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# PHOTON STIMULATED DESORPTION FROM ALUMINUM AND STAINLESS STEEL*

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ABSTRACT

Photon Stimulated Desorption of neutral species (PSD) is the major dynamic gas load in electron synchrotron light source. In the National Synchrotron Light Source, (NSLS) PSD presented initial machine commissioning difficulty. Sensitivity to surface contamination on PSD has been experienced during an incident of Fomblin Oil contamination[1].

U10B-Photon Stimulated Desorption Experimental Station is constructed to investigate: 1 - the degree of the contribution to the photon stimulated desorption (PSD) from primary photon flux and scattered secondary photon flux, 2 - the underlying mechanism for photon stimulated desorption, 3 - criteria to chose the proper beam tube material for future accelerators such as SXLS, FEL, SSC, ALS... . In this report, only photon stimulated desorption of neutral species (PSD) from stainless steel and aluminum is reported.

## INTRODUCTION

General consensus on the underlying mechanism of PSD in operating electron synchrotron light source can be found in the literature [2,3,4]. Many attempts to elucidate the PSD mechanism have failed due to either lack of experimental data or insufficient instrumentation. AT CERN, PSD from baked Al alloy vacuum chambers for the CERN LEP 100 GeV $e^+$ $e^-$ storage ring cleaned using alkaline

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detergents have been measured[5] in a test beam line at the DCI storage ring at LURE, Orsay France. Photoelectrons have been measured. In this case a diffusion model for $H_2$ and CO have also been applied, but emission of $CH_4$ and $CO_2$ has been left unexplained. At low photon dosage, occasionally the $CO_2$ has a higher yield



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than CO in the CERN's results. In electron stimulated desorption[6] the consistently higher $CO_2$ yield compared to CO in various surface treatments on CERN Al chamber lead us to investigate further the underlying mechanism of PSD in the electron storage ring. Only $CO_2$ has been observed in strong low photon energy (1.4 to 6.2 eV) photodesorption from aluminum [7]. U10B PSD Experimental Station is constructed to investigate 1.-the degree of contribution to PSD from primary photon flux and scattered secondary photon flux, 2.-the underlying mechanism for PSD, 3 -criteria for future accelerator beam tube selection. In this paper only photon stimulated desorption of neutral species (PSD) from 6063 aluminum and 304 stainless steel are reported. With further instrumentation and a monochronmator, this station is capable of determining the underlying mechanism of PSD.

EXPERIMENT

PSD experiments are carried out in UI0B beam line of VUV ring of the NSLS. Three electrically isolated samples are located 120° apart on a rotating drum in the UHV chamber. Either 6063 Aluminum or 304 stainless steel samples 39 inches long by 2 inches wide were machined from 2.75 inches in diameter (one eighth inch wall) tubing was used to obtain the results reported. Figure 1, shows a view of experimental set-up of U10B PSD Experimental Station. The main UHV vacuum chamber was mounted on the top of an aluminum platform which could be rotated 5° in a horizontal plane. The station was capable of baking to 300°C. An all metal gate valve was used so that the station could be pretreated before installation in the beam line and sample surface could be treated in-situ in the beam line. A 0.005 inch titanium wire, which could be retracted from the light path, was used for in-situ glow-discharge surface treatment. A rotating drum, composed of high precision ball bearings and Beryllium-copper worm gears, provided a mechanism for interchanging to any of three sample positions.

Photoelectric current of each individual sample can be measured with an ammeter. Before each PSD experiment, the system is either baked for 48 hours at

150° C or pumped down for a long time (more than a week) after venting the system to atmosphere. A photon alignment beam was used only after the system pressure is lower than 1 x $10^{-9}$ Torr. The station was then pivoted to let sample 1 intercept the incoming photon (primary photon) to the maximum extent with certain aperture setting. Figure 2, shows the general experimental lay-out. The primary photon strikes the sample with 5- milliradian grazing angle and covered about 100 square centimeters. PSD vs Photon dosage starts with low current at low dosage (300ma or less for four hours) and ends up with total dosage of 10 ampere-hours. Only quadrupole mass spectrometer is used for aluminum results since $CO_2$ decomposed by Bayard-Alpert gauge had been noticed.

Two different treatments of 304 stainless steel samples have been measured S.S.1 was 900°C degassed in a vacuum furnace, S.S. 2 was S.S. 1 taken after the system has been vented to moist atmosphere and evacuated without bake. Two different surface treatments of aluminum have been measured without BAG interference. All was 150° C Baked, Al 2 is Al 1 after oxygen glow discharge treatments.

## RESULTS AND DISCUSSION

Table I shows the results of photon stimulated desorption of 304 S.S. for different radiation treatment. In Table I, Sample 1 is the first sample to intercept the primary photon at the beginning of PSD experiment. After Sample 1 has received 10 Amper-hours from primary beam, the position of three samples is interchanged by turning the rotating drum 120° clockwise. After this rotation Sample 2 occupies Sample 1's original position, Sample 3 occupies Sample 2's, Sample 1 occupies Sample 3's. After Sample 2 received 10 ampere-hours dosage from primary photons, the same procedure repeats again. This result is labeled in Table I as Sample 3. The last column of Sample 1, in Table I is the PSD result of Sample 1 after all three samples receive 10 amper-hours from primary photons. 0.1 amper-hours dosage of Sample 1 in Table I means this 304 S.S.

sample has been irradiated with 10 amper-hours of scattered photons plus 0.1 amper-hours of primary photons. The smallness of photon desorption of Sample 2 compared to Sample 1 at same low photon dosage shows the effectiveness of scattered photon desorption. By carefully examining the PSD results of Sample 1 at the last column and Sample 2 in Table I, one concludes that photon stimulated hydrogen desorption must be governed by different desorption mechanism than PSD behavior from the rest of desorption species. In these experiments we did not observe the similarity between $H_2$ and CO PSD as was observed at CERN [5].

In Table I and Table II, desorption yield was listed as Torr/Amp instead of molecules/photons and dosage as ampere-hours instead of photons. The reason is two fold: First - the experimental results of PSD from previous experiments[3,4,5] and this work has shown the desorption yield contributed by both primary photon (photon comes from the source) and the scattered photons which were the photons bounce back from the environment (wall, other sample, . . .) after it struck the sample target. This quantity (total photon flux at the target) has not been measured or evaluated correctly yet. Second - To convert Torr/amp to molecules/photon one not only needs to convert beam current to actual photon flux (as mention in the first reason) at the sample but also to calibrate the pumping speed for each individual species so Torr/amp will multiply with pumping speed $\ell$/s to get Torr•$\ell$/s/amp, which is the molecular flux/photon flux, ie., photon desorption yield, molecules/photon; but if one interests only in the relative yield with different treatments in the identical experimental condition the Torr/amp was as good a quantity as, molecules/photon.

Comparing the results of different samples in Table I, clearly shows that the scattered photons do a fairly good job on cleaning metallic surfaces as far as the PSD is concerned. This is especially true for $H_2$ desorption.

Table II shows the results of PSD of 304 S.S. and 6063 Aluminum with different treatments. SS1 was 304 S.S. vacuum outgassed at 900° C for two hours in a vacuum furnace. SS2 is SS1 wetted with moist atmosphere after it receives

10 ampere-hours photon dosage. Comparing the results of SS1 and SS2, it is clear that PSD has a strong memory effect and water was photon desorbable by synchrotron white light. Al 1 is 6063 T5 Aluminum with NSLS standard cleaning treatment (OAKITE 166). Al 2 is Al 1 oxygen glow-discharge treated for 1 ampere-hour in-situ after it receives 10 amper-hours photon dosage. Table II shows clearly that glow discharge clearly removes every outgassing species from PSD. The water outgassing from Al 1 is due to imperfection in the bake-out process. The results from SS1 and Al 1 show that aluminum with chemical treatment was inferior to stainless steel with high temperature outgassing. Aluminum PSD results in Table II indicate that water was desorbed by synchrotron white light.

Further Investigation is necessary on the underlying mechanism for PSD. We believe after the basic mechanism is truly understood the criteria for beam tube selection can be furnished with ease. Dynamic outgassing in the electron synchrotron can be understood with the help of this further investigation.

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**TABLE I**

**PHOTON STIMULATED DESORPTION (TORR/AMP) OF 304 S.S.**

| OUTGASSING SPECIES | *DOSAGE (AMP-HR)* 0.1 | 1 | 10 | >10 |
|---|---|---|---|---|
| | | **SAMPLE 1** | | |
| $H_2$ | $1.01X10^{-6}$ | $3.20X10^{-7}$ | $1.00X10^{-7}$ | $4.50X10^{-8}$ |
| $CH_4$ | $1.60X10^{-8}$ | $4.00X10^{-9}$ | $1.30X19^{-9}$ | $1.80X10^{-10}$ |
| CO | $4.00X10^{-8}$ | $1.60X10^{-8}$ | $5.00X10^{-9}$ | $1.80X10^{-10}$ |
| $CO_2$ | $8.30X10^{-9}$ | $3.30X10^{-9}$ | $1.30X20^{-10}$ | $1.80X10^{-11}$ |
| $C_2H_6$ | $2.00X10^{-9}$ | $5.00X10^{-9}$ | $1.30X10^{-10}$ | $1.80X10^{-13}$ |
| | | **SAMPLE 2** | | |
| $H_2$ | $4.50X10^{-8}$ | $3.20X10^{-8}$ | $2.40X10^{-8}$ | |
| $CH_4$ | $1.90X10^{-9}$ | $1.40X10^{-9}$ | $1.10X10^{-9}$ | |
| CO | $3.40X10^{-10}$ | $2.70X10^{-10}$ | $2.20X10^{-10}$ | |
| CO | $3.40X10^{-10}$ | $2.70X10^{-10}$ | $2.20X10^{-10}$ | |
| $CO_2$ | $3.30X10^{-10}$ | $2.80X10^{-10}$ | $2.50X10^{-11}$ | |
| $C_2H_6$ | $2.00X10^{-9}$ | $5.00X10^{-9}$ | $1.30X10^{-10}$ | |
| | | **SAMPLE 3** | | |
| $H_2$ | $4.20X10^{-8}$ | $2.20X10^{-8}$ | $1.90X10^{-8}$ | |
| $CH_4$ | $1.80X10^{-9}$ | $9.30X10^{-10}$ | $8.30X10^{-10}$ | |
| CO | $2.80X10^{-10}$ | $1.80X10^{-10}$ | $1.50X10^{-10}$ | |
| $CO_2$ | $2.80X10^{-10}$ | $1.80X10^{-10}$ | $1.50X10^{-10}$ | |
| $C_2H_6$ | $2.20X10^{-11}$ | $1.80X10^{-11}$ | $1.50X10^{-11}$ | |

**TABLE II**

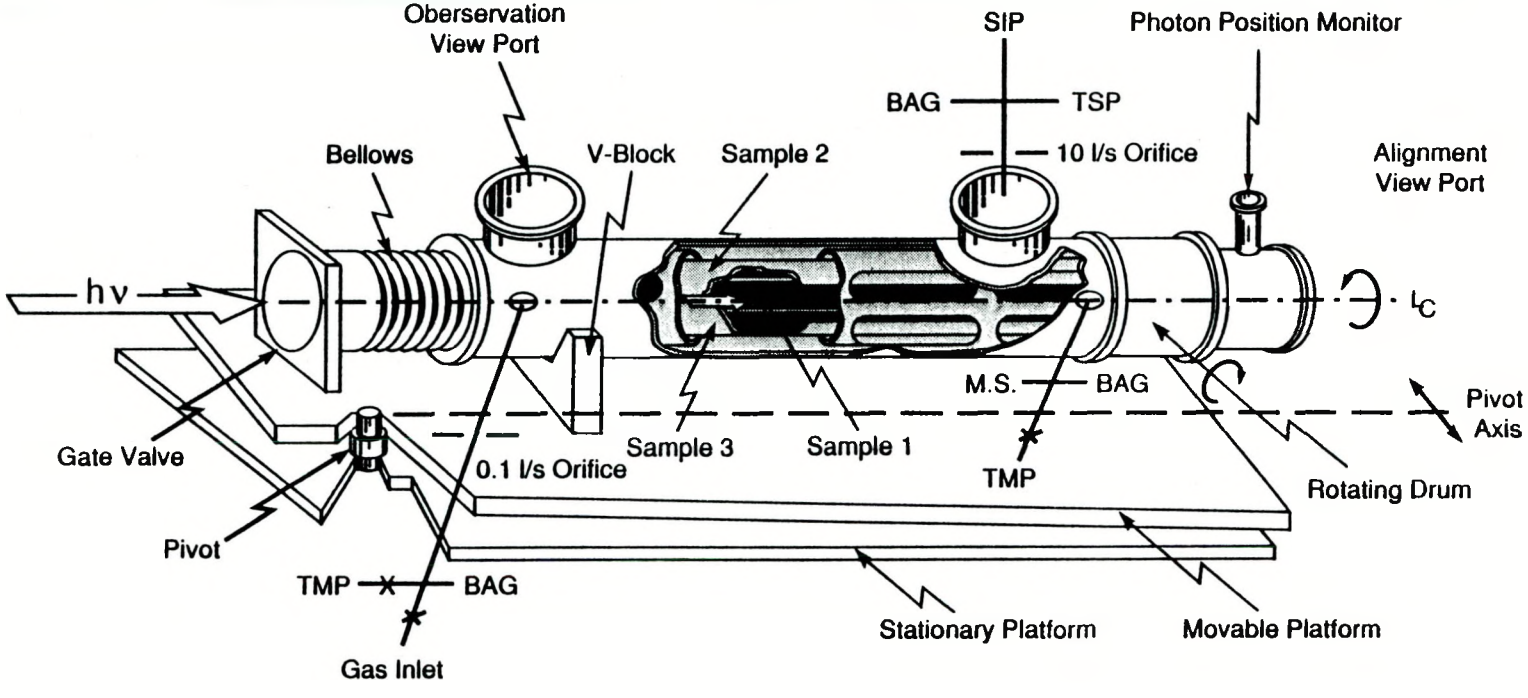
**PHOTON STIMULATED DESORPTION (TORR/AMP)
OF 304 S.S. AND 6063 ALUMINUM
WITH DIFFERENT SURFACE TREATMENT**

| OUTGASSING SPECIES | *DOSAGE (AMPER-HOURS)* 0.1 | 1 | 10 |
|---|---|---|---|
| | | **SS1** | |
| $H_2$ | $1.00X10^{-6}$ | $3.20X10^{-7}$ | $1.00X10^{-7}$ |
| $CH_4$ | $1.60X10^{-8}$ | $4.00X10^{-9}$ | $1.30X10^{-9}$ |
| CO | $4.00X10^{-8}$ | $1.60X10^{-9}$ | $5.00X10^{-9}$ |
| $CO_2$ | $8.30X10^{-9}$ | $3.30X10^{-9}$ | $1.30X10^{-10}$ |
| $C_2H_6$ | $2.00X10^{-9}$ | $5.00X10^{-9}$ | $1.00X10^{-10}$ |
| | | **SS2** | |
| $H_2$ | $2.07X10^{-7}$ | $1.35X10^{-7}$ | $8.51X10^{-8}$ |
| $CH_4$ | $1.60X10^{-9}$ | $7.11X10^{-10}$ | $3.16X10^{-10}$ |
| $H_2O$ | $8.32X10^{-9}$ | $5.37X10^{-9}$ | $3.63X10^{-9}$ |
| CO | $5.51X10^{-9}$ | $3.60X10^{-9}$ | $2.52X10^{-9}$ |
| $CO_2$ | $1.60X10^{-9}$ | $7.71X10^{-10}$ | $3.16X10^{-10}$ |
| $C_2H_6$ | $1.00X10^{-10}$ | $6.53X10^{-11}$ | $4.27X10^{-11}$ |
| Ar | $2.51X10^{-10}$ | $1.32X10^{-10}$ | $1.26X10^{-10}$ |
| | | **Al 1** | |
| $H_2$ | $1.00X10^{-6}$ | $3.16X10^{-7}$ | $1.00X10^{-7}$ |
| $CH_4$ | $1.24X10^{-8}$ | $3.03X10^{-9}$ | $711.10^{-10}$ |
| $H_2O$ | $2.31X10^{-8}$ | $5.06X10^{-9}$ | $1.11X10^{-9}$ |
| CO | $2.35X10^{-7}$ | $5.74X10^{-8}$ | $1.60X10^{-8}$ |
| $CO_2$ | $1.00X10^{-7}$ | $2.35X10^{-8}$ | $5.50X10^{-9}$ |
| $C_2H_6$ | $7.74X10^{-9}$ | $1.67X10^{-9}$ | $3.59X10^{-10}$ |
| Ar | $3.24X10^{-9}$ | $6.31X10^{-10}$ | $1.29X10^{-10}$ |
| | | **Al 2** | |
| $H_2$ | $1.08X10^{-8}$ | $4.14X10^{-9}$ | $2.15X10^{-9}$ |
| $CH_4$ | $5.84X10^{-11}$ | $1.41X10^{-11}$ | $5.01X10^{-12}$ |
| $H_2O$ | $4.19X10^{-10}$ | $1.53X10^{-10}$ | $6.56X10^{-11}$ |
| CO | $4.47X10^{-10}$ | $1.53X10^{-10}$ | $6.56X10^{-11}$ |
| $O_2$ | $4.19X10^{-12}$ | $1.43X10^{-12}$ | $1.53X10^{-13}$ |
| $CO_2$ | $3.98X10^{-11}$ | $7.08X10^{-12}$ | $1.58X10^{-12}$ |
| Ar | $4.19X10^{-10}$ | $1.43X10^{12}$ | $4.41X10^{-13}$ |

## FIGURES

FIGURE 1. U10B PHOTON STIMULATED DESORPTION EXPERIMENTAL STATION
BAG: BAYARD-ALPERT GAUGE; SIP: SPUTTER ION PUMP
TMP: TURBOMOLECULAR PUMP; TSP: TITANIUM SUBLIMATION PUMP
M.S.: QUADROPOLE MASS SPECTROMETER

FIGURE 2. EXPERIMENTAL LAY-OUT FOR THIS EXPERIMENT AT VUV RING OF NATIONAL SYNCHROTRON LIGHT SOURCE.

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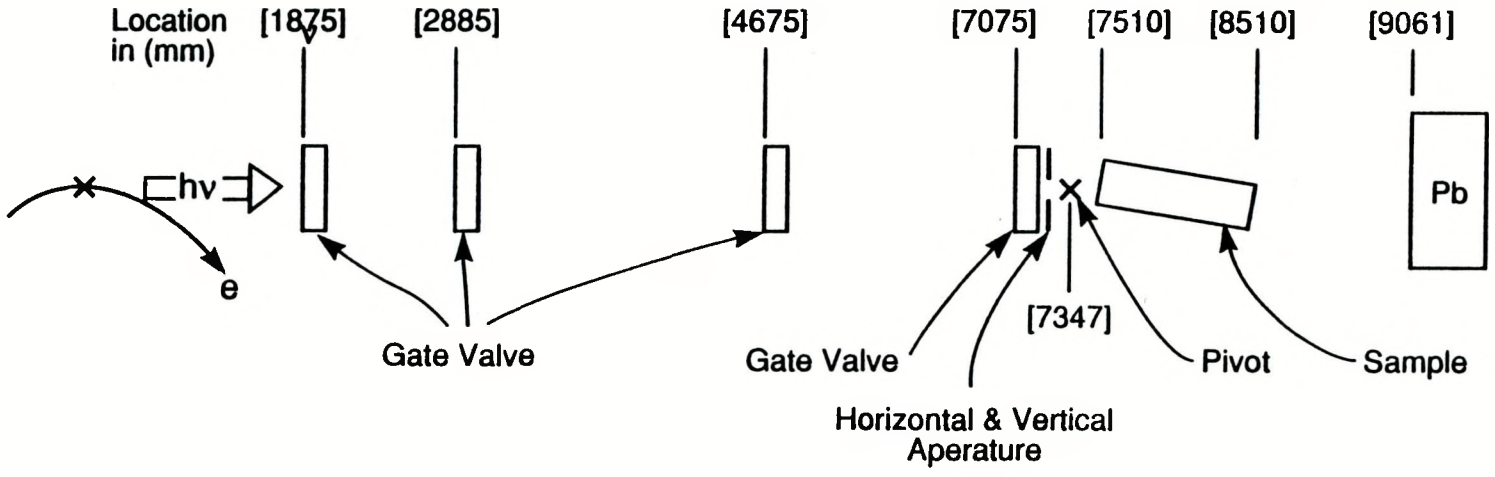
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Horizontal & Vertical
Aperature