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Photon stimulated desorption measurement of an extruded aluminum beam chamber for the Advanced Photon Source

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The Advanced Photon Source (APS), presently being commissioned, will produce x rays of unprecedented brightness. The high energy ring of the APS is a 7 GeV positron storage ring, 1104 m in circumference designed to operate at less than 10^{-9} Torr with 300 mA of beam and a greater than 10 h lifetime. The storage ring vacuum chamber is constructed from an extruded 6063 aluminum alloy. During the construction phase, a 2.34-m-long section of the APS extruded aluminum chamber was set up on National Synchrotron Light Source (NSLS) X-ray Beamline X28A and photon stimulated desorption (PSD) was measured. Cleaning and preparation of the chamber was identical to that of the APS construction. In addition to the chamber, small samples of Al, Be, and Cu were also exposed to white light having a critical energy of 5 keV. In addition to PSD, measurements were made of the specular and diffuse scattering of photons. The chamber and samples were each exposed to a dose greater than 10^{23} photons per m. Desorption yields for H_2, CO, CO_2, CH_4, and H_2O are reported as a function of accumulated flux, critical energy, incidence angle, and preparation. These results are compared with previous results for aluminum on NSLS Beamline U10B and PSD results of other laboratories published for aluminum.

I. INTRODUCTION

The ultrahigh vacuum (UHV) ring beam chambers for the Advanced Photon Source (APS) are fabricated from an extruded 6063 aluminum alloy. During the circulating beam operation the walls of the chambers will be struck by photons not exiting to the experimental beam lines or not eliminated by the various absorbers in the sectors that comprise the ring. The resulting photon stimulated desorption (PSD) will result in increased pressure[1] which limits stored beam current and lifetime. PSD is well known and procedures for assembly, cleaning, and preconditioning of UHV components have been established to minimize its adverse effects.

Environmental and safety concerns are forcing major changes to accelerator vacuum cleaning procedures worldwide.[2] Cleaning procedures were developed for the APS that pose little risk for the environment or for safety issues. In addition to the initial testing to approve the cleaning materials and process, a section of the APS beam chamber was cleaned and sent to Brookhaven National Laboratory (BNL) for PSD measurements. The test chamber was cleaned using the same process used to clean the 240 sections of aluminum tubing that make up the 1104 m circumference APS storage ring.[2] The cleaning procedures for the aluminum beam chamber and other component materials for the APS were established[3] based on x-ray photoelectron spectroscopy (XPS) surface analysis and the need for safe materials. The aluminum extrusion was degreased followed by a mild alkaline detergent (Almeco 18) cleaning. After preparation and the leak test of the test chamber at the APS it was sealed and shipped with static vacuum.

The APS test chamber consists of three main sections:[4] the positron beam chamber, the pump antechamber, and the 10 mm interconnecting photon beam channel. The nonevaporable getter (NEG) strips were left out of the antechamber for the PSD measurements. The 2.4-m-long test chamber was fitted with two Conflat flanges (CF) on each (for beamline installation) end and two in the middle for electrical probes.

II. EXPERIMENT

The APS test chamber was set up for measurement on Beamline X28A on the NSLS X-ray Ring at BNL (see Fig. 1). The basic setup was the same as the previously described[5] setup for copper test chambers run for the PEP-II asymmetric B factory. Some of the pertinent parameters and details are repeated for completeness. A water cooled beryllium filter (0.25 mm thick) can be moved into the beam path to eliminate photons with energies less than 2 keV from the measurement. A water cooled rectangular collimator with an opening measuring 48 mm horizontally and 38 mm vertically is located 12 m from the source. The vertical cutoff of the aperture is photons of less energy than 6 eV full width at half-maximum (FWHM). Total photon flux is used in the calculations of η (eta), which represents the desorption yield in molecules/photon.

The NSLS X-ray 2.5 GeV ring provides white light with a critical energy of 5 keV. During the photon exposure measurements the chamber was positioned for a primary photon incident angle of 21 mrad. Calibrated nude ion gauges (NIGs) were used to measure the pressure drop across a 51.8 $\ell\,s^{-1}$ conductance, which is used to determine the amount of

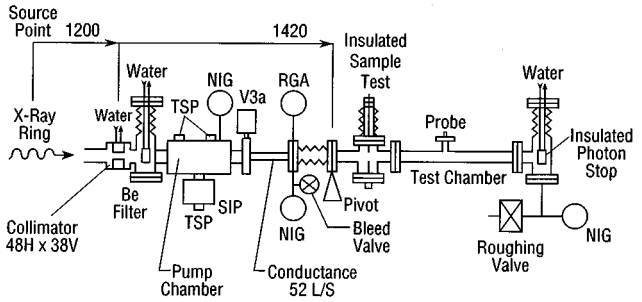

FIG. 1. Schematic diagram of experiment of NSLS X28A Beamline setup. SIP: sputter ion pump; TSP: titanium sublimation pump; NIG: nude ion gauge; and RGA: residual gas analyzer. Source points are in cm.

gases produced during test chamber exposure. A calibrated residual gas analyzer (RGA) was used to determine constituents of the total gas pressure measurements. Pressure rises ($\Delta P/P$) are determined for H_2, CH_4, CO, O_2, CO_2, and H_2O from the NIG and RGA readings. The respective yields in molecules per photon are calculated from these results. An electrically insulated water cooled photon stop was located at the end of the beamline which was used to measure specular photons.

A. Test chamber

Two electrically insulated probes were located in the middle of the chamber to measure diffusely scattered photons (see Figs. 1 and 2). The chamber and beamline were baked to 150 °C prior to the start PSD measurements. One of the center chamber probes was located in the middle of the beam chamber and it consisted of a small block (1 cm×1 cm×2 cm) on the end of an insulated shaft. The other center probe was the same size block on an insulated shaft and it was located in the antechamber with its surface even with the interior wall. The 1 cm×2 cm surface faced the center of the antechamber. The photon beam was incident on the antechamber wall as shown in Fig. 2. The ends of the beam

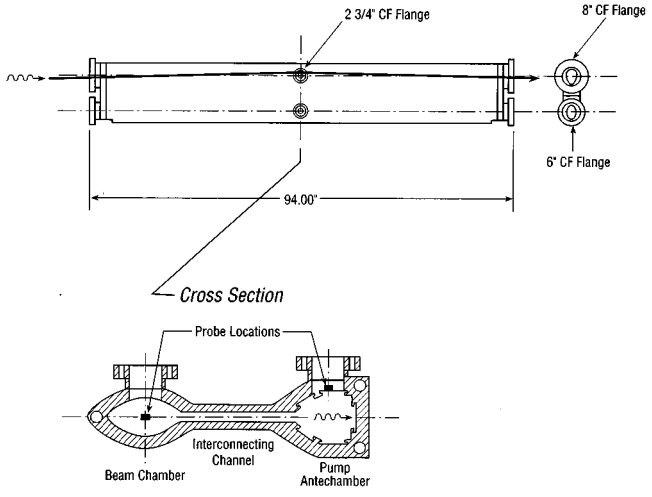

FIG. 2. Sketch of the APS storage ring chamber test piece.

chamber section were blanked off with CF flanges. All probes were normally at ground potential during the run, but were biased at −40 VDC during measurement to minimize photo electron effects.

B. Sample tests

Four different sample block materials were mounted on a water cooled copper holder. The water cooled holder was mounted on an external motor driven manipulator mounted on top of a stainless steel cross between the test chamber and the pressure drop conductance. The sample blocks tested were beryllium, oxygen-free high-conductivity (OFHC) copper, aluminum, and Glidcop. Glidcop is a dispersion strengthened copper (C15715). Approximately 47 mm×12 mm of the sample block faced normal incident photons for each measurement. A similar area on the lower part of the copper holder was initially moved into the photon beam path to first condition surrounding surfaces with secondary photons and photoelectrons. A probe was located below and in front of the sample holder even with the chamber inner wall. Prior to installation in the sample setup, the OHFC copper and Glidcop samples were hydrogen annealed at 970 °C to simulate conditions used in brazing the APS photon absorbers. The sample setup was baked to 150 °C along with the beamline and test chamber prior to measurements. The sample holder was raised up out of the beam path during the APS test chamber measurement.

The samples were run after the test chamber was exposed to approximately 10^{23} photons. The setup was conditioned by first exposing the lower portion of the sample holder into the photon beam without hitting the samples. The samples were then moved into the beam in their order of mounting. Including all photons passing through the collimator, the cross section of the photon beam at the sample chamber is 57 mm horizontal×45 mm vertical. The cross section of the holder is 47 mm horizontal×91 mm vertical and was stepped into the beam for each sample. Steps were in increments of 12.5 mm for each sample exposed. The first step intercepted 20% of the beam cross section, the second intercepted 43%, the third 67%, and the fourth and fifth each intercepted 83% of the beam.

III. MEASUREMENT AND COMMENT

A. Test Chamber

PSD measurements were performed with and without the beryllium filter in the photon beam path. The filter was briefly inserted periodically for measurements such that the majority of exposure was to unfiltered white light. The PSD results are shown in Fig. 3. As was the case with B-factory copper chambers, PSD with the filtered light was larger, most likely due to a slight scattering of the photon beam. The PSD results for the aluminum test chamber were much larger than was found for B-factory copper chambers run on the same beamline. Aluminum has previously been found to exhibit higher PSD yields[6] than other common chamber materials. When compared to a NSLS vacuum chamber run[7] on Beam-

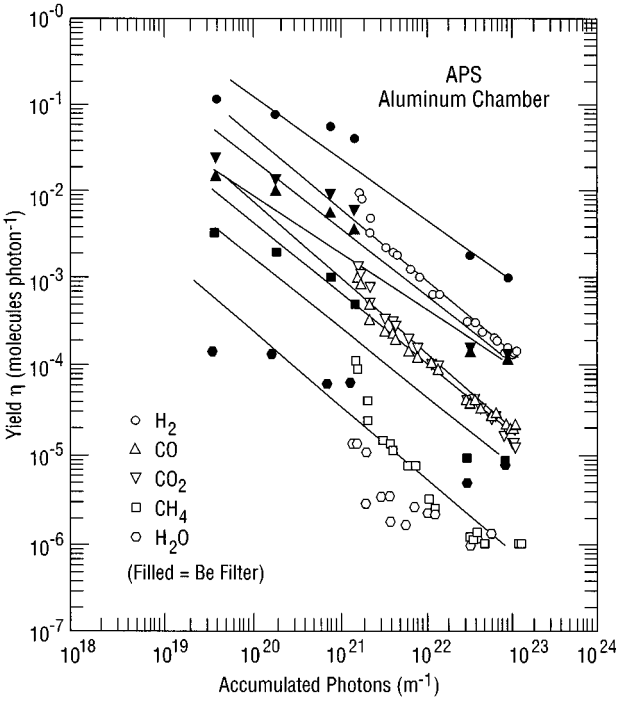

FIG. 3. Molecular desorption yields for the APS extruded storage ring chamber. Filled gas molecule symbols indicate that the beryllium filter was in the photon beam path.

line U10B, the desorption yields are less than a factor of 3 lower. Our results for H_2 and CO are almost the same as those from the DCI storage ring,[8] Orsay, France, and our result for CO_2 is within a factor of 2 compared to DCI for their baked aluminum chamber. O_2 was always less than CH_4 and is not reported. H_2O is uncalibrated but is given for reference.

The photoelectron currents measured on various test probes are given in Table I. Our lower detection limit was 1×10^{-4} Å. The specular reflection measured for the test chamber with unfiltered white light was approximately 3.5%, which is almost the same as that previously measured for the B-factory welded copper chamber. With the beryllium filter in the photon beam path, no specular photons were detected on the photon stop. The same results using the photon filter were found with the B-factory chamber measurements but were not reported. Our nondetection of specular photons on the stop with the filter is not surprising since the specular reflectivity[9] for aluminum oxide or aluminum with mirror density at an angle of 25 mrad decreases considerably at higher photon energies. The beryllium filter in the photon path eliminates photons with energies less than 2 keV.

Small currents of 10^{-3}–10^{-4} μA mA^{-1} were detected on the sample holder while it was in its out of beam path position during test chamber measurements, which indicated the holder was at the upper edge of the photon beam. The currents during test chamber measurements were reduced more than 50% with the beryllium filter in the beam path. Very small or no currents were detected on the sample chamber probe during PSD runs. Except for the end stop, probe measurements were not calibrated and are given as reference only. Very little current was detected on the beam chamber probe.

B. Sample measurements

The results of sample exposures are given in Table I and Table II. They were all run without the beryllium filter in the photon beam and were exposed in the order given in Tables I and II. The copper holder yielded the largest η (molecules/photon), as expected since it was used to condition the sample setup. The samples are within a factor of 2 or 3 of each other for the principal gases reported (H_2, CO, CO_2, CH_4). O_2 was always less than CH_4 and is not reported. When compared to the test chamber, the PSD yields start an order of magnitude lower but all end up a factor of 2 or 3 higher.

Except for the last two samples an increase in photoelectron current on the sample holder was measured each time the sample holder is stepped into the beam path to expose an additional new sample. As the holder stepped into the photon path, a corresponding decrease in photon electron current was measured on the end stop except for the last two samples. The last two samples intercepted the same cross section of photon beam. The current on the sample decreased approximately 25% but the current on the stop stayed the same when the last sample was moved into the photon path. We have previously[10] calculated similar currents for aluminum, gold, and copper that would explain our results. Al-

TABLE I. Photoelectron currents in μA/mA at -40 VDC measured on various test probes.

Primary photon		Sample chamber		Test chamber		End stop
Target	Be filter	Holder	Lower probe	Antechamber	Beam chamber	
Test chamber	Yes	5.2×10^{-4}	0.0	3.6×10^{-3}	0.0	0.0
Test chamber	No	1.1×10^{-3}	0.0	1.67×10^{-2}	5.3×10^{-4}	8.8×10^{-2}
Sample holder						
Holder copper	No	0.62	8.7×10^{-4}	1.3×10^{-3}	0.0	5.2×10^{-2}
Glidcop	No	0.75	0.0	6.4×10^{-4}	0.0	3.0×10^{-2}
Aluminum	No	0.92	0.0	8.5×10^{-4}	0.0	3.2×10^{-2}
OHFC copper	No	1.33	4.8×10^{-4}	9.6×10^{-4}	0.0	3.4×10^{-2}
Beryllium	No	0.98	0.0	9.1×10^{-4}	0.0	3.4×10^{-2}

TABLE II. Photon stimulated desorption for principal gases from exposed sample blocks.

Run	Sample	Exposure photons	Gas yield of (molecule/photon)			
			H_2	CO	CO_2	CH_4
0	Holder copper	1×10^{21}	1.9×10^{-3}	3.5×10^{-4}	4.5×10^{-4}	2.6×10^{-5}
	Holder copper	5×10^{23}	7.3×10^{-4}	9.8×10^{-5}	1.0×10^{-4}	5.8×10^{-6}
1	Glidcop	1×10^{21}	1.2×10^{-3}	1.5×10^{-4}	1.6×10^{-4}	7.5×10^{-6}
	Glidcop	5×10^{23}	6.0×10^{-4}	1.0×10^{-4}	$1.1x10^{-4}$	5.0×10^{-6}
2	Aluminum	1×10^{21}	1.1×10^{-3}	1.2×10^{-4}	9.6×10^{-4}	5.0×10^{-6}
	Aluminum	5×10^{23}	4.2×10^{-4}	5.0×10^{-5}	3.2×10^{-5}	1.8×10^{-6}
3	OHFC copper	1×10^{21}	8.0×10^{-4}	8.8×10^{-5}	7.0×10^{-5}	3.3×10^{-6}
	OHFC copper	5×10^{23}	5.6×10^{-4}	8.1×10^{-5}	5.6×10^{-5}	2.3×10^{-6}
4	Beryllium	1×10^{21}	1.1×10^{-3}	1.1×10^{-4}	9.5×10^{-5}	5.9×10^{-6}
	Beryllium	5×10^{23}	4.1×10^{-4}	5.2×10^{-5}	4.1×10^{-5}	4.2×10^{-6}

though we did not have photoelectric quantum efficiencies to calculate beryllium, we did measure[10] approximately 25% less current on the beryllium than on the copper sample.

Very little photon induced current was detected on the sample chamber lower probe located below the sample faces. Currents of 10^{-3}–10^{-4} μA mA^{-1} were measured on the antechamber test probe. Photons not stopped by the sample holder setup would be incident on the previously desorbed test chamber wall. No currents were detected on the beam chamber test probe. End stop currents measured 3×10^{-2}–5.2×10^{-2} μA mA^{-1}.

Each sample stepped into the beam path exposes a 20% of new cross sectional area to photon incidence. The rest of the photon beam's primary incident is on the previously exposed sample or the test chamber surfaces.

IV. CONCLUSIONS

The APS photon stimulated desorption results are similar to previous clean aluminum beam chambers tested at the NSLS and at DCI.

The new environmentally safe Almeco 18 based cleaning procedures developed for the APS storage ring construction are acceptable for storage ring UHV operation.

There were no major differences in the small sample PSD results from sample to sample. They all yielded similar desorption and are most likely moderated by desorption from the sample chamber and the test chamber due to diffusely scattered photons.

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