CONTINUED EXPOSURE OF A STAINLESS STEEL CHAMBER TO PHOTONS

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1. INTRODUCTION

This is a continuation of the previous series of measurements of the synchrotron radiation induced gas desorption from a stainless steel vacuum chamber$^1$ (Runs 01-05).

Since these measurements had shown that, from stainless steel, the desorption yield was relatively independent of photon critical energy between 2.95 keV and 194 eV it was decided to run EPA (Electron Positron Accumulator) at even lower beam energies, and hence critical energies, in order to determine how the desorption behaved.

In this note we report on the measurements of the synchrotron radiation induced gas desorption at EPA beam energies of 565 MeV, 500 MeV, 345 MeV, 270 MeV and 200 MeV corresponding to photon critical energies of 280 eV, 194 eV, 63.5 eV, 30.5 eV and 12.4 eV respectively.

In parallel, as in Ref. 1, the photoelectron currents produced in the test chamber were measured.

2. GAS DESORPTION RESULTS

The measurements at the different beam energies were not carried out in any particular order but are reported here in chronological order.

On each figure the dose scale refers to the photon dose accumulated at that particular energy.

2.1 500 MeV

The test chamber was exposed to the 194 eV synchrotron radiation and accumulated a total photon dose of $7 \times 10^{18}$ photons/m. The results are shown in Fig. 1 where it can be seen that, compared with the previous measurements at 500 MeV (Fig. 3, Ref. 1) the desorption yields are close to what was measured at the end of the exposure indicating that little or no readssorption had taken place in the 3 weeks since the last exposure to synchrotron radiation.

The photodesorption yield for H$_2$ was the highest, lying between $1 \times 10^{-3}$ and $2 \times 10^{-3}$ mol/photon followed by CO$_2$, CO then CH$_4$ in the low $10^{-4}$ mol/photon range.
Also it can be seen that no beam cleaning for CO and CO$_2$ was evident during this latest exposure, but CH$_4$ decreased slightly and H$_2$ decreased by about a factor of two. At 2.95 keV critical energy a dose of about $10^{19}$ photons/m is required before any beam cleaning is observed$^2$.

![Figure 1](image_url)

**Fig. 1** The photon induced desorption yields as a function of photon dose at 194 eV critical energy.

### 2.2 565 MeV

At this beam energy, which corresponds to a photon critical energy of 280 eV, close to the photon critical energy in the SSC at 20 TeV beam energy (284 eV), the test chamber was exposed to an accumulated photon dose of $7.5 \times 10^{18}$ photons/m. The results are shown in Fig. 2 where it can be seen that, at this higher critical energy, the desorption yields are, in general, all slightly higher and, apart from H$_2$, no beam cleaning was obvious.

Again the photodesorption yield for H$_2$ was the highest at around $2 \times 10^{-3}$ mol/photon followed in order by CO$_2$, CO and CH$_4$ in the $10^{-4}$ mol/photon range.
2.3 345 MeV

This beam energy corresponds to the photon critical energy in the LHC at 7.7 TeV beam energy namely 63.5 eV. The test chamber accumulated a photon dose of about $2.0 \times 10^{20}$ photons/m at this critical energy and the results are shown in Fig. 3.

Compared to the desorption yields at 194 eV, the measured values for all gases are somewhat lower and there was practically no beam cleaning, except for, perhaps, CO$_2$.

At this critical energy the photodesorption yield for H$_2$ was around $4 \times 10^{-4}$ mol/photon followed by CO$_2$ at $2 \times 10^{-4}$ mol/photon, then CO at $1 \times 10^{-4}$ mol/photon and finally CH$_4$ at about $5 \times 10^{-4}$ mol/photon.
2.4 **200 MeV**

This beam energy corresponded to the lowest photon critical energy reached of 12.4 eV. For various reasons, the beam lifetime at 200 MeV was only a few minutes and a maximum beam current of only 8.4 mA was available. However, the desorption yields for all four gases could be measured and, except for H$_2$, were found to be again lower than those measured at the higher critical energies.

At this critical energy the photodesorption yield for H$_2$ had not decreased and was still around 4 \(10^{-4}\) mol/photon followed by CO$_2$ at 2 \(10^{-5}\) mol/photon, then CO at 1 \(10^{-5}\) mol/photon and finally CH$_4$ at about 7 \(10^{-6}\) mol/photon.

The actual values are shown in Fig. 4 where, as expected, due to the low photon dose no beam cleaning was observed.
The last set of measurements was taken at a photon critical energy of 30.5 eV where a photon dose of about $2.3 \times 10^{19}$ photons/m was accumulated. The results are shown in Fig. 4 where it can be seen that again there was little evidence of beam cleaning.

As at 63.5 eV and 12.4 eV critical energies, the $\text{H}_2$ desorption yield remained around $4 \times 10^{-4}$ mol/photon followed by $\text{CO}_2$ at $9 \times 10^{-5}$ mol/photon, then CO at $4 \times 10^{-5}$ mol/photon and finally $\text{CH}_4$ at about $3 \times 10^{-5}$ mol/photon.
2.6 CRITICAL ENERGY DEPENDENCE

To show the dependence of the desorption yields on critical energy, they have been plotted as a function of critical energy in Fig. 6. Also shown in this figure are the desorption yields at 500 eV and 2.95 keV critical energies taken from Ref. 1. It is comforting to note that the results from Brookhaven at 500 eV on a similarly prepared test chamber are in good agreement with the measurements presented here.

Between 3 keV and about 194 eV critical energy the photodesorption yields remain relatively constant and it is only below 194 eV that any change is observed. From 194 eV to 12.4 eV the photodesorption yields for CO, CO$_2$ and CH$_4$ decrease by about a factor of 10. From 194 eV to 63.5 eV the H$_2$ photodesorption yield decreases by about a factor of about 5 but from there remains constant down to 12.4 eV.
Fig. 6 The photon induced desorption yields as a function of the photon critical energy.

The dependence of the desorption yield on critical energy is more clearly seen by plotting the total N₂ equivalent desorption yield instead of the yield for the individual gases. The total N₂ equivalent desorption yield is the total pressure increase per mA of beam per photon incident on the test chamber. We consider that the only gas desorbed is N₂ (or CO) and the appropriate pumping speed is used to calculate the desorption yield.

This is shown in Fig. 7 where the almost constant photodesorption yield between 3 keV and 194 eV critical energy (a decrease of only a factor of 2) is evident compared to a decrease of more than a factor of 10 from 194 eV to 12.4 eV.
Fig. 7 The total N₂ equivalent photon induced desorption yields as a function of the photon critical energy.

3 PHOTOELECTRON CURRENTS

The photoelectron currents in the test chamber were measured by applying a +1 kV bias to a 200 mm long, 1 mm diameter stainless steel wire running along the axis of the chamber and suspended from an insulated feedthrough.

The results are shown in Fig. 8 where, for each critical energy (280, 194, 63.5, 30.5 and 12.4 eV), the total pressure increase per mA of beam, \( \Delta P/I \) (Torr/μA), was plotted as a function of the corresponding photoelectron current per mA of beam, \( I_{pe}/I \) (μA/μA). It can be seen that there is a good linear relation between the photoelectron currents in the test chamber and the increase in pressure, once more indicating that the photoelectrons play an important role in the gas desorption process\(^3\) and that they can be used for scaling the dynamic pressure rise with beam energy.
In Fig. 9 is shown the critical energy dependence of the photoelectron current. It is interesting to note that the photoelectron current is also a linear function of the critical energy between 12.4 eV and 280 eV and that, by extrapolation, is found to be zero at a critical energy of 5.8 eV.

Since the pressure is directly proportional to the photoelectron current, it also varies linearly with critical energy (Fig. 10) and the pressure is found to be zero at a critical energy of 10 eV which compares favourably with the previous figure of 5.8 eV. Thus below about 10 eV critical energy the photon induced gas desorption from stainless steel can be considered negligible.
Fig. 9 The photoelectron current per mA of beam in the test chamber as a function of the critical energy.

Fig. 10 The pressure per mA of beam in the test chamber as a function of the critical energy.
In Ref. 3 it was shown that the machine energy dependence of the measured photoelectron currents in an Al chamber exposed to synchrotron radiation at 11 m rad grazing angle of incidence could be calculated using published photoyield data and assuming that the photons were totally reflected below a certain cutoff energy and hence do not contribute to the photoelectron production.

Repeating this calculation for Al, since photoyield data for stainless steel are not available, it is found that, with a 100 eV cutoff, a good linear dependence of the photoelectron current on the critical energy is obtained up to about 250 eV critical energy. The results of the calculation for six critical energies are shown in Fig. 11 and it must be stressed that linearity is only found over this restricted range of critical energies. At higher critical energies the dependence is strongly non linear.

The calculation was for Al but it is not excluded that with the appropriate cutoff energy and photoyield data a similar linear dependence of the photoelectron current on the critical energy could be found for stainless steel.

![Graph showing photoelectron current vs. critical energy for Al with a 100 eV cutoff.](image)

Fig. 11 The calculated photoelectron current per mA of beam in an Al test chamber as a function of the critical energy. Photons below the cutoff energy have been neglected.

**4 CONCLUSIONS**

Between 2.95 keV and 194 eV critical energy the total photodesorption yields decrease only by a factor of about 2. Below 194 eV the decrease is more than a factor of 10 down to 12.4 eV critical energy.
The individual photodesorption yields, despite some scatter, showed essentially the same tendency except that the H\textsubscript{2} photodesorption yield remains constant below about 100 eV.

The photoelectron currents produced by the synchrotron radiation were measured in the test chamber and found to be directly proportional to the total pressure increase indicating that the photoelectrons play an important, if not major part in the gas desorption process.

Extrapolation of the critical energy dependence of the pressure and photoelectron measurements to zero both indicate that the photon induced gas desorption from stainless steel at ambient temperature is negligible below about 10 eV critical energy. Whether this is still true for thick layers of gas condensed on surfaces at cryogenic temperatures remains to be seen.

In Al, for critical energies below about 250 eV critical energy, the photoelectron currents calculated with a 100 eV cutoff are directly proportional to the critical energy thus a similar situation could occur in stainless steel to explain the observed linear dependence.

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6 REFERENCES