Measurements of Gas Desorption Rates from a Copper Beam Duct

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Abstract

A trial model of copper beam duct for the KEK B-Factory was fabricated and gas desorption rates were measured. The duct was made of OFC (Oxigen Free Copper) and degreased in a freon bath. The ultimate total pressure was about 4×10^{-10} Torr after a baking at 150°C for 48 hours and the thermal gas desorption rate was calculated as about 1.5×10^{-12}Torr$\cdot$ $l/(\mathrm{s}\cdot\mathrm{cm}^2)$ in N_2 equivalent. The measurement of the photon stimulated gas desorption rate was performed using the synchrotron radiation with a critical energy of 26.3 keV from the TRISTAN Accumulation Ring. The photo-desorption coefficients in the order of 10^{-2} molecules/photon were observed for main gases desorbed at the initial stage. These relatively high gas desorption rates indicate that more careful surface preparation must be necessary.

I. INTRODUCTION

For the purpose of achieving a high luminosity, KEK B-Factory rings are operated with high current beams. Intensity of synchrotron radiation (SR) emitted from beams consequently becomes higher than any other existing e^--e^+ collider. How to treat this intense SR is a major subject in designing the vacuum system [1].

The choice of duct material, among others, has been the most important R&D point. The most prospective material is copper. Copper has many excellent properties compared to aluminum alloy, i.e. a high thermal conductivity, a high melting point and a low photo-desorption coefficient [2].

We have made a trial model of copper beam duct to get a base for the final duct design [3]. The thermal gas desorption rate and the photon stimulated gas desorption (PSD) rate were measured using the model duct. We report here these experimental results.

II. COPPER BEAM DUCT

The duct material is the Class 1 OFC (Oxigen Free Copper) provided from HITACHI Cable, Ltd. The duct consists of a beam channel, a pump channel and a cooling channel like a conventional beam duct. Each channel was independently extruded at first in a circular pipe and then extracted to its design shape. They were welded each other by EBW (Electron Beam Welding). The flanges (304 stainless steel) were welded by TIG welding in Argon atmosphere inserting Inconel-625 between OFC and 304 stainless steel. The duct is straight and the total length is 3.7 m. The aperture of the beam channel is 100 mm in width and 50 mm in height. The copper beam duct manufactured is shown in Figure 1.

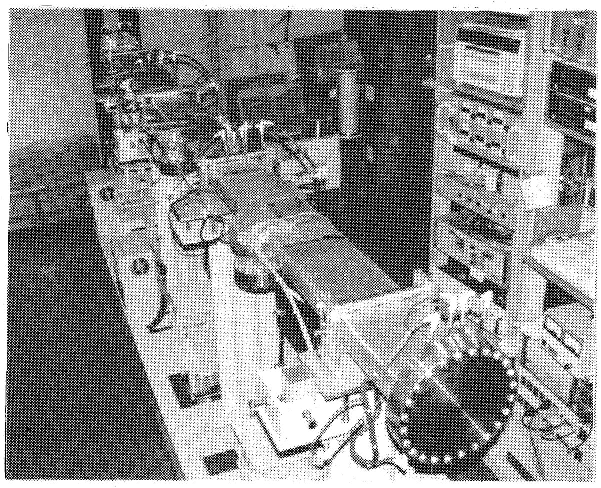

Figure 1. Copper beam duct for test.

Since we had no definite idea to specify what surface treatment is the most appropriate for a copper beam duct, no special treatment was tried to the duct except for ultrasonic cleaning in a freon bath to get reference data for future studies. The roughness of the surface is less than 10 μm, but we can see many narrow lines on the surface along the duct marked in the extraction process.

III. MEASUREMENTS OF GAS DESORPTION RATES

A. Thermal gas desorption

The duct was evacuated by a turbo-molecular pump (300 l/s) and two ion pumps (130 l/s) combined with NEG pumps (100 l/s). Two B-A gauges measured the total pressures in the beam channel and the pump head. The pump down curve is shown in Figure 2. After a baking at 150°C for 48 hours, the pressure reached to about 1×10^{-10} Torr at the beam channel in N_2 equivalent. The main residual gas was H_2. Ar was hardly detected. Assuming the total effective pumping speed of 300 l/s at the base pressure,

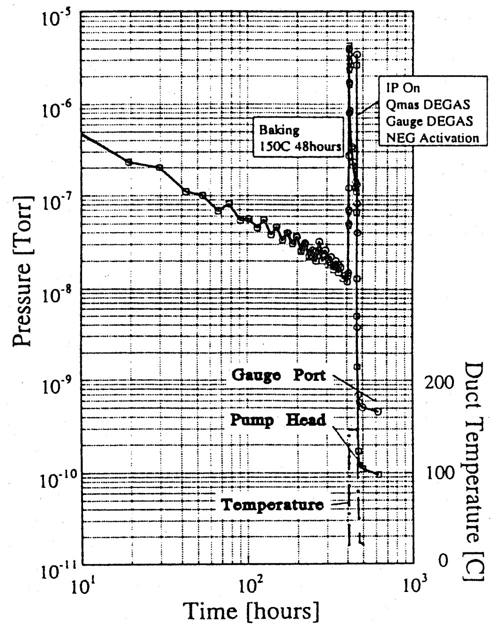

Figure 2. Pump down curve of the copper duct.

the thermal gas desorption rate was calculated as about 1.5×10^{-12} Torr. l/(s. cm^2). This desorption rate is not so good value as a vacuum chamber. Carefully treated vacuum chambers of aluminum alloy or stainless steel will give the thermal gas desorption rate in the order of or less than 10^{-13} Torr. l/(s. cm^2).

B. Photon stimulated gas desorption (PSD)

The photon stimulated gas desorption rate was measured using the synchrotron radiation (SR) from the TRISTAN Accumulation Ring (AR) having a critical energy of 26.3 keV. Schematic diagram of the beam line is shown in Figure 3. The duct received the photon directly from the source at a 14.8 mrad incident angle. The x-y slit limited the photon beam vertical and horizontal opening angle to 0.50 mrad and 2.4 mrad, respectively. About 3 m out of 3.7 m long duct was directly irradiated by the SR with a height of about 8 mm. The incident photon flux N_p per beam current per second was about 1.54×10^{15} photons/(mA. s). The total pressures and partial pressures at the upstream and downstream side of the orifice (O_r) were measured by two extractor gauges (EXG1 and EXG2) and two quadrupole mas analyzer (QMA1 and QMA2), respectively. The photo-desorption coefficient η_i for i-th gas species is given by

$$\eta_i = 3.3\times10^{19}\frac{C_i\Delta P_i}{N_p I_b} \qquad \text{molecules/photon},$$

where ΔP_i is the pressure difference between the upstream and downstream side of the orifice in Torr, C_i is the conductance of the orifice (50 mm wide × 12 mm height) in l/s and I_b is the beam current in mA. The downward beamline from the valve GV2 was baked up to 130°C for 48 hours. The base pressure of the copper duct was about 1×10^{-9} Torr.

Main gases desorbed was H_2, CH_4, CO and CO_2. The η for these gas species as a function of photon dose are presented in Figure 4. The η at the initial stage are in the order of 10^{-2} molecules/photon. The η decreased with photon dose with an average slope of $-\frac{2}{3}\sim -1$ beyond 1×10^{20} photons/m. The desorbed gas reached up to 1 Torr. l at 1×10^{21} photons/m.

The η and the total quantity of desorbed gases are larger by about one order of magnitude than the data of copper ducts reported so far by O.Gröbner et al.[4], A.G.Mathewson et al.[5], R.Gavaggio et al.[6] in DCI, and H.J.Halama et al. [7] in NSLS, and almost the same order as those of aluminum-alloy ducts [5,6,7]. All of copper duct refered, however, had received chemical etching before the experiments. The large gas desorption from our model copper duct, therefore, will be due to the insufficient surface treatment.

The η for main gas species were measured to see the "memory effect" after the duct was exposed to air for 3 hours. The duct was again for 24 hours at 130°C. Figure 5 shows the results. Almost the same η as those at the final stage of the previous measurement were obtained from the initial stage.

IV. SUMMARY

Basic data of gas desorption rates from a copper beam duct were obtained. The results were not good compared to those reported so far due to the insufficient surface treatment. Chemical surface cleaning will decrease the gas desorption rates. We are now planning to make several copper ducts with different surface treatments and to compare the η this year.

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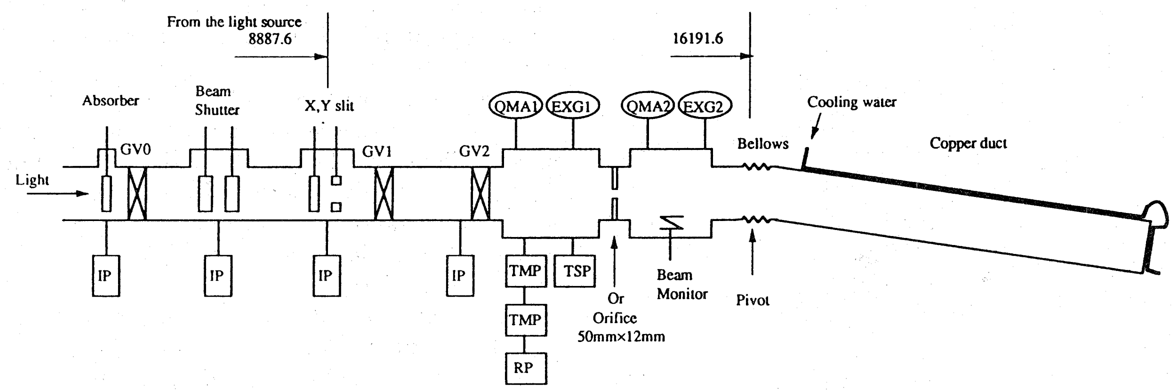

Figure 3. Schematic diagram of the beamline for PSD measurement.

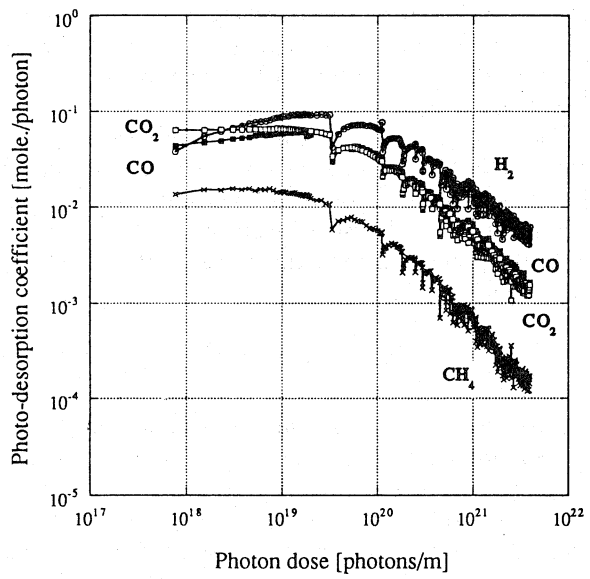

Figure 4. Photo-desorption coefficients for H_2, CH_4, CO and CO_2 as a function of photon dose.

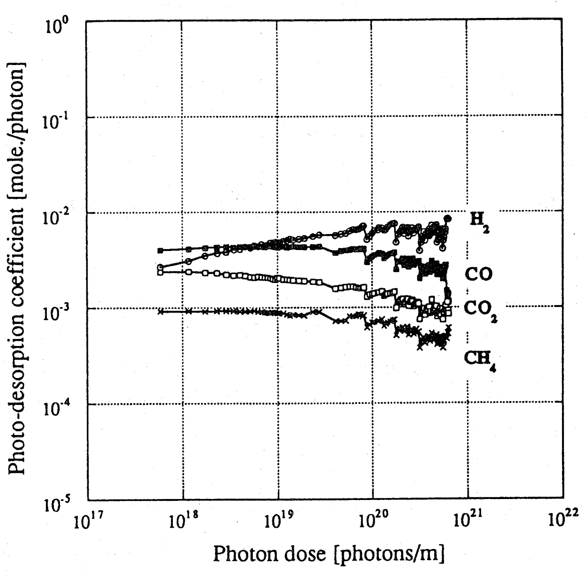

Figure 5. Photo-desorption coefficients for H_2, CH_4, CO and CO_2 as a function of photon dose, where the duct was exposed to air for 3 hours and then baked for 24 hours at 130°C after the previous measurement.

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