SECONDARY ELECTRON YIELD AND GROOVE CHAMBER TESTS IN PEP-II*

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Abstract

Possible remedies for the electron cloud in positron damping ring (DR) of the International Linear Collider (ILC) includes thin-film coatings, surface conditioning, photon antechamber, clearing electrodes and chamber with grooves or slots [1]. We installed chambers in the PEP-II Low Energy Ring (LER) to monitor the secondary electron yield (SEY) of TiN, TiZrV (NEG) and technical accelerator materials under the effect of electron and photon conditioning *in situ*. We have also installed chambers with rectangular grooves in straight sections to test this possible mitigation technique. In this paper, we describe the ILC R&D ongoing effort at SLAC to reduce the electron cloud effect in the damping ring, the chambers installation in the PEP-II and latest results.

INTRODUCTION

In the beam pipe of the positron damping ring of the International Linear Collider (ILC), an electron cloud may be first produced by photoelectrons and ionization of residual gases and then increased by the secondary emission process [2]. The electron cloud density depends on characteristics of the circulating beam (bunch length, charge and spacing) and the secondary electron yield of the wall from which the electrons are generated. The space charge from the cloud, if sufficiently large, can lead to beam instability and losses ultimately causing a reduction in the collider luminosity. The electron cloud has been observed at many storage rings [2] and it is an issue for future machines aiming at high beam intensity.

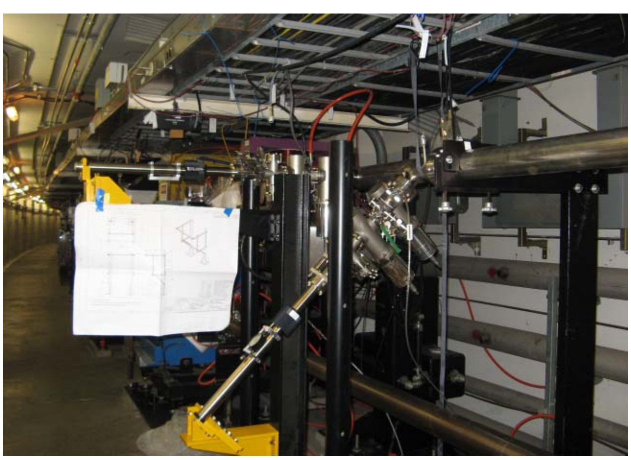

Figure 1. Installation of the SEY test chamber in the PEP-II tunnel, LER ring above and HER below.

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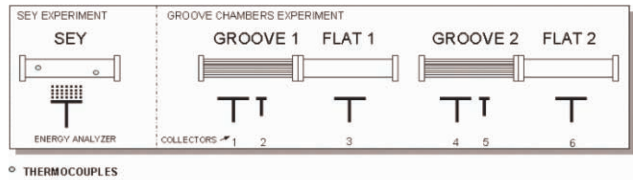

Figure 2. Layout of the electron cloud test chambers.

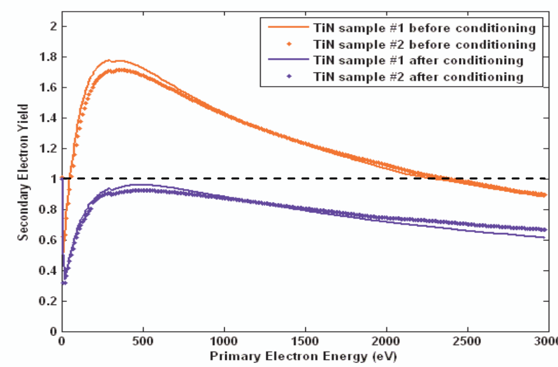

Figure 3. SEY before and after conditioning. TiN/Al samples were inserted in the PEP-II stainless steel chamber respectively in the plane of the synchrotron radiation fan (0º position) and out of this plane (45º position).

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, a peak SEY value range is δ_{max}~1.5-2.2 for as-received technical vacuum chamber materials, and for aluminum δ_{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 [9-13].

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 δ_{max}~1.2.

In the ILC DR, the single bunch instability threshold is for a central cloud density of 1.4e11 e/m^3 [14], which is easily achieved if an electron cloud is allowed to develop. A solution to mitigate the formation of the electron cloud is to ensure that the vacuum chamber wall has low secondary emission yield.

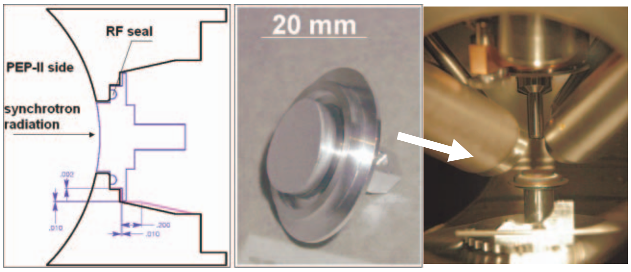

Figure 4. Left-Center-Right respectively: layout of the sample installed in the PEP-II LER chamber, sample and sample positioned in SLAC set-up for surface analysis.

SEY TEST CHAMBER INSTALLATION

The electron conditioning or bombardment reduces the surface SEY to low values [3-8]. Nevertheless, an electron cloud is still observed in several existing storage rings. The conditioning effect may depend on the presence of electron cloud, radiation and vacuum chamber materials. 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 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). Fig.1, and 2 shows the installation in the PEP-II and a layout of the chambers installation in the LER.

The samples are transferred 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 RF leak or the generation of higher order modes.

Two samples are inserted at a time: directly exposed to the fan of synchrotron radiation or outside of the fan. During beam operations, the samples are left in the beam line for a period of few weeks and then transferred to the laboratory set-up for surface analysis, as shown in Fig. 4.

SURFACE CONDITIONING

The SEY of two TiN/Al samples after two months conditioning period, e- dose ~40 mC/mm^2, is shown in Figure 3 compared to before installation. Conditioning of the surface, decreased the SEY to δmax~0.95 similarly in both samples, from an initial value of δmax~1.8.

The carbon content is strongly reduced after exposition to electron, radiation and ion conditioning from an initial 25% to 3%. This is a different result if compared to the use of electron beam conditioning for conditioning, where

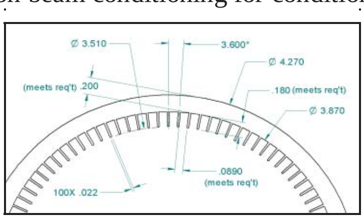

Figure 5. Fin chamber cross section and dimensions.

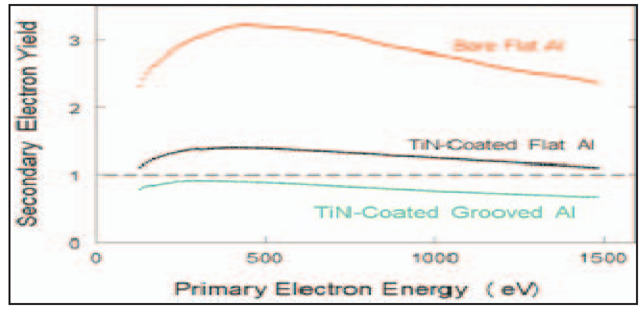

Figure 6. Flat and grooved "witness" samples during the TiN-coating process and before installation in PEP-II.

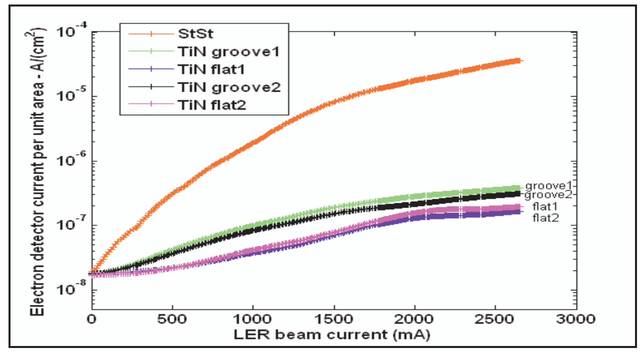

Figure 7. Experimental observation of the electron signal [A/cm^2] in stainless steel, fin (groove) and flat chambers.

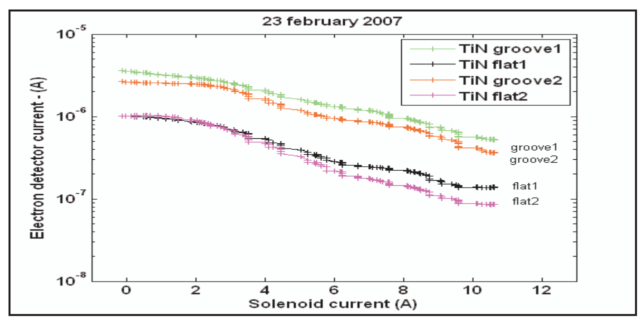

Figure 8. The collector current (not normalized to unit area) with external solenoid field ~20Gauss (at 11A).

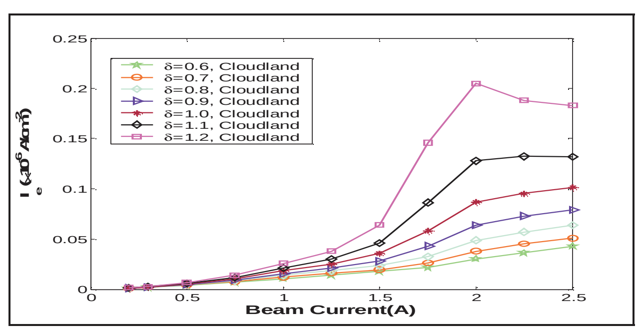

Figure 9. Simulated collector current of flat chamber using CLOUDLAND [19]. A SEY close to 1 is needed to fit the experimental observations for the flat TiN-chambers.

a growth of carbon crystals has been observed at many laboratories [4, 5, 8, 14]. A secondary yield below 1 considerably reduces the formation of an electron cloud.

FIN AND FLAT TIN-COATED CHAMBERS

We have manufactured TiN/Al chambers with a rectangular groove profile, Figure 5, and installed in PEP-II LER field free region. Simulation and direct measurements of rectangular groove samples have shown a SEY below unity, see Figure 6, and as low as δ_{max}~0.6 [16-18].

Figure 7 compares the measured electron collector signals as measured in the stainless steel chamber (SEY Station), fin and flat TiN-chambers. The electron signal in flat and fin chambers is much lower than in the stainless steel chamber. The collector signal in the flat chambers is lower than the electron signal in the fin chambers. Previous laboratory measurements showed a lower SEY for surfaces with grooves. It was expected that the electron signal in the groove chamber would be lower than the flat chamber. Near a bend, grooved chambers may be more efficient to generating photoelectrons.

An external solenoid field (20 Gauss) was applied. Figure 8 shows that independently of the field the electron signal is still higher in groove, suggesting that photoelectrons are dominating over the secondary electron yield in groove chambers.

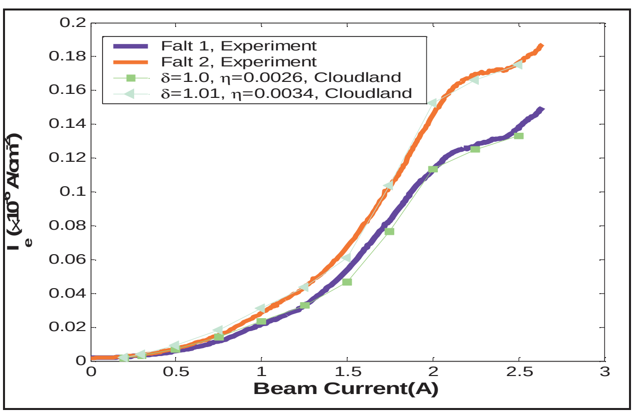

Figure 10. Experimental and simulated using CLOUD_LAND. A $\delta_{max}=1$ and η~0.0026-0.0034 fit the experimental observations for the flat chambers.

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. Results of simulations are presented in Figure 9.

Fitting with a given photon-electron ratio extrapolated at low beam currents are shown in Table 1 and Figure 10. The estimated SEY of both flat chambers is about 1.0.

A rectangular groove profile is not yet implemented in the code and fitting of the experimental data is not optimal.

Table 1: Estimated SEYs for the flat chambers by fitting simulations with experimental data.

	Photoelectrons η	SEY
Flat 1	0.00248~0.0027	0.99 ~1.02 (best fit 1.0)
Flat 2	0.003~0.0036	0.99 ~1.04(best fit 1.01)

Finally we have to report that very recently, we found that the chambers are not aligned. An horizontal offset results in a masking effect for both flat chambers from being hit by synchrotron radiation and in fewer photoelectrons generated in flat chambers, which might be responsible for the unexpected results. We are aligning all the chambers, then test again. More time is needed to complete these studies and no conclusive results yet on groove experiment.

SUMMARY

In January 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 directly measured a drastic reduction of the secondary electron yield to δ_{max}~~0.95 for TiN coated samples after exposure to the accelerator beam line. We installed chambers with grooves and without (flat) and compared to the stainless steel chamber results. The electron signal in grooved and flat chambers is much lower than in a stainless steel chamber. The signal in the flat TiN-chamber is lower than in the grooved TiN-chamber. Very recently we found that an horizontal chamber offset causing a masking effect for both flat chambers from synchrotron radiation that may explain these latter results. The chambers need to be aligned and there are no conclusive results yet on groove experiment.

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