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INVESTIGATION OF REDUCED BAKING TIME ON DYNAMIC PRESSURE IN A TAIWAN PHOTON SOURCE FRONT END SYSTEM

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Abstract

Taiwan photon source (TPS) front end (FE) vacuum systems are located between the storage ring and beamline of synchrotron accelerator, wherein the influence of FE dynamic pressure is critical in beam operation. This study proposes the baking time reduction to recover the system to its previous dynamic pressure level over a finite maintenance time. Results show that the static pressure can reach 5.5 × 10−9 Pa after 12 h bake at 200°C and dynamic pressure can be recovered to its previous level at 10 Ah; therefore, the system possesses a similar beam cleaning efficiency. The residual gas analyzer (RGA) data show that H2, CO, and CO_2 still dominate the static and dynamic pressure after 12 h bake-out, indicating that after vacuum intervention and bake time reduction and static and dynamic pressures of the FE vacuum system can still effectively restore its previous level within a short time.

INTRODUCTION

The Taiwan photon source (TPS) synchrotron accelerator at the National Synchrotron Radiation Research Center in Taiwan is a third-generation accelerator operating at 3 GeV designed to create a high-energy photon source. The front end (FE) of the TPS systems is located between the storage ring and beamline, and it is designed to protect the user's safety and control of experimental requirements. The FE vacuum systems need to maintain low dynamic pressure because they can influence the vacuum pressures of the storage ring and beamline. Therefore, each FE vacuum system should be baked at 200°C for 24 h at the initial stage of FE system construction. Other accelerators also require considerable baking time and high temperature to reach ultra-high vacuum (UHV) [1-3]. Furthermore, vacuum interventions are required to upgrade or maintain the FE systems; they need to be baked for 24 h to recover low dynamic pressure. The 24 h baking process requires on-site manpower support to ensure the safety of the facilities in the TPS tunnel, requiring two duty days with one overnight stay. Therefore, reducing baking time or operating without baking is an essential issue to be considered in TPS facility. Moreover, replacing B1 chamber without baking in-situ has been successfully executed in a TPS storage ring case [4]; the aperture and materials of the FE vacuum chamber differ from those of the B1 chamber, and FE installation without baking in-situ is not necessarily feasible because the thermal outgassing occupies a certain proportion in dynamic pressure [5]. Herein, we present the beam cleaning efficiency after a reduced baking time of less than 12 h in one duty day to shorten the machine downtime and monitor the residual gas and pressure during the 12 h baking process and beam operation. The layout of FE vacuum system is shown in Fig. 1.

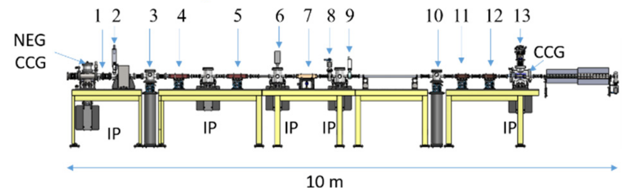

Figure 1: The layout of standard front end vacuum sys-tem, where (1) is pre-mask, (2) is screen monitor, (3) is XBPM 1, (4) and (5) are fixed mask, (6) is RGA, (7) is photon absorber, (8) is metal gate valve, (9) is fast-closing valve, (10) is XBPM 2, (11) and (12) are slit. 13 is heavy metal shutter.

VACUUM INTERVENTION PROCEDURE

TPS downtime is usually short because the beam time is very valuable. In this case, we have downtime of a week to upgrade several FEs; the vacuum intervention steps are as shown below:

1. Close the ion pump (IP), cold cathode gauge (CCG) controller, and water cooling.
2. Check if upstream and downstream FE valve are closed to avoid influencing the beamline and storage ring vacuum.
3. Vent the FE vacuum system using dry nitrogen gas (purity 99.999%).
4. Upgrade the XBPM2 system for 2–3 days.
5. Bake-out at 200°C for 12 h in one day.

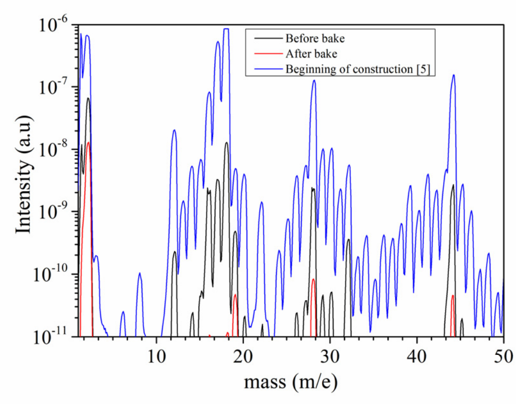

Figure 2: The RGA signal before, after bake-out, and at the beginning of construction.

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RESULTS AND DISCUSSION

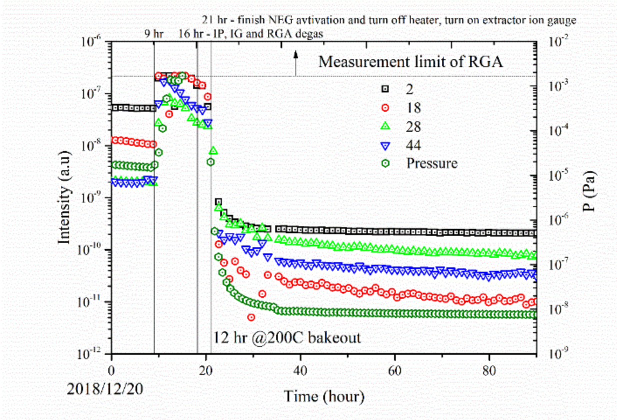

Figure 3: The trends of RGA signal during 12 h bake-out at 200°C.

RGA data of the initial construction before and after bake-out at 200°C during 12 h are shown in Fig. 2. H_2 (mass-to-ratio (m/z) = 2) and H_2O (mass-to-ratio (m/z) = 18) are the dominant gases present in the vacuum chamber before baking process. The RGA data demonstrate that the re-adsorption surfaces exposed can be seen from the m/z = 18; H_2 is a common residual gas in stainless steel materials. The function of baking is mainly to remove the adsorption gas from the surface; residual gases H_2 (m/z = ~2), H_2O (m/z = ~18), CO (m/z = ~28), and CO_2 (m/z = ~44) are detected after 12 h baking at 200°C, which is typical mass spectrometry after bake-out. To understand gas adsorption behavior under 12 h baking process at 200°C, consider the residual gas analyzer (RGA) signal and vacuum pressure during bake-out (Fig. 3). The RGA signal focuses on common gases generated after bake-out, such as H_2, H_2O, CO, and CO_2, with m/z corresponding to 2, 18, 28, and 44 amu, respectively. We observed that the CO and CO_2 dropped rapidly after 4 h bake-out. However, after IP , IG, and RGA degassing (7 h bake-out), the H_2O and H_2 signals were decreased simultaneously because the FE vacuum system during these degassing can effectively remove adsorption gases H_2O and H_2. Although H_2O needs 7 h baking to be removed from a surface, the H_2O signal has the lowest intensity in common gases; thus, the RGA signals show that $H_2 > CO > CO_2 > H_2O$. After bake-out at 200°C for 12 h, the ultimate pressure was from 7.5×10^{-9} to 5.5×10^{-9} Pa before and after vacuum interventions, respectively. Additionally, the RGA data exhibit that the surface is cleaner after vacuum intervention than that at the initial stage of its construction [5], which implies that the surface adsorption condition is less terrible than that at the beginning of the construction due to dry nitrogen gas venting. Therefore, removal of surface adsorption can be achieved in a short-time bake. In the case of TPS FE vacuum system, the source of FE vacuum pressure is mainly dominated by H_2, CO, and CO_2 [5], and it is mainly pumped by non-evaporable getters (NEG) and IP. The initial beam cleaning of FE vacuum causes a considerable amount of photon stimulated desorption (PSD) outgassing and most of the gases are mainly pumped using IP and NEG; a very small amount is adsorbed by the unirradiated chamber wall. Therefore, bake-out and NEG reactivation process can induce improvement in pumping efficiency and chamber wall re-desorption; thus, the ultimate pressure can reach 5.5×10^{-9} Pa. In addition, Table 1 lists the different states of static pressure. The status of before beam cleaning implies the initial stage of the FE system construction, and the results show that the static pressure at high-temperature baking was 10^{-8} Pa. After beam cleaning, the static pressure reaches to 7.5×10^{-9} Pa owing to the removal of tightly bound absorbates with high-energy photons irradiated [4, 6]. After vacuum intervention and baking, the static pressure reached 5.5×10^{-9} Pa owing to the removal of weakly bound absorbates via bake-out and NEG reactivation [7].

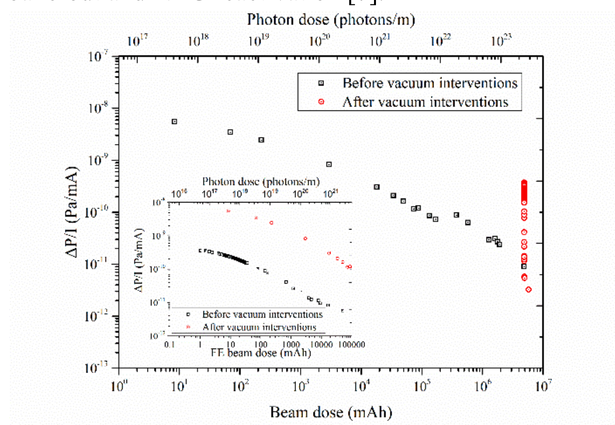

Figure 4: The dynamic pressure vs. accumulated beam dosage before and after vacuum interventions. Inset shows rescale (return to zero) of FE beam dose.

Table 1: Different Status of Static Pressure in FE05 Vacuum System

Status	Static pressure for FE05
Before beam cleaning	15.2×10^{-9} Pa
Before vacuum intervention	7.5×10^{-9} Pa
After vacuum intervention and baking	5.5×10^{-9} Pa

To understand the effect of reduced baking time on dynamic pressure, the dynamic pressure vs. accumulated beam dosage is shown in Fig. 4, which shows that the dynamic pressure recovers to the previous status within the accumulated dosage of 10 Ah. The inset figure shows the dynamic pressure after vacuum interventions vs. accumulated beam dosage rescale from 0 mA, which was used to evaluate beam cleansing efficiency compared with dynamic pressure before vacuum interventions. Result shows

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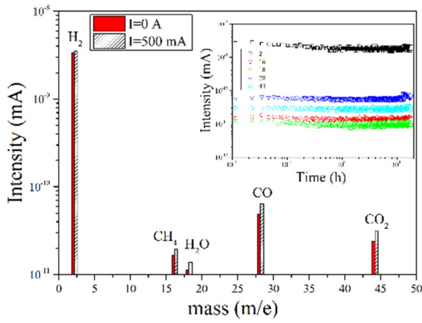

Figure 5: The intensity of RGA signal with and with-out 500 mA operating current. Inset shows the trend of RGA signal during 500 mA operating beam current.

that the slope of dynamic pressure exhibited was close to 0.5 before 10 Ah, which was similar to the value obtained prior to vacuum interventions. This result implies that the beam cleaning efficiency is almost irrelevant to the static pressure after baking. However, the static pressure is still important in FE vacuum system. Although the slope is similar, the intercept is different after the baking at low dynamic pressure; thus, baking is still important in FE vacuum system.

To understand the behavior of residual gas at dynamic pressure, the RGA signals from the operation with and without 500 mA beam current are shown in Fig. 5 (Fig. 5 inset is a trend of RGA data with 500 mA). The RGA started 5 h before beam operation to improve the accuracy of the system. The RGA data exhibited a strong H_2 signal with and without beam operation; the other gases accounted for small portions. H_2 gas is mainly from the chamber materials itself, the other gases (H_2O, CO, and CO_2) are mainly from surface adsorption. In this case, even after the high current operation, there is no drastic increase in the gases adsorbed on the surface, indicating that the beam cleaned the chamber successfully after a short-time bake and does not affect the dynamic pressure in the TPS FE vacuum system.

CONCLUSIONS

Herein, we evaluated the TPS FE vacuum system using short-time bake (owing to short-term maintenance) to recover UHV. We observed that the static pressure of 5.5×10^{-9} Pa after short-time baking is better than that of $\sim 7.5 \times 10^{-9}$ Pa before vacuum interventions. Additionally, we discovered that dynamic pressure shows similar beam cleaning efficiency and recovers to the previous level within the accumulated dosage of 10 Ah. At 500 mA high current operation, the RGA signal exhibits H_2 signal that dominates the dynamic pressure because of the nature of the chamber materials, and no significant enhancement occurs from the use of surface adsorption gases such as H_2O, CO, and CO_2 signals. Until now, the dynamic pressure has been steadily decreasing because of beam cleaning. Moreover, we verified that the TPS FE vacuum system attempts to upgrade or maintain lead to vacuum intervention, the vacuum chamber after beam cleaning can recover to its previous level through a short-time bake.

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