MEASUREMENT OF THE PHOTOELECTRON YIELD FROM THE SYNCHROTRON RADIATION FOR THE NEG-COATED TUBES

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Abstract

NEG-coated chambers have been adopted as the beam ducts for large particle accelerators and synchrotron light sources for the sake of the lower yields of the photon stimulated desorption (PSD) and the photoelectrons (PE) from the NEG films in addition to their pumping performance. Measurement of the photoelectron yield (PEY) was performed at the BL19B (PSD) beamline of the 1.5 GeV Taiwan Light Source (TLS) which simultaneously measures the PSD-yield. An aluminium cathode was inserted in the tubes and a positive bias of voltage for extraction of the photoelectrons applied. The PEY was obtained by dividing the photoelectron current by the photon flux of the synchrotron radiation. Measurements of the PEY include various types of NEG-coated stainless steel tubes and the bare tubes of titanium and aluminium alloys for the comparison. The experimental system and the results will be described in this presentation.

INTRODUCTION

For large particle accelerators, extraction of the photoelectrons generated by the synchrotron radiation from the beam duct results in an e-cloud problem. For synchrotron light sources, significant outgassing from the surface of beam duct induced by the photon stimulated desorption (PSD) causes a beam instability problem. Investigations to find the lowest yield of PSD (ηPSD) and photoelectron PEY (ηe) from beam ducts with various surface treatments or interior coatings become important for designing a new machine. Nowadays, NEG-coated chambers adopted for large accelerators have become popular and investigations of the ηPSD or ηe for NEG-coated tubes by synchrotron radiation have been studied in some light source facilities [1, 2]. It should be interesting to know the relationship between ηPSD and ηe and if they can be simultaneously measured. The BL19B, a white-light beamline of the 1.5 GeV Taiwan Light Source (TLS), has been dedicated to measuring the PSD (ηPSD) of sample tubes or sheets at a critical energy of 2.14 keV [3]. It is able to simultaneously measure the ηe, by inserting a metallic cathode into the sample tubes closed to the photon-exposure area, during the PSD-measurement. The NEG-coated tubes to be measured were prepared by ASTeC with different compositions of NEG film for various purposes. The measurement of the ηPSD and ηe for the NEG-tubes at BL19B beamline is described.

EXPERIMENTAL

Beamline BL19B for the Measurements

The beamline BL19B at TLS extracts a confined photon span angle (ϕ) of 2.53 mrad of synchrotron radiation (SR) from a bending magnet to the sample tube for measuring the PSD-yield (ηPSD), as shown in Fig. 1 [3]. The total photon flux (N), in units of photons/s, is obtained from Eq. (1) [4]. Figure 2 shows the schematic layout of PEY-measurement in which an aluminum stick, 2 mm thick and 400 mm long, as an “Al-cathode” to measure the PEY (ηe), was inserted into the sample tube from the end. This cathode, had a positive bias voltage (+V) applied, the photoelectrons from the SR-irradiated surface of the tube during the photon exposure are extracted and measured by a pico-ammeter (A) shown as the electric loop in Fig. 2. By transforming the value of the current (-Ie) to the photoelectron flux (Ne), in units of electrons/s, in Eq. (2), the PEY (ηe) defined by Ne/N in Eq. (3), in unit of electrons/photon, is obtained.

\[
N = 8.05 \times 10^{17} E \cdot I \cdot \frac{\phi}{2 \pi} = K \cdot I
\]

\[
N_e = \frac{I_e}{1.6 \times 10^{-19}} = C \cdot I_e
\]

\[
\eta_e = \frac{N_e}{N} = \frac{C \cdot I_e}{I} \approx 12.78 \left( \frac{I_e}{I} \right)
\]

Figure 1: BL19B beamline for PSD-measurement [3].

Figure 2: Schematic layout of PEY-measurement.

- Ne: Total photon flux in units of photons/s
- Ne: Total photoelectron flux in units of electrons/s

In these equations, E (beam energy) = 1.5 GeV, I (beam current) ~ 362 mA (top-up), ϕ (photon span) = 2.53×10^{-3} rad, Ie (photoelectron current) is in units of Amperes.

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Table 1 lists the sample tubes, of inner diameter 38 mm and length 0.5 m, to be measured. Those tubes made of 316LN stainless steel (SS-) were coated with different compositions of the Non-Evaporable Getter (NEG) films provided by the vacuum science group of ASTeC, STFC, UK [5]. The three samples: SS-1(NEG-c), SS-2(NEG-t), SS-3(NEG-d) represent a conductive-NEG (TiZrVAg) [6], a triple-layer-NEG (columnar/dense/TiZrVN), and a dual-layer-NEG (columnar/dense TiZrV) [7], respectively. The experiment for each tube was carried out by the procedure: (1) install the tube at BL19B and bake (Ba-), at 80°C for the NEG-tube and 120°C for the ambient chambers, to UHV, (2) SR-exposure to a beam dose < 1 Ah for measuring the $\eta_{PSD}$ and $\eta_e$ of the NEG (Baked without activation), (3) activate the NEG (Ac-) at 180°C for 24 hours, 24°C for ambient chambers, (4) continue the SR-exposure to higher beam dose for measuring $\eta_{PSD}$ and $\eta_e$ after activation. To compare with bare tubes without NEG-coating, an aluminium (Al) tube provided by NSRRC and a titanium (Ti) tube provided by ASTeC were measured for $\eta_{PSD}$ and $\eta_e$, respectively. The non-coated tubes were baked at 150°C, 24 h to UHV prior to the experiment.

Table 1: Sample Tubes for the Experiment

<table>
<thead>
<tr>
<th>Label of Tube</th>
<th>Composition of the NEG</th>
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<tbody>
<tr>
<td>SS-1 (NEG-c)</td>
<td>conductive (TiZrVAg)</td>
</tr>
<tr>
<td>SS-2 (NEG-t)</td>
<td>triple-layer (columnar/dense/TiZrVN)</td>
</tr>
<tr>
<td>SS-3 (NEG-d)</td>
<td>dual-layer (columnar/dense TiZrV)</td>
</tr>
<tr>
<td>AL</td>
<td>Ozone water (O3W) cleaned</td>
</tr>
<tr>
<td>Ti</td>
<td>Chemical cleaned + O3W cleaned</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSIONS

Measurement of PSD-Yield

Each sample tube on the beamline was cooled with cooling jackets to keep the temperature rise < 0.7 °C on the tube throughout the SR-exposure. The average pressure of the entire vacuum system after baking or activation was < 2.6×10^{-8} Pa prior to the experiment. The curves of $\eta_{PSD}$ for Al, Ti, and the three SS (NEG) tubes vs. the Beam Dose (D) in unit of ampere-hour (Ah) are shown in Fig. 3, where 1 Ah equals to 7.963×10^{19} photons/m of dosage [3]. For the three SS(NEG) tubes, the left parts of curves (after baking) at D < 1 Ah are similar to each other and declined from an initial ~ 2×10^{-3} of $\eta_{PSD}$ to 1×10^{-4} molecules/photon at 1 Ah of D. The right parts of three curves (after NEG-activation), at D > 0.7 Ah almost overlap and decrease linearly with a slope ($\alpha$) ~ -0.55 and approach a $\eta_{PSD}$ ~ 1×10^{-6} molecules/photon at 10 Ah of D; “$\alpha$” is defined by Eq. (4) [3]. The two curves of the Al and Ti tubes (Fig. 3) are close to or slightly higher than those of the SS(NEG) tubes (baked), and decreased linearly at slope ($\alpha$) ~ -1. The $\eta_{PSD}$ of 2×10^{-5} and 1×10^{-5} molecules/photon for Al and Ti tubes, respectively, at 10 Ah of D are more than 10 times higher than those for SS(NEG) tubes (activated).

$$\eta_{PSD} = D^\alpha$$ (4)

Several spike-like peaks appeared on the curves in Fig. 3 representing bursts of pressure associated with gas desorption stimulated by the photoelectrons (ESD) hitting on the Al-cathode when supplied with a positive bias.

Figure 4 depicts a typical mass spectra of the residual gas from PSD, e.g. SS-2 tube, at 1 Ah (Ba-) after baking and 10 Ah (Ac-) after NEG-activation, respectively. The dominant PSD-outgas components are H2, CH4, CO, CO2, C2H6, (hydrocarbons), and a small amount of Kr. It clearly shows a significant decrease in the peaks of CO and CO2 between the two spectra in Fig. 4 that possesses the relatively lower yields of PSD from the NEG film after activation.

Measurement of PEY

During the SR-exposure for each sample tube, the photoelectron current (PE-current, $I_e$) was measured by applying a positive bias voltage, 0 ~ 1000 V, to the Al-cathode. Fig. 5 depicts the curves of the $I_e$ of tubes, after baking (Ba-) or after NEG-activation (Ac-), versus cathode bias voltage. The $I_e$ increases with increased bias voltage and reaches to approximate maximum value at 1000 V. It is assumed that more than 90% of the photoelectrons are extracted by the Al-cathode at +1000 V bias and contribute to the measurement of $I_e$. By calculation from Eq. (3), 1000...
μA of Ie equals to 0.035 electrons/photon of PEY (ηe) at a beam current (I) of 362 mA. The values of Ie for all the sample tubes (in Fig. 5) at +1000 V bias cover from 550 to 1300 μA, that equates to the ηe from 0.019 to 0.046 electrons/photon. Table 2 lists the values of PE-current and ηe for the sample tubes at various beam dose. Figure 6 depicts the values and the curves of ηe versus beam dose for each tube in the cases of either baked (Ba) or NEG-activated (Ac).

The ηe for SS(NEG) tubes "Baked", 0.024 ~ 0.036, are 1.2 ~ 1.6 times higher than "NEG activated", 0.019 ~ 0.028. While ηe of Al (Ba-) at D ~ 1 Ah is about 1.4 times higher than that of SS-3_Ba. It reveals that the NEG-coating (baked) samples possess lower ηe than the bare aluminum surface. The ηe of NEG-coating after activation is further reduced compared to those that are only baked. However, the ηe of Ti tube, 0.021 ~ 0.025, is as low as those of SS(NEG) tubes (activated). It is not clear why the Ti alloy possesses lower electron emission that is competitive with the activated SS(NEG) tubes. In Fig. 3, the curves of ηPSD for the Ti tube and baked SS-1(NEG_c) tube overlap, which implies the possibility of a similar mechanism of surface bonding and the consequent control of ESD by the ηe from the surface oxide layers. The change of ηe (in Fig. 6) for those tubes subject to even more beam dose of photon exposure is not much different.

**CONCLUSION**

The ηe for SS(NEG) tubes with different NEG-coatings and bare Al and Ti tubes was measured at beamline BL19B of the 1.5 GeV TLS. An Al-cathode inserted in the tube with a positive bias extracted the photoelectrons from the surface during SR-exposure; meanwhile the ηPSD was measured. The SS(NEG) tubes after NEG-activation possessed both lower ηe and ηPSD than those tubes after baking. The lower ηe results in a lower ηPSD, however, a longer exposure of SR beam dose decreases the ηPSD significantly with little reduction for the ηe. The SS-2(NEG_t) possesses the lowest ηe compared to the other tubes. The ηe of a bare Ti tube is as low as those of the SS(NEG) tubes after NEG-activation. More experiments on the investigation of ηPSD and ηe for NEG-coated tubes or other samples with various surface treatments or coatings can be performed at this beamline.

**REFERENCES**


