VACUUM PERFORMANCE CHARACTERISTICS OF 4m-LONG VACUUM CHAMBER WITH NEG STRIP FOR SPring-8

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To investigate vacuum performance characteristics of the 4m-long Al-alloy vacuum chambers, we measured and compared the outgassing rate with and without a NEG strip. We also measured the pumping speed of the NEG strip distributed in the chamber. The results were in approximate agreement with that of a short piece of NEG strip. The ultimate pressures which can be achieved with combination of NEG and the other kinds of pumps such as a sputter ion pump (SIP) and a titanium sublimation pump (TSP) were investigated. It was found that the best ultimate pressure could be obtained at a combination of the NEG strip and SIP. Results of residual gas analysis are also discussed briefly.

Introduction

Super Photon ring-8 (SPring-8) is in the progress of design as a high-brilliance synchrotron radiation source. In this storage ring, Zr-V-Fe (St 707) non-evaporable getter (NEG) strip is considered as a main pump. We are considering to use an extruded Al-alloy (A6063-T5 whose strength is equivalent to that of T6) as the material of the vacuum chamber to minimize synchrotron radiation (SR) induced desorption as well as thermal outgassing. The chemical composition of A6063-T5 is 0.55 w/o of Mg, 0.44 w/o of Si and the balance is Al. This Al-alloy chamber is extruded in atmosphere of Ar + O_2. Cross-sectional views of the vacuum chamber for the straight section (SSC) and for the bending magnet (BMC) are shown in Fig.1 (a) and (b), respectively. These vacuum chambers consist of an electron beam chamber and a slot-isolated antechamber in which the NEG strip is installed. In the BMC a distributed ion pump is also installed. SR is almost intercepted by crotches and absorbers placed just downstream and upstream of a bending magnet, and not intercepted with the vacuum chamber all around the storage ring.

To investigate vacuum performance characteristics of the vacuum chamber, we manufactured 4m-long Al-alloy vacuum chambers, and measured 1) the outgassing rate with and without a NEG strip, and 2) the pumping speed of a NEG strip distributed in the chamber. Effects of combination with different pumps such as SIP and TSP on the ultimate pressure were also investigated.

In this paper we present a series of measurements of the outgassing rate and the pumping speed of the NEG strip distributed in the chamber. The experimental results of this NEG strip were compared to those of Lee et al.[1]. We also discuss the ultimate pressure which can be achieved by combination with different pumps in connection with results of residual gas analysis.

Outgassing rate of the chamber

In the design of a pumping system, it is required to estimate exactly a thermal outgassig rate as well as a dynamic one due to photo-desorption. In particular, in the design of the system of roughing pumps we have to estimate exactly the thermal outgassing rate during bake out of the chamber and activation of the NEG strip. Therefore, we carried out experiments for measuring the outgassing rate of the chamber with and without a NEG strip using the throughput method.

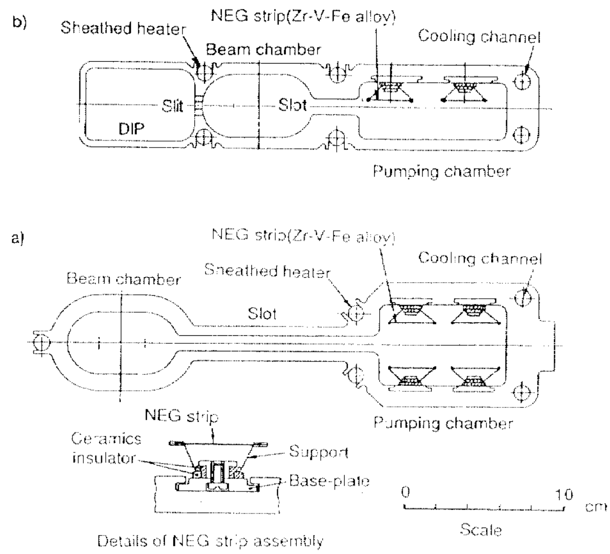

Fig.1 Cross-sectional views of the chambers (a) for the straight section and (b) for the bending magnet.

Results and discussion

Figure 2 shows the outgassing rate of SSC itself without a NEG strip. We obtained the outgassing rate of the order of 10^{-10} Torr·l/sec·cm^2 after a few 10 hour evacuation without bakeout. After ~70 hour evacuation following bakeout at 140°C for 40 hours, the outgassing rate of the chamber (Al-alloy) was measured to be 1×10^{-13} Torr·l/sec·cm^2.

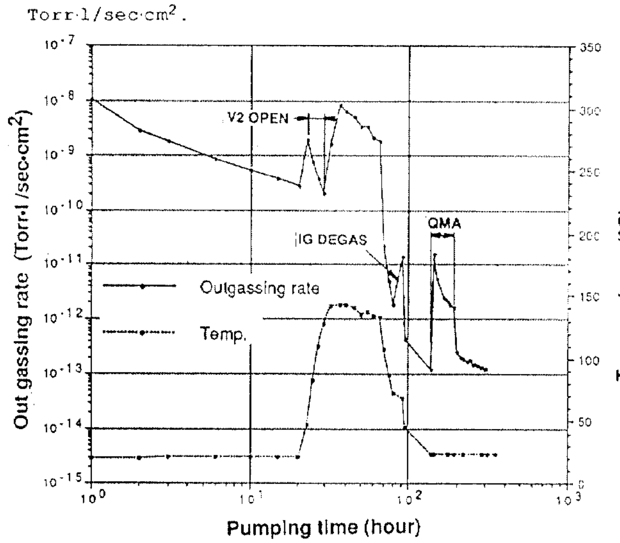

Fig.2 Outgassing rate vs pumping time for SSC without a NEG strip. Total surface area of the sample (or the chamber itself) is 30000 cm^2.

The outgassing rate of BMC was also measured with a virgin NEG strip (Fig.3). In this case, although we have another source of outgassing gases from the surface of the NEG strip and its support (SUS 304 and ceramics) as well as the chamber itself, we got the overall outgassing rate of 10^{-10} Torr·l/sec·cm^2 after a pumping of a few 10 hours without bakeout. On the other hand, the outgassing rate after ~70 hour evacuation following a bakeout at the same condition as that for SSC was 2×10^{-12} Torr·l/sec·cm^2 which is much higher than the outgassing rate of Al-alloy chamber itself. This can be interpreted by the fact that the bakeout is not enough for the NEG strip and its support because of low bakeout temperature of 140°C.

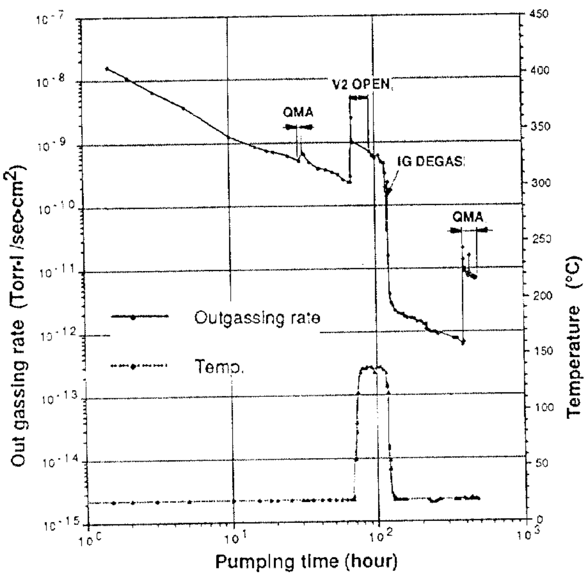

Fig.3 Outgassing rate vs pumping time for BMC with a NEG strip. Total surface area of the sample, which is composed of the chamber itself, and the NEG strip and its support, is 56000 cm^2 (30700 cm^2 for the chamber itself, and 8700 and 16600 cm2 for the NEG strip and its support, respectively). Length of the NEG strip is extended to 14.4m.

Pumping speed of NEG strip

Experimental

To investigate pumping performance characteristics of a NEG strip, which is distributed in a practical chamber of 4m-length, we carried out experiments with the setup as shown in Fig.4. The NEG strip installed has a total active length of 720 cm, and total active surface area is 3888 cm^2. After a baking at 140° for 40 hours, the NEG strip was activated at 450°C for 50 minutes. As a result, initial gas loading for the other gases besides H_2 is regarded as zero. A pumping speed was measured periodically by the throughput method. The pumping speed at the beam chamber S_{ue} (l/sec·cm) can be expressed [2] as follows, assuming that the pumping speed is independent of the positions along the chamber axis.

$$S_{ue} = [C(p_1-p_2)/Lp_3]\coth[\cosh^{-1}(p_3/p_5)] \times \cosh^{-1}(p_3/p_5) \quad (2)$$

where C is the conductance of orifice in l/sec, p_1, p_2, p_3 and p_5 the pressure in Torr at IG1, IG2, IG3 and IG5, respectively, and L the length of distributed NEG strip in cm. Considering the conductance of the slot C_s (l/sec·cm), the pumping speed of the NEG strip per unit length S_u (l/sec·cm) is:

$$S_u = 1/(S_{ue}^{-1} - C_s^{-1}) \quad (3)$$

Finally, we got the pumping speed of the NEG strip per unit area S_o(l/sec·cm^2) from Eq.(4).

$$S_o = S_u/11 \quad (4)$$

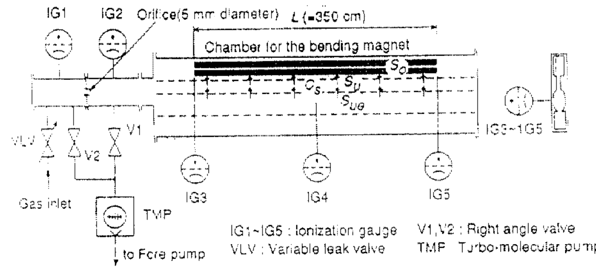

Fig.4 Schematic diagram of measurement set up for pumping speed.

Results and discussion

Figure 5 shows pumping speeds for H_2, CO, CO_2 and N_2 with respect to sorbed gas quantity. The pumping speed for H_2 is relatively constant because of bulk-diffusion even at room temperature as well known [3]. On the other hand, those for other gases decrease rapidly with an increase in the sorbed quantity [4]. The initial pumping speeds for all gases are in the same order of 10^{-1} l/sec·cm^2.

The tendencies of these pumping speed variation vs sorbed quantity are similar to those of a short piece of NEG strip for all the gases. The pumping speed for H_2 is almost the same as that of the NEG strip piece. However, pumping speeds for CO and CO_2 become smaller than those of the NEG strip piece by one order. This may be caused by the assumption that the pumping speed is independent of the positions along the chamber axis in Eq.(2). During the gas injection, the pressure in a test chamber has a distribution along the axial direction of the chamber : The sorbed quantity decreases with the distance from a gas injection location. As a result, the pumping speeds for CO and CO_2, which are influenced remarkably by the sorbed quantity compared to the pumping speed of H_2 gas, would be different at the positions along the chamber axis. Thus the pumping speeds of CO and CO_2 might be calculated on average along the longitudinal direction. A N_2 pumping speed in this experiment becomes by a factor of approximately two larger than that of the NEG strip piece. This reason is not clear at the present time.

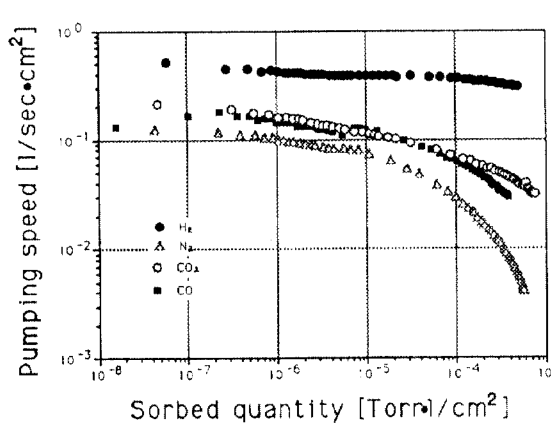

Fig. 5 Pumping speed of St 707 NEG strip vs sorbed quantity for H_2, CO, CO_2 and N_2.

Ultimate pressure of the chamber with a combination of pumps

Experimental

We measured the ultimate pressure of SSC in which NEG strip, TSP, SIP and a turbo-molecular pump (TMP) were installed. A total active length and surface area of the NEG strip are 1440cm and 7776 cm^2, respectively. Nominal pumping speed of SIP is 110 l/sec and that of TMP 300 l/sec.

Results and discussion

The pressure variation vs pumping time is shown in Fig.6. After 145 hour evacuation we carried out a bakeout for the chamber and an activation for the NEG strip simultaneously ((1) in Fig.6), and at the last stage of them we performed pre-conditioning for TSP and SIP ((2)). After that, we got the ultimate pressure of 5.6×10^{-11} Torr with NEG strip and TMP((3)). However, the pressure with only NEG strip was increased up to 1.2×10^{-8} Torr((4)) with a build-up of CH_4(M/e=16) , as shown in Fig.7 a), which could not be pumped by the NEG strip. We obtained the ultimate pressure of 4.7×10^{-11} Torr with the NEG strip and SIP((5)), and measured mass spectrum (Fig.7 b). Although TSP was finally flashed((6)), the pressure did not become lower ((7)) than that with the NEG strip and SIP. This means that additional TSP is not useful to achieve better ultimate pressure in the pressure of the order of 10^{-11} Torr.

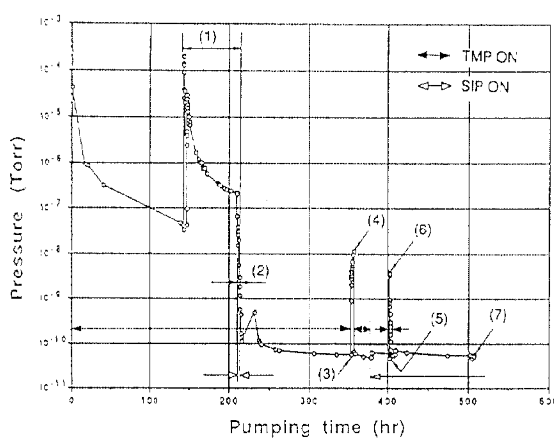

Fig.6 Pressure variation vs pumping time.

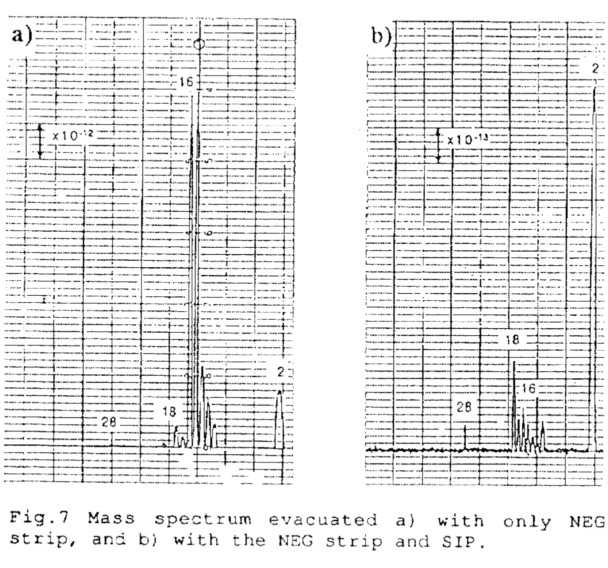

Fig.7 Mass spectrum evacuated a) with only NEG strip, and b) with the NEG strip and SIP.

Conclusions

In the experiments to investigate vacuum performance characteristics of the vacuum chambers, which were test-manufactured for SPring-8 storage ring, we found the following :

1) We can get the outgassing rate of 1×10^{-13} Torr·l/sec·cm^2 for the chamber (Al-alloy) and that of 2×10^{-12} Torr·l/sec·cm^2 for the chamber with a NEG strip, after ~70 hour evacuation following bakeout at 140°C for 40 hours.

2) The NEG strip (St 707) distributed in the chamber has the initial pumping speed of the order of 10^{-1} l/sec·cm^2 for H_2, CO, CO_2 and N_2. Although its pumping speed for H_2 is relatively constant, those for CO, CO2 and N_2 decrease drastically with an increase in the sorbed gas quantity. This tendency of variation in the pumping speed is similar to that of a NEG strip piece.

3) We can obtain the ultimate pressure of 4.7×10^{-11} Torr in the Al-alloy chamber with a combination of the NEG strip and SIP.

References

[1] YoungPak Lee et al.,"The Performance Characteristics of a St 707 Non-Evaporable Getter Strip for SPring-8", J.Vac.Soc.Jpn. vol. 33(3), pp.154, 1990.

[2] T. Momose et al.,"A new distributed ion pump made of aluminum alloy with an aluminum or a titanium cathode in the transposable ring intersecting storage accelerators in Nippon $e^+ e^-$ colliding ring" , J.Vac.Sci.Technol.A, vol. 7(5), pp.3100, Sep/Oct 1989.

[3] R. J. Knize and J. L. Cecchi,"Theory of bulk gettering", J.Appl. Phys.,vol. 54(6), pp.3183, June 1983.

[4] C. Benvenuti and F. Francia,"Room -temperature pumping characteristics of a Zr-Al nonevaporable getter for individual gases", J.Vac.Sci.Technol.A, vol. 6(4), pp.2528, Jul/Aug 1988.