VACUUM BEHAVIOR OF THE X-RAY LITHOGRAPHY SOURCE*

H. J. Halama and J. B. Murphy

Brookhaven National Laboratory, Upton, New York 11973 BNL--46996

DE92 007172

Photon stimulated desorption, PSD, is the major source of the gas load in electron storage rings and therefore strongly influences both beam lifetime and beam quality. The 200 MeV compact ring at the NSLS is an ideal tool to study PSD since its energy can be varied from 60 to 200 MeV and the photoelectrons produced by synchrotron radiation can be measured in clearing electrodes installed to collect trapped ions. Using these electrodes we show: [a] photoelectrons are produced only by photons having energy above 10eV and [b] desorption is proportional to the number of photoelectrons.

Using calibrated gauges we conclude that a) time-integrated beam current of 10-20 Ampere-hours is needed for initial vacuum chamber clean-up, b) venting the chamber to dry nitrogen has a negligible effect on subsequent desorption and c) venting to air requires about 10 Ampere-hours of beam conditioning.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

*Work performed under the auspices of U.S. DOE under contract DE-AC02-76CH00016.

MASTER
DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

I. Introduction

The 200 MeV X-Ray Lithography Source^{1,2} was constructed to investigate the properties of high current compact rings such as low energy injection, beam stability, ion trapping, beam lifetime and vacuum performance. Thus, the information obtained in our studies will be useful for all future compact rings. After these studies are completed, the 1.1 T normal conducting magnets will be replaced with 3.87T superconducting magnets to reach 700 MeV which corresponds to λ_c of 10Å.

We will divide the work reported in this paper into two parts. In the first part we discuss pressure behavior from the turn-on of the machine through the first 60 Ampere-hours of conditioning at 200 MeV, to determine the initial beam tube clean up time necessary for a good life-time. Then we discuss venting the vacuum system first to dry nitrogen and measure vacuum recovery time to simulate the conditions of controlled intervention into the vacuum chamber. This is followed by the same measurements for an atmospheric air vent to simulate an accidental air dump.

In the second part we present photocurrent measurements as a function of machine energy. Fitting photon spectrum to these data yields 10eV photon cut-off energy, i.e., only photons with energy larger than ~ 10 eV produce photoelectrons. Measured pressure rises due to photodesorption are also in good agreement with photoelectron production.

II. Vacuum Conditioning

The schematic of the XLS containing the locations of the gauges, pumps and clearing electrodes is shown in Fig. 1. The vacuum chamber is made of stainless steel type 304L and Inconel 625 using either welded construction or conflat flanges. An installed in-situ bake-out

system brings the temperature of straight sections and magnet chambers to 200° C and 120° C, respectively. The system is roughed by a Seiko magnetically levitated turbomolecular pump backed by a dry pump. These pumps are permanently mounted on the ring and are also used during bake-out cycles. After a four day bake-out including TSP and NEG activations, the pressures read on G₁, G₂ and G₄ were $\leq 1 \times 10^{-10}$ Torr. The RF cavity gauge G₃ read $\sim 3 \times 10^{-9}$ Torr after several days of high power rf conditioning.

Since the final cleaning of the vacuum system has to be done by synchrotron radiation, very large pressure rises were recorded when the beam was first injected (more than an order of magnitude larger than the values shown at 0.1 A-hr in Fig 2). After 0.1 A-hr, which corresponds to 4×10^{22} incident photons s⁻¹ m⁻¹ in the magnets, the pressure rises in n Torr/ mA are plotted in Fig 2. Gauges 2 and 4 read higher because they are located in higher photon flux regions at the downstream end of the dipoles. It is seen that between 0 and 20 A-hrs the pressure rise has improved by almost 4 orders of magnitude. At this point the vacuum chamber is cleaned up and subsequent running produces only small reductions in pressure, i.e., a factor of 3 in the subsequent 50A-hrs. In addition to total pressure measurements, partial pressures were measured on an RGA (Fig. 1) which yielded the following gas composition at 17 A-hrs and 500 mA beam current:

H ₂	50%
CH ₄	25%
CO	16%
CO ₂	9%

This partial pressure differs significantly from partial pressures measured at the VUV and the X-Ray ring³ where CH₄ content is almost negligible due to distributed ion pumps (DIP)

inside the dipoles. The XLS, being pumped predominantly by NEG and TSP, has no pumping speed for methane and inert gases inside the vacuum chamber, but the four lumped ion pumps (Fig 1) are quite adequate to keep the methane pressure satisfactory. Comparing the XLS chamber clean-up time with that of the aluminum chambers in the X-Ray and VUV Rings we note that the XLS cleans up in a much shorter time. The two main reasons for this difference are the stainless steel chamber^{3,4} and the lower beam energy.

Since the XLS ring is designed to be incorporated into a VLSI semiconductor facility, we have to know the downtimes required for a) replacement of a component (controlled dry nitrogen bleed-up) and b) an accidental bleed-up to atmospheric air. Fig. 3 shows the results of these tests. In the case of controlled bleed-up to LN₂ boil-off, the machine can be used almost immediately after the system has been pumped down to low pressure, i.e., no beam conditioning is required. For an air vent without an in-situ bake-out, about 10 A-hrs of conditioning are required. We note that the NEG was regenerated too late due to a faulty time integrated beam current meter read-out.

III. Photons, Electrons and Desorption

The strong correlation between photoelectron production and gas desorption^{5,6} due to synchrotron radiation suggests that the gas desorption in e⁻e⁺ storage rings is primarily caused by photoelectrons created by incident photons. The XLS compact storage ring at Brookhaven is ideally suited to study this correlation because:

- a) XLS energy can be varied between 60 and 200 MeV which corresponds to photons with a critical energy between 0.8 and 30 eV
- b) photoelectrons can be collected on metal plates known as clearing electrodes⁷ (CE)

- c) pressure can be continuously measured on 4 calibrated BA gauges.

The circulating electron beam produces synchrotron radiation which hits the surface of the curved stainless steel chamber at an angle of 17° . Due to the rather low photon energy, many photons are reflected to other parts of the chamber. Biasing the CEs either positively or negatively permits us to measure both scattered and absorbed photons⁷. Photoelectrons produced by these photons are collected on various CEs and the resulting current is measured as a function of machine energy using a Kiethley pico-ampere meter. Since the absolute photo current value depends on the beam energy, beam current and the position of the CE, all currents are normalized to the current at 200 MeV and plotted in Fig 4. Only CE 4 and 11 are shown because they are located at the point of the maximum photon flux and give, therefore, the greatest accuracy. The normalized XLS photon flux was calculated and fitted (solid line in Fig 4) to the photoelectron flux. The best fit is obtained for (10 ± 2) eV low energy cut-off which is in good agreement with the work function of stainless steel. Finally, the normalized pressure increases measured at four beam energies are superimposed on the curve in Fig. 4. The large error bar at 90 MeV ($E_e = 2.7$ eV) is due to low photon energy and low stored beam current. Fig 4 thus provides convincing evidence that photon stimulated desorption (PDS) is caused by photoelectrons produced by incident photons with energy larger than 10 eV.

Acknowledgments

We would like to thank Walter deBoer, Tom Romano and the NSLS operators for their invaluable help.

References

1. J. C. Schuchman, et. al., Proceedings 1989 IEEE Part. Accel. Conf., 569, (1989)
2. J. B. Murphy, et. al, Proc. 1991 IEEE Part, Accel. Conf. (1991)
3. H. Halama, AIP Conf. Proceedings No. 236, 39 (1990)
4. C. L. Foerster, H. J. Halama and C. Lanni, J. Vac. Sci. Technol. A8, 2856 (1990)
5. T. Kobari and H. J. Halama, J. Vac. Sci, Technol. A5 2355 (1987)
6. O. Grobner, A. G. Matewson, P. Strubin, E. Alge and R. Souchet, J. Vac. Sci. Technol. A7, 223 (1989)
7. H. Halama and E. Bozoki Proc 1991 IEEE Part. Accel. Conf. (1991)

Figure Captions

- Fig. 1. Schematic diagram of the XLS: G_1 through G_4 Bayard-Alpert gauges; P-combination of Ti sublimation filaments and 120 ℓ /, ion pump; clearing electrodes.
- Fig. 2. Normalized pressure change versus beam dose.
- Fig. 3. Recovery from dry nitrogen and atmospheric air vents.
- Fig. 4. Normalized photon flux-solid line; photoelectron production x , o ; and pressure vs beam energy.

**DATE
FILMED**

3 / 3 / 92