PERFORMANCE OF INSERTION DEVICE VACUUM CHAMBERS AT ELETTRA

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Abstract

Ten long straight vacuum chambers for insertion devices (ID) are currently installed at ELETTRA. Four different types are employed:

a) four stainless steel (SS) vacuum chambers with a rectangular cross section 80 mm x (17-20) mm, pumped by two central 120 l/s sputter-ion pumps connected to an antechamber;

b) one pump free SS vacuum chamber with an elliptical cross section of 82 mm x 14.8 mm;

c) four pump free extruded aluminum vacuum chambers with an elliptical cross section of 81 mm x 14 mm;

d) one pump free extruded aluminum vacuum chamber of the same cross section, coated with a low temperature activation NEG.

Results of standard laboratory vacuum tests will be discussed. Vacuum measurements during commissioning, such as dynamic pressure and Bremsstrahlung (BS) radiation, are also reported. The lifetime variation due to the reduction of the total pressure for all types of ID chambers will be compared.

1 TYPES OF ID VACUUM CHAMBERS

The ID chamber is a low conductance vacuum system. During machine operation its inner surface is exposed to an intense flux of synchrotron radiation. Consequently the local pressure rises; above a certain threshold other than reducing the beam lifetime, an unacceptable level of gas bremsstrahlung is exceeded.

Besides the mechanical requirements, the design of an efficient ID vacuum chamber should take into account at least the following aspects: 1) the effective pumping speed should be as high as possible (this necessity is in contrast with the required small cross section of the chamber), 2) the outgassing rate should be low; materials and cleaning procedures have to be chosen carefully, 3) the photon stimulated desorption should be as low as possible.

The ELETTRA storage ring (SR) contains twelve long straight sections: ten are currently equipped with ID's (see Tab.1), one is reserved for future special components, and the last one is used for injection. Each ID chamber is connected to the SR by means of two vacuum vessels, which joint the rhomboidal cross section of the SR to the elliptical or rectangular internal shape of the ID chamber. Each of these vessel hosts a 120 l/s sputter-ion pump (SIP) and an inverted magnetron gauge (IMG).

Four different types of ID vacuum chambers are presently installed (see Fig.1):

Tab. 1 – ID vacuum chambers at ELETTRA.
L^* = chamber length without the tapers
α = horizontal angle of the photon-beam, from the previous bending magnet, hitting the chamber

ID	Type	L^* [mm]	α [mrad]
1	Al (no ante-chamber)	4743	7.6
2	Al (no ante-chamber)	4651	7.3
3	SS (with ante-chamber)	4800	7.8
4	SS (no ante-chamber)	4020	6.1
5	SS (with ante-chamber)	4800	7.8
6	SS (with ante-chamber)	4800	7.8
7	SS (with ante-chamber)	4800	7.8
8	Al (no ante-chamber)	4743	7.6
9	Al (no ante-chamber)	4743	7.6
10	Al + NEG (no ante-ch.)	4743	7.6

a) the ID chamber obtained from a sheet of stainless steel AISI 316 LN-ESR (bended and welded) with a cross section of 75 mm x 17-20 mm. Two further SIPs are connected to the ID chamber by means of an antechamber (fig. 1, A).

b) the ID chamber obtained from a pipe of stainless steel AISI 316 LN-ESR (rolled and drawn) with an elliptical cross section of 82 mm x 14.8 mm without any additional pump (fig. 1, B).

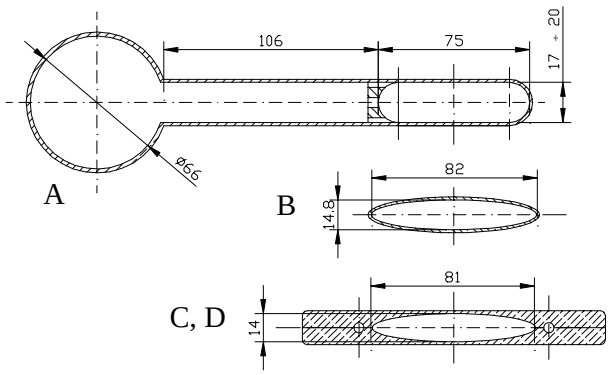

Figure 1 – Cross-section of the ID vacuum chambers.

c) the ID chamber obtained from a milled extrusion of 6060-T6 aluminum alloy. It has an elliptical cross-section of 81 mm x 14 mm, (fig. 1, C). It can be water cooled by means of two channels made during the extrusion process.

d) the ID vacuum chamber as in case c) with a 1 micron thick NEG coating (Ti-Zr-V) [1].

2 LABORATORY TESTS

All the new vacuum chambers have to pass mechanical and vacuum acceptance tests before their final installation in the storage ring. After a dimensional check, only the SS chambers are baked in a vacuum oven for 48 hours up to a maximum temperature of 400 °C (the aluminium vessels cannot withstand this heat treatment).

Afterwards each new ID vacuum vessel is equipped with its two tapered chambers at both ends; the SIPs and the pressure gauges are also connected in a similar way as the configuration of the final installation in the SR. A further small SS vacuum chamber is joined at one end. It hosts a residual gas analyser and an all-metal valve used to connect the forevacuum system (a turbomolecular pump and a membrane one). The whole system is subsequently baked-out for 24 hours (150 °C for SS, 120°C for Al, while the ion pumps are baked at 220°C using their own heating system). The final total pressure is measured by means of the IMGs; after cooling a pressure less than $1x10^{-9}$ mbar must be measured. Mass spectra are also acquired. They must correspond to a very clean ultra high vacuum (UHV) where only hydrogen, water, carbon monoxide, carbon dioxide, and methane peaks are significantly detectable.

All the installed ID chambers fulfilled these requirements.

The specific outgassing rates were also measured by using the pressure rise method: the corresponding values were in the low 10^{-12} and 10^{-13} mbar.l/s/cm^2 range, respectively for SS and Al chambers.

In the case of the ID chamber made of aluminium with NEG coating the photon stimulated desorption (PSD) coefficient was also evaluated. It was measured at the D31 beamline of the European Synchrotron Radiation Facility [2]. Figure 2 shows the measures of η performed at ESRF [3].

The chamber was exposed to a photon flux of $2.94x10^{15}$ photons/s/mA. After an accumulated dose of about 10^{23} photons/m the desorption yield coefficient decreased to the 10^{-6} molecules/photon range, comparable with yield from SS and quite lower than that one from Al [4].

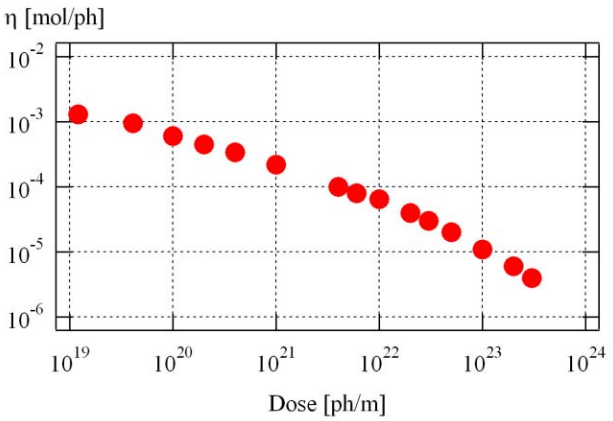

Figure 2 – Desorption yield of the Al + NEG chamber.

Laboratory vacuum tests were later performed at ELETTRA. The ID chamber had an IMG at one end and at the other a small SS chamber with a residual gas analyser and an all-metal valve connecting a turbomolecular pump. It was baked-out at 100°C for 12 hours and the total pressure increased to $4.5x10^{-7}$ mbar. Afterwards the NEG was activated at a temperature of 180°C for 4 hours and a residual gas analysis was performed. After switching off the gauge and closing the valve, peak 84 (Kr^+) appeared. This was expected due to the fact that krypton was used for sputtering the NEG materials. After about 10 hours the partial pressure of the Kr reached its equilibrium value (see Fig.3). Peaks 16 ($CH4^+$) and 40 (Ar^+) were also evident and are due to the inability of the NEG to pump methane and noble gases. Switching on the gauge again and reopening the valve, the initial good UHV was quickly obtained again.

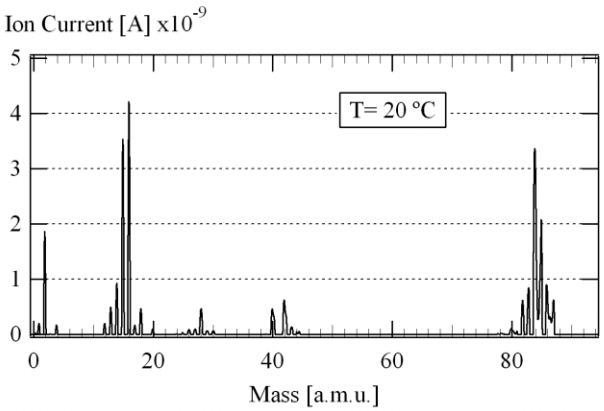

Figure 3 – Mass spectrum of the Al + NEG chamber pumped only by the NEG itself.

3 OPERATIONAL EXPERIENCE

The conditioning of an ID vacuum chamber is performed by photons generated from the upstream bending magnet, which generates a photon flux of $7.6x10^{16}$ phot/s/mrad/0.1%BW, for a stored current of 300 mA at an energy of 2 GeV; the critical energy is 3.2 keV.

After installation in the SR, each chamber was again in situ baked as described in the previous paragraph. In the case of the NEG coated chamber, it was once again activated; initially the chamber was heated to 100°C for 24 hours together with a "refreshing" bake-out of the pumps. Then the heating of the pumps was switched off and the ID chamber temperature was increased up to 200°C for 2.5 hours. In all cases at room temperature, a pressure in the 10^{-10} mbar range was established.

The conditioning of the SS chambers a) and b) started with a stored current of 10 mA at 1 GeV. The conditioning of the chambers proceeded well and the dynamic pressure (p_D) vs integrated current is shown in Fig. 4 (ID5, ID4 respectively).

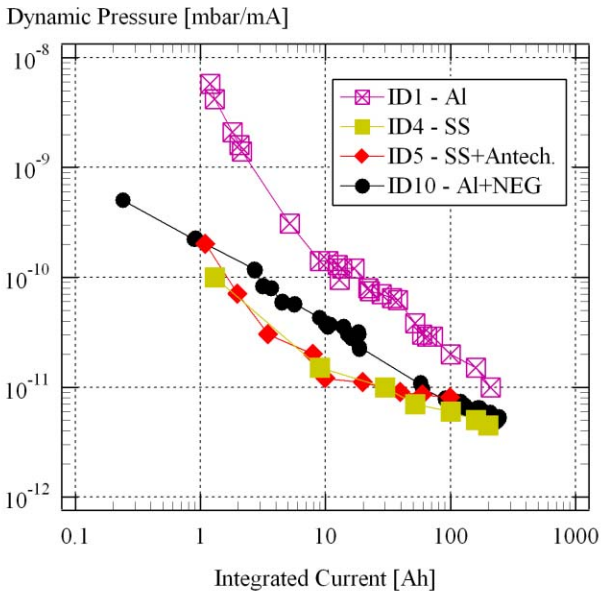

Figure 4 – Conditioning of different types of ID chambers at 2 GeV.

There was no evident difference in the dynamic pressure decrease between a) and b) chambers. They were conditioned (p_D<1x10^{-11} mbar/mA) after approximately 35 Ah of integrated current. For chamber b), the nominal lifetime (NLT) was reached after less than 30 Ah.

The conditioning was more complicated in the case of the c) type chamber [5]. As can be seen in Fig. 4 (ID1) the dynamic pressure after more than 100 Ah of conditioning was still higher than the SS chambers. 80% of the NLT was recovered after about 40 Ah, and NLT was reached in 100 Ah. The Bremsstrahlung, measured by means of an ionisation chamber placed on the ID chamber axis at a distance of about 8 m from its centre, was extremely high (see Fig.5, ID8) [6]. Only Bremsstrahlung emissions from ID 8 and ID10 are reported because in these two cases data were acquired under the same conditions.

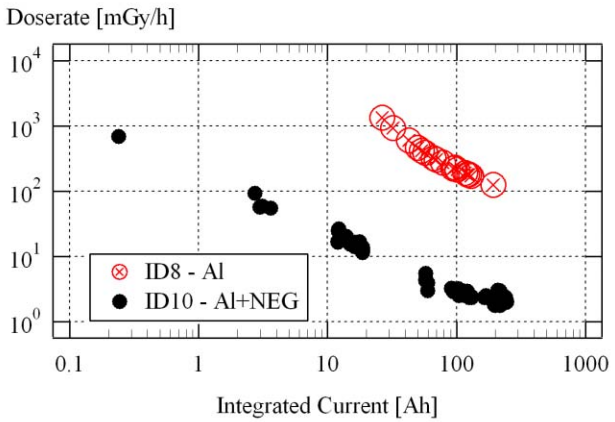

Figure 5 – Bremsstrahlung comparison for c) and d) types of ID chambers at 2 GeV.

The conditioning of the d) chamber is also shown in Fig. 4 (ID10). In this case, it was possible to immediately store a current of 100 mA at 0.9 GeV. Because of the good pressure profile the beam energy was increased up to 2 GeV after only a few minutes. A second accumulation in normal operative conditions (300 mA, 2 GeV) followed. The dynamic pressure p_D decreased from 5x10^{-10} to 6x10^{-11} mbar/mA after only about 5 Ah. For the same dose the lifetime grew up to 80 % of its nominal value. After 80 Ah the chamber was completely conditioned.

The low BS measured since the beginning of the conditioning is consistent with a low-pressure profile along the ID chamber, as expected for a vacuum vessel with an activated NEG surface (see Fig.5, ID10).

4 CONCLUSIONS

After more than eight years of experience with different types of ID chambers at ELETTRA it can be concluded:

1) chamber a) was quickly conditioned. It is expensive and very complex because of the technology used for its fabrications. Moreover the vertical dimension cannot be easily reduced with this technology, whilst ensuring at the same time the uniformity of the vertical gap and the planarity of the chamber. It is difficult to apply an efficient cooling system, the cost of central pumps is not negligible.

2) chamber b) was quickly conditioned. It is cheap and easy to manufacture. As for chamber a), it is also difficult to apply a cooling system.

3) chamber c) is cheap, simple to manufacture and easy to cool. Due to the high value of η of Al its conditioning was very long and the Bremsstrahlung emission was very high; in some cases additional radiation shielding was required.

4) chamber d) seems to be a good compromise between the b) and c) chambers. Its fabrication is very simple, gaps of few millimeters can be obtained, it can be effectively cooled, but the cost of NEG sputtering should be added. It was rapidly conditioned, in particular the start-up was very short and smooth: it was possible to store full current at full energy almost immediately. The BS was about two orders of magnitude lower than that one produced in the type c) chamber.

5 REFERENCES

[1] C. Benvenuti et al., "Vacuum properties of TiZrV non-evaporable getter films", Vacuum 60, 2001.

[2] R. Kersevan, "Synchrotron radiation-induced desorption from a NEG-coated vacuum chamber", Vacuum 60, 2001.

[3] R. Kersevan, Private communication, ESRF, 2001.

[4] A. Mathewson, "Electron and Photon Induced Gas Desorption in Vacuum Systems", Proc. of the Workshop on Vacuum for Synchrotron Light Sources, Orsay, 1996.

[5] A. Gambitta et al., "Experience with Aluminium Vacuum Chambers at ELETTRA", EPAC2000, Vienna, 2000.

[6] K. Casarin, Private communication, Sincrotrone Trieste, 2002.