# Extended Study of Photon Stimulated Gas Desorption from OFHC Copper by 3.75 keV Critical Energy Photons

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*Abstract*

The gas desorption from prolonged irradiation of an OFHC copper chamber by 3.75 keV critical energy photons from DCI is reported in detail. The measurements of the molecular yield evolution, of many transitory effects and finally of the wall pumping speed at the end of the irradiation are presented. Tentative models are proposed.

## 1. INTRODUCTION

The main aspects of the set up which is schematically shown on Fig. 1 have been described on several occasions [1]. The white beam from a dipole magnet of DCI is admitted to the system by lowering a fast shutter. It then enters a system with a large pumping speed (I.P. and Ti sublimators) and goes through a small diaphragm which defines the pumping speed of the test chamber, 72.5 $ls^{-1}$ for $N_2$. The chamber is equipped at the upstream end with a B.A. gauge and a RGA (Balzers model Q511) and at the downstream end with another B.A. gauge and a leak valve.

The system was baked for 24 hours at 300° C for the stainless steel part and at 150° C for the chamber. This was cleaned according to usual standards prior being installed.

The RGA was calibrated against the adjacent B.A. gauge by letting in, separately, several gas species, namely $H_2$, $CH_4$, CO, $O_2$ and $CO_2$. The system was then ready for Photon Stimulation Desorption (PSD) studies. It is computer controlled and record total and partial pressures, beam current and integrated beam doses at regular intervals, down to a minimum of 2 minutes.

Altogether, 53 different beams were prepared with an initial intensity of 315 mA ± 2 %. After 16 hours the beam intensity was still around 200 mA. The experiment was run over 10 weeks, with a 50 hour shut down during each week-end. A short interruption scheduled in the middle of each week allowed one to investigate transitory effects. The integrated beam dose cumulated was 207 A.h.

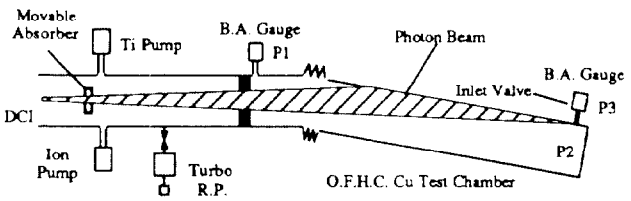


Fig. 1. The experimental set up for the measurement of PSD at DCI.

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## 2. EXPERIMENTAL DATA

### 2.1. *Molecular Desorption Yield per Photon versus Integrated Beam Dose*

The main reason for undertaking the present experiment, was to investigate the cleaning rate for large integrated beam doses after what had been obtained in a preliminary run with 1.5 A.h [2]. The data in this type of experiment being always plotted in Log versus Log scales, it was found necessary to replace a dense accumulation of points from a beam fill by a single point represented by the asymptotic values ΔP/I, ΔQ at the end of the particular fill.

The data have been separated in two plots. Fig. 2 (a) corresponds to the gas species $H_2$, $CH_4$, and $H_2O$. Over the range of integrated beam dose accumulated here, the decay of $H_2$ is around 60, whereas $CH_4$ and $H_2O$ decay by a factor of 500 and 2 000 respectively. Fig. 2 (b) corresponds to CO, $O_2$ and $CO_2$. Similarly to hydrogen, these gas species decay by a factor of about 60.

The total number of gas molecules pumped during the course of the irradiation is in the range of $2.10^{19}$. If it were all attributed to the desorption by the primary photons from the beam it would correspond to a rough figure of 20 monolayers.

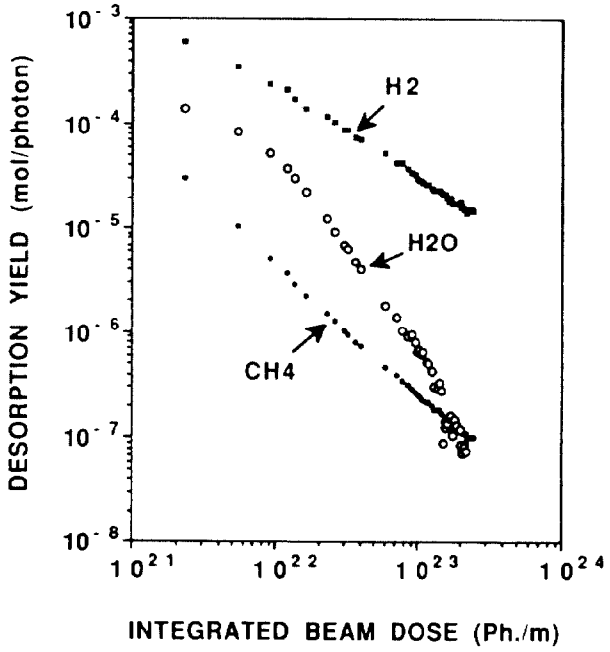


Fig. 2 (a). The desorption yield versus integrated beam dose for $H_2$, $CH_4$, $H_2O$.

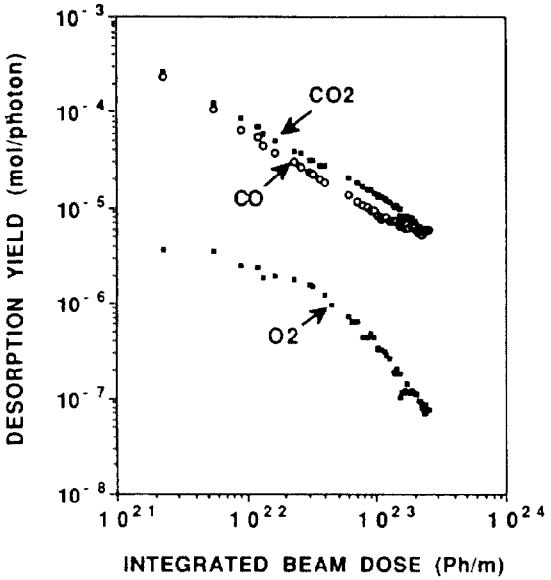


Fig. 2 (b). The desorption Yield versus Integrated Beam Dose for CO, $O_2$ and $CO_2$.

*2.2. Short Term Decay of the Pressure after Interrupting the Photon Beam*

In a situation where dynamic equilibrium has been reached for many hours, the photon beam was interrupted using the fast shutter and an abrupt change of the partial pressure is observed immediately. It is followed by a slow decay as shown by Fig. 3 for the specific case of $CO_2$. However the ratio of the pressures Beam OFF/Beam ON, varies from one gas species to another. For $H_2$, $CH_4$, $H_2O$, CO, $O_2$ and $CO_2$ the respective values are : 0.18, 0.50, 0.95, 0.73, 0.41 and 0.45.

From this simple experiment, we deduce that whatever the mechanism of molecule formation at the surface is, the gas species have two ways of leaving it : thermal and direct beam break up of molecule to surface bonds in proportions depending on the gas species.

Many hours after the beam was interrupted a slow decay of the pressures was still observed. Lowering the chamber temperature by 6° C reduced the pressure by a factor ranging from 1.7 for $H_2$ to 2.7 for $H_2O$. This temperature variation of the desorption rate is somewhat unusual for baked and non irradiated chamber elements.

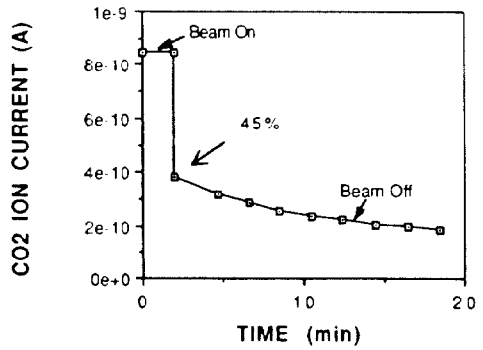


Fig. 3. Short Term Pressure Decay after Stopping the Photon Irradiation.

*2.3. Pressure Variation at the Beginning of a New Fill*

Five hours after aborting a beam (N° 17), irradiation was resumed with another beam (N° 18). Fig. 4 shows the observed variation of the partial pressure for each of the gas species over a period of less than 2 hours.

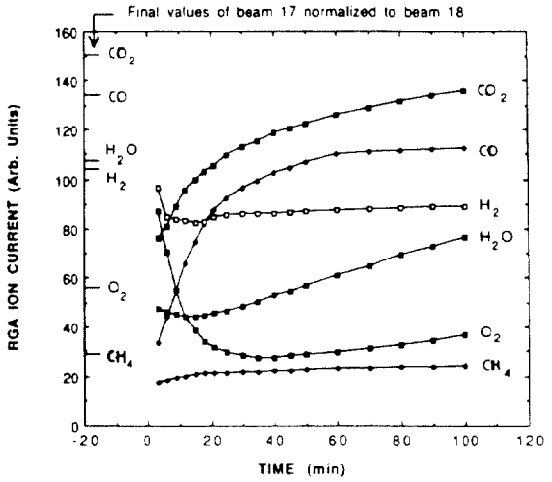


Fig. 4. Pressure Variation at the Beginning of a New Fill.

The behaviour of $CH_4$, CO and $CO_2$ is as expected from two different mechanisms : the replenishing of the surface through the production of these molecules by the new beam and the enhanced thermal desorption by the beam power which increases by 12.5° C the temperature of the copper chamber.

In contrast the behaviour of $O_2$ appears quite strange. However, assuming that the oxygen atoms from the break up of copper oxides by photo electrons still diffuse towards the surface during the 5 hour period between two successive fills, the strong decrease observed can be understood by an accumulation of molecules on the surface. One understands also why the desorption rate with the new beam is higher than the one for the preceding beam, even after normalizing to the current. Similar arguments can be developed for $H_2$ and $H_2O$.

When irradiation is continued, all gas species present a saturation of the desorption rate at a certain level which decreases gradually from one beam to another according to Fig. 2 (a) and (b).

## 3. WALL PUMPING SPEED MEASUREMENTS

Very soon during the course of the experiment, several observations on the pressure gradient along the tube indicated a non zero pumping speed. At the end of the irradiation period, small quantities of $H_2$, $CH_4$, CO, $O_2$ and $CO_2$ were injected through the leak valve at the downstream end of the tube. The pressure gradient along the system, in fact $P_3/P_1$ (see Fig. 1), was then compared to the value measured at the beginning of the experiment, when calibrating the RGA.

Strikingly different results are obtained. For $H_2$ and $CH_4$, the pressure gradient remains the same, see Fig. 5 (a). For CO, $O_2$ and $CO_2$ instead, a large pressure increase is observed, see Fig. 5 (b). Assuming a uniform longitudinal photon distribution, one can compute the ratio $P_3/P_1$ as a function of the various conductances and of the wall pumping speed. It is close to zero for $H_2$ and $CH_4$. For CO, $O_2$ and

$CO_2$ and for the full active length of 3 m, we get the values 1 165 $ls^{-1}$, 83 $ls^{-1}$ and 284 $ls^{-1}$ respectively. In actual machines, as apposed to our test chamber, these beam doses would be achieved rather rapidly since the photon density per meter is much higher.

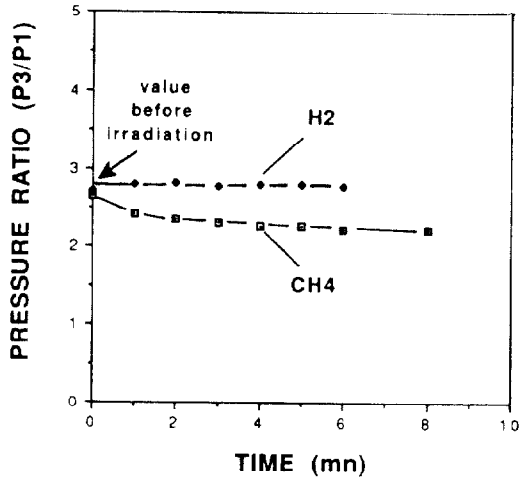


Fig. 5 (a). Pressure Gradient along the Chamber after Irradiation, for $H_2$ and $CH_4$.

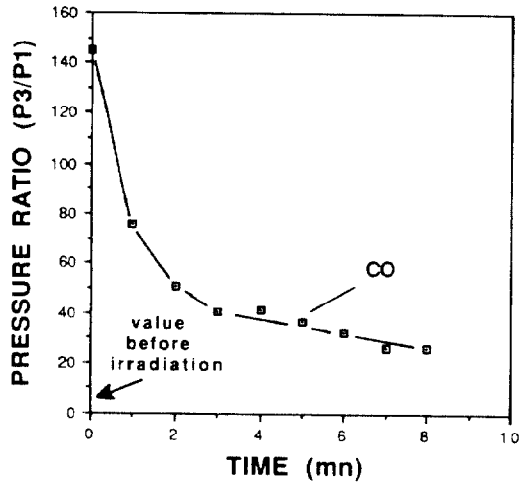


Fig. 5 (b). Pressure Gradient along the Chamber after Irradiation, for CO.

## 4. TENTATIVE MODELS FOR PSD FROM OFHC COPPER

### *4.1. At the Macroscopic Level*

The extrapolation of the results of the present experiment to the vacuum system of a Tau-c factory or a high current medium energy synchrotron radiation source should take into account :

- For the primary beam, the longitudinal photon density.
- For the secondary photons (from fluorescence or scattering), the total chamber surface area.
- The chamber temperature which should be run as high as practically possible.
- The effect of readsorbed molecules which may be reduced by a high distributed pumping speed.

### *4.2. At the Microscopic Level*

Fig. 6 represents a crude model with three parts, OFHC Copper, a copper oxide layer and a suface carbon layer for the inner surface of the test tube. Most of the previously described transient effects can be qualitatively understood if one assumes that the H atoms and the C and O atoms from the break up of the oxide layer diffuse due to both thermal and photon stimulated effects.

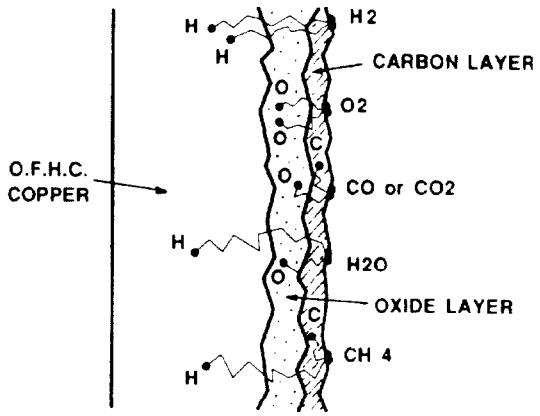


Fig. 6. Tentative Microscopic Model for PSD from OFHC Copper.

## 5. CONCLUSIONS

The results of this experiment have a direct application for the design of the vacuum system for several types of medium energy, electron, circular machines, with regards to the molecular yield for PSD. They point to the significance of many transient effects which can influence the understanding of beam gas lifetime measurements. We have demonstrated the high level of wall pumping speed reached with photon irradiated Cu surfaces, even at moderate integrated beam doses. This emphasizes even more the need for distributed pumping for the next generation of such machines.

## 6. REFERENCES

[1] O. Gröbner, A.G. Mathewson, P. Strubin, CERN, Geneva, Switzerland, and R. Souchet, LURE, Orsay, France, "Studies of Photon Induced Gas Desorption using Synchrotron Radiation" Vacuum, Vol. 33, N° 7, 1983, pp. 397-406.

[2] A.G. Mathewson, O. Gröbner, P. Strubin, CERN, Geneva, Switzerland and P.C. Marin, R. Souchet, LURE, Orsay, France, "Comparison of Synchrotron Radiation Induced Gas Desorption from Al, Stainless Steel and Cu Chambers", American Vacuum Society Series 12, Conf. Proc. N° 236, Vacuum Design of Synchrotron Light Sources, Argonne National Laboratory, Nov. 13-15, 1990, pp. 313-324.