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MEASUREMENT OF THE PHOTON STIMULATED DESORPTION FOR VARIOUS VACUUM TUBES AT A BEAM LINE OF TLS

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Abstract

For most light sources, the synchrotron radiation (SR) hit on the beam ducts or absorbers results in higher pressure-rise and the consequent higher radiation level through the commissioning stage. Various surface treatments, e.g. chemical cleaning, oil-free machining, NEG-coating, etc., for the beam ducts or absorbers have developed worldwide for mitigating the yield of Photon Stimulated Desorption (PSD). A beam line, BL19B, of 1.5 GeV Taiwan Light Source (TLS) have modified to measure the PSD-yield of the vacuum tubes. The white light of BL19B covers the critical length at 2.14 keV is suitable for generating higher yield of the photo-electrons (PEY) and the consequent PSD-yield to be measured can be resolved wide range of $10^{-2} \sim 10^{-7}$ molecules/photon. The PSD-outgas, measured by RGA, contains the typical H_2, CO, CO_2, hydrocarbons (C_xH_y), and the Kr from NEG-coating, the alcohol from ethanol-machined surface in some cases. The effect of beam cleaning reflects the PSD-molecules generated from the SR-irradiated surface. This paper will describe the results about PSD-measurement for various vacuum tubes.

INTRODUCTION

The beamline BL19B(PSD) of the 1.5 GeV Taiwan Light Source (TLS) has been constructed since 1999 and dedicated to measure the photon stimulated desorption (PSD) from the samples at UHV for inspecting the qualities of the surface cleaning. The TLS, at the critical photon energy of 2.14 keV, has routinely operated at 362 mA top-up mode that delivered an angular power of 7.35 W/mrad. The yield of PSD was obtained via the throughput method that measures the pressure rise near the sample converted to the outgassing rate and divided by the photon flux. The outgas molecules desorbed from the surface irradiated by the synchrotron radiation (SR) reflects the concentration of the atoms out of the absorbed or residual molecules on the surface or oxide layers. In this paper, the sample tubes including the aluminum (AL), provided by NSRRC, and the titanium (Ti), stainless steel (SS) with NEG-coating, provided by ASTeC were measured. Selection of the tube-materials considered the application as the beam ducts for most of the accelerators that the results of the PSD experiment must be interesting to be a reference.

EXPERIMENTAL

The experiment was carried out by introducing the horizontal photon span of 2.53 mrad, confined by the XY-Slits, from the TLS-BL19B beamline [1]. A machined Reducer Flange (tilted-angle: 3°) was inserted between the beamline and the sample tubes (38 mm I.D., 0.5 m length) that spreads the photon beam on the inner side of tube uniformly. Figure 1 and Fig. 2 show the photographs and the layout of the BL19B (PSD) beamline respectively. In Fig. 2, P1 and P2 indicate the pressures measured closed to the sample tube and the end of beamline, respectively. An aluminum pipe, I.D. 20×68 mm and Long 0.8 m, possesses a conductance (label "C" in Fig. 2) of 10 l/s for the throughput-measurement [2]. A residual gas analyser (RGA) installed near the P1-gauge measures the outgas species dominantly from the tube.

Figure 1: The BL19B (PSD) beamline at TLS.

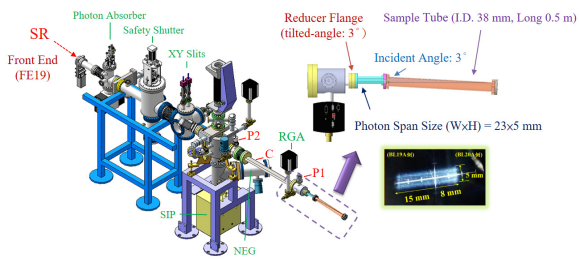

Figure 2: Layout of the experimental system at BL19B.

The four sample tubes for the measurement are listed in Table 1. The AL-1 and AL-2 tubes were machined inside with ethanol (Eth), then AL-2 tube was further cleaned with ozonied water (O_3W: 10 ppm, 30 min) [3]. The Ti-3 tube was originally cleaned via standard proceedure of ASTeC [4], and cleaned with O_3W at NSRRC prior to the experiment. The SS-4 (NEG) tube was prepared and coated the Dual-NEG, TiZrV column and dense, film at ASTeC. All the tubes except the SS-4 were in-situ baked at 150°C, 24 h to the UHV at the ultimate pressure under 2×10^{-10} Torr (2.7×10^{-8} Pa) at the beamline prior to the experiment. While the SS-4 tube was first baked at 80°C, 24 h, only for inspecting the PSD without NEG-activation within a short exposure beam dose (< 0.8 Ah), and then activated the NEG at 180°C, 24 h for another PSD measurement with long exposure dosage afterwards.

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The yield of the PSD (η) is calculated from the PSD outgassing rate (Q) divided by the photon flux (Ṅ), as shown in the following equations [1]:

$$\dot{N} = 8.05 \times 10^{17} E \cdot I \cdot \frac{\varphi}{2\pi} = K \cdot I \quad (1)$$

$$Q = C(P1 - P2) \quad (2)$$

$$\eta = \frac{Q}{\dot{N}} = \frac{C}{K} \cdot \frac{(P1-P2)}{I} \sim 676230 \cdot \frac{dP}{I} \quad (3)$$

where E (beam energy) = 1.5 GeV, I (beam current), C (conductance) = 10 l/s, and φ (photon span) = 2.53 mrad.

Table 1: Sample Tubes for the Experiment

Label (note)	Treatment prior to SR exposure
AL-1 (Ethanol)	In-situ Bake (150°C, 24h)
AL-2 (Eth+O_3W)	In-situ Bake (150°C, 24h)
Ti-3 (O_3W)	In-situ Bake (150°C, 24h)
SS-4 (NEG)	(a) In-situ Bake (80°C, 24h)
	(b) Activation (180°C, 24h)

RESULTS AND DISCUSSIONS

The trends of pressure (P1, P2) and the RGA spectra during the in-situ baking, activation of the NEG, and the PSD measurement for the four sample tubes as shown the plot curves, figures, and the analysis are described in the following subsections, respectively.

In-situ Baking

The vacuum system including the sample tube, closed to the gauge-P1, and the ambient chambers, between gauge-P1 and P2, was in-situ baked out after replacement of the tube. Figure 3 depicts the typical curves of the pressures (P1, P2) and temperature of tube and ambient chamber, as well as the RGA spectra from the AL, Ti, SS tubes, through the baking. The ultimate pressure achieved the UHV after baking. The initial outgas typically contained the H_2O, H_2, CO, CO_2, and Hydrocarbons (C_xH_y), similar for all the tubes. Most of them were desorbed from the physi-sorption.

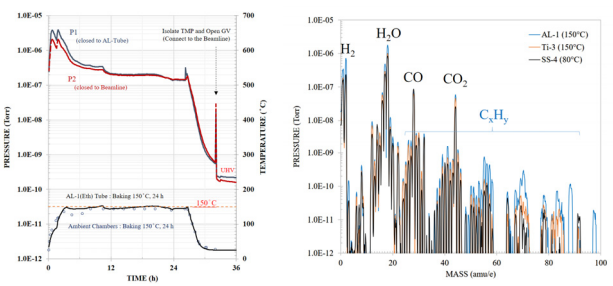

Figure 3: Curves of pressures, temperature, and RGA spectrum for the AL, Ti, and SS tubes during the baking.

Activation of the NEG

The NEG film in the SS-4 tube was activated by heating the tube up to 180ºC for 24h with the tape-heater wrapped on the tube, while the ambient chamber was kept at room temperature. Figure 4 shows the trend curves of pressure, temperature, and the RGA spectrum, through the activation. The initial outgas contains majorly the H_2, CH_4, C_2H_4, CO_2, and Kr. The Kr desorbed from the film was the discharge gas during the NEG-coating. Although the pressures rise in the preliminary 8 hours of activation was reduced to over 100 times lower value ~ 2×10^{-9} Torr, however the desorption of C_xH_y and Kr was maintained till cooling down.

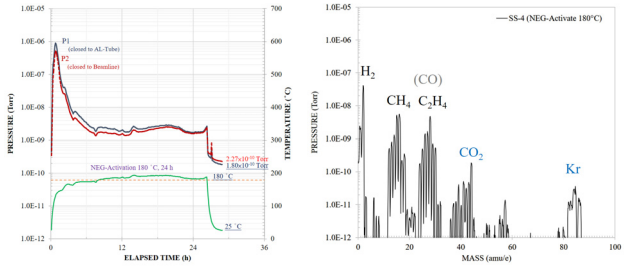

Figure 4: Curves of pressures, temperature, and RGA spectrum for the SS-4 tube during the NEG-activation.

PSD Measurement

The curves of the PSD-yield (η) versus the accumulated photon dose (*D*) for the four tubes are illustrated in Fig. 5. It is easier to estimate the accumulated beam dose (Ah) by converting the unit of photon dose, i.e. 1 ampere-hour (Ah) equals to 7.963×10^{19} photons/m, through the photon exposure. The curves of AL-1, AL-2 and Ti-3 in Fig. 5 depict the split-difference at the most earlier accumulated photon dose < 2×10^{19} photons/m (~ 0.25 Ah of beam dose) and closed to each other through the long exposure afterwards. The curves declined and approached to a slope (α) ~ -1 comply with the Eq. (4). For the SS-4(NEG) tube after the NEG activation, the α ~ -0.37 and η is about 1-2 order of magnitude lower than those of other bare tubes.

$$\eta = D^{\alpha} \quad (4)$$

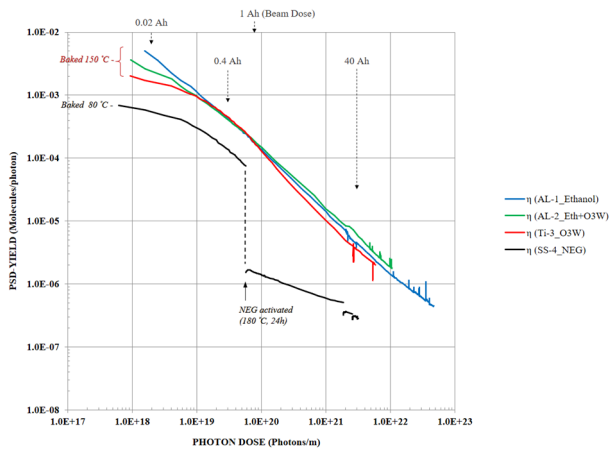

Figure 5: Curves of the PSD-yield of the four tubes versus the accumulated photon dose.

The partial pressure, measured by RGA, has normalized to the pressure by gauge-P1 through all the experiment. Figure 6 shows the trend-curves of the partial pressure rise

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versus the photon dose. The RGA spectra for each tubes at beam dose of 0.02 Ah, 0.4 Ah, and 40 Ah, are illustrated in Fig. 7 for the comparisons.

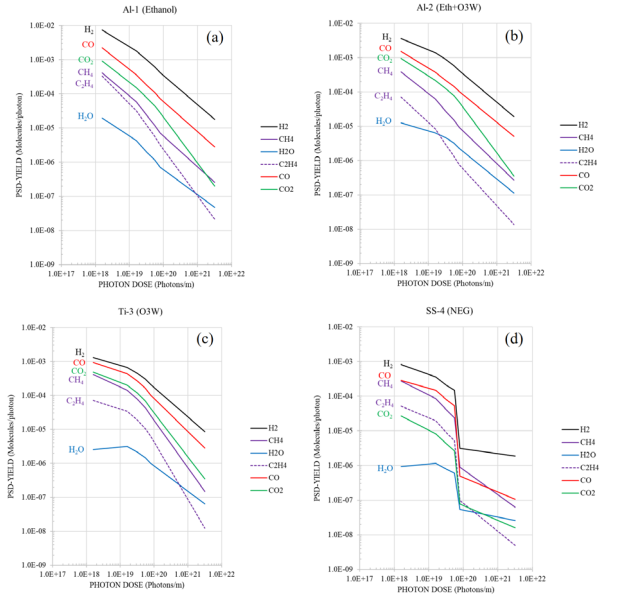

Figure 6: Curves of the partial pressure rise of the four tubes versus the photon dose during the PSD exposure.

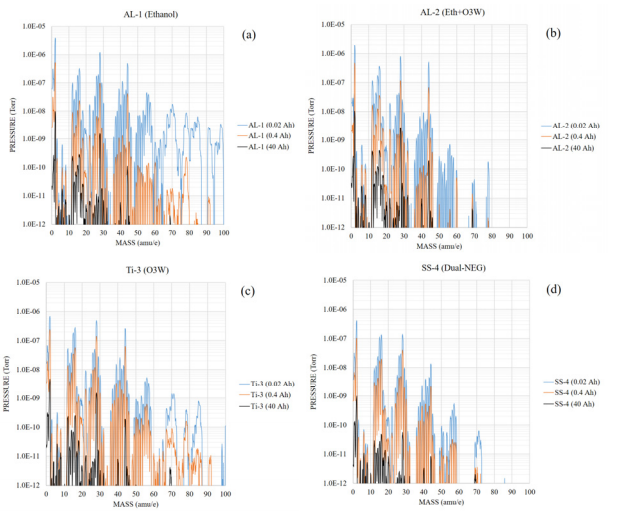

Figure 7: RGA spectra for the four tubes at beam dose of 0.02 Ah (blue), 0.4 Ah (orange), and 40 Ah (black).

From Fig. 6, typically, the PSD outgas comprises of the H_2, CO, CO_2, Hydrocarbons (CH_4, C_2H_4, etc.), and H_2O. The curves show the continuous decay of desorption along the increase of photon dose that reveals the effect of beam cleaning and the PSD outgas molecules were continuously generated from the SR-irradiated surface. In Fig. 6, the curves of partial pressure H_2 and H_2O for Ti and NEG (only baked) tubes are lower than that of AL-tubes. It reveals the non-hydroxide layers on Ti and the NEG surfaces was different from the AL surface oxides.

In Fig. 7(a), the AL-1(Eth) possesses higher η of C_xH_y at 0.02 Ah that suspected desorption from residual contaminations on the top surface. For the AL-2(Eth+O_3W) in Fig. 7(b), the η of C_xH_y at 0.4 Ah is much lower in comparison with others that reveals a low-carbon oxide layers cleaned with the ozonized water.

In case of the SS-4(NEG) tube, as shown in Fig. 6(d) and Fig. 7(d), the partial pressure of the H_2, CO, CO_2 are much lower than that of other tubes and presented a much lower yield of PSD from the fresh surface after NEG-activation.

CONCLUSION

The BL19B (PSD) beamline of 1.5 GeV Taiwan Light Source (TLS) is capable of measuring the PSD-Yield and inspecting the residual atoms on the sample surface and the consequent desorption behaviour efficiently and precisely. A quick experiment for each sample tube takes 2 weeks including the installation, baking, and the PSD measurement up to 40 Ah beam dose, thanks to the top-up operation mode of TLS at beam current of 362 mA. The yield of PSD was measured via the throughput method that covers a wide range of η in $10^{-2} \sim 10^{-7}$ molecules/photon. The results depict the similar behaviour of the PSD between the bare tubes, AL and Ti, with efficient ethanol machined or ozonized water cleaned surface qualities. While the PSD from the SS (NEG) tube possesses relatively lower desorption yield especially after the activation of the NEG film that refreshed the surface. Desorption of the C_xH_y and Kr appears through the NEG-activation that presents the degassing property and eliminates after cool-down. However, sometimes the residual inert outgases were observed in the PSD-measurement. More works on in-situ measurement of the photon electron yield (PEY) associated with the PSD yield will carry out on BL19B beamline in the near future.

REFERENCES

[1] G. Y. Hsiung and C. M. Cheng, "Directly oil-free machined aluminum ultrahigh vacuum parts for the beamline screen monitor", *AIP Conf. Proc.,* vol.2054, p. 060055, 2019.

[2] P. A. Redhead, "Recommended practices for measuring and reporting outgassing data", *J. Vac. Sci. Technol.,* vol. A20, no. 5, pp. 1667-1675, 2002.

[3] J. R. Chen *et al*, "Vacuum system of the 3 GeV Taiwan Photon Source", *J. Vac. Sci. Technol.,* vol. A28, no. 4, pp. 942-946, 2010.

[4] O.B. Malyshev, *Vacuum in Particle Accelerators.* Willey, 2020, pp. 102-105.