

## R&D STATUS OF VACUUM COMPONENTS FOR THE UPGRADE OF KEKB

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### Abstract

An upgrade plan of the KEK B-Factory (KEKB), Super KEKB (SKEKB) has been discussed in KEK. The R&D of main vacuum components for the SKEKB, such as beam ducts, bellows chambers and connection flanges etc., are now undergoing. Trial models of a beam duct with an antechamber and a bellows chamber with a comb-type RF shield were installed in the KEKB positron ring and tested with beam. Coatings with a low secondary electron yield were also investigated with the positron beam. A special connection flange with small impedance was examined in a test bench.

### INTRODUCTION

The Super KEKB (SKEKB) is a future  $e^-/e^+$  collider aiming a luminosity of  $4 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$  by upgrading the KEK B-Factory (KEKB) in KEK [1, 2]. To achieve the high luminosity, the design stored beam currents are 4.1 ( $e^-$ ) and 9.4 ( $e^+$ ) A, and the bunch length is 3 mm. The main issues of the vacuum system, therefore, are how to manage the resultant highly intense synchrotron radiation (SR) power, and how to reduce the beam impedance [3]. The suppression of the electron cloud instability (ECI) is also a serious problem in the positron ring [4]. The R&D for basic vacuum components is undergoing to deal with the problems. Copper beam ducts with an antechamber were manufactured for a test [5]. They were installed in the KEKB positron ring, and the vacuum property and the number of electrons in the beam channel were measured. The effect of the coatings of NEG materials (Ti, Zr, V) and TiN, which are said to have a low secondary electron yield (SEY) [4, 6], were also studied in the positron ring. Several bellows chambers and a gate valve with a comb-type RF shield were installed in the ring, and the shielding property was investigated [7, 8]. A special connection flange, the MO-type flange, which has little step or gap inside, was developed and examined in a test bench [9]. The conceptual design of movable masks with low impedance has just started.

### BEAM DUCT WITH ANTECHAMBER

Beam ducts with antechambers have been proposed for SKEKB [3]. The power density of SR decreases due to its vertical and horizontal spread since the SR hit the side wall of the antechamber along the duct. Since the vacuum pumping ports (holes) are at the antechamber, the impedance of the beam channel greatly decreases. For the positron ring, furthermore, the electron density in the beam channel can be reduced since the photoelectrons are

emitted from the side wall of antechamber, which is an effective way to suppress the electron cloud instability (ECI) [4, 5].

Two test copper chambers with an antechamber were manufactured. One chamber was made by the pressing from plates, and other was formed by the cold drawing from a pipe. A test chamber is shown in Fig.1. The diameter of the beam channel is 94 mm and the outer half aperture of duct including the antechamber is 112 mm. The thickness and total length are 6 mm and 5.2 m, respectively. No essential problem was found in the manufacturing.

They were installed in the positron ring of the KEKB in the winter shutdown, 2004. The beam energy is 3.5 GeV and the maximum stored beam current is 1.7 A. The vacuum scrubbing after the installation was smooth but lots of pressure bursts possibly due to arcing inside were observed in one of these chambers that had several transverse joints.

The number of electrons in the beam channel was measured by a special electron monitor attached at the bottom of beam channel [5]. The monitor measured electron currents,  $I_e$ , composed of electrons entering to a collector (+100 V) through a retarding grid (-30 V). The  $I_e$  was measured in DC mode during the usual beam operation, and reflected the average number of electrons just near the bunch. The chamber was installed at just downstream side of a bending magnet, and the direct photon density there was about  $1 \times 10^{16} \text{ photons m}^{-1} \text{ s}^{-1} \text{ mA}^{-1}$  (critical energy,  $\epsilon_c$ , is 6.5 keV). The measurements were done after the electron doses over  $10 \text{ mC mm}^{-2}$ , which was enough to reduce the SEY from the initial value [4, 6]. The behaviour of  $I_e$  against the beam current,  $I_b$ , for the test chamber and a circular chamber are presented in Fig.2, where the bunch numbers and the bunch spaces are 1284 and 3.77 RF buckets in average (1 RF bucket is 2

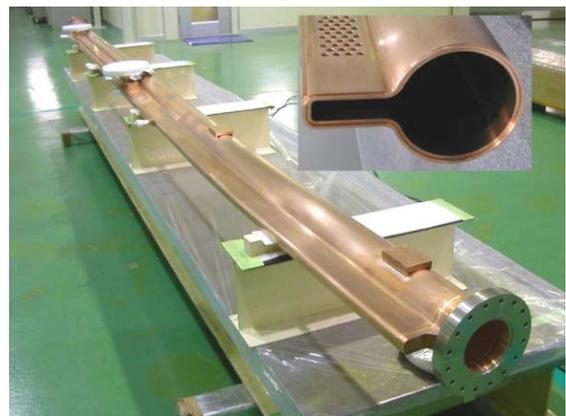


Figure 1: Appearance and cross section of test chamber with an antechamber.

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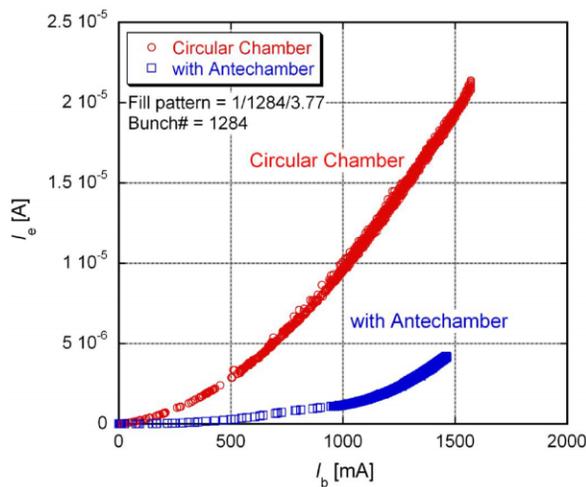


Figure 2:  $I_e$  vs.  $I_b$  for circular chamber and test chamber with antechamber. The fill pattern 1/1284/3.77 means one train of 1284 bunches by 3.77 RF buckets spacing in average.

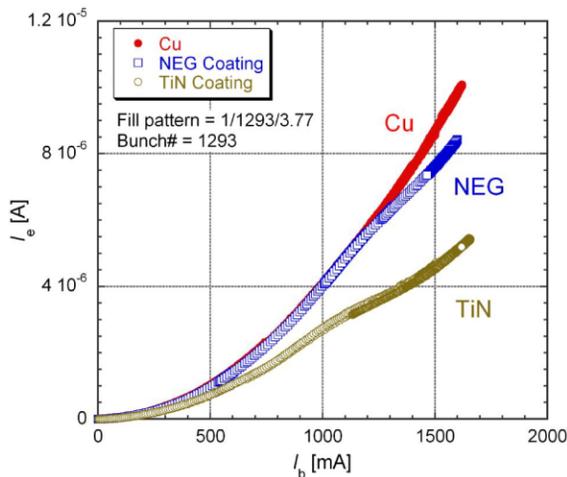


Figure 3:  $I_e$  vs.  $I_b$  for non-coated copper, NEG-coated and TiN coated chambers.

ns), respectively. The  $I_e$  of the test chamber at low  $I_b$  ( $\leq 100$  mA) was smaller by two orders of magnitude than that of the circular chamber. The difference, however, decreased to only several factors at high  $I_b$  of about 1500 mA, 1.2 mA/bunch. That means that the antechamber can suppress the photoelectrons effectively, but at high current region, where the multiplication of secondary electrons are likely to occur, the effect is weakened. Some other measures to reduce the SEY will be necessary in the high current region if necessary.

A beam duct with two antechambers at opposite sides for a wiggler section is now under manufacturing, and will be installed in the ring this summer.

### SURFACE WITH LOW SEY

To suppress the multiplication of secondary electrons, two promising coatings, NEG materials (Ti, Zr, V) and TiN, were investigated [5, 6]. Two circular copper

chambers with a diameter and a length of 94 mm and 2.56 m, respectively, were prepared with these coatings and installed in the KEKB positron ring. The coating of NEG materials and TiN were performed in BINP and in BNL, respectively, by a magnetron sputtering. The thickness was about 1  $\mu\text{m}$  for both cases. They were baked at 150°C for 24 hours before installation. The NEG-coated chamber was baked again in the ring up to 220°C for 2 hours to activate the coated NEG. The base pressure was in the order of  $10^{-8}$  Pa.

The vacuum scrubbing by beam after the installation proceeded smoothly for both cases, but the pressure of NEG-coated chamber was lower than that of TiN-coated and non-coated copper chamber by several factors of magnitude. That is because the NEG-coated chamber has a low gas desorption rate and, at the same time, the coated NEG has a pumping speed by itself [10].

The electron current,  $I_e$ , in the chamber was measured in the same way described above. The chamber was installed at about 5.4 m downstream side of a bending magnet, and the direct photon density at that point is about  $6.5 \times 10^{14}$  photons  $\text{m}^{-2} \text{s}^{-1} \text{mA}^{-1}$ . The  $I_e$  was again measured after the electron doses of over  $10 \text{ mC mm}^{-2}$ . Although the detailed analysis of the result is now undergoing, a typical one is presented in Fig.3. The  $I_e$  for NEG-coated chamber was almost the same as that of the non-coated chamber at low  $I_b$  ( $\leq 1200$  mA), but small at high  $I_b$  ( $\geq 1300$  mA). That means roughly that the photoelectron yield for both surfaces is almost the same but the SEY of NEG coating is smaller than that of copper. The abundant photoelectrons make the property of low SEY of NEG coating unclear. On the other hand, the  $I_e$  of TiN-coated chamber was about a half of the case of non-coated chamber. The  $I_e$  is low even at the low  $I_b$ . That means the TiN chamber has a low SEY as well as a low photoelectron yield. From these results so far, the combination of a beam duct with antechambers and TiN coating is the best solution to suppress the ECI at present. The demonstration of the combination using a positron beam is planned as a next step.

### BELLOWS CHAMBER AND GATE VALVE

A comb-type RF shield has been developed in KEKB and applied to several bellows chambers [7, 8]. The first circular ( $\phi 94$  mm) bellows chambers have been installed in the KEKB positron ring for about two years. The temperature rise of corrugation decreased to 1/6 compared to that of bellows with a conventional finger-type RF shield. No pressure burst indicating arcing inside has been observed. A racetrack shape (76 mm in width  $\times$  48 mm in height) bellows chamber was then installed last summer and no essential problem was observed. .

Four bellows were installed both side of the movable masks in the ring, where the bellows should absorb the bending up to 20mrad to adjust the mask head position [11]. The temperature rise of the corrugation decreased to about 1/3 (with cooling fans for the finger-type). No problem was found for this one year's operation.

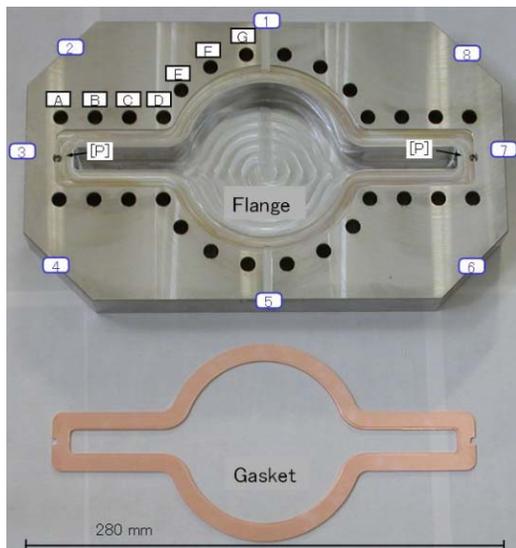


Figure 4: Test model of MO-type flange for beam duct with antechambers.

The comb type RF-shield was also applied to a circular gate valve under the collaboration with VAT Vakuumentile AG. One gate valve with a diameter of 94 mm has been installed in the KEKB positron ring in the winter shutdown, 2004. The temperature rise of the body decreases to 1/3 compared to the conventional one. The gate valve with a racetrack aperture is now considering.

### CONNECTION FLANGE

The connection flange in the accelerator has usually a RF bridge to fill the transverse gap between flanges. The conventional ones are lots of fingers or metal O-rings. For a short bunch as in the case of SKEKB, however, even the step or dip with a depth or a width of 1 - 2 mm can be a big impedance source. Higher thermal strength and more reliable electric contact than ever before are also required.

The MO-type flange, which had been developed for the vacuum flange of wave guides [9], seals the vacuum at the inner edge of the flange by a copper gasket, and makes little gap or step at the inner surface. A test flange and gaskets with a shape of a beam duct with antechambers were manufactured as shown in Fig.4, and the vacuum properties were tested. The gasket and the flange are made of pure copper (C1011) and stainless steel (SS316), respectively. The horizontal aperture is 224 mm including antechambers, and the diameter of beam channel at the centre is 94 mm. The thickness of flange is 35 mm, and the flange is fastened by 28 stainless steel bolts (M8). The vacuum sealing was achieved (helium leak rate less than  $1 \times 10^{-11}$  Pa  $m^3 s^{-1}$ ) with a reasonable fastening torques of 15 - 18 Nm. The sealing was kept even after a baking at 250°C for 24 hours. The experiment using a beam is planned as a next step.

### MOVABLE MASK

The movable mask (collimator) will be one of the biggest HOM sources in the SKEKB [3], and any drastic improvement is required. At present design, the movable mask will have almost the same system as used in the KEKB [11]. The mask head, however, will be made of carbon (graphite) to avoid damage by beam instead of titanium at present. The mask head, furthermore, will be supported by slender ceramic rods to reduce the interference with the bunch-induced field and to decrease the impedance. The charge up of the head will be cured by a thin conductive coating on the ceramics support. In order to absorb the higher order modes (HOM) generated by the mask head, the HOM absorber, such as SiC rods, will be prepared just near to the mask head. The heat deposited to the head will be transferred mainly by radiation to outer chamber. The design study has just begun, and the test of carbon mask head will begin this year as a start of the R&D.

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