**Photon Stimulated Desorption (PSD) Measurements of Extruded Copper *
and of Welded Copper Beam Chambers for the PEP II Asymmetric B-factory**

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ABSTRACT

PEP II is being built as a higher luminosity electron-positron collider, with asymmetric beams of 9 GeV and 3.1 GeV, having maximum currents of 3.0 A. Based on our previous work on the NSLS VUV beamline U10B, a copper was selected for construction of UHV beam chambers and absorbers to minimize the pressure rise from synchrotron radiation during operation. An extruded beam chamber and a welded beam chamber were fabricated from the selected copper for PSD measurements on NSLS X-ray beamline X28A. The chambers were exposed to white light with a critical energy of 5 KeV, both direct and through a 0.010 inch thick Beryllium filter. Each chamber was exposed to a dose of approximately 10^{23} photons per meter at an incidence angle of 25 mrad, after argon glow conditioning and a 150°C vacuum bake. Desorption yields for H_2 , CO, CO_2 , and CH_4 are reported as a function of accumulated photon flux, critical energy, and chamber preparation. The results are compared with the previous work on beamline U10B and with those of other published work for copper.

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I. INTRODUCTION

Based on previous studies¹ of various materials and a prototype chamber on our VUV beamline U10B, high purity oxygen free copper was selected for PEP-II vacuum chamber construction. The copper chambers and copper absorbers will intercept the synchrotron radiation during B-factory operations and the resulting gas desorption can be successfully resolved, thus minimizing degradation of stored beam operations. The pressure rise during beam operation can limit the beam lifetime during operation and can be an important source of background in the detector systems².

The synchrotron white light used for our VUV ring exposures has a critical energy of 486 eV and the PEP-II B-meson factory will have a much higher critical energy, therefore we set up several experiments on our X-ray ring which has a critical energy of 5 KeV. Our previous U10B results for OFHC copper are in excellent agreement with those obtained at DCI^{1,2,3} which has synchrotron radiation at 3.75 KeV critical energy.

Based on U10B testing of various coppers, pure grade C10100 was the copper selected for B-factory construction. Two prototype test chambers three meters long were fabricated to the B-factory cross section design using the selected copper, to be exposed to synchrotron radiation on NSLS X-ray ring beamline X28A. One beam chamber prototype was fabricated using extruded copper, and the other by electron beam weld using formed copper sheet metal sections. Presently, extruded copper beam chambers are planned for B-factory. Stainless steel to copper joints for conflat flanges were brazed together for both prototypes.

II. EXPERIMENT

A. Beamline X28A

The prototype chamber to be measured was installed near the downstream end of the beamline set

up. At the end of the set up is an electrically insulated water cooled copper beam stop which is used to measure direct or specular photons, depending how the test chamber is set up. Upstream of the chamber for test is a bellows and spool piece assembly with a Residual Gas Analyzer (RGA), nude ion gauge (NIG) and a bleed valve. Next is a conductance tube leading upstream towards the X-ray ring and into a large pump chamber which includes another calibrated ion gauge, a titanium sublimation pump (TSP) and a $120 \text{ litersec}^{-1}$ sputter ion pump (SIP). This pump chamber is used to pump the upstream end of the pressure drop conductance gauge set up. The valve between them is mainly used to prevent titanium from getting to the conductance set-up during sublimation in the pump chamber, and is also used to isolate the two sections when changing test chambers. Upstream of the pump chamber is a water cooled Beryllium shutter (0.010 inch thick) which can be moved into the white light path to eliminate photons of approximately 2 KeV or less from the experiment. Upstream of the shutter is a water cooled copper collimator with a $220 \text{ litersec}^{-1}$ SIP. The collimator is 12 meters from the source and has a rectangular opening, 48mm horizontally and 38mm vertically. The vertical cut off of the aperture for photons is less than 6 eV (FWHM). Total photon flux is used in the calculations.

During test chamber measurements the chamber is positioned so that photons are at an incident angle of 25 mrad. Photo electron yields, absorbed photons, and reflected photons were measured using variable DC voltage supplies connected to a pick up electrode and to the water cooled copper end stop. The Beryllium filter was calibrated by measuring the number of photons at the end stop with and without the filter in the beam path.

The conductance tube between the calibrated nude ion gauges (NIG) was designed to be $51.8 \text{ litersec}^{-1}$. The pump chamber speed upstream of the conductance was designed to be very high so that the speed downstream of the conductance tube changes very little during

measurement. The RGA was calibrated in situ using the bleed valve for the gases of interest. Pressure rises ($\Delta P/I$) for the principal disturbed gases are obtained from NIG and RGA readings and the respective yields in molecules per photon are calculated³.

B. Prototype Chambers

Both prototype chambers were vacuum baked to 250° C and Argon (100% Ar) glow discharge conditioned to 2×10^{18} ion cm⁻² prior to installation in the beamline. A pre-glow discharge and vacuum bake conditioning is presently planned for B-factory construction. The welded copper chamber has an electrically insulated copper pick up strip along the side opposite the primary photon impact sites. Periodic measurements of photon and photo electron currents were made using the copper strip. Specular photons were measured with the water cooled copper end stop for both extruded and welded test chambers.

III. MEASUREMENT AND DISCUSSION

A. Beryllium Filter and Water Cooled Beam Stop

To investigate PSD, measurements were performed with and without the beryllium filter during each run. The results are shown in figure 1 and figure 2. The Be filter transmission was tested by measuring the photoelectric effect with the filter in the photon beam path and without the Be filter in the path, direct to the copper end stop. We measured 7.0 percent of the total current with the filter compared to without, which agreed with estimated current using the beryllium transmission results from an NSLS study⁴, the distribution of photons at various energies⁵ for the NSLS X-ray ring, and the quantum efficiencies⁷ for copper.

On the NSLS VUV ring, at Beamline U10B we previously measured⁶ $0.4 \mu\text{a ma}^{-1} \text{ mrad}^{-1}$ for white light directly on the same water cooled copper beam stop. On X28A we now measure $0.7 \mu\text{a ma}^{-1} \text{ mrad}^{-1}$ for white light directly on the copper stop, which is a factor of 1.6 from the

VUV to X-ray ring. The result would be a corresponding higher PSD yield for the X-ray ring white light since gas desorption has been shown to be mediated by photo electrons^{6,8,9,10}.

During the white light exposures, the beryllium filter was periodically moved in and out of the photon beam path during the exposure. The filter is water cooled and is opaque to photons with energies less than approximately 2 KeV. The filtered white light results in a larger photo desorption coefficient (η) than the unfiltered white light results (see Figures 2 and 3). Since the quantum efficiency (electron/photon) is less at higher energy and PSD has been shown to be a two step process depending on photoelectrons, the PSD yield should be less using the filter. The photon beam is probably scattered a little by the filter. The scattered beam would therefore hit a larger area which includes surfaces only slightly desorbed by diffuse photons and still contains a much larger number of more loosely bound surface gas. No photons had been detected striking the copper strip in the welded chamber (i.e. scatter) with the Be filter in the beam path and with the photons direct to the photon stop. The PSD effect is greater after longer exposure to white light since the added area of primary incidence using the filter has been desorbed less than the area without the filter.

B. Welded Copper Chamber

The PSD results for the welded chamber are shown in Figure 2 are compared with results for the extruded chamber and previously reported U10B results in Table 1. The amount of gas desorbed is given in Table 2 and the measured specular reflection is given in Table 3. The specular reflection was the same as that found for the B-factory prototype on beamline U10B. Compared to the VUV results for the prototype copper chamber baked to 200° C (see Run 1 Ref. 1); the H₂ yield is a factor of two higher, CO and CO₂ are roughly the same although CO₂ is larger than CO and CH₄ is slightly lower. Yields for O₂ were always less than CH₄. Yields for H₂O are

not calibrated and are shown for reference. The clean up rate is a little better for the VUV prototype. The agreement is good considering the incident angle is smaller, the energy is larger, the welded chamber was pre-baked and argon glow conditioned. Increased energy and/or a smaller incident angle have been shown to increase PSD, whereas bake and glow discharge condition have been shown to decrease PSD.

Our results are slightly lower than recent DCI published¹⁰ results for OFHC copper. The agreement is excellent when estimating the factors for energy, angle, and chamber preparation. We also note a temperature dependence as did the DCI researchers¹⁰. Both the extruded and the welded B-factory chambers had only ambient air cooling during the runs and their temperatures increased 5 to 10° C during exposures; no change in H₂ and CH₄, a slight change in CO and CO₂ and a significant increase in H₂O and O₂ yields were noted.

C. Extruded Copper Chamber

The PSD results for the extruded chamber are shown in Figure 3 and compared in Table 1. The amount of gas desorbed is given in Table 2 and specular reflection in Table 3. The specular reflection is more than twice that of the welded chamber. Initial white light PSD values for principal gases from the extruded chamber were approximately double those measured for the welded chamber. After exposure to 10²³ photon the PSD values were almost the same. We also found CO₂ higher than CO for extruded chamber PSD on the X-ray beamline as was found with the welded chamber. The PSD results with the Beryllium filter are within a factor of two of that found for the welded chamber result for H₂, CO, and CO₂, initially and after 10²³ photon exposure. The total amount of gas desorbed after 10²³ photons of exposure is almost the same

IV CONCLUSIONS

The PSD results with the Beryllium filter in the beam path were increased due to a slight

scattering of the photon beam by the filter. We did not measure the beam scatter, but since we did not detect any photons on the copper strip during the welded chamber measurement direct to the stop, significant scattering must be less than 15 mrad. The primary photon incident area is increased due to the slight scattering.

Either welded or extruding chamber construction is acceptable for B-factory vacuum beam chamber construction. After 10^{23} photon meter⁻¹ exposure the PSD results are almost the same.

Specular photons from the extruded chamber are almost twice that from the welded chamber. The result most likely due to internal surface finish of the extrusion.

The amount of gas desorbed after 10^{23} photon exposure is almost the same for the welded and the extruded chamber.

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TABLE 1

PHOTON STIMULATED DESORPTION FOR PRINCIPAL GASES

(see Fig. 1 and 2 also Fig. 6, Ref. 1)

Beamline	Chamber	Be Filter In	Exposure Photons	Gas Yield η (Mol./Photon)			
				H ₂	CO	CO ₂	CH ₄
X28A	Welded	No	10 ²¹	5.0 x 10 ⁻⁴	6.0 x 10 ⁻⁵	8.0 x 10 ⁻⁵	5.0 x 10 ⁻⁶
X28A	"	"	10 ²³	8.0 x 10 ⁻⁵	4.0 x 10 ⁻⁶	1.2 x 10 ⁻⁵	1.0 x 10 ⁻⁶
X28A	Welded	Yes	10 ²¹	2.2 x 10 ⁻³	3.0 x 10 ⁻⁴	5.0 x 10 ⁻⁴	5.2 x 10 ⁻⁵
X28A	"	"	10 ²³	8.0 x 10 ⁻⁵	8.0 x 10 ⁻⁵	1.2 x 10 ⁻⁴	2.2 x 10 ⁻⁵
X28A	Extruded	No	10 ²¹	8.0 x 10 ⁻⁴	1.2 x 10 ⁻⁴	1.8 x 10 ⁻⁴	1.2 x 10 ⁻⁵
X28A	"	"	10 ²³	5.0 x 10 ⁻⁵	4.0 x 10 ⁻⁶	1.3 x 10 ⁻⁵	3.2 x 10 ⁻⁷
X28A	Extruded	Yes	10 ²¹	2.6 x 10 ⁻³	4.0 x 10 ⁻⁴	5.0 x 10 ⁻⁴	1.2 x 10 ⁻⁴
X28A	"	"	10 ²³	5.0 x 10 ⁻⁴	4.0 x 10 ⁻⁵	7.0 x 10 ⁻⁵	2.2 x 10 ⁻⁵
U10B ^{Ref 1}	Welded	No	10 ²¹	3.0 x 10 ⁻⁴	2 x 10 ⁻⁴	1.2 x 10 ⁻⁴	1.5 x 10 ⁻⁵
U10B ^{Ref 1}	"	"	10 ²³	5.0 x 10 ⁻⁵	1.2 x 10 ⁻⁵	8.0 x 10 ⁻⁶	4.0 x 10 ⁻⁷

TABLE 2

GAS DESORBED FROM PROTOTYPE CHAMBERS

DURING PHOTON EXPOSURE (Torr-Liter)

Chamber	Gas	Total Photon Exposure			
		10^{20}	10^{21}	10^{22}	10^{23}
Extruded	H ₂	0.0751	0.307	0.643	1.58
"	CH ₄	0.00319	0.00927	0.0127	0.0203
*	CO	0.0183	0.0629	0.116	0.198
"	CO ₂	0.0214	0.0714	0.141	0.357
Welded	H ₂	0.0476	0.176	0.488	1.62
"	CH ₄	0.00087	0.00303	0.00822	0.0230
"	CO	0.00822	0.0301	0.0753	0.138
"	CO ₂	0.0128	0.0418	0.119	0.355

TABLE 3
SPECULAR REFLECTION FROM COPPER CHAMBERS
FOR 25 DEGREE INCIDENT WHITE LIGHT

Chamber	Dose Photons	Beam Stop Current $\mu\text{a/ma}$	Reflection %
Welded	10^{20}	0.108	4.17
"	10^{23}	0.090	3.49
Extruded	10^{20}	0.251	9.73
"	10^{23}	0.219	8.49

FIGURE LEGENDS

FIG. 1 Schematic Diagram of X28A Beamline and Test Chamber Set Up:

SS - Safety Shutter, BS- Beam Stop, SIP - Sputter Ion Pump, TSP- Titanium Sublimation Pump, NIG - Nude Ion Gauge, RGA - Residual Gas Analyzer, V1a, V2a, and V3a - All metal gate valves. There are other components between the Safety Shutter and the X-ray Ring not shown. Source point distances are in centimeters.

FIG. 2 Molecular Desorption yields for electron beam welded oxygen free high conductivity copper B-factory vacuum chamber. Filled in gas molecule symbols indicate Beryllium filter was in the photon beam path.

FIG.3 Molecular desorption yields for extruded oxygen free high conductivity copper B-factory vacuum chamber. Filled in gas molecule symbols indicate the Beryllium filter was in the photon beam path.

X28a Beamline

FIG 1.

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FIG. 2

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FIG 3
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