

ELECTRON CLOUD DIAGNOSTIC CHAMBERS WITH VARIOUS EC-SUPPRESSION COATINGS*

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Abstract

Suppression of electron cloud (EC) growth and density is critical for many high intensity accelerators of positively charged particles, such as positron rings for Super KEKB and ILC's positron damping ring. Among various suppression techniques, passive coating with low secondary electron emission (SEY) coefficient is the most economic method. During CEsrTA EC study program, we have created two dedicated short sections in the CESR vacuum system to study effectiveness of various SEY reduction coatings. During last 4 years, six one-meter-long EC study vacuum chambers were constructed, and rotated through these short sections. The EC chambers were not only equipped with EC diagnostics (including a RFA and RF-shield pickups), they were also installed in CESR with vacuum instrument, including a cold cathode ion gauge and a residual gas analyser. With these EC study chambers, EC-suppression effectiveness of TiN, amorphous carbon and diamond-like carbon coatings were evaluated, relative to bare aluminium chamber. In this report, we will report vacuum properties of these coatings. In particular, the photon-induced desorption and beam conditioning histories are presented.

pipe is machined from a standard CESR aluminium (Type 6061-T4 alloy) extrusion. For EC measurements a retarding field analyser (RFA) port and a set of four shielded pickups (SPUs) are added to the chamber. The SPUs are directly welded to the top of the beam pipe, using explosion-bonded aluminium-to-stainless steel (ExB Al/SST) blocks. Arrays of small holes (0.75-mm in diameter) connecting the SPUs to the beam space are directly drilled vertically through the beam pipe top wall (~2.5-mm in wall thickness). The RFA housing was machined from a separate block of ExB Al/SST material, and was directly welded to a cut-out on top of the beam pipe. Small holes are drilled through three milled flats, connecting the RFA port to the beam space. These RFA holes have similar geometrical dimensions as the SPUs. These holes are grouped into nine 'segments', three segments on each flat, with a total of $9 \times 4 = 36$ holes. The segmented hole pattern allows the sampling of the transverse distribution of the EC density in the beam pipe. The dimensions of the RFA and SPU holes are chosen to ensure no significant leakage of the beam's RF fields into the EC detectors, while allowing adequate transmission of cloud electrons from the beam pipe into the detectors.

EXPERIMENTAL SECTORS IN CESR TA

During conversion of Cornell Electron Storage Ring (CESR) into the ILC-DR test accelerator (CesrTA)[1], two very short sectors were created for studies of electron cloud suppression coatings, by addition of a pair of RF-shielded gate valves. The gate valves may isolate a section of roughly 6.5-meter in length, containing a dipole bending chamber and a 1-meter long EC study test chamber. The locations of these two short EC experimental sectors (dubbed Q15W and Q15E sectors) are shown in fig.1. The short sectors provide significant flexibility for exchanging test chambers, while minimize impact to CESR operations. As a matter of fact, we have rotated six vacuum chambers with four types of surfaces through these two short experimental sectors over the past 3+ years of CesrTA program (see Table 1), with minimum impact to both CesrTA research program and CHES (Cornell High Energy Synchrotron Source) operations.

VACUUM CHAMBER FOR EC STUDIES

The experimental chamber design was developed to allow the characterization of the EC growth and decay and its transverse density distribution within the vacuum chamber for different wall surfaces and with progressive beam processed conditions. The design of this EC experimental chamber is illustrated in fig.2. The beam

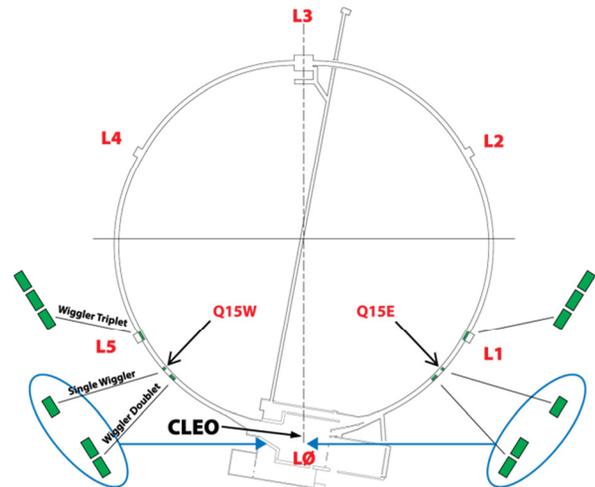


Figure 1: Locations of the short Q15W and Q15E sectors for electron cloud studies in CesrTA. As a reference, CESR ring has a circumference of ~786-m.

Over the past 3+ years CesrTA program, six Q15 EC vacuum chambers were fabricated and tested in the Q15W and Q15E sectors. Among these chambers, four types of interior surfaces and two styles of RFA designs were tested. The four tested surfaces are: bare aluminium (as extruded), amorphous carbon coating (in collaboration with CERN.CLIC [2]), TiN coating and diamond-like carbon coating ((in collaboration with KEK [3]). The

*Work supported by US NSF Grant# PHY-0734867, PHY-1002467
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three types of coatings are proposed EC mitigation techniques for the ILC's positron damping ring, CLIC's positron damping ring and KEK SuperB's positron ring, due to their reduced secondary electron yields (SEYs). Table 1 summarizes these test chambers, and fig.3 shows a typical installation of these EC vacuum chambers.

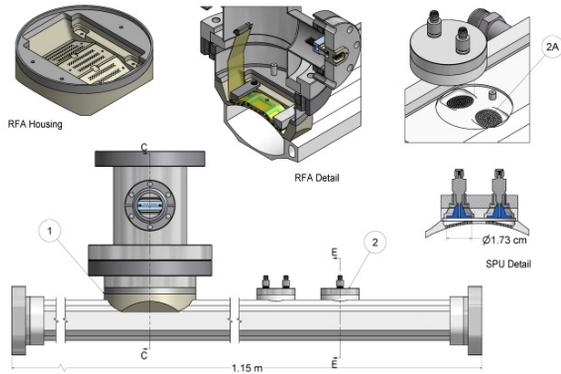


Figure 2: Design of the EC Experimental Vacuum Chamber.

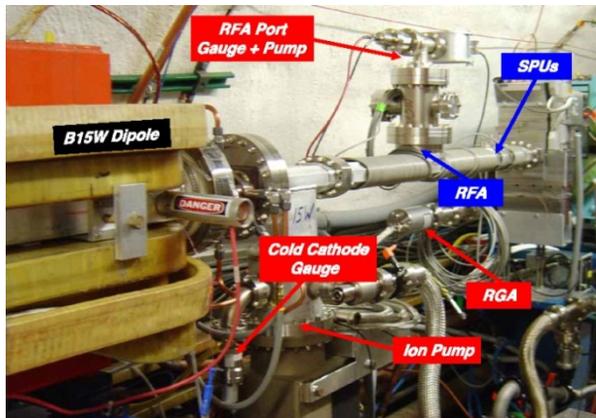


Figure 3: An EC vacuum chamber, with EC and vacuum instrumentation as shown installed at Q15W in CESR.

Table 1: Summary of EC Vacuum Chamber (VC)

VC	Surface	RFA	Test Period	Position
1	Alum #1 Run1	1	2009.07~2009.11	Q15E
	Alum #1 Run2	1	2010.04~2010.09	Q15W
6	Alum #2	2	2012.08~present	Q15E
3	TiN Run1	1	2009.12~2010.04	Q15E
	TiN Run2	1	2010.08~2011.01	Q15W
	TiN Run3	2	2011.02~2011.05	Q15W
	TiN Run4	2	2012.08~present	Q15W
2	a-C #1	1	2009.07~2010.04	Q15W
4	a-C #2 Run1	1	2010.04~2010.12	Q15E
	a-C #2 Run2	2	2011.09~2012.06	Q15W
5	DL-C	2	2011.02~2012.06	Q15E

Notes: (1) Surfaces: Alum=bare aluminium; TiN=TiN coating; a-C=amorphous carbon coating; DL-C=diamond-

like carbon coating. (2) RFA styles (see text): 1=thin; 2=insertable

Two generations of RFA designs were used on the Q15 EC vacuum chambers. The first style was adapted from the thin-style RFA used for a CESR dipole chamber [1]. As listed in Table 1, the thin-style RFAs were deployed in the first four EC chambers, including bare aluminium, two amorphous carbon coated and a TiN coated chambers. In the thin-style RFA (see photos in fig.4), fine Au-coated copper meshes (with high transparency, high-T, >90%) were used as retarding field grids. The electron collector is a flexible printed circuit board made of copper-clad Kapton film, of a thickness of 0.15 mm. To electrically isolate the collector from the grids, UHV-compatible thin Kapton tapes (Accu-Glass Products, Inc.) with silicone adhesive were used. Vacuum property of the flexible collector and the Kapton tapes were evaluated at temperature as high as 230°C with a RGA, and no unusual outgassing from the tapes were observed. However, traces (~6% monolayer) of silicon were detected on the a-C coated witness samples that were present during pre-installation 150°C vacuum bakeout of the a-C coated vacuum chamber, resulting in significant increase in secondary electron yield (SEY) [4].

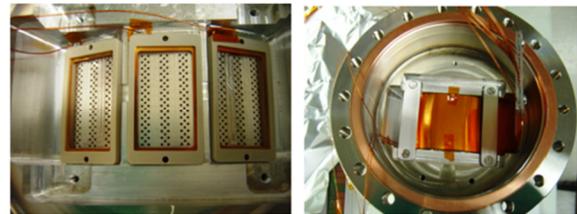


Figure 4: Photos of thin-style RFA assembly, as it was being installed into a Q15 test chamber. Left: the RFA holes on the beampipe are clearly visible through the fine grid meshes, Right: a flexible collector was pinned and clamped down to complete the RFA assembly.

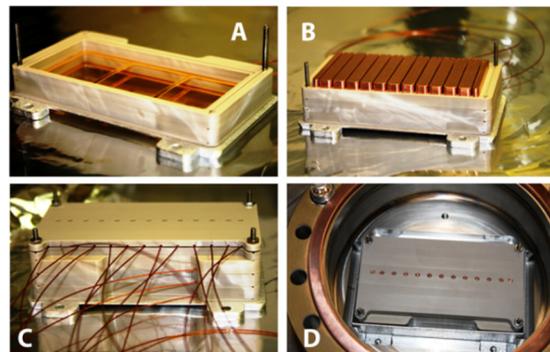


Figure 5: Photos of insertable RFA assembly. (A) High-T meshes nested in PEEK frames; (B) Copper bar collectors mounted above the grids; (C) Completed assembly, with Kapton coated wires for 2 grids and 13 collectors; (D) RFA installed in the vacuum port of a test chamber.

Thus a second generation of RFA design was developed, to be completely free of adhesives. This fully insertable RFA (see fig 5) consists of three high-T mesh grids, with the bottom grid grounded and 2nd and 3rd mesh

individually biased. These meshes are nested in frames made of PEEK, and the flexible printed collector was replaced with discrete copper bars.

VACUUM PERFORMANCES OF SEY SUPPRESSION COATINGS

The vacuum pumping of the chamber is a 110-l/s noble-diode ion pump, and two adjacent distributed ion pumps. As the gas conductance between the beam pipe and the RFA port is very limited, a small ion pump (8-l/s) was installed for the RFA port. The vacuum performance of each test chamber is monitored by a cold cathode ion gauge (CCG) and a residual gas analyser (RGA) during the beam runs.

During beam operations, photon-induced desorption (PSD) from bend synchrotron radiation (SR) dominates the gas load. As for all newly installed vacuum chambers, very high dynamic pressure rises were measured due to PSD from these EC chambers, but the PSD yield decreases rapidly with accumulated beam doses. In fig.6, beam conditioning histories of the six test chamber, with four types of surfaces, are compared. With calculated SR flux at Q15W/E locations $\sim 4.7 \times 10^{18}$ ph/s·Amp·m, and estimated local linear pumping speed ~ 9.5 liter/s·m, the dynamic pressure rises, dP/dI , can be converted into PSD yield, also shown in fig.6. The data in fig.6 indicates:

- All coatings, except the DL-C, have similar PSD yield and beam conditioning characteristics. By contrast, the DL-C coating showed significantly higher PSD yield, similar to reported observation [3].
- However, the RGA data (fig.7) showed that DL-C coating has a much ‘cleaner’ desorbed gas composition, with hydrogen dominating, and much less C- and O-containing molecules.

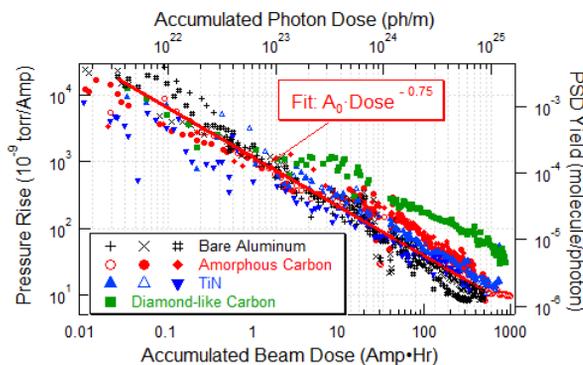


Figure 6: History of beam-conditioning of EC experimental chambers with different interior surfaces.

CONCLUSION REMARKS

We have evaluated three types of coatings for electron cloud suppression with vacuum chambers equipped with EC diagnostic instrument. The RFA provided information of steady state EC build-up in the beam pipe and the transverse EC distribution at various conditions. Examples of RFA data are given in fig. 8, where the RFA signals of three coated chambers were compared against

the bare aluminium chambers. The SPUs on these test chambers provided time-resolved data on EC dynamics [5]. We also demonstrated that all three EC-suppression coatings are suitable for accelerator UHV systems.

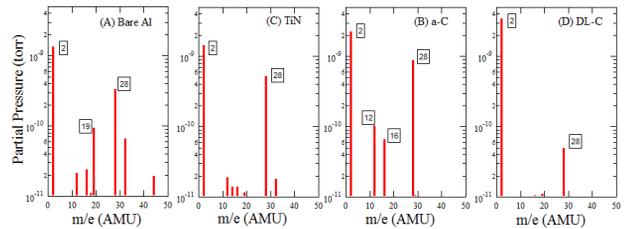


Figure 7: Typical RGA spectra for four Q15 EC chambers with different interior surfaces, as labelled. All RGA spectra were recorded during CHES operations, with ~ 400 mA stored beam current in CESR, after significant beam process (> 400 Amp-hr accumulated beam doses).

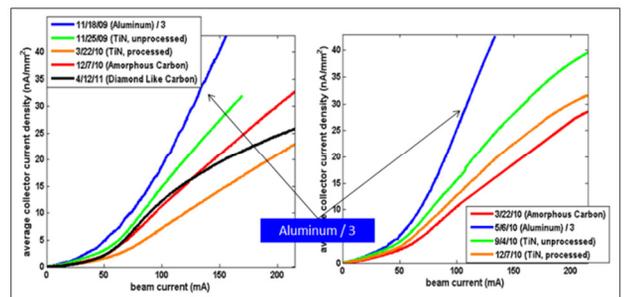


Figure 8: Comparison of RFA signals measured from four surfaces of the Q15 chambers, all taken with 45-bunch train of positron with 4-ns bunch spacing [6].

ACKNOWLEDGMENT

M. Taborelli, G. Rumolo, and S. Calatroni of CERN/CLIC team arranged amorphous carbon coating on two EC chambers. Shigeki Kato of KEK, Japan, arranged diamond-like carbon coating on one EC chamber.

REFERENCES

- [1] Y. Li, *et al* “CesrTA Vacuum System Modifications” in Proceedings of the 2009 Particle Accelerator Conference, Vancouver, BC, 2009, p. 357.
- [2] C. Y. Vallgren, *et al*, “Amorphous carbon coatings for the mitigation of electron cloud in the CERN Super Proton Synchrotron”, Phys. Rev. STAB 14, 071001 (2011)
- [3] M. Nishiwaki, S. Kato, in Proceeding of IPAC’10, Kyoto, Japan, 2010, p.3852
- [4] S. Calatroni, private communications
- [5] J.P. Sikora, *et al*, “Electron Cloud Measurements Using Shielded Pickups at CesrTA”, in Proceedings of IBIC 2012, Tsukuba, Japan
- [6] J. Calvey, *et al* “Studies of Electron Cloud Growth and Mitigation in a Field Free Environment Using Retarding Field Analyzers.” Phys. Rev. STAB (to be published)