PHOTON INDUCED GAS DESORPTION FROM ALUMINUM SAMPLES

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ABSTRACT

The construction of the photon induced gas desorption measurement system in the TRISTAN accumulation ring (AR) is reported. Some experimental results are also presented.

INTRODUCTION

In high energy electron and positron storage ring, synchrotron radiation from circulating relativistic electrons and positrons causes serious amount of photon induced gas desorption. For example, in the TRISTAN accumulation ring (AR), a running time corresponding to beam dose of a few thousand mA.h is necessary to achieve planned vacuum conditions.[1] To reduce the gas desorption by synchrotron radiation saves conditioning time and required pumping system for the vacuum chamber.

Gas desorption by synchrotron radiation arises from not only chamber surface but also bulk near the surface.[2] So the degasing process which lessen a gas content in the chamber material also seems to be useful as much as usual surface cleaning. KEK vacuum staff has been trying various processes to reduce this photon induced gas desorption, for example, aging of chamber by micro wave, cleaning of chamber by an electron bombardment, improvement of gas content in the material, etc.

To evaluate various attempts, the synchrotron radiation from the AR is used. Photon induced desorption measurement system was set up at the light port of AR for the synchrotron radiation extraction. The merit is that, beam energy being adjustable from 2.5 GeV up to 6.5 GeV, various spectra with ε_c (critical energy) from 1.57 KeV to 26.0 KeV is available. But difficulty comes from being unable to keep constant beam current, since for almost all cases other machine studies are done parallely with vacuum study.

EXPERIMENTAL SET-UP

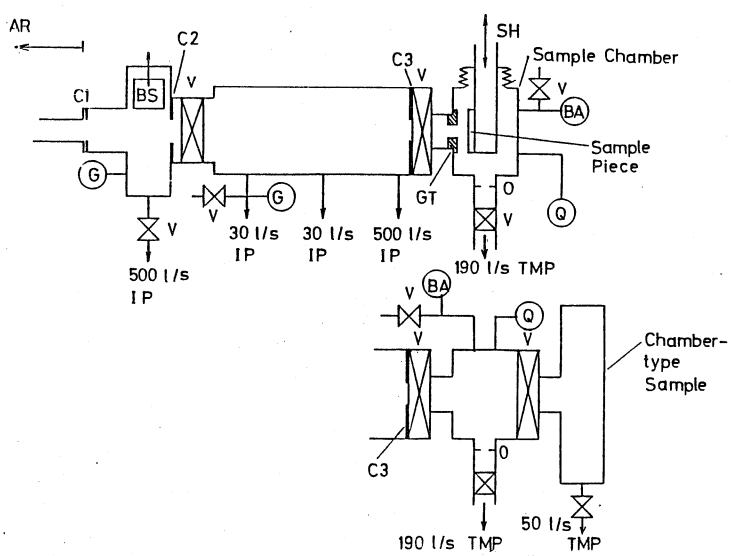
Vacuum system

Fig. 1 shows the layout of the vacuum system for the apparatus. Two gate valves divide the system into three parts, extension of AR, duct for light beam transport and sample chamber. Beam stopper belongs to the extension of AR. A 500 l/s is provided to evacuate the outgas from the beam stopper. Third collimator (5 mm x 18 mm) is placed before the second gate valve. Here also a 500 l/s is provided to evacuate the outgas from the third collimator. Light beam transport duct constructs differential pumping system to isolate the sample vacuum chamber from AR. The sample chamber is made of stainless steel with volume about 0.63 l, and pumped by a 190 l/s turbomolecular pump through an orifice of 30 l/s. The pressure in the sample chamber is monitored by a B-A gauge and a quadrupole residual gas analyzer. At the entrance for synchrotron radiation, a guide tube 10 mm in diameter is installed to cover the scattered light from the sample surface. Two specimens, 20 mm x 20 mm and 3 mm thick, are mounted on the sample holder which is vertically movable. The sample holder, made of Aluminum, is water cooled. The sample chamber is baked whenever samples are renewed. The pressure, after bakeout 150° C, 24 h, was $1\sim2 \times 10^{-8}$ Torr. This rather high background pressure is due to the viton O-ring used in the gate valve in front of the sample chamber.

In the experiment using chamber-type sample, the sample holder is removed and a gate valve is added at the end of the sample chamber. The chamber-type sample is attached to this gate valve without venting of the sample chamber. Outgas is measured using a B-A gauge and a quadrupole residual gas analyzer in the sample chamber. The chamber-type sample is pumped by an auxiliary turbomolecular pump. Before measurement the turbomolecular pump is valved off. Backgruond pressure in the sample chamber was $1\sim2 \times 10^{-7}$ Torr after 10 h pumping without baking a chamber-type sample.

Synchrotron light collimation

Fig. 2 shows the alignment of the collimating system. The opening of the AR synchrotron light port is 18 mm high 100 mm wide and located at the distance about 5 m from the source point. Collimators C1, 18 mm high 30 mm wide, and C2, 18 mm high 36 mm wide, collimate radiation so that a beam width at the third collimator C3 may be equal to the inner diameter of the light beam transport duct. C3 is a 18 mm high 5 mm wide collimator and last one when a chamber-type sample is tested. In the case of small sample pieces, a guide tube, 10 mm in the inner diameter, collimates radiation finally.



C1, C2, C3	collimator
GT	guide tube
BS	beam stopper
SH	sample holder
BA	Bayard-Alpert gauge
G	cold cathode gauge
Q	quadrupole residual gas analyzer
V	valve
O	pumping orifice, 30 l/s for N_2
TMP	turbomolecular pump
IP	ion pump

Fig. 1 The layout of the vacuum system

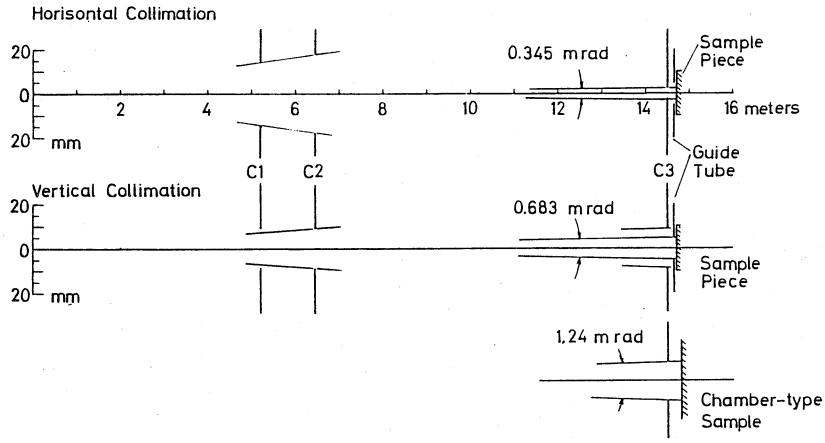


Fig. 2 The alignment of the collimating system

Radiation property

The total photon flux F per unit length of bending magnet is

$$F=1.28 \times 10^{17} IE/\rho \quad \text{photons/s/m}$$

where I is the beam current in mA
E is the machine energy in GeV
ρ is the bending radius in meters.

The vertical angular spread $\Delta\psi$ (FWHM) for photon energies $\varepsilon \ll \varepsilon_c$ is[3]

$$\Delta\psi=1.33 \times 10^{-2} (\rho\varepsilon)^{-1/3} \quad \text{rad.}$$

For the AR with ρ=23.173 m, in 2.55 GeV operation, F is geven by

$$F(AR)=1.41 \times 10^{16} I \quad \text{photons/s/m}$$

and $\Delta\psi$ for ε=5 eV ($\Delta\psi_o$) is

$$\Delta\psi_o=2.73 \quad \text{mrad.}$$

The ratio of the linear photon flux F(AR) to that at the sample piece or chamber-type sample F(Sample) is

$$\frac{F(AR)}{F(Sample)} = \frac{L_s}{L_o} \cdot \frac{\sin\theta_o}{\sin\theta_s} \cdot \frac{\Delta\psi_o}{\Delta\psi_s}$$

where L_o is the tangential distance from the source point to the AR chamber surface
L_s is the distance from the source point to the sample chamber
θ_o is the angle of incidence on the AR chamber
θ_s is the angle of incidence on the sample
$\Delta\psi_s$ is the vertical opening angle at the last collimator.

In our set-up

L_o=1.4 m L_s=15 m
θ_o=3.57 deg θ_s=90 deg
$\Delta\psi_s$=0.683 mrad (sample piece case)
=1.24 mrad (chamber-type sample case)

then above ratio becomes

$$\frac{F(AR)}{F(Sample)}=2.61 \quad \text{(sample piece case)}$$

$$=1.63 \quad \text{(chamber-type sample case).}$$

If $(\sin\theta)^{-1}$ dependance is assumed, the ratio of the secondary photo-electrons is

$$\frac{AR}{Sample}=42 \quad \text{(sample piece case)}$$

$$=23 \quad \text{(chamber-type sample case).}$$

EXPERIMENT AND DISCUSSION

A series of measurement using sample pieces was done to see the influence of the gas content of a sample on the photon induced desorption process. A sample is 20 mm high 20 mm wide and 3 mm thick. All samples were made of Aluminum and the following specimens were prepared,

(A) 6063-T6-EX, specially extruded for the AR chamber
(B) 1070 with degasing process
(C) 1060 with degasing process
(D) 1060 without degasing process.

Three series of measurement are performed, a pair of samples was set at one measurement, the combinations were as follows,

first series (A) and (B)
second series (B) and (C)
third series (C) and (D).

During the measurement +300 V potential was applied to the sample to bring back photo-electrons. Accumulated beam dose per one sample was about 50 mA.h. Beam current was not constant but varied from 0 mA to some 30 mA durring measurement, except The sample (D) case.

Fig. 3 shows the specific pressure rise $\Delta P/I$ (N_2 equivalent) for each sample. The partial pressure rise was also measured. But the signal stability of the residual gas analyzer during measurement was bad, so the data are omitted here. In general, dominant components in the desorbed gases were H_2 and CO_2 and the pressure rise of CO_2 decayed faster than that of H_2, CO was also desorbed but desorption of H_2O was not observed. The molecular desorption yield η (N_2 equivalent) at 10 mA.h was about 10^{-2} molecules per photon. For each sample, η at 10 mA.h is listed in Table 1 and compared to other measurements at the same dose.

Table 1

This experiment	Ref. 4 (sample pieces 16 mm high 22 mm wide)	Ref. 5 (chamber-type sample)
(A) 4.7×10^{-2}		
(B) 2.5×10^{-2}	2.8×10^{-3} (*)	2.1×10^{-2} (*)
(C) 1.2×10^{-2}		
(D) 2.2×10^{-2}		

* Converted from η for H_2 to N_2 equivalent value. 10 mA.h in this experiment corresponds to 1.94×10^{18} photons/cm^2 and 1.94×10^{20} photons/m.

Our values of η are not so different from that of Ref. 5. One order smaller value in Ref. 4 may reflect their one order lower background pressure (2×10^{-9} Torr). $\Delta P/I$ in Fig.3 shows rather slow variation with respect to the accumulated beam dose D than other experiments and $D^{-1/2}$ dependance which may be associated to the (enhanced) gas diffusion process near the sample surface. This result seems to be caused by

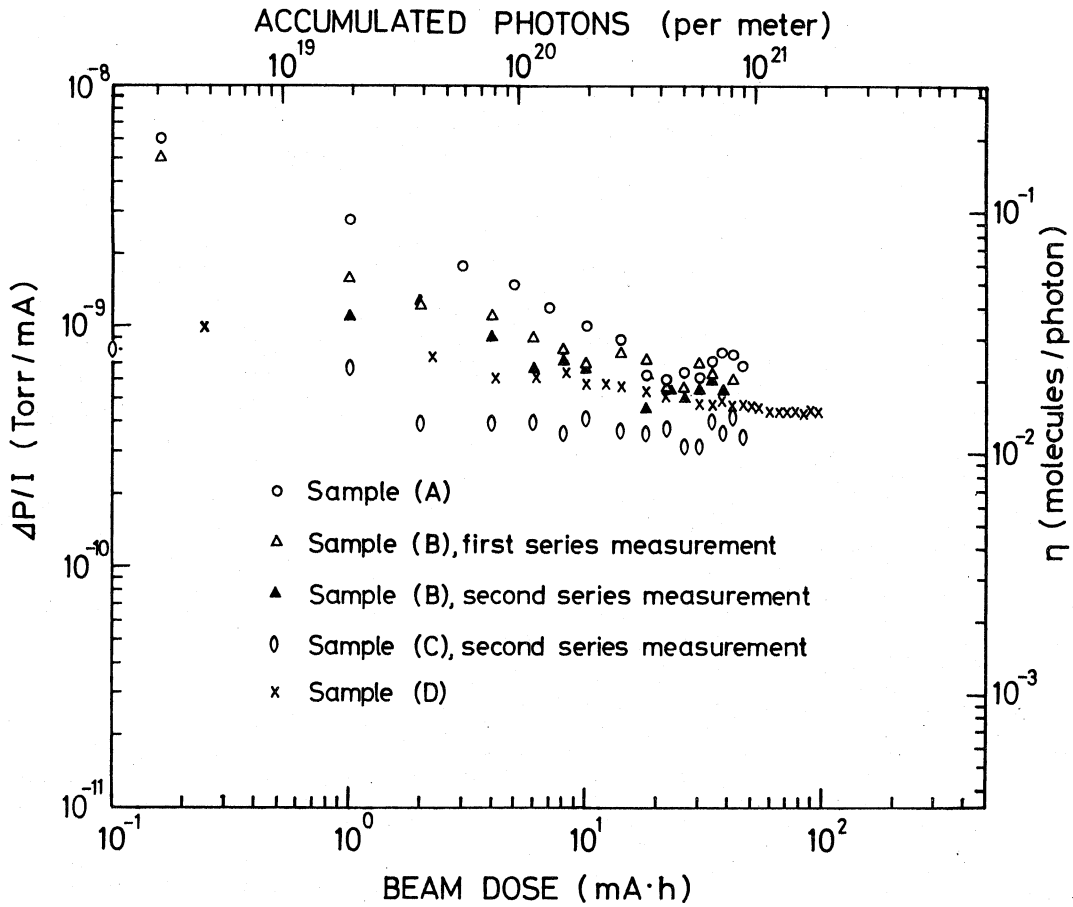


Fig. 3 The specific pressure rise ΔP/I (N_2 equivalent) as a function of the beam dose. The molecular desorption yield η and the accumulated numbers of photon are also shown. The data of the sample (C) in the third series mesurement is omitted.

(1) the effect of scattered photons which desorb gases on the surface other than the sample,

(2) unsufficient light beam cleaning of the guide tube.

Total desorbed gas in each measurement amounts to 10^{17} molecules (N_2 equivalent). This corresponds to one or two monolayers for a 100 cm^2 surface. So only surface cleaning may have been done during experiment. This point of view will be supported by another feature that ΔP/I curves in Fig. 3 seems to be grouped according to the difference of the finishing surface in preparing samples.

The influence of the adsorbed gas is inevitable under the background pressure such as 10^{-8} Torr. Combined with rather low beam dose, our experiment was incomplete. A countermeasure for the scattered photons and improvements of the background pressure are now going on, and an experiment with large accumulated beam dose is intended next time.

SUMMARY

The light port for the photon induced desorption measurement was installed to the TRISTAN AR. Experiment with ε_c=1.57 KeV ∿ 26.0 KeV is possible. Present background pressure in the sample chamber is not adequit to check the influence of the gas contained in the sample on the photon induced desorption process. Hereafter a realization of sufficiently low background pressure and reduction of the influence of scattered photons, will make possible to measure the photon induced gas desorption from the inside of a sample.

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