GAS DESORPTION FROM TiN-COATED COPPER BEAM DUCT

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Abstract

The gas desorption from a copper beam duct with a titanium nitride (TiN) coating was studied. The vacuum pressure of a TiN-coated duct was measured and compared with that of a non-coated one. The TiN film (200 nm thick) was coated by a DC magnetron sputtering. After an air exposure for a previously-determined period, the duct was evacuated by a turbo-molecular pump (0.3 $m^3 \cdot s^{-1}$). After 60 hours' evacuation, the pressure was about 5 times larger than that of the non-coated one. In order to find the minimum baking temperature to decrease the gas desorption from the TiN coating, the pressures were measured after a baking by changing the temperatures in a practical range, from 50 to 150 °C. The gas desorption rate of the TiN coating after a baking at 80 °C was finally found to be sufficiently low and comparable to that for the non-coated one.

INTRODUCTION

For future advanced positron/proton rings, it is an important issue to mitigate the electron cloud instability [1]. In order to reduce the electron cloud, it is effective to decrease the secondary electron yield (SEY) of the inner surface of beam ducts. A titanium nitride (TiN) coating is a promising candidate for this purpose, and has been attracting attention [2-4]. In KEK, several beam ducts coated with TiN have been installed into the KEKB positron ring (low energy ring, LER), and the electron cloud density in the beam ducts has been measured to study the effect of the coating [5, 6]. As a result, the effectiveness of the TiN coating was verified, but it was also found that the vacuum pressure of the TiN-coated duct was higher than that of the non-coated copper one, especially just after the installation. The histories of the surface aging of the ducts with beams are shown in Fig. 1. A non-coated duct was replaced by the TiN-coated one and the pressures were measured by a nearest cold cathode gauge before and after the replacement. At first, the pressure rise per unit beam current, $\Delta P/I$, near the TiN-coated duct was about two times higher than that near the non-coated duct, although the difference between them gradually reduced with the advance of aging.

The large gas desorption from beam ducts can be a problem during the commissioning stage. As is well known, in order to reduce the pressure of a newly installed beam duct, the *in-situ* baking is effective. In this case, however, the thermal expansion of a duct can be a problem. For example, if the baking temperature is 150 °C, which is typical for the KEKB copper beam ducts, the change in the length of a copper duct with a length of 2 m

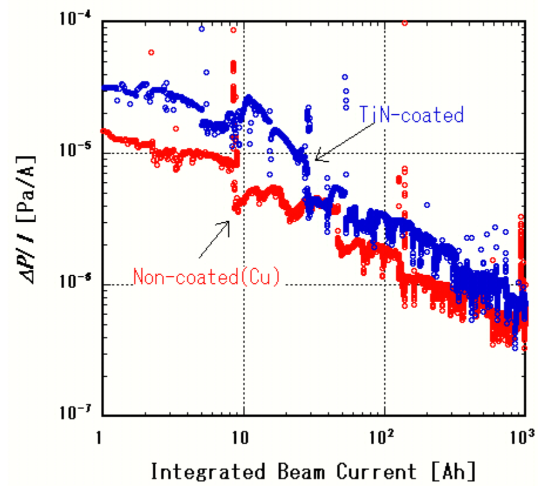

Figure 1: Histories of the surface aging with beams for the TiN-coated duct and non-coated one.

is about 4 mm, and it is almost equal to the available stroke of a bellows chamber. Moreover, for some components such as BPM, the *in-situ* baking at 150 °C is structurally difficult. In the case of KEKB, for example, beam ducts are normally baked at 150 °C for 24 hours before the installation. After the baking, the ducts are purged by the boil-off nitrogen gas from liquid nitrogen and installed into the ring. However, it is hardly possible to completely prevent the inner surface from the contamination by atmosphere. If the baking at low temperature is effective, the *in-situ* baking can be useful in reducing the pressure of a newly installed beam duct.

Here studied is the properties of the gas desorption from a TiN-coated copper beam duct after a baking. The pressures of a TiN-coated duct and a non-coated one were measured after the baking by changing the temperatures in a practical range, and the possibility of the *in-situ* baking at a low temperature was investigated.

EXPERIMENT

The experimental setup is shown in Fig. 2. A beam duct was connected to a turbo-molecular pump (pumping speed S = 0.3 $m^3 \cdot s^{-1}$) via a manifold (conductance C =

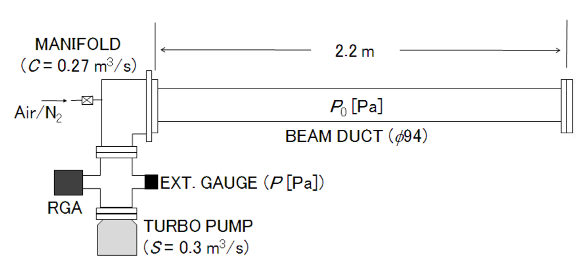

Figure 2: Experimental setup.

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0.27 $m^3 \cdot s^{-1}$) which has an extractor gauge, a residual gas analyser (RGA) and a leak valve. The beam duct can be baked by heaters and the pressure were measured by changing the baking temperatures from 25(non-baking) to 150 °C to find the lowest effective baking temperature for the TiN coating.

Each measurement was carried out according to the following procedure.

1. Pre-baking:
   The duct was baked at 150 °C for 24 hours and naturally cooled down to the room temperature (~25 °C). The base pressure after the baking was ~10^{-8} Pa.
2. Purge and exposure:
   The duct was purged by air or the boil-off nitrogen gas from liquid nitrogen, and then the inner surface of the duct was exposed to it for 1 hour.
3. Baking and pressure measurement:
   The duct was evacuated and the pressure was measured during the evacuation. The duct was baked at a pre-set temperature (25(non-baking), 50, 80, 100 and 150 °C) for 24 hours and naturally cooled down to the room temperature. The pressure was monitored for more than 60 hours in total during the evacuation.

The pressures were measured for two ducts; a TiN-coated copper duct and a non-coated copper one of the KEKB LER for reference. The TiN coating was done by a DC magnetron sputtering at KEK, and the thickness was 200 nm [7]. The length and diameter of the duct were 2.2 m and 94 mm, respectively (the inner surface area A = 0.66 m^2). The pressure in the beam duct, P_0, and the gas desorption rate of the inner surface, q, can be estimated from the pressure measured by the extractor gauge, P, by

$$P_0 = -P + PS/C, \quad (1)$$

$$q = PS/A, \quad (2)$$

respectively.

RESULTS AND DISCUSSION

Figure 3 shows the histories of the pressure, P, of the TiN-coated duct (a) and the non-coated one (b) during the evacuation. Purge gas was not nitrogen gas but air. If the duct was not baked (25 °C), the pressure of the TiN-coated duct after 60 hours' evacuation was about 5 times larger than that of the non-coated one. The baking, however, can reduce the pressure of the TiN-coated duct as in the case of the non-coated one.

Figure 4 shows the components of the residual gases of the TiN-coated duct (a) and the non-coated one (b) after approximately 100 hours' evacuation. Without baking, for the TiN-coated duct, there remained some species of residual gases such as H_2O, CH_4, CO and CO_2, which was not so noticeable for the non-coated duct. The baking, however, can reduce these gases. The vacuum property of the TiN-coated duct after a baking was comparable with that of the non-coated copper duct. The residual gas was mainly H_2 in both ducts after the baking.

The pressures in the ducts after 60 hours' evacuation estimated by Eq. (1) are shown in Fig. 5, and the gas desorption rates of their inner surfaces obtained by Eq. (2) are summarized in Table 1. For each baking temperature under 80 °C, the pressure decreased with increasing the baking temperature. Above 80 °C, however, the pressure was almost constant independently of the baking temperature. In this region the pressures were too low, and so they might fall below the measurable limit of the present experimental setup, which comes from the gas desorption from the gauge and RGA. The nitrogen purge was effective to reduce the pressure in some degree, but its effect was not so apparent for the TiN coating.

The gas desorption rate of the TiN-coated duct after the air exposure with the baking at 80 °C was 1.23×10^{-10} $Pa \cdot m^3 \cdot s^{-1} \cdot m^{-2}$, and it was smaller than that of the non-coated duct without any baking after the exposure to nitrogen (2.03×10^{-10} $Pa \cdot m^3 \cdot s^{-1} \cdot m^{-2}$). It is expected that the pressure of a newly installed TiN-coated duct after the *in-situ* baking at 80 °C can be lower than that of a copper duct of KEKB installed by the normal procedure, that is, without the *in-situ* baking. From this viewpoint, it can be

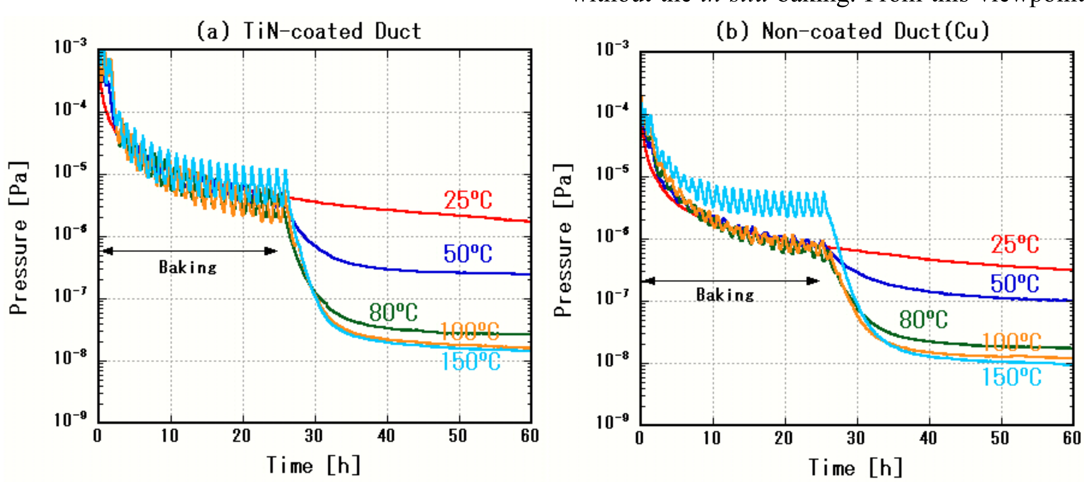

Figure 3: Pressure histories of the TiN-coated duct (a) and the non-coated one (b). After the air exposure, the ducts were baked at 25 (non-baking), 50, 80, 100 and 150 °C for 24 hours and naturally cooled down to the room temperature (~25 °C).

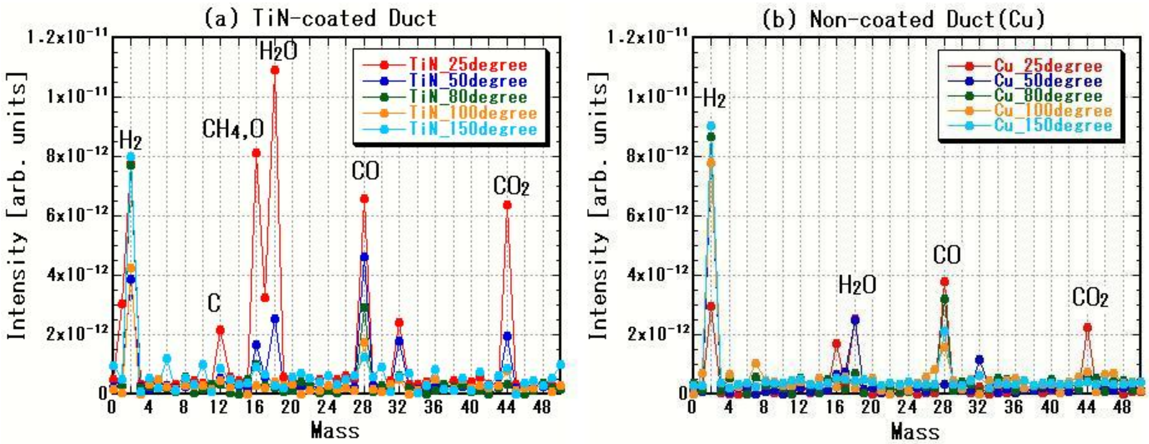

Figure 4: Main components of the residual gases of the TiN-coated duct (a) and the non-coated one (b) after approximately 100 hours' evacuation.

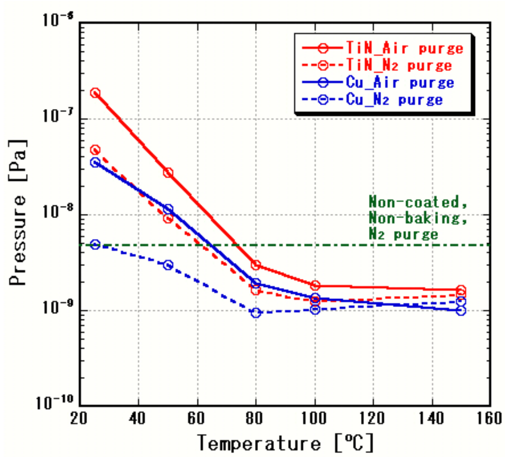

Figure 5: Pressures in the TiN-coated and non-coated copper ducts after 60 hours' evacuation for various baking temperatures.

said that the gas desorption rate of the TiN coating after the baking at 80 °C is sufficiently small for a practical purposes.

At 80 °C, the thermal expansion of the copper duct with a length of 2 m at 80 °C is about 1.8 mm. It is acceptable to KEKB, and so the *in-situ* baking at 80 °C will be practically available for the TiN-coated duct of KEKB, and probably for that of an upgrade of KEKB (SuperKEKB).

During this summer shutdown, several TiN-coated ducts will be installed in KEKB LER. At this time the *in-situ* baking at 80 °C will be tested and its effect will be investigated.

SUMMARY

The gas desorption of a TiN-coated copper beam duct was studied. Without baking, the pressure of the TiN-coated duct after 60 hours' evacuation was about 5 times larger than that of the non-coated one. It was found that the baking can reduce the gas desorption rate of the TiN-

Table 1: Gas desorption rates of the TiN-coated and non-coated duct for various baking temperatures

Baking Temp. [°C]	Gas Desorption Rate [Pa·m^3·s^{-1}·m^{-2}] TiN-coated Duct		Non-coated Duct (Cu)	
	Air Purge	N_2 Purge	Air Purge	N_2 Purge
25	7.77×10^{-9}	1.95×10^{-9}	1.44×10^{-9}	2.03×10^{-10}
50	1.14×10^{-9}	3.75×10^{-10}	4.73×10^{-10}	1.23×10^{-10}
80	1.23×10^{-10}	6.68×10^{-11}	7.86×10^{-11}	3.90×10^{-11}
100	7.50×10^{-11}	5.09×10^{-11}	5.50×10^{-11}	4.15×10^{-11}
150	6.68×10^{-11}	5.95×10^{-11}	4.10×10^{-11}	5.05×10^{-11}

coated duct as low as that of the non-coated one. The lowest effective baking temperature for the TiN coating was 80°C, and its gas desorption rate after 60 hours' evacuation was 1.23×10^{-10} Pa·m^3·s^{-1}·m^{-2}, which is smaller than that of the non-coated duct without baking after the exposure to nitrogen. The thermal expansion at 80 °C was within the acceptable range in the real ring. The *in-situ* baking at 80 °C will be useful to the TiN-coated duct for KEKB and SuperKEKB.

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