DESIGN OF THE TPS BENDING CHAMBER

C. K. Chan, G. Y. Hsiung, C. C. Chang, Y. B. Chen, C. Y. Yang, C. L. Chen, H. P. Hsueh,
S. N. Hsu, Y. H. Liu, NSRRC, Hsinchu, Taiwan.
Ivan Liu, NTHU, Hsinchu, Taiwan.
J. R. Chen, NSRRC, Hsinchu; NTHU, Hsinchu, Taiwan.

Abstract

This article describes the design, manufacture and treatment of the bending vacuum chamber (B-chamber) of the 3-GeV Taiwan Photon Source (TPS). The B-chamber is a aluminium-alloy chamber ~5 m long with an antechamber on the near side of the beam duct. The design of the B-chamber is aimed to diminish the power density and the photon-stimulated desorption (PSD) induced by synchrotron radiation. Simulations, by finite-element analysis, of the B-chamber deformation due to evacuation and pressure profiles of the vacuum systems of a unit cell by a Monte-Carlo method are also described.

INTRODUCTION

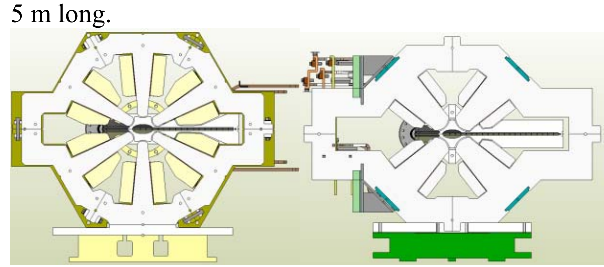
The TPS is a continuing project to construct a third-generation synchrotron source at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. The TPS storage ring, a 6-fold super-period of DBA structure with 24 unit cells, has an electron beam energy 3 GeV and a beam current 400 mA. Aluminium alloy is chosen as the B-chamber material because of its properties well known for the construction of accelerators, including large thermal conductivity, absence of magnetism, small rate of thermal outgassing, small residual radioactivity, and ease of machining. Because the latest lattice design alters the circumference of the storage ring from 518.4 m to 486 m, the design of the vacuum systems must be amended. The following sections update the design of the TPS B-chamber.

BENDING CHAMBER

Figure 1 shows the drawing of the TPS B-chamber, which consists of two pieces of aluminium plate (lower and upper halves); each has thickness 50 mm. The TPS B-chamber is designed to have the following features: (1) a large triangular aluminium chamber (~5 m) to confine almost outgassing sources induced by the PSD inside the B-chamber; (2) absorbers located as far from the beam source as possible to decrease the heat load on absorbers; (3) vacuum pumps arranged on the antechamber and near the outgassing sources to increase the effective pumping speed and to decrease the beam impedance generated by the pumping orifices.

Although many advantages can be gained, the compromise requires more complicated interfaces between the B-chambers and the magnets. Fig. 2(a) and 3(b) depict the cross-sectional views of the B-chamber combined with the quadrupole (Q-) and sextupole (S-) magnets, respectively. To attain a criterion of deformation < 0.1 mm in the beam duct, the outer profiles of the aluminium plates are machined according to the shape of the poles and coils of the Q-magnets and S-magnets. The clearance is generally maintained at 3 mm. The spaces with a clearance < 3 mm will be tested in the engineering with care taken during assembly. The channel between the beam duct and the antechamber has a height 10 mm. Figure 3 shows, by finite-element analysis, the deformation of half of the B-chamber due to evacuation. The result shows the maximum deformation at the coil of Q-magnet to be 0.13 mm, and the deformation in the beam duct is controllable within 0.1 mm.

Figure 1: Assembly drawing of a TPS bending chamber 5 m long.



(a) (b)

Figure 2: Cross-sectional views of a B-chamber combined with a Q-magnet (a), and a S-magnet (b).

TREATMENTS

Some research reveals that ozone is effective to remove carbon on the surface and in the sputter-profiled passivation layer of aluminium alloys [1-3]. Treatments of three kinds, proposed to machining and to clean materials of the aluminium-alloy vacuum chambers for the TPS project, are listed below and evaluated by the techniques of thermal outgassing and PSD.

(A) Oil machining
-chemical cleaning with strong alkaline etching [4].
(B) Ethanol machining
- cleaning with ozonized water with a flow rate 5 L/h and a concentration 6.7~6.9 ppm at 24 ^{0}C for 30 min.
- drying with pure nitrogen gas (99.9999 %).
(C) Ethanol machining only

Thermal Outgassing

Figure 4 shows curves of the rate of thermal outgassing versus time measured with the throughput method [5]. Thirty aluminium alloy A6063 specimens, of size 50 mm × 70 mm × 5 mm, were fabricated according to each treatment mentioned above and placed into an aluminium alloy chamber with an orifice (φ=3 mm) for measurement. After pumping 10 h at room temperature, the outgassing rate of the samples with treatment A, q_{10}(A), is the least at ~ 9.7 × 10^{-11} Torr L s^{-1} cm^{-2} compared to q_{10}(B) ~ 5.3 × 10^{-10} Torr L s^{-1} cm^{-2} and q_{10} (C) ~ 5.9 × 10^{-10} Torr L s^{-1} cm^{-2}. The aluminium-alloy chamber containing the samples was baked at 120 ^{0}C for 24 h after pumping for 24 h. The rate of outgassing of the samples with treatment B measured after 24 h from bakeout, q_{72}(B), decreased to ~ 4.8 × 10^{-15} Torr L s^{-1} cm^{-2} less than q_{72}(A) ~ 9.5 × 10^{-14} Torr L s^{-1} cm^{-2} and q_{72}(C) ~ 1.4 × 10^{-14} Torr L s^{-1} cm^{-2}.

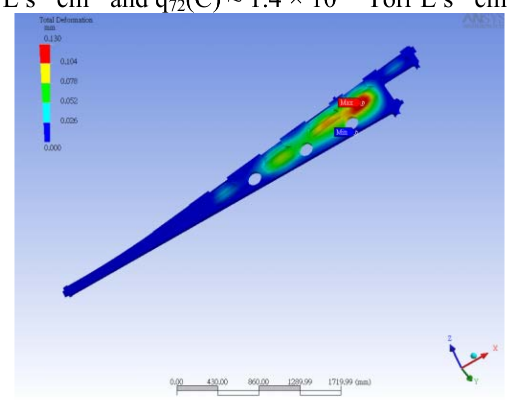
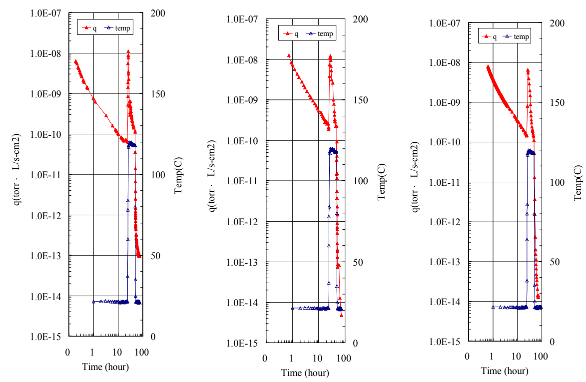


Figure 3: Deformation on the lower half of the B1 chamber due to evacuation, by finite-element analysis.

Photon-stimulated Desorption

A dedicated beam line of BL-19B at NSRRC used to study PSD is described elsewhere [6]. The design of aluminium samples with cooling channels can make the temperature increase < 0.5 ^{0}C to decrease noise from the thermal effect during exposure. The aluminium samples were baked in situ at 150 ^{0}C for 24 h before illumination with synchrotron radiation. Figure 5 shows the relation of the dynamic pressure rise per mA beam current vs. the accumulated beam dose. The PSD curves of aluminium samples subjected to treatments A, B and C are plotted in the figure with open squares, solid circles and open circles, respectively. It shows that treatment B is superior to the other treatments, especially at the beginning (beam dose < 10 mA h). At an accumulated beam dose 1000 mA h, ΔP/I of the samples with treatment B can even attain the range of 7 × 10^{-11} Torr/mA. The PSD data of treatment A are referred to our previous measurement for comparison in this paper [7].



(a) (b) (c)

Figure 4: Curves of outgassing rate vs. time for aluminium samples with treatments A (a), B (b) and C (c) during 24 h pumping at room temperature, 24 h bakeout at 150 ^{0}C and after baking.

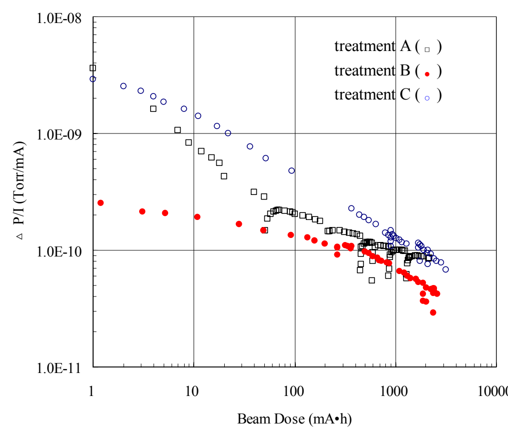


Figure 5: Total pressure rise per beam current as a function of the beam dose for aluminium samples according to three treatments.

PRESSURE PROFIE

In the storage ring of the synchrotron light source, a large gas load will be induced by synchrotron radiation from the vacuum chamber wall [8]. The dynamic pressure must be kept below a certain limit to meet the required beam lifetime. The design goal of the TPS vacuum systems is to achieve a dynamic pressure < 1×10^{-9} Torr for a beam lifetime 10 h for commission at 3 GeV, 400 mA. Figure 6 shows the vacuum system of a unit cell of the TPS storage ring, which comprises straight chambers, vacuum pumps, two gate valves and two B-chambers (B1, B2). For such a long triangular B-chamber, the photon span of synchrotron radiation emitted from the dipole magnet is almost (~92 %) contained inside the B-chamber, and we estimate a gas load ~2.3 × 10^{-6} Torr L s^{-1} induced by the PSD inside each B-chamber. Lumped NEG pumps and sputter-ion pumps (SIP) are employed as the principal pumps and placed near the gas source to prevent the conductance from limiting the pumping speed of the vacuum pumps. According to the pumping configuration in Fig. 6, the pressure profiles stimulated by the Monte-Carlo method for desorption coefficients η =

1×10^{-5}, 5×10^{-6} and 1×10^{-6} molecules/electron are shown in Fig. 7 [9-10]. The average pressures for these three cases are correspondingly 1.9×10^{-9}, 9.5×10^{-10} and 1.9×10^{-10} Torr. A conditioning period ~300 A h is estimated to decrease the desorption coefficient to 5×10^{-6} to satisfy an average pressure $<1\times10^{-9}$ Torr [11]. Two local pressure pumps near the downstream crotch absorbers of B1 and B2 reflect lack of space for installation of vacuum pumps.

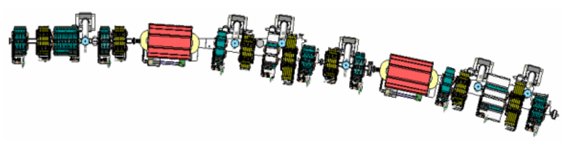


Figure 6: Layout of the vacuum system of a unit cell of the TPS storage ring.

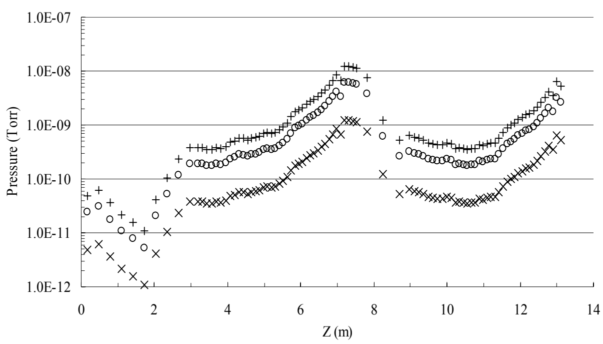


Figure 7: Pressure profiles for a unit cell of the TPS storage ring at $\eta = 1\times10^{-5}$ (+), 5×10^{-6} (○) and 1×10^{-6} (×) molecules/electron for an electron beam operated at 3 GeV, 400 mA.

CONCLUSIONS

The unique designs for the TPS bending chamber are reported in this paper. The simulation by finite-element analysis shows that deformation due to evacuation in the beam duct can be controlled within 0.1mm. A treatment with ethanol machining and ozonized-water cleaning is suitable for an aluminium-alloy material according to the thermal outgassing measurement and the PSD data. A calculation of the pressure with a Monte-Carlo method indicates that an average pressure 1×10^{-9} Torr can be achieved after a conditioning period 300 A h for electrons operated at 3 GeV and 400 mA.

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REFERENCES

[1] T. Momose, K. Asano, N. Ohta, Y. Kanda and H. Ishimaru, J. Vac. Sci. Technol. A13(2) (1995) 488.
[2] T. Momose, Y. Maeda, K. Asano and H. Ishimaru, J. Vac. Sci. Technol. A13(3) (1995) 515.
[3] T. Momose, E. Hayasaka, K. Saitou, K. Nagayama and S. Abe, J. Vac. Sci. Technol. A16(3) (1998) 961.
[4] A.G. Mathewson, J. –P. Bacher, K. Booth, R. S. Calder, G. Dominichini, A. Grillot, N. Hilleret, D. Latorre, F. LeNormand and W. Unterlerchner, J. Vac. Sci. Technol. A7(1) (1989) 77.
[5] J. R. Chen, K. Narushima and H. Ishimaru, J. Vac. Sci. Technol. A3(6) (1985) 2188.
[6] J. R. Chen, K. Y. Yang, J. Y. Yang and G. Y. Hsiung, J. Vac. Sci. Technol. A20(3) (2002) 859.
[7] G. Y. Hsiung, K. Y. Yang, Y. J. Hsu and J. R. Chen, J. Vac. Sci. Technol. A19(4) (2001) 1657.
[8] A. G. Mathewson, G. Horikoshi and H. Mizuno, KEK-78-9, 1978.
[9] C. K. Chan, G. Y. Hsiung, T. L. Yang and J. R. Chen, "Pressure Distribution for TPS Storage Ring", SRI'06, Daegu, Korea, May 2006.
[10] Y. Suetsugu, J. Vac. Sci. Technol. A14(1) (1996) 245.
[11] G. Y. Hsiung, J. R. Huang, J. G. Shyy, D. J. Wang, J. R. Chen, and Y. C. Liu, J. Vac. Sci. Technol. A12(4) (1994) 1639.