A Simulation of the Gas Desorption in the LHC Using Low Critical Energy Synchrotron Radiation

J. Gómez-Goñi, O. Gröbner, A. G. Mathewson and A. Poncet
CERN, 1211 Geneva 23, Switzerland

Abstract

The photon induced gas desorption yields for vacuum degassed stainless steel have been measured at photon critical energies of 280 eV, 194 eV, 63.5 eV, 30.5 eV and 12.4 eV. The gases desorbed were H_2, CH_4, CO and CO_2 and it was found that the desorption yield was relatively independent of critical energy between 2.95 keV and 194 eV. Between 194 eV and 12.4 eV the yield decreased by a factor of about 10.

Measurement of the photoelectron currents in the test chamber revealed that there was a good linear relation between them and the increase in pressure indicating that the photoelectrons play an important role in the gas desorption process.

1. INTRODUCTION

In the Large Hadron Collider (LHC) proton storage ring the magnets are superconducting and operate at a temperature of 1.9 K with the vacuum chamber also at this temperature. The 7.7 TeV protons emit synchrotron radiation with a critical energy of 63.5 eV which desorbs H_2, CH_4, CO and CO_2. A knowledge of the magnitude of these photon induced gas desorption effects is vital to be able to accurately predict the vacuum behaviour of the LHC and to estimate the time required to build up thick condensed layers of gas on the cold bore surfaces.

Since similar measurements have only been made at much higher critical energies (DCI, Orsay - 3 keV and Brookhaven - 500 eV) a dedicated beam line has been constructed on the CERN Electron Positron Accumulator (EPA) where synchrotron radiation from 12.4 eV to 280 eV critical energy is available. The results of the first measurements on a stainless steel test chamber are presented and compared with the measurements at higher critical energies.

2. EXPERIMENTAL DETAILS

2.1. Test Chamber Treatment

The 4.2 m long, 131 mm diameter, stainless steel chamber was manufactured from 316 L+N stainless steel tube. It was 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 test chamber was degassed in a vacuum oven at 950°C. The test chamber was then vacuum tested by baking at 300°C for 24 h. When installed in the synchrotron radiation beam line, it was baked at 150°C for 24 h after which the base pressure was typically 1 10^{-10} Torr.

One of the DCI test chambers followed exactly the same treatment.

2.2 EPA Parameters

EPA was run in storage mode at its nominal energy of 0.5 GeV which corresponds to a photon critical energy of 194 eV and also at beam energies of 565 MeV, 345 MeV, 270 MeV and 200 MeV corresponding to photon critical energies of 280 eV, 63.5 eV, 30.5 eV and 12.4 eV respectively.

3. RESULTS

3.1 Critical Energy Dependence

The desorption yields have been plotted as a function of critical energy in Fig. 1. Also shown in this figure are the desorption yields at 500 eV (Brookhaven) and 2.95 keV (DCI) critical energies taken from Ref. 1 and Ref. 2. 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.

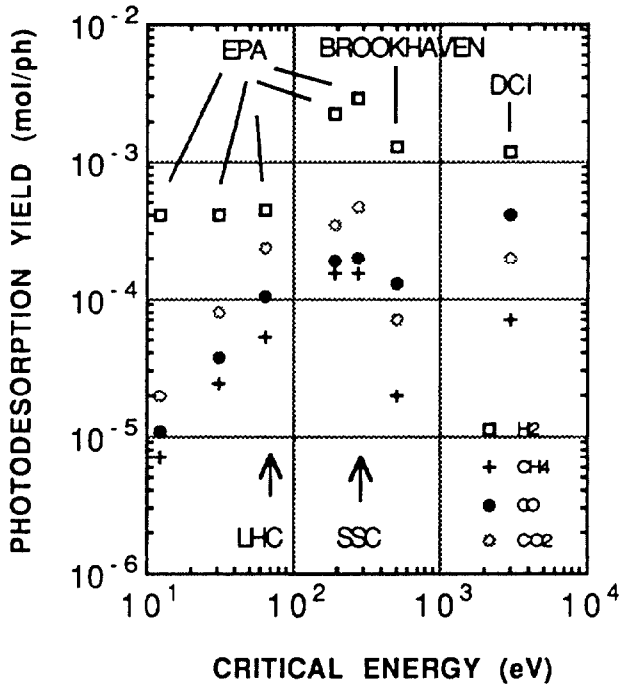

Figure 1. The photon induced desorption yields as a function of the photon critical energy.

Also indicated are the critical energies of the photons in both the LHC and SSC (Superconducting Super Collider) proton storage rings.

Between 3 keV and about 194 eV critical energy the photodesorption yields remain relatively constant and it is only below 194 eV that any significant reduction 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.

The dependence of the desorption yield on critical energy is more clearly seen by plotting the total N_2 equivalent desorption yield instead of the yield for the individual gases. The total N_2 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 N_2 (or CO) and the appropriate pumping speed is used to calculate the desorption yield.

This is shown in Fig. 2 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.

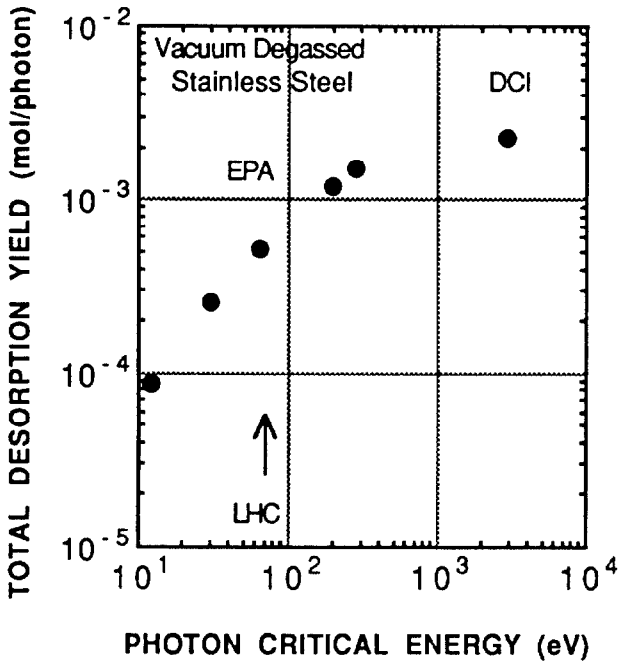

Figure 2. The total N_2 equivalent photon induced desorption yield as a function of the photon critical energy.

3.2 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. 3 where, for each critical energy (280, 194, 63.5, 30.5 and 12.4 eV), the total pressure increase per mA of beam, ΔP/I (Torr/mA), was plotted as a function of the corresponding photoelectron current per mA of beam, I_{pe}/I (μA/mA). 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 photoectrons 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.

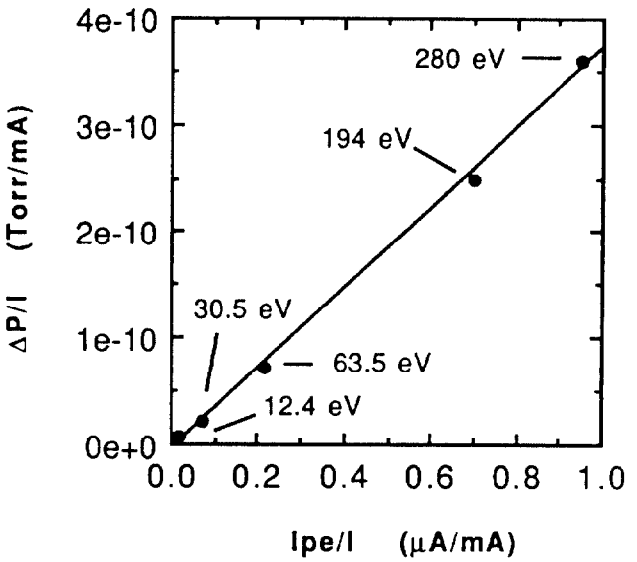

Figure 3. The total pressure increase per mA of beam, ΔP/I, in the test chamber as a function of the corresponding photoelectron current per mA of beam, Ipe/I.

In Fig. 4 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.

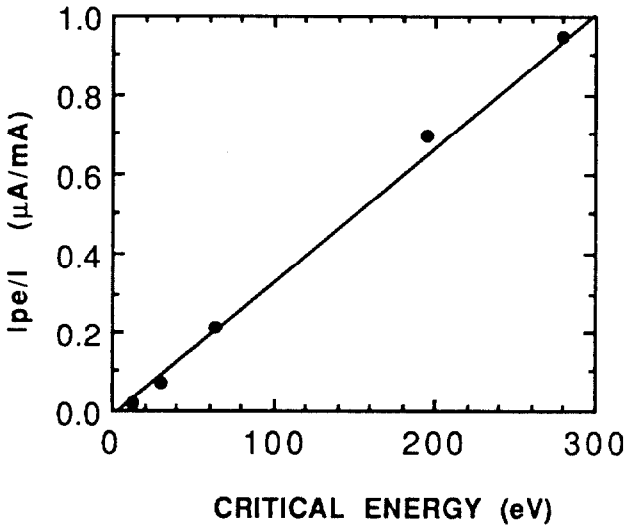

Figure 4. The photoelectron current per mA of beam, Ipe/I, in the test chamber as a function of the critical energy.

Since the pressure is directly proportional to the photoelectron current, it also varies linearly with critical

energy (Fig. 5) 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 at room temperature but may be different for condensed layers of gas on the cold surfaces of the LHC since infrared radiation coming from room temperature surfaces can desorb cryopumped H_2 [4].

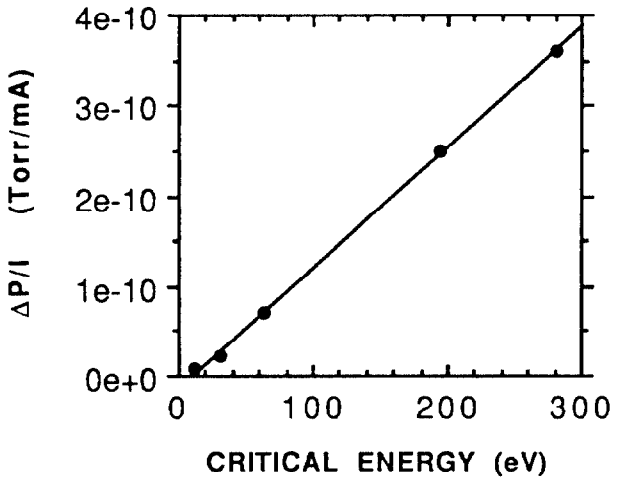

Figure 5 The pressure per mA of beam, ΔP/I, in the test chamber as a function of the critical energy.

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.

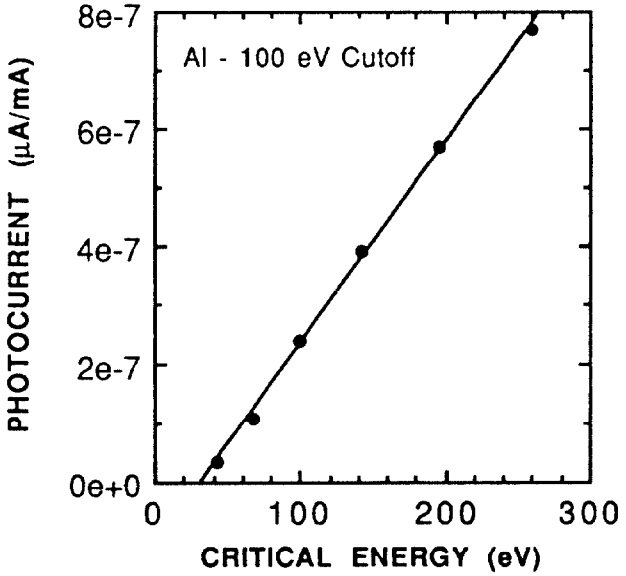

Figure 6 The calculated photoelectron current per mA of beam in an Al test chamber as a function of the critical energy. Photons below the cutoff energy have been neglected.

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. 6 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.

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_2 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.

5. ACKNOWLEDGEMENTS

The authors are indebted to J.-P. Potier, J.-P. Delahaye and the EPA operations crew for their support and expertise in running EPA at energies well outwith its normal operating range.

6. REFERENCES

[1] L. Foerster, H. Halama and C. Lanni, J. Vac. Sci. Technol. vol. A8(3), 1990, pp. 2856-2859.

[2] O. Gröbner, A. G. Mathewson, P. Strubin, P. Marin and R. Souchet. American Vacuum Society Series 12, Conference Proceedings No. 236, Vacuum Design of Synchrotron Light Sources, Argonne, 1990, pp. 313-324.

[3] O. Gröbner, A. G. Mathewson, P. Strubin, E. Alge and R. Souchet, J. Vac. Sci. Technol. vol. A7(2), 1989, pp. 223-229.

[4] C. Benvenuti, R. S. Calder and G. Passardi, J. Vac. Sci. Technol. vol. 13, No.6, 1976, pp. 1172-1182.