EXPOSURE OF A BAKED AI LINED STAINLESS STEEL CHAMBER TO PHOTONS

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1. INTRODUCTION

In this note we report on the measurements of the synchrotron radiation induced gas desorption at EPA beam energies from 200 MeV to 565 MeV, corresponding to photon critical energies from 12.4 eV to 284 eV, from a baked Al lined stainless steel chamber. This is a continuation of the measurements of the exposure of an unbaked Al lined stainless steel chamber described in a previous Technical Note1.

In addition, the photoelectron currents produced in the test chamber could be measured by applying +1 kV to a 200 mm long wire suspended along the axis of the chamber.

2. TEST CHAMBER PREPARATION AND HISTORY

To simulate an Al chamber, liners made of Al were inserted in a 4.2 m long, 131 mm diameter stainless steel test chamber. The Al liners were made from 1mm thick Al alloy (Anticorodal, ISO Al-Si1-Mg-Mn 6082) sheets rolled into a cylindrical form, but not welded.

They were chemically cleaned first by immersion in perchloroethylene vapour at 121°C, then by immersion in an alkaline detergent at 65°C followed by rinsing in cold demineralized water and finally drying in a vacuum oven at 150°C. As an additional treatment, the bare stainless steel chamber without the Al liners was degassed in a vacuum oven at 950°C then baked at 300°C for 24 hours in the laboratory for a vacuum limit test.

The system was mounted on the beam line and pumped for two months, but not baked, after which the base pressure was 2.4x10^-9 Torr. Then it was exposed to synchrotron radiation without baking1. The system was then baked at 150°C for 24 hours, after which the base pressure was 1x10^-10 Torr. The gas composition was dominated by H₂, with traces of CH₄, H₂O, CO and CO₂.

3. GAS DESORPTION RESULTS

3.1 200 MeV

The baked, Al lined chamber was first exposed to a photon beam of 12.4 eV critical energy. The 200 MeV electron beam current was 42 mA. A dose of about 7x10¹⁷ photons m⁻¹ was accumulated. The results are shown in Fig. 1. The order of the synchrotron radiation induced gas desorption yields was CO₂ as the highest, with 1.1x10⁻⁴, followed by H₂, CO, and CH₄, with 5.0x10⁻⁵, 1.8x10⁻⁵ and 3.3x10⁻⁶ mol photon⁻¹ respectively. The water yield was in the 10⁻⁷ mol photon⁻¹ range and did not increase with dose as in the unbaked case.

No significant cleaning effects were seen during the exposure.
The chamber was then exposed to photons of 194 eV critical energy, which corresponds to an electron energy of 500 MeV, the EPA nominal energy. The results are shown in Fig. 2. The accumulated dose was about $2 \times 10^{18}$ photons m$^{-1}$, and the desorption yields were, in order of importance, CO$_2$, with $3.5 \times 10^{-3}$ mol photon$^{-1}$, H$_2$, with $1.7 \times 10^{-3}$ mol photon$^{-1}$, CO with $6.5 \times 10^{-4}$ mol photon$^{-1}$ and CH$_4$, with $1.7 \times 10^{-4}$ mol photon$^{-1}$. The water yield was in the $10^{-6}$ mol photon$^{-1}$ range and did increase very slightly with dose.

No significant cleaning effects were seen during the exposure.
Figure 2: The photon induced gas desorption yields as a function of dose at 194 eV critical energy for the baked Al lined stainless steel chamber.

3.3 270 MeV

The chamber was subsequently exposed to photons of 30.5 eV critical energy. The results are shown in Fig. 3. The accumulated photon dose was about $2 \times 10^{18}$ photons m$^{-1}$, and the desorption yields were, in order of importance, CO$_2$, with $4.4 \times 10^{-4}$ mol photon$^{-1}$, H$_2$, with $2 \times 10^{-4}$ mol photon$^{-1}$, CO with $7.2 \times 10^{-4}$ mol photon$^{-1}$ and CH$_4$, with $2.2 \times 10^{-5}$ mol photon$^{-1}$. The water yield was in the $10^{-7}$ mol photon$^{-1}$ range and did not increase significantly with dose.

No significant cleaning effects were seen during the exposure.
3.4 321 MeV

The chamber was then exposed to photons of 51.2 eV critical energy, which corresponds to an LHC energy of 7.256 TeV. The results are shown in Fig. 4. The accumulated dose was about $2.6 \times 10^{18}$ photons m$^{-1}$ and the desorption yields were, in order of importance, CO$_2$, with $3 \times 10^{-3}$ mol photon$^{-1}$, H$_2$, with $1 \times 10^{-3}$ mol photon$^{-1}$, CO with $6 \times 10^{-4}$ mol photon$^{-1}$ and CH$_4$, with $1 \times 10^{-4}$ mol photon$^{-1}$. The water yield was in the high $10^{-7}$ mol photon$^{-1}$ range and did not change with dose.

No significant cleaning effects were seen during the exposure.
Figure 4: The photon induced gas desorption yields as a function of dose at 51.2 eV critical energy for the baked Al lined stainless steel chamber.

3.5 345 MeV

The following exposure was to a photon beam of 63.5 eV critical energy corresponding to an LHC critical energy of 7.7 TeV. The results are shown in Fig. 5. A dose of about $3 \times 10^{18}$ photons m$^{-1}$ was accumulated. The order of the desorption yields was again the same, with CO$_2$, H$_2$, CO, and CH$_4$, with $7.5 \times 10^{-4}$, $3.4 \times 10^{-4}$, $1.1 \times 10^{-4}$ and $3.9 \times 10^{-5}$ mol photon$^{-1}$ respectively. The water yield was in the high $10^{-7}$ mol photon$^{-1}$ range and increased with dose.

No significant cleaning effects were seen during the exposure.
Finally, the chamber was exposed to a 284 eV critical energy photon beam (EPA energy of 565 MeV). This energy corresponds to the SSC critical energy. The results are shown in Fig. 6. A dose of about $4 \times 10^{18}$ photons m$^{-1}$ was accumulated. The order was again the same, with CO$_2$, H$_2$, CO, and CH$_4$, with $4 \times 10^{-3}$, $2.2 \times 10^{-3}$, $6.7 \times 10^{-4}$ and $2.4 \times 10^{-4}$ mol photon$^{-1}$, respectively. The initial water yield was $3 \times 10^{-7}$ mol photon$^{-1}$ and increased slightly with dose.

No significant cleaning effects for the other gases were seen during the exposure.
Figure 6: The photon induced gas desorption yields as a function of dose at 284 eV critical energy for the baked Al lined stainless steel chamber.

3.7 Critical energy dependance

The dependance of the photon induced gas desorption yields as a function of the critical energy is shown in Fig. 7.

The photon induced gas desorption yields over the complete critical energy range were fitted to an empirical expression of the form

$$\eta = CE_c^\alpha$$

where $\eta$ is the desorption yield, $E_c$ is the critical energy and $C$ and $\alpha$ are positive constants. The best fit was obtained with the following constants:
\[ \eta_{H_2} = 2.60 \times 10^{-6} E_c^{1.21} \quad \text{with } R=0.995 \]
\[ \eta_{CH_4} = 1.69 \times 10^{-7} E_c^{1.32} \quad \text{with } R=0.986 \]
\[ \eta_{CO} = 1.03 \times 10^{-6} E_c^{1.18} \quad \text{with } R=0.990 \]
\[ \eta_{CO_2} = 6.87 \times 10^{-6} E_c^{1.16} \quad \text{with } R=0.992 \]

It can be seen in Fig. 7 that the fit is reasonable.

**Figure 7**: The critical energy dependence of the photon induced gas desorption yields for a baked Al lined stainless steel chamber.

### 4. PHOTOELECTRON PRODUCTION

The photoelectron current was measured as in previous EPA runs, by applying +1000 V to a 200 mm long wire suspended along the central axis of the test chamber. The resulting currents, divided by the beam current and energy of the machine are plotted in Fig. 8 as a function of the critical energy.
Figure 8: The photoelectron current per mA of beam current per GeV versus critical energy.

We have fitted the data to the following empirical expression,

\[
\frac{I_{PE}}{I_B} = 9.23 \times 10^{-3} E_c - 0.16 \quad \text{R} = 0.998
\]

\[
\frac{I_{PE}}{I_B} = + 1.5777 \times 10^{-2} E_c + 2.687 \times 10^{-2} \quad \text{R} = 0.997
\]

It can be seen that the fit to the straight line is reasonable.

where \( I_{PE} \) is the photoelectron current in \( \mu A \), \( I_B \) is the beam current in mA, \( E_B \) is the beam energy in GeV and \( E_c \) is the critical energy in eV. Since the product \( I_B E_B \) is proportional to the photon flux, the measured photoelectron current, \( I_{PE} \), divided by \( I_B E_B \) is a measure of the average photoelectron yield (electrons/photon) of the Al surface.

We have also plotted the total specific pressure rise divided by the product of the beam current and energy versus the photoelectron current, also divided by the
product of the beam current and energy. The result is shown in Fig. 10. Essentially these quantities are proportional to the number of desorbed molecules per photon and the number of photoelectrons per photon respectively.

**Figure 9:** The total specific pressure rise versus photoelectron current per mA of beam.

We have also fitted these data with the same type of empirical function giving,

\[
\frac{\Delta P}{I_B E_B} = 7.01 \times 10^{-10} \frac{I_{PE}}{I_B E_B} - 4.26 \times 10^{-11}
\]

\[R = 0.998\]

This dependence shows a linear relation between the specific pressure rise and the photoelectrons produced in the test chamber, suggesting a double step process: first, production of a photoelectron which subsequently desorbs a molecule from the metal surface.
5. CONCLUSIONS

The initial photon induced gas desorption yields for a baked Al vacuum test chamber has been obtained for critical energies ranging from 12.4 to 284 eV.

Over the range of photon doses used there was no significant cleaning observed for H₂, CH₄, CO, and CO₂. Unlike the unbaked case, the H₂O yield remained constant during the measurement except when exposed to photons of 284 eV critical energy.

For critical energies between 12.4 eV and 284 eV, the photoelectron currents in the chamber increased linearly with the critical energy and there appeared to be a minimum critical energy below which no photoelectrons are produced.

The total specific pressure rise increased linearly with the photoelectron currents suggesting a double step desorption process where a photoelectron is first produced and then subsequently desorbs a molecule from the Al surface.

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7. REFERENCES