SECONDARY ELECTRON YIELD MEASUREMENTS AND GROOVE CHAMBERS UPDATED TESTS IN THE PEP-II BEAM LINE*

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Abstract

Beam instability caused by the electron cloud has been observed in positron and proton storage rings and it is expected to be a limiting factor in the performance of the positron Damping Ring (DR) of future Linear Colliders such as ILC and CLIC [1, 2]. In the Positron Low Energy Ring (LER) of the PEP-II accelerator, we have installed vacuum chambers with rectangular grooves in a straight magnetic-free section to test this promising possible electron cloud mitigation technique. We have also installed a special chamber to monitor the secondary electron yield of TiN and TiZrV (NEG) coating, Copper, Stainless Steel and Aluminum under the effect of electron and photon conditioning *in situ* in the beam line. In this paper, we describe the ongoing R&D effort to mitigate the electron cloud effect for the ILC damping ring, the latest results on *in situ* secondary electron yield conditioning and recent update on the groove tests in PEP-II.

INTRODUCTION

An electron cloud may be initially generated by photoelectrons or ionization of residual gas and increase by the surface secondary emission process. The electron cloud has been observed at many storage rings [1] and it will likely be an issue for future machines aiming at high beam intensity.

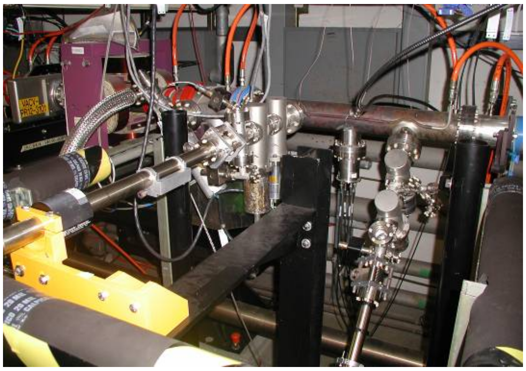

Figure 1. Installation of the SEY test chamber in the PEP-II beam line, the chamber and the two sample transferring manipulators are visible at 0º and 45º positions.

Over the last few years at SLAC, we have investigated several possible countermeasures to reduce the electron cloud effect in the ILC DR and we invested considerable effort on both simulation and experimental programs. Recently, we installed a new chicane to test electron cloud mitigations in magnet regions as discussed in a separated paper at this conference. In this paper, we describe two of experimental projects involving coating, conditioning and grooves as possible remedies.

SECONDARY ELECTRON YIELD SEY

Parameters determining the cloud formation are the secondary electron yield (SEY or δ), secondary electrons generated per incident electron, and the secondary electron energy spectrum. Typically, the peak SEY value range is δ_{max}~1.5-2.2 for as-received technical vacuum chamber materials except for aluminum with $\delta_{max}>2.3$. The SEY of technical surfaces has been measured in the past for example at SLAC [3-4], at CERN [5-6], at KEK [7-8] and in other laboratories [9].

Figure 2. Layout of the installation in PEP-II LER: Groove chambers (left chamber on upper beam line) and smooth chamber (right).

SEY Threshold and Requirements

In the arcs and wigglers sections of the ILC DR an electron cloud is expected with a high density even at low SEY values of $\delta_{max}>1.2$.

In the ILC DR, the single bunch instability threshold is for a central cloud density of 1.4e11 e/m^3 [2], which is easily generated if an electron cloud is allowed to develop. The most robust solution to mitigate the electron cloud is to ensure that the vacuum chamber wall has low secondary emission yield.

SEY TEST CHAMBER STATION

The electron conditioning or bombardment reduces the surface SEY to low values [3-9]. Nevertheless, an electron cloud is still observed in several existing storage rings. The conditioning effect may depend on the electron cloud, radiation and vacuum chamber materials as well as the residual vacuum. Thus, it is important to measure the effect of beam photon and electron cloud conditioning of samples exposed directly to an accelerator beam line.

To closely monitor the evolution of the SEY in an accelerator environment, we have built and installed a dedicated stainless steel chamber used to expose samples

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to PEP-II LER beam environment and then measure the samples surface in a laboratory set-up (transport under ultra-high vacuum by means of a load-lock system). Figure 1 and Figure 3 show a layout of the chambers installation in the PEP-II LER. An electron monitor retarding field analyzer type [10, 11] has been arranged in the test chamber.

The samples are positioned in contact with the chamber wall and facing the internal side of the beam line, as shown in Figure 4-Left. Particular care was taken to avoid beam RF leakage or the generation of higher order modes.

Two samples are inserted at a time: directly exposed to the fan of synchrotron radiation 0° or outside of the fan 45°. During beam operation, the samples are left in the beam line for a period of several weeks until access to the machine is possible. Then, the samples are transferred to the laboratory for surface analysis, as shown in Fig. 4.

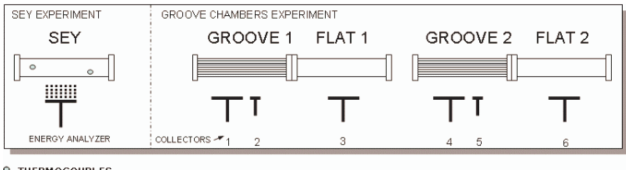

Figure 3. Layout of the electron cloud test chambers.

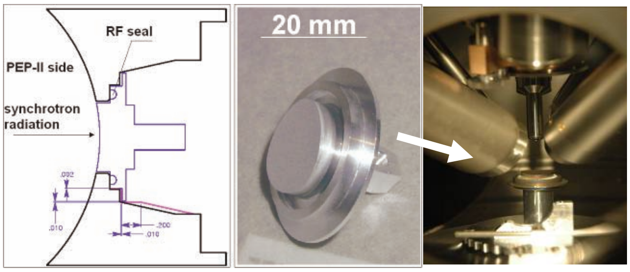

Figure 4. Left-Center-Right respectively: layout of the sample installed in the PEP-II LER chamber, sample and sample positioned in SLAC set-up for surface analysis.

SURFACE CONDITIONING

The SEY of two TiN/Al samples after two months conditioning period, e- dose ~40 mC/mm^2, decreased to δmax~0.95 similarly in both samples, from an initial value of δmax~1.7 [12]. The carbon and oxygen content was strongly reduced. Following the conditioning period in the beam line, the TiN sample was kept in the laboratory set-up for ~1000 hours in ultrahigh vacuum 1E-9 Torr, in atmosphere 10:1 H_2:CO, and then still measured a SEY<1. A secondary yield below 1 considerably reduces the formation of an electron cloud.

During the year 2007 and 2008, we have manufactured a set of different sample materials, in particular we have coated samples with TiZrV non-evaporable getter (NEG) and measured the as received SEY, as shown in Figure 5. Aiming at the NEG activation, we have heated the NEG sample at 200ºC for more than 2 hours in a dedicated set-up. After heating, we transferred the sample in the analysis set-up and took another measurement before installation in the beam line. The SEY decreased to ~1.33. Note that although we took the best precautions during the sample heating and transferring, the sample might have been exposed to CO and CO_2 contamination which would affect its SEY. Finally, we have transferred the NEG sample into the PEP-II beam line, exposed to the beam environment for several weeks, and then transferred back to the analysis set-up measuring a SEY ~1.05.

Furthermore, we manufactured samples in Aluminum 6063, Stainless Steel and OFE Copper and installed in the beam line. A summary of the SEY measurement results is shown in Table 1.

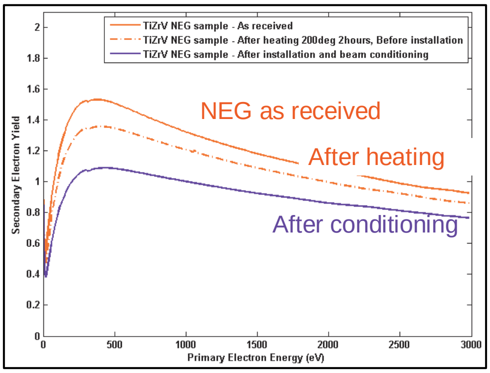

Figure 5. SEY of non-evaporable getter NEG, as received, after heating and following conditioning in the beam line.

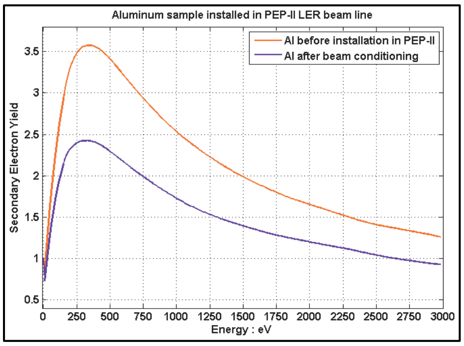

Figure 6. SEY of aluminum as received and after conditioning in the beam line. High SEY > 2 even after long-term conditioning in the beam line.

Figure 6 shows a survey of the SEY for the aluminum sample before and after conditioning in the beam line. Following the beam line conditioning, the SEY reduced to δmax ~ 2.4, unacceptably high for the ILC DR and a concern for the electron cloud in existing storage rings using aluminum chambers, as Daϕne and CesrTA. This finding on high the SEY of conditioned aluminum is in good agreement with laboratory measurement [4].

Table 1. Samples installed in the PEP-II beam line. SEY before installation and after conditioning in the beam line.

	SEY before	SEY after
TiN/Al	1.7	0.95
TiZrV	1.33	1.05
Al	3.5	2.4
Cu	1.82	1.22

GROOVED CHAMBERS

Simulation and direct measurements of rectangular groove samples have shown a SEY below unity, as low as δ_{max}~0.6 [13-16]. We have manufactured two aluminum chambers with a rectangular groove profile, see Figure 7 and two chambers with a smooth (flat) surface, coated all the chambers with TiN and installed them in a magnetic-free section of the PEP-II LER. Each chamber was supplied with electron monitors. The grooves run longitudinally and cover the whole pipe perimeter with heights 4.5 and 3.3 mm for a chamber diameter of 89 mm.

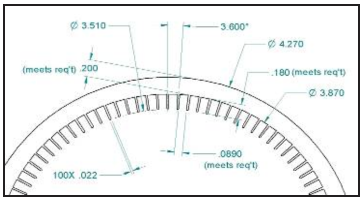

Figure 7. Groove chamber cross section.

After installation and following an alignment survey, we found that the chambers were horizontally misaligned by ~ 5 mm towards the inner ring side. A horizontal offset results in a masking effect for the downstream flat chambers from being hit by synchrotron radiation and in fewer photoelectrons generated in flat chambers, which might be responsible for initially unexpected results [12]. We corrected the configuration by properly aligning all the chambers along the beam line. The following results correspond to the configuration with the correct alignment.

Figure 8 shows the electron flux signal at the wall in the flat (smooth) and groove chambers. The signal in the groove chambers is up to a factor ~20 smaller at a beam current 2500 mA, suggesting that a groove profile is effective at reducing the electron cloud current. The groove profile may reduce both the photoelectron rate and the secondary electron generation.

Estimation of SEYs

In order to fit the data, a large number of simulations have been performed by scanning the photoelectron η yield and SEY δ parameter space. Fitting with a given photon-electron ratio extrapolated at low beam currents are shown in Table 2. The estimated SEY of both flat chambers is about 1.0. A rectangular groove profile is yet to be implemented in the simulation code.

Table 2. Estimated SEYs for the flat chambers by fitting simulations with experimental data.

	Photoelectrons η	SEY
Flat 1	0.0024~0.0027	0.97 ~1.02
Flat 2	0.0030~0.0036	0.99 ~1.04

SUMMARY

In 2007, we have installed 5 chambers in the PEP-II LER to study electron cloud and secondary electron yield in accelerator beam line. We have measured a drastic reduction of the secondary electron yield to δ_{max}~0.95 for TiN and a still high value for aluminium δ_{max}>2.0 after exposure in the accelerator beam line. We measured other technical vacuum chamber materials including NEG coated samples.

In magnetic-free regions, we have installed chambers with and without rectangular groove profiles meant to reduce the secondary electron generation at the surface. The electron signals in the grooved chambers are much reduced with respect to the smooth chambers.

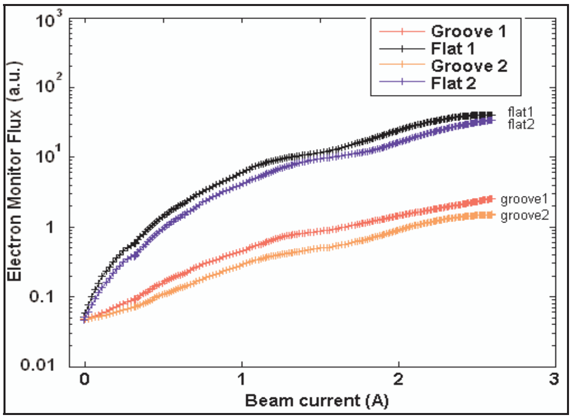

Figure 8. Electron cloud signal measured in the two flat (smooth) and two groove chambers installed in PEP-II straight magnetic-free section. The electron current signal in the groove chambers is much reduced with respect to flat chambers. All chambers are coated with TiN.

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