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MEASUREMENTS OF A PROTOTYPE SYNCHROTRON RADIATION PUMPED ABSORBER FOR FUTURE LIGHT SOURCES*

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ABSTRACT

In the new generation of advanced synchrotron light sources, the conventional concept of distributed pumping is no longer suitable for removing the gas load caused by photon stimulated desorption (PSD). A new concept using a combination of photon absorber and pumping station has been designed, constructed, and installed in the U10B beam line at the VUV ring of the National Synchrotron Light Source. The system consists of an electrically insulated water cooled copper block, a titanium sublimation pump, calibrated BA gauges, a calibrated RGA, and a known conductance. A photon beam 10 milliradian wide and 3.26 milliradian high, having critical energy of 500 eV, is directed on the absorber. PSD yield is studied as a function of total beam dose and absorber surface preparation. The results from this experiment, pump characteristics, design of an absorber pump for future light sources, and the pressure improvement factors will be presented.

INTRODUCTION

In the existing synchrotron light sources, the conventional concept of distributed pumping for removing the gas load caused by photon stimulated desorption (PSD) has several shortcomings. Large pressure rise inside the dipole vacuum chamber is responsible for short beam lifetime, ion trapping, and lengthy conditioning of the storage rings. A new concept proposed for future machines utilizes discrete photon absorbers[1] that intercept synchrotron radiation outside the beam chamber where more space for pumping is available. Large pumping speed using inexpensive titanium sublimation near the abosrber can be provided to prevent desorbed molecules from diffusing into the beam chamber to interact with circulating electrons. The beam lifetime is extended, trapped ion problems are reduced, and conditioning time is decreased.

A model of this "photon absorber-pump combination" has been constructed and thoroughly tested in the U10B beam line of the VUV storage ring, operating at 750 MeV. In future machines, this device can be installed into the front ends to define synchrotron radiation exit ports for respective beam lines.

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EXPERIMENT

The absorber experiment was set up on beam line U10B of the NSLS vacuum ultraviolet ring. It is a white beam line having neither mirrors nor monochromators and has adjustable collimators, located 4.5 meters from the source. As shown in Fig. 1, a water cooled photon absorber was located along with a titanium sublimator pump (TSP) in a modified cross at the end of the beam line 6.78 meters from the source point. The TSP was shielded so that the titanium could be confined to the walls of a open-ended water-cooled can. Calibrated varian nude gauges and a calibrated VG mass spectrometer were used. The pyrex window was installed on the experiment cross for low beam current alignment of the absorber position and to verify correct adjustment of the collimators. The absorber was electrically insulated to allow current measurements and electrical biasing during photon bombardment.

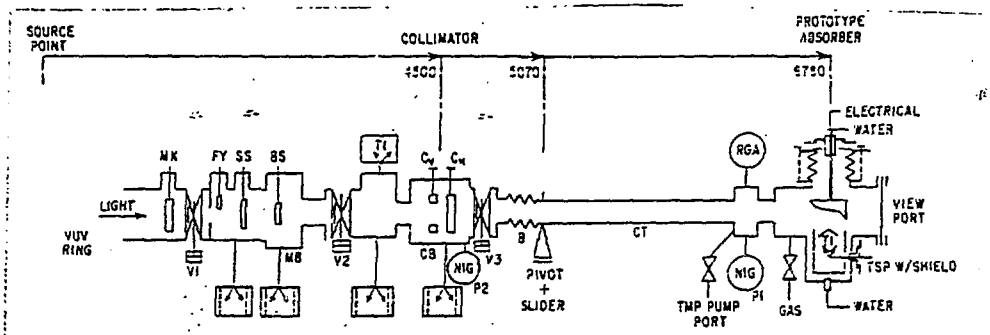

Fig. 1 Schematic diagram of the beamline and prototype absorber. Components: MK-mash for front end valve-VI; FV-fast valve; SS-safety shutter; BS-beam stop; MB-mirror box; V2-U10B isolation valve; CB-collimator box with adjustable vertical-CV and horizontal collimators-CH; V3-isolation valve; B-bellows; and CT-conductance tube.

The beam line and the experiment were vacuum baked at 200'C for three days. Gauges, pumps, and RGA were conditioned at the end of each vacuum bake cycle. The beam line between the ring and valve, V3, was pumped by Perkin-Elmer 220 liter/second differential ion pumps and a titanium sublimation pump having a hydrogen pumping speed greater than 1,000 liters per second. The conductance of the tube, CT, is much smaller than the net speed at the collimator end. The absorber assembly was mounted through bellows and adjusted with three fine threaded rods with ruled indicators on each. During initial alignment, the absorber was moved out of the beam and for the final alignment was positioned to mask it. The TSP was designed to be as close to the absorber as possible.

As described in a previous experiment[2], most of the synchrotron radiation has a nominal angular spread $1/\gamma$, which represents an angle of 0.68 mrad. The absorber is illuminated by white synchrotron light with a vertical opening angle of 3.26 mrad and with a horizontal opening angle of 10 mrad. See Ref. 2, Fig. 8, where it is shown that photon stimulated outgassing is primarily induced by the photo electrons. The photo electron yield is very small for photon energy less than the surface work function, which is approximately 10 eV for most structural material. For our experiment, 20% of 20 eV or less photons will be lost due to this small opening angle. Thus, ~4% or less of total photons will not strike at our absorber. Therefore, total photon flux is used to calculate the desorption yield.

Photon Flux = $8.06 \times 10^{17} \times E(GeV) \times I(mA)$ where E = .745 GeV total flux in 10 mrad is 9.5×10^{14} photons sec^{-1} mA^{-1}.

The molecular abundance of the desorbed species is obtained from the partial pressure rise of the calibrated residual gas analyzer normalized to the calibrated ion gauge pressure.

$$\text{Desorption yield} = \frac{G \times Si \times \Delta Pi/I}{\text{photon flux}}, \text{ molecules per photon}$$

where

G = 3.3×10^{19}, molecules per Torr-liter;

Si = pumping speed, liter per second for each gas species;

$\Delta Pi/I$ = specific pressure rise, Torr per mA;

Flux = photons on absorber/mA s.

EXPERIMENTAL RESULTS

A. Brief Run Description

The same absorber was used for ten experimental runs. The following table outlines each run. The experimental set up was vacuum baked before each run.

TABLE 1
DESORPTION YIELD EXPERIMENTAL RUNS

Run Number	1	2	3	4	5	6	7	8	9	10
Absorber Acid Cleaned	Y	N	N	N	N	N	Y	Y	N	N
Backfilled with Air and C_o	N/A	Y	Y	Y	Y	Y	N	N	N	N
Absorber Removed and Reinstalled	N	N	N	N	N	N	Y	Y	N	N
Active TSP	N	Y	Y	N*	Y	Y	N	Y	Y	Y
TSP Shielded	N/A	Y**	N	N/A	Y	N	N/A	Y	N	N
TSP Speed Measured During Run	N/A	N	N	N/A	N	N	N/A	Y	Y	Y

Y = Yes
N = No
N/A = Not Applicable
* TSP still pumping H_2 after backfill.
** Shield not completely effective.

As the results were evaluated, it was found that for Runs No. 2 through 6, the gas backfill was not sufficient to restore initial conditions. For subsequent Runs No. 7 and 8, the absorber was reetched and recleaned. In addition, it was necessary to measure pumping speeds for H_2, CO, and CO_2 at intervals during each run when the TSP was activated. After reestablishing vacuum for Run No. 5, a high speed for hydrogen still existed. Therefore, only Runs No. 1, 7, 8, and 9 were used for accurate desorption meauserments.

B. Absorber TSP Pumping Speed

Two calibrated ion gauges across a known conductance gas inlet system was added to measure absorber TSP pumping speeds. For maximum TSP pumping speed, a minimum eight-minute flash at 50 amps was needed. Speeds were measured during periodic interruptions of the photo desorption runs. Maximum speed with the TSP shielded to contain the titanium within the pump wall (Fig. 1) was limited by the conductance at its inlet. Initial speeds of the unshielded pump were very much larger than the shielded case as would be expected due to the larger surface coated. Sublimation of Ti for unshielded TSP operation also coated the absorber surface such that the desorption yield was from the coating. Initially, TSP speeds for H_2, CO, and CO_2 were measured prior to each run.

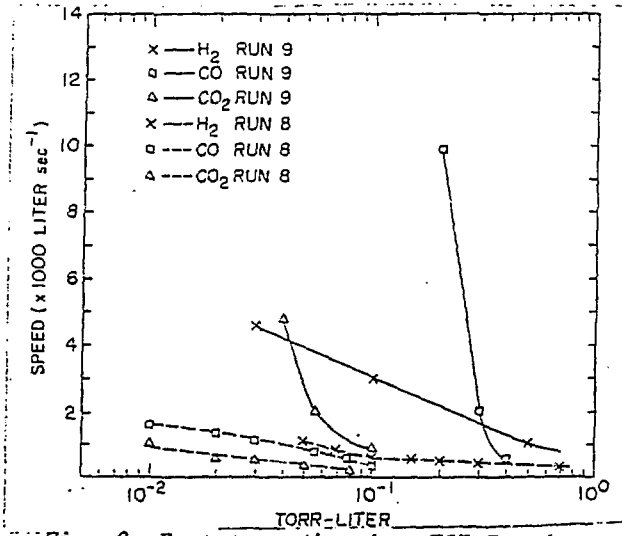

Fig. 2 Prototype Absorber TSP Pumping Speeds for Run 8 and Run 9

In Runs No. 6 and 9 (Fig. 2), the unshielded TSP speed for H_2 started at 4.5k liter/sec and dropped to 600 liter/sec after gettering one Torr liter of H_2. Shielded speeds (Run 8) were initially a great deal less. Unshielded CO speed started at 10k liter/sec and dropped to 300 liter/sec after a Torr liter was gettered. Shielded CO and CO_2 speeds started at 1 and 1.8k liter/sec, respectively, and dropped to the similar speeds of 300 liter/sec for CO and 200 liter/sec for CO_2, after almost a Torr liter of each gas.

C. Molecular Desorption Yields

Desorption yields are determined from the specific pressure rise $\Delta Pi/I$ as in previous experiments on aluminum chambers[2,3] in order to compare our results with others. The area of the absorber exposed to photons during each run is 64 cm^2 so that 1 x 10^{-3} Torr-liter corresponds to one monolayer desorbed. Due to the design of this absorber face, the most energetic photons with a vertical spread of 0.8 mrad strike it at a 5° angle and the rest strike at a 45° angle. Initial desorption yields for copper measured during Run 1 and Run 7 (Fig. 3) with the TSP not active are within the same range as those reported for aluminum[2,3]. Our clean-up rate per photon was less for all gases reported. Approximately 10^{22} photons were accumulated for each run. Run No. 4 was discounted as it was found that the TSP was still active after backfill.

Three runs (2, 5, 8) were made with the TSP active and with a shield to keep titanium well away from the absorber. The shield did not function as desired and a different design was installed for Run No. 8. Desorption yields for the shielded absorber (Fig. 4) were less and desorption clean-up rates were the same when compared with the unpumped run. Data from Runs No. 2 and 5 were not used due to significant desorption memory effects, unknown TSP speeds, and the problem with the shield.

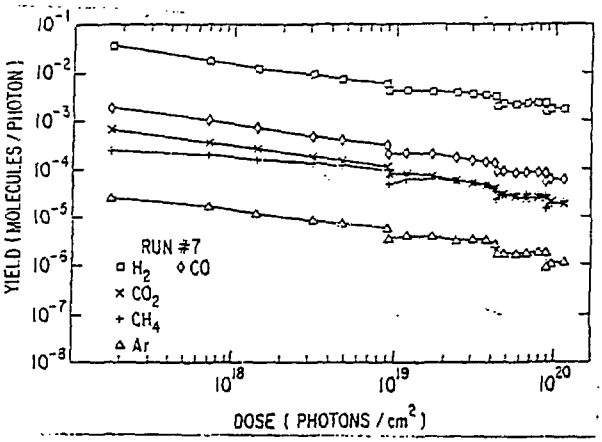

Fig. 3 Molecular Desorption Yields for Run 7

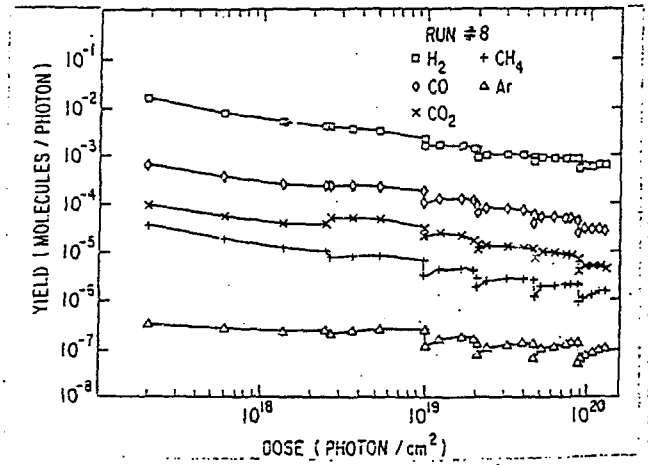

Fig. 4 Molecular Desorption Yields for Run 8

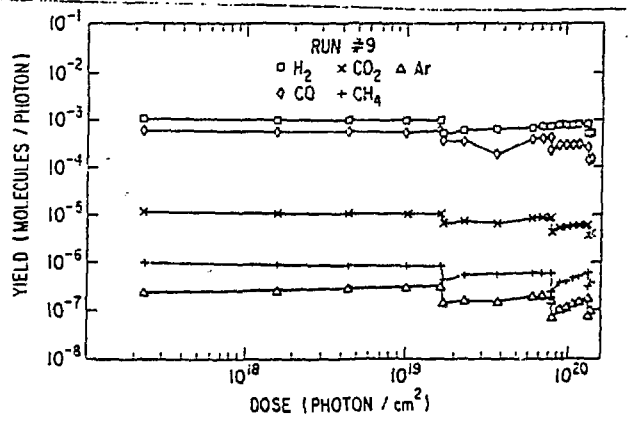

Fig. 5 Molecular Desorption Yields for Run 9

For the unshielded activated TSP runs, the shield was removed and titanium was allowed to sublimate on all line-of-sight surfaces. The TSP speed for H_2, CO, and CO_2 was measured at intervals during Run No. 9 in order to make the desorption calculation as accurate as possible (Fig. 5). Yields for these principle species were initially significantly lower than those for the copper absorber runs and did not decrease a great deal during the run.

Biasing the absorber with either negative or positive voltages served only to increase the desorption yields. Voltages up to 2 KVDC were tried and desorption increased voltage.

D. Pressure Improvements

The desorption yield and the rate of decrease were approximately the same for desorbed gases of Run 1 and Run 7. The unpumped run data were used as a base to evaluate the data from the runs with the TSP activated. With the TSP shielded to keep the sublimated titanium within the pump, the total pressure was improved by a factor of 28 and was due to the partial pressure of hydrogen (Fig. 6). The partial pressure improvements of CO and CO_2, which have a greater effect on stored beam, are factors of 46 and 420, respectively. These factors decrease as the desorbed gases are pumped and the Ti film is saturated.

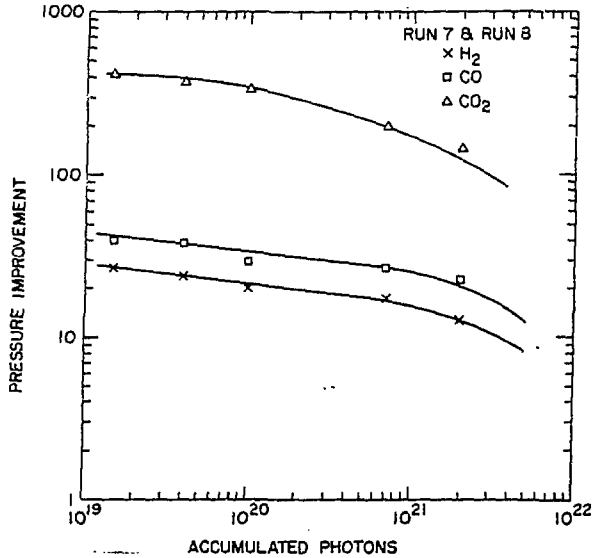

Fig. 6 Pressure Improvement Ratios for Prototype Absorber, Run 7/Run 8 VS. Accumulted Photons.

The total pressure improvement factor due to hydrogen is almost 500 (Fig. 7) with the pump activated without the shield allowing titanium to be deposited on the absorber face and chamber walls. The partial pressure factor is around 450 for CO and is ~ 9000 for CO_2. These factors decrease as the desorbed gases are pumped and pumping speeds decrease.

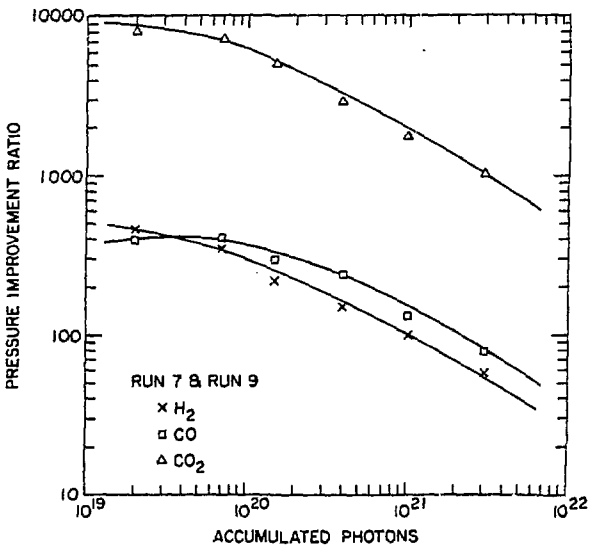

Fig. 7 Pressure Improvement Ratios for Prototype Absorber, Run/7 Run 9 VS. Accumulated Photons

CONCLUSION

PSD (photon stimulated desorption) decreases when Ti is deposited on the pumping surface on the absorber (Figs. 2-4). This may be due to increased pumping speed in the vicinity of the absorber which results in lower pressure at the absorber and lower TSP Without Shield readsorption of desorbed molecules. Another possibility is that a good Ti coating may constitute a better surface.

Due to the large pumping speed of Ti films, a dramatic improvement in pressure is observed, which would result in a corresponding improvement in beam lifetime. Pressure improvement ratios show that CO_2, which is the most detrimented of the desorbed gas to circulating beam lifetime due to its high Z^4, is practically eliminated. Pressure ratios for CO, the most abudant gas during machine operation[5], are 46 and 450; a substantial improvement. The ratios depend on the thickness and the condition of titanium films.

Applying positive voltages to the absorber increases PSD slightly, due to electron bombardment. Applying negative voltage to the absorber increases substantially both PSD and pressure due to positive ion bombardment, produced by synchrotron radiation.

Based on the experimental results, a grounded absorber with as much Ti pumping as possible appears to be the best solution. A small ion pump should be added to lower the pressure during Ti flashing and to pump argon and methane.

ACKNOWLEDGMENTS

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