COMPARISON OF PHOTODESORPTION YIELDS FROM ALUMINUM STAINLESS AND
CU-PLATED BEAM TUBES*

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Photon Stimulated Desorption (PSD) from the walls of beam ducts constitutes the most serious gas load in storage rings and therefore exerts a great influence on both beam quality and lifetime. With the exception of the SSC which plans to use a Cu-plated beam tube, all existing and proposed machines use either aluminum or stainless steel beam tubes. In order to develop techniques for producing surfaces with the lowest PSD, we have studied the above materials using a dedicated beam line at the National Synchrotron Light Source (NSLS). Three meter long tubes were exposed to white light beams having critical energy of 500 eV and the desorption yields were measured as a function of beam dose. Several treatments commonly used for cleaning surfaces (prebaked, baked, fired, chemically cleaned and dc glow discharged) were investigated, and their relative merits are discussed. The results from sample tube measurements are compared with those from the X-ray ring Al beam tube during operation. The agreement is found to be quite good. Glow discharge cleaned stainless steel exhibited the lowest desorption yield.

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I Introduction

The most commonly used metals in accelerators and storage rings are aluminum and stainless steel. Until recently copper was used only in RF cavities and photon absorbers. With the advent of the SSC, Cu-plated stainless tubes have also been envisioned as beam chambers.

Once the materials for a vacuum system have been selected, they are subjected to various treatments¹ in order to lower both thermal and photon, ion and electron stimulated desorptions. Since we are mainly interested in storage rings, where photo-desorption predominates, we will limit our discussion to PSD. Incidentally, ion and electron desorption are also lowered by surface treatment used to lower PSD. The work reported was carried out on the VUV ring, the X-ray ring and U10B beam line.

Pertinent quantities and equations used in evaluating our results are^{2,3}:

$$\text{Photon Flux, } \dot{N} = 8.08 \times 10^{17} I E f N(r) \quad (\text{photons/s}) \quad (1)$$

$$\text{Radiated Power, } P = 88 I E^4 \rho^{-2} f E(r) \quad (\text{W}) \quad (2)$$

$$\text{Critical photon energy, } \epsilon_c = 2.2 \times 10^3 E^3 \rho^{-1} \quad (\text{eV}) \quad (3)$$

$$\text{FWHM vertical angular spread, } \psi_{\max} = \frac{1}{2} (\epsilon_c / \epsilon)^{1/3} \quad (\text{rad}) \quad (4)$$

Where I = beam current (mA), E = beam energy (GeV), ρ = dipole bending radius (m), γ = relativistic factor, ϵ = photon energy (eV), and fN and fE are plotted in Ref 2 and 3 as functions of (ϵ/ϵ_c) .

Desorption coefficients η (molecule photon⁻¹) are calculated⁴ from specific pressure rise $\Delta P/I$ and plotted versus accumulated

photons. In all experiments vertical opening angle was 4.5 mrad which yields $\gamma \psi = 3.4$. $\psi_{\max}$ corresponds to 13 eV. Thus only photons with energy < 10 eV are excluded in significant numbers. Using Ref. 2 and 3, more than 98% of radiated power and 60% of all photons are incident on the tube samples. Due to the low energy of the excluded photons, the effect on η is small, as shown in Fig. 1, where pressure rise from the sample and photo current from a wire traversing the photon beam are plotted as a function of vertical angle ⁴. All photons up to a = 11 mm strike the sample. In order to be able to compare our results with those of other labs, all radiated photons ($\dot{N}$) are used to calculate η .

II Experimental Runs

Desorption studies were carried out on the U10B beamline (Fig. 2) which was described previously⁴. Briefly, a white photon beam with $\epsilon_c = 500$ eV strikes 3m long tubes at ~ 10 mrad incidence. The following tubes with various surface treatment were measured:

Aluminum ⁴	A-1	baked at 150° C
	A-2	90%A 10%O ₂ GDC
	A-3	N ₂ GDC
	A-4	RF GDC
Stainless Steel ⁵	SS-1	pre-baked
	SS-2	baked 200° C.
	SS-3	90%Ar 10%O ₂ GDC
	SS-4	Vacuum fired at 950°C
Cu-plated Stainless ⁵	Cu-1	pre-baked
	Cu-2	baked 270°C

In Fig. 3 we compare A-1, SS-1 and Cu-1. A-1 had standard NSLS chemical cleaning¹ and a 150°C, 24 hour in-situ bake. SS-1 was pre-baked for 48 hours, bled up to LN₂ boil-off, installed and pumped for five days until $P = 1.5 \times 10^{-9}$ Torr was reached. Cu-1 was pre-baked at 250°C for five days to remove plating contaminants (predominantly fluorocarbons peak 69 AMU in Fig 4). It was bled up to LN₂ boil-off, installed and pumped for a week to reach $P = 1.5 \times 10^{-9}$ Torr. It is seen in Fig. 3 that SS-1 and Cu-1 η s are almost identical. The only difference not included in this figure is the high H₂O peak ($\approx$ CO peak) which persisted throughout the entire run and the high content of fluorocarbons. A test run of a pre-baked Al tube was started but was terminated, because very high initial η s especially for H₂O would have required lengthy low current operation.

In Fig. 5 we compare A-3 and SS-3 which represent the lowest η s for the two metals. A-3⁴ was first glow discharged (GDC) in 90% A 10% O₂ followed by N₂ GDC (4×10^{17} ions cm⁻² at 150°C), bled to LN₂ boil-off, installed and baked at 200°C for twenty-four hours. SS was GDC in 90%A 10% O₂ ($\sim 10^{18}$ ions cm⁻² at 200°C), bled up to LN₂ boil-off, installed and baked at 200°C for twenty-four hours.

In Fig. 6 we compare three commonly employed stainless steel surface treatments used in storage rings: SS-2, SS-3 and SS-4. All three samples were baked for twenty-four hours at 200° C after installation. SS-4 was fired in a vacuum furnace at 950°C for two hours and $P = 10^{-5}$ Torr.

III X-Ray Ring Results

The data presented allow us to make some predictions as to how much time is likely to be required to reach reasonable beam lifetime since it is governed by beam-gas interaction. Furthermore, Coulomb scattering for CO and CO₂ is fifty and eighty times more effective in degrading lifetime than H₂. Hence H₂ is omitted in subsequent figures. $\Delta P/I$ in the X-Ray ring dipole Al chamber baked to -120°C decreases by a factor of four from 1 to 7×10^{23} photons/m during initial commissioning (Fig. 7)⁶. $\Delta P/I$ is plotted rather than η because the pumping speed is not known sufficiently well. Assuming $S < 100$ l/s m in the dipole magnet, η_{co} at 1×10^{23} photons/m $\leq 4 \times 10^{-5}$. This should be compared to $\eta_{co} = 8 \times 10^{-5}$ for the same number of accumulated photons in baked Al in Fig. 3. Similarly, the decrease in η_{co} by a factor of four with an accumulated dose of 7×10^{23} photons m⁻¹ (Fig. 7) should be compared to a decrease by a factor of 3.2 in Fig. 3. One must remember that in the dipoles 25% of photons were extracted into beam lines, ϵ_c was 1700 eV instead of 500 eV (Fig. 3) and additional commissioning was carried out at 175 eV during stacking and ramping. Despite this, the agreement between Fig. 3 and 7 is quite good. A decrease in η_{co} and η_{co_2} by a factor of ~10 and 40, respectively, occurred after 600 A-hours of operation at 2.5 GeV, which corresponds to $\sim 6 \times 10^{25}$ photons/m (Fig. 8). Only a small change occurred between 400 and 600 A-hours. All $\Delta P/I$ s reported have been measured in the dipoles, where photon flux is the highest. In

machine straight sections $\Delta P/I$ s are almost ten times lower, which results in a lower average $\Delta P/I$ used to calculate lifetimes.

Finally we have also measured $\Delta P/I$ as a function of beam energy between 0.75 and 2.5 GeV (Fig. 8) which corresponds to ϵ_c between 147 and 5000 eV (Fig. 9). We note that high energy machines are more efficient in achieving good lifetimes (shorter commissioning time) for two reasons:

- a. $\dot{N}$ is proportional to machine energy E (Eq 2)
- b. higher energy photons have higher η_s (Fig.9)

This is evident in the VUV (.75 GeV) and X-Ray rings (2.5 GeV). As the machine becomes conditioned the slope of the curves in Fig. 9 decreases.

IV Conclusions

Based on the measurements carried out on both the X-Ray ring and the U10 beamline, we draw the following conclusions:

1. η_s measured in long tubes predict adequately partial pressure behavior of electron storage rings during operation and can be used to estimate lifetimes.
2. 5 keV photons are ~ 4.5 times more effective in desorbing CO and CO₂ than 150 eV photons.
3. After a week of pumping to a pressure $\sim 1 \times 10^{-9}$ Torr, the water peak in an unbaked stainless tube is desorbed within $\sim 10^{23}$ photons m^{-1} . In a storage ring this is likely to take longer due to reflected photons.
4. PSD yields of common gases found in vacuum systems, i.e., H₂, CO and CO₂, are similar in Cu and stainless for comparable surface treatments.

5. Aluminum exhibits initial yields between 10 and 100 times greater than stainless. The steeper slope in aluminum catches up with stainless within a dose of $\sim 10^{24}$ photons m^{-1} .
6. The lowest η s are measured on surfaces which are subjected to glow discharge cleaning.
7. Plated Cu requires a long 300°C vacuum bake to make it compatible with storage ring operation.⁵
8. Fig. 3 suggests that in situ bake-out may not be necessary for stainless steel vacuum chambers, which represents an additional advantage. In situ bake is essential in both NSLS storage rings employing aluminum beam tubes after every exposure to the atmosphere. Otherwise, conditioning time would be prohibitively long.

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FIGURE CAPTIONS

FIG. 1 RELATIVE PRESSURE AND PHOTOCURRENT VS DISTANCE FROM BEAM CENTER FOR A SLIT WIDTH OF 1.3 mm.

a - 10 mm CORRESPONDS TO VERTICAL HALF ANGLE $\psi/2 = 2.2$ mRAD.

FIG. 2 SCHEMATIC DIAGRAM OF U10B BEAMLINE AND TEST CHAMBER.

Mk - MASK;

FV - FAST VALVE;

SS - SAFETY SHUTTER

BS - BEAM STOP;

C_V AND C_H - VERTICAL AND HORIZONTAL COLLIMATORS;

B - BELLOWS;

O1 AND O2 - ORIFICE

FIG. 3 COMPARISON OF DESORPTION YIELDS FOR BAKED ALUMINUM (A-1), PRE-BALED STAINLESS (SS-1) AND PRE-BAKED CU PLATED STAINLESS (Cu-1).

FIG. 4 DESORPTION YIELDS OF PRE-BAKED Cu PLATED STAINLESS.

FIG. 5 COMPARISON OF DESORPTION YIELDS FOR GLOW DISCHARGED ALUMINUM (A-3) AND STAINLESS (SS-3).

FIG. 6 COMPARISON OF DESORPTION YIELDS FOR BAKED (SS-2), FIRED (SS-4) AND GLOW DISCHARGED (SS-3) STAINLESS STEEL.

FIG. 7 NORMALIZED PRESSURE RISE $\Delta p/I$ IN X-RAY RING DIPOLE DURING INITIAL CONDITIONING OF FIRST 7 A-HRS.

FIG. 8 NORMALIZED PRESSURE RISE $\Delta P/I$ IN X-RAY RING DIPOLE VS BEAM
ENERGY (1 A-HOUR $\approx 1 \times 10^{23}$ PHOTONS/m).

FIG. 9 $\Delta P/I$ IN X-RAY RING DIPOLE VS CRITICAL PHOTON ENERGY.