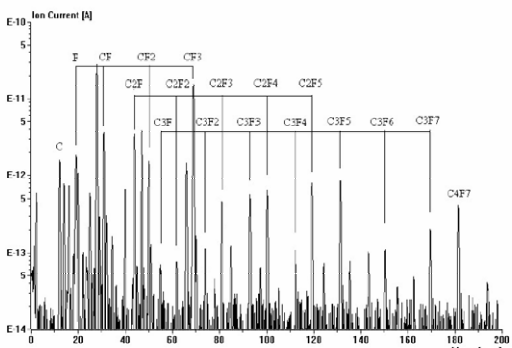

Figure 6: A mass spectrum shows the families of cracking for "CxFy" gas species.

Figure 7: A feedthrough of an IP was broken by HV breakdown during the degassing of baking.

Usually, the sputtering ionization pumps (IP) will be vacuum baked to the temperature > 200ºC for completed degassing and obtaining the higher efficiency of pumping at pressure < 1 × 10^{-7} Pa. Somehow, the feedthrough of the IP could not against the high voltage breakdown during the degassing process at high temperature baking and broken as shown in figure 7. Routine inspection and cleaning on the feedthrough and the connector of HV cable will be done during shutdown period.

Radiation Damaged Problems

An O-ring for a turbo-molecular pump located near the extraction chamber of 1.5 GeV booster synchrotron accelerator was damaged after high dosage rate irradiation. Figure 8 shows the damaged O-ring. The O-ring becomes brickle when exposed to the high dosage of radiation and loses the elastic features.

Figure 8: A damaged O-ring removed from a turbo-molecular pump located near the high radiation zone.

CONCLUTIONS

The TLS storage ring has been operated for 10 years since 1993. The energy for the electron beam has increased from 1.3 GeV to 1.5 GeV since 2000. The Al beam ducts exhibited a lower rate of PSD after fast commissioning stage in several months. However, some problems due to in-sufficient cooling or protection will damage the components, especially the high heat load components, unexpectedly. Finally, all the components adopted in the storage ring and the front ends have been replaced by the metal ones to avoid the damage and the outgassing problems. The high voltage feedthroughs and the connectors for the IP will be routinely visual inspected and cleaned to avoid the breakdown damage problems during the high temperature baking and degassing processes.

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