BAKING TEST FOR AN IN-VACUUM UNDULATOR

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Abstract

For Taiwan Photon Source in NSRRC, an in-vacuum undulator (IU) will be set in a straight section. The baking test took place in NSRRC, using heating wires, tape heaters, a hot water unit and so on. The heating wires were welded onto the external wall of the stainless-steel chamber. The tape heaters were used for the sites without heating wires. After the acceptance test, we assembled the residual gas analyzer (RGA) and extractor gauge in the IU. The pumping curve and RGA spectrum were recorded and investigated. The slope of the pumping curve near 1 h was -0.99. When the temperature gradually increased to about 180 °C, the pressure was about 8.7×10^{-5} Torr. Most of the gas source is water before baking. After the baking test, the major residual gases include H_2, CH_4, H_2O, CO and CO_2. We analyzed the RGA spectrum during the baking and discuss the results in this paper.

INTRODUCTION

For an in-vacuum undulator, the magnet arrays are assembled in the vacuum chamber [1-5]. To achieve an ultra-high vacuum for the in-vacuum undulator, the vacuum chamber must be baked at a high temperature to decrease the outgassing, but the temperature of the magnet arrays cannot exceed 125 °C [6]. During baking, the baking temperatures of the chamber and magnet arrays are adjusted for consideration of the deformation and displacement of the vacuum chamber. The baking test of an undulator in vacuum has many details, including preparation of bake-out, bake-out, NEG pump activation, decreasing temperature, and scrutiny after bake out.

EXPERIMENTS

The vacuum chamber includes one main chamber and two end chambers, manufactured by Toyama. The material of the vacuum chamber is stainless steel (304). The cleaning of the vacuum chamber includes soap cleaning followed by electrolytic polishing three times. This process is dependent on the experimental experience from SPring-8. Two ion pumps (125 L s^{-1}, Anelva, PIC-052NP) and four NEG pumps (GP 500 MK5-SP8) were assembled for pumping. One pumping cart was connected to the metal angle valve for evacuation. The residual gas analyzer (RGA) (Inficon, Transpector 2 Gas Analysis System H100M (100 amu)) was installed in the IU to record the spectrum. In this paper, the pressure, recorded as the pumping curve, is from the extractor gauge. After baking degassing, the two BA gauges (Anelva, NIG-2TF) were turned on to read the pressure for sites upstream and downstream.

RESULTS AND DISCUSSION

Figure 1 shows the pumping curve vs. time in the IU during pumping at 25 °C, at least 48 h baking at 180 °C for the main chamber, and after baking. Because the displacement between the magnet arrays and the main chamber was influenced by the temperature of the magnet arrays and the chambers, the rate of temperature increase for the magnet arrays and vacuum chamber can adjust the displacement. We tried our best to control the displacement not to exceed 1 mm. To measure the displacement between the magnet arrays and the end chamber during baking, dial gauges were set in the position of upstream and downstream sections of the in-vacuum undulator. For the baking test of the IU, it was observed that the displacements between the magnet arrays and the main chamber were about 1.18 mm and 1.32 mm for upstream and downstream sites, respectively. The baking temperature of the main chamber is therefore 180 °C in the IU, limited by the displacement between the magnet arrays and the main chamber. The slope of the pumping curve near 1 h for IU is -0.99, from fitting the pumping down curve as log P (Pressure) vs log T (Time). There are two pressure maxima in Figure 1. The first pressure maximum occurred on starting baking to increase the temperature in the IU. The second maximum is from activation of non-evaporate getter (NEG) pumps before decreasing the temperature of IU. The final pressure in the IU was about 7.46×10^{-11} Torr.

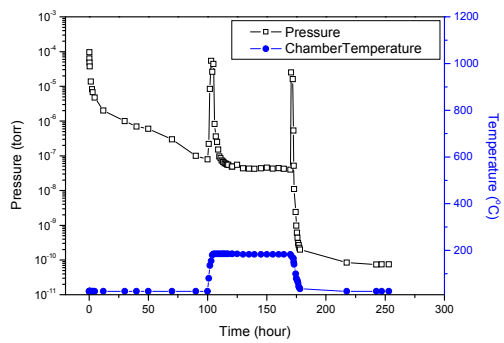

Figure 1: Pumping curves for IU vs time during a baking test.

Figure 2 shows the baking temperature of the main chamber and magnet arrays in the IU vs time. In the baking test of IU, the system of in-vacuum undulator was connected to the hot water unit for baking magnet arrays. In the baking period, the temperature of the magnet arrays was increased by flowing hot water. As

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we know, the temperature of magnet arrays cannot exceed 125 °C to avoid demagnetization.

Because the thermal expansion coefficient of the magnet arrays is larger than that of the chamber, the relative displacement was controlled by varying the rate of increase and monitored with the dial gauge. The rising rate of temperature of "exit from hot water source" was set to be 2.5 °C per 5 min. The rising rate of temperature of main chamber was set to be 5 °C per 5 min. Therefore, if the displacement became larger, the control of the rising rate of temperature can adjust the displacement. After the temperature of magnet arrays was 110 °C, the control mode of hot water for magnet arrays was switched to the CNT mode (automatic mode). In the CNT mode, a "Bypass" valve was usually on. If the temperature of magnet arrays was too high, the pressed valve was on and "Bypass" valve was off, automatically. At this time, the hot water was pressed into the magnet arrays to cool the magnet arrays. As the temperature of magnet arrays gradually raised to 120 °C, the temperature of magnet arrays therefore displayed periodic oscillation. To maintain the equilibrium temperature in the magnet arrays, the "Bypass" valve and the pressed valve were switched with each other, dependent on the temperature of the magnet arrays. The function of the "Bypass" valve was to maintain the temperature of hot water and not to alter suddenly the temperature of the magnet arrays. The variation period of temperature on the top side of the magnet arrays was less than that on the bottom side of the magnet arrays. Because the heat flows upward, the temperature of the magnet arrays was higher on the top side and the valves are switched more frequently.

After about seven hours, the temperature gradually attained a stable state. The chamber temperature was 180 °C. The baking duration of keeping the stable high temperature takes at least 48 h.

In addition, there is a cold water tube for cooling the linear guide of the magnet arrays. The water pressure of the cold water was 0.1 MPa. The temperature of cold water was set to 23.5 °C. It was noticed that the temperature of the RF taper, inside the end chamber, cannot exceed 145 °C, to protect the mechanical strength of the RF taper from damage.

Before decreasing the temperature, an extractor gauge, two BA gauges, ion pumps, and a RGA were degassed and NEG pumps were activated. Before this activation, the temperature of the chamber decreased to 168 °C and the temperature of the hot water decreased 5 °C individually. The activation temperature of NEG pump all reached 460 °C for 1 h at current 3.5 A. After NEG activation, the baking temperature of the IU system began to decrease. For the main chamber, the temperature continued decreasing at a rate 5 °C per 5 min. For the hot water unit, the temperature continued decreasing at a rate 2.5 °C per 5 min. The temperature of the main chamber and magnet arrays decreased continuously. As the temperature of chamber was about 95 °C, the temperature values that we set can not control the real temperature. The chamber heater was therefore switched off. When the temperature of "exit from hot water source" was about 35 °C, the control mode of "exit from hot water source" was switched off and the power of hot water is off.

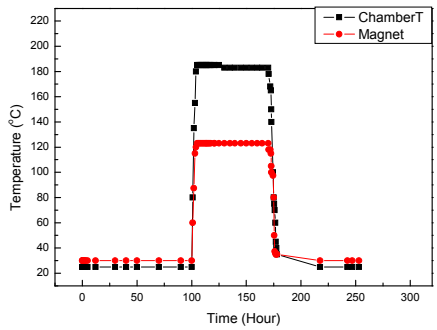

Figure 2: Baking temperature of the main chamber and magnet arrays in IU vs time.

Next, we analyzed the RGA spectra during baking at 180 °C (chamber temperature), shown in Figure 3. Because the pressure was too great to take the RGA data from the RGA directly equipped with the IU port, these RGA data, shown in Figure 3, were taken from the RGA equipped with the pumping cart.

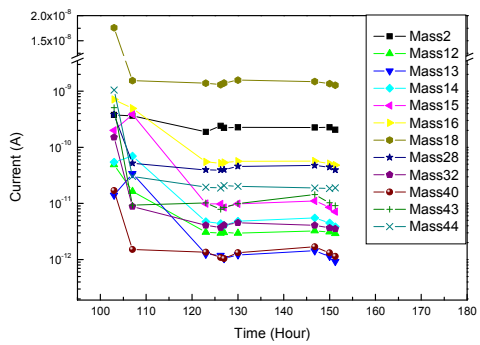

Figure 3: Residual gas during baking test at 180 °C (the chamber temperature).

The main residual gases before baking were observed to contain H_2O, CO_2 CH_4, acetone, H_2, and CO. After baking, the main residual gas species were H_2O, H_2, CH_4, CO, and CO_2. Compared with the RGA spectrum before baking, it was found that, after baking, the gas amount of H_2O, CO_2, CH_4, acetone, H_2, and CO decreased 92.7 %, 98.2 %, 96.4 %, 98.2 %, 45.6 %, 89.7 %, individually. The acetone might result from the cleaning of all vacuum parts inside the IU.

Figure 4 shows the RGA spectrum of the IU after decreasing the temperature for 24 h. These RGA data were taken from the RGA equipped with the IU port. The main residual gas species were H_2, H_2O, CO, CO_2 and CH_4 after decreasing the temperature for 24 h.

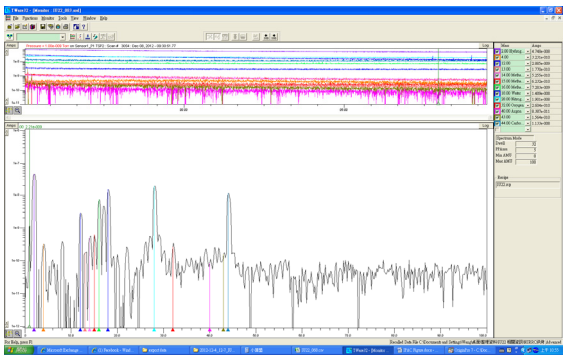

Figure 4: RGA spectrum in IU after decreasing the temperature for 24 hours.

We finally tested the leakage in the IU system, including all flanges and connection sites of water pipes. We verified whether the wrinkle occurs on the Ni-plated Cu sheet, covered on the surface of magnet arrays. The occurrence of wrinkles means that the tension of the Ni-plated Cu sheet on the surface of magnet arrays must be adjusted properly.

CONCLUSION

The baking test for the in-vacuum undulator took place first in NSRRC, using the heating wires, tape heaters, a hot water unit and so on. The RGA data can help us investigate the residual gas in the vacuum chambers. Next time, we will plan to take the RGA data from the RGA directly equipped with the IU port during the baking.

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