EXPERIENCE WITH ALUMINIUM VACUUM CHAMBERS AT ELETTRA

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1 INTRODUCTION

Eight new vacuum chambers fabricated from aluminium have been installed in the ELETTRA storage ring, replacing the usual stainless steel (SS) chambers. In the case of the four bending magnet (BM) chambers aluminium was chosen in order to handle the increased thermal load on the chamber caused by the larger vertical opening angle of non-planar insertion devices. The four insertion device (ID) chambers are made from extruded aluminium, chosen for its high mechanical accuracy, better electrical conductivity, and cheapness. Experience with these chambers is reported.

2 DESIGN, CONSTRUCTION AND INSTALLATION OF THE CHAMBERS

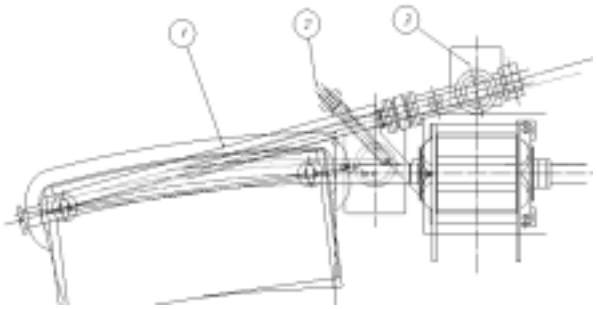

Figure 1: Layout of the new aluminium bending magnet chamber (1), Photon Absorber (2) and Beam Shutter (3).

The BM chambers are greatly simplified with respect to the original SS type, the main differences being the absence of an internal NEG strip and the repositioning of the photon beam shutter in a separate (SS) chamber after the fixed copper mask ("Photon Absorber"), which defines the angular dimensions of the extracted radiation beam. The resulting chamber is therefore much more compact in form (see fig. 1), thus minimising the deformation under the vacuum load. The body has been constructed from two welded machined halves in 5083-H321 aluminium alloy. An internal surface roughness of 0.2 µm was achieved.

The chamber is pumped by one 400l/s sputter-ion pump (SIP) located partly under the beam chamber and partly under the ante-chamber, in the region of the Photon Absorber. A slot-height of 10 mm connects the beam chamber and ante-chamber, except in the case of two chambers where a height of 20 mm has been permitted over a limited length. Another 120l/s SIP is mounted under the separate Beam Shutter. Residual gas analyses (RGA) are made with Balzers QMA 421 heads installed over the 400 l/s SIP on the SS tube connecting the pump to the aluminium chamber.

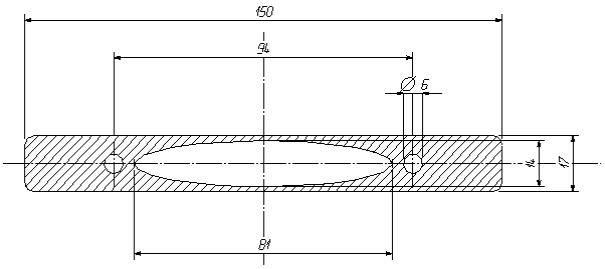

Figure 2: Cross-section of the aluminium ID chamber

The ID vacuum chambers are fabricated from an extrusion of 6060-T6 aluminium alloy and are approximately 4.7 m long with internal 14 mm x 81 mm elliptical cross section (see fig. 2). Following the positive experience with a previous stainless steel ID vacuum chamber that had no lateral pumping [1] the same solution was adopted for these chambers. At either end of the ID chamber are located two pumping tees for 120 l/s SIPs, which also form the smooth taper between the ID and the standard rhomboidal vacuum chamber cross-section. Two inverted magnetron gauges are installed over the corresponding SIPs for pressure measurement.

Care was taken during fabrication of both chamber types in order to avoid contamination of the Al surfaces. For the BM chambers, CIMSTAR MB-602 was used as the cutting lubricant. Machined surfaces were cleaned by brushing with an alkaline detergent solution (3 % Almeco 18, Henkel), followed by rinsing with distilled water, the same procedure adopted successfully for the Dafne vacuum system [2]. The ID chambers were degreased by water jet cleaning machine, rinsed in tap water, washed in alkaline solution (3 % Almeco 18) in an ultrasonic bath for 2 minutes, then rinsed and dried in a vacuum oven, according to [3].

All of the new aluminium chambers were tested in the vacuum laboratory before mounting in the storage ring. After bake-out at 120 °C an ultimate pressure in the low 10^{-10} mbar range was achieved, with a normal RGA spectrum typical of a clean UHV system. The specific outgassing rate (measured by the pressure rise method) in the 10^{-13} mbar l s^{-1} cm^{-2} range was also reached.

After installation no in-situ bakeout of the BM chambers was performed, however some ID chambers were baked out at 120 °C. After bake-out of the SIPs an equilibrium pressure in the low 10^{-9} mbar range was established. The mass spectra scanned before start-up were similar for all Al vacuum chambers and typical for an unbaked vacuum system, with varying amounts of mass

18 as expected. Mass 32 was also present in one case, which could have been caused by the fact that before installing the Al chamber the vented part of the storage ring had been saturated by dry air instead of dry nitrogen.

3 CONDITIONING WITH BEAM

3.1 Vacuum Conditioning

Figures 3 and 4 show the dynamic pressure decrease as a function of the integrated beam current dose for each of the new Al BM and ID chambers. All data refer to the standard mode of operation at 2 GeV. For comparison the conditioning of several SS chambers is also shown, following an accidental let-up of the entire ring to close to atmospheric pressure in August '99.

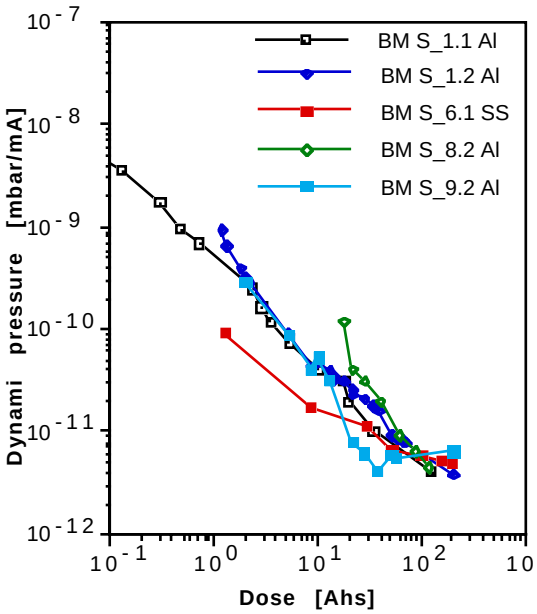

Figure 3: Conditioning of the Al BM vacuum chambers.

Regarding the BM vessels, as expected the new Al chambers conditioned slightly more slowly than the SS vessel. However an operating pressure at 300 mA in the low 10^{-9} mbar range was reached after about 80 Ahs of conditioning, corresponding well with predictions [4]. The anomalous behaviour of one chamber around 30 Ah was probably caused by bad pressure readings influenced by abnormal temperature conditions in the tunnel.

The situation is more complicated in the case of the aluminium ID chambers. As can be seen in Fig. 4, the dynamic pressure after more than 100 Ahs of conditioning is still higher than the SS ID chamber. In the mass spectra scanned by the MID (Multiple Ion Detection) versus Time RGA mode, during injection, the level of the mass 32 (O_2^+) drastically increased, but no leak was able to be localised. This effect was also accompanied by the increase of the masses 40 (Ar^+) and 28 (CO^+). A possible mechanism is that during a conventional extrusion process the end of the aluminium chamber is open to a

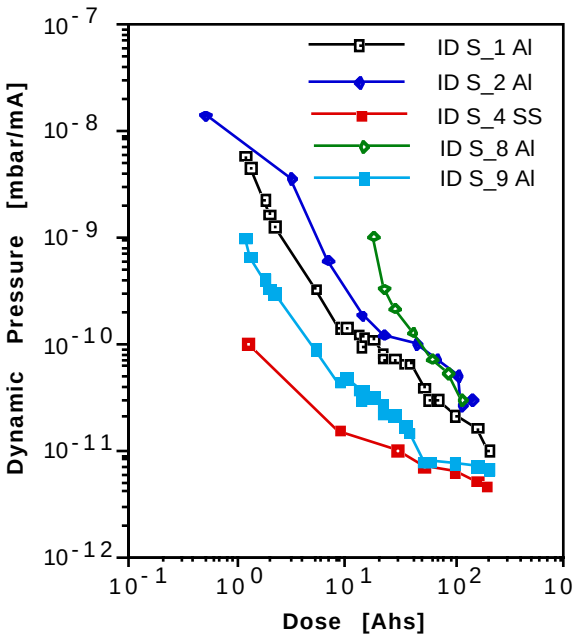

Figure 4: Conditioning of the Al ID vacuum chambers.

contaminating atmosphere. Therefore, the active inner surface, at a temperature of about 500 °C, is immediately covered with a porous aluminium oxide/hydroxide layer [5]. In the presence of beam the breakdown of $Al(OH)_3$ and Al_2O_3 molecules is caused by photoelectrons, then O and H atoms diffuse to the surface and O_2 (H_2, H_2O) molecules are formed. This explanation is confirmed by the fact that the mass level 32 significantly decreased after prolonged conditioning time. The mass spectrum obtained after 100 Ah of conditioning is dominated by H_2 and CO.

3.2 Beam Lifetime

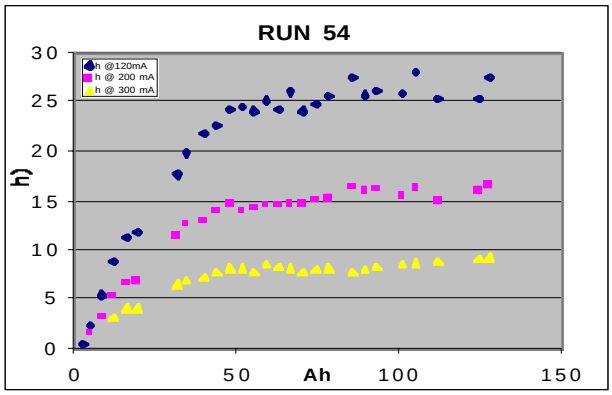

Figure 5: Variation of lifetime at different current levels with dose following installation of Al chambers.

Figure 5 shows an example of the variation of lifetime during conditioning following the installation of both a new BM and a new ID vacuum vessel [6]. Because of different circumstances, including how much of the ring was opened up, conditioning proceeded differently after each installation. The fastest conditioning was after a single BM chamber installation, when 50 % of standard

beam lifetime was recovered after only 5 Ah, 100 % after 80 Ah. More typically however these figures were 20 Ah and 100 Ah respectively.

3.3 Gas Bremsstrahlung

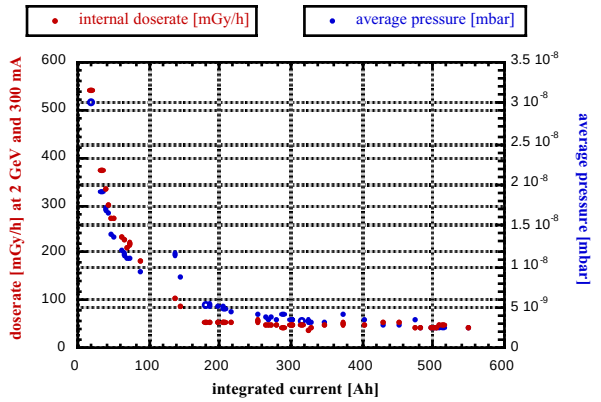

Figure 6: Gas bremsstrahlung rate (red) and pressure at the ends of the ID vacuum chamber (blue) during conditioning after ID_S9 chamber installation.

A much more sensitive parameter to the local vacuum conditions in the ring, particularly in the straight sections, is the level of high energy bremsstrahlung radiation produced by collision of the electron beam with gas molecules. Figure 6 shows the decrease of bremsstrahlung rate with beam current dose in one case, as measured inside the ring tunnel in line with the ID light exit port, before mounting of the beamline front-end. It can be seen that the trend follows closely that the of the vacuum pressure, measured at the ends of the ID chamber.

Table 1: Bremsstrahlung rates and pressure on various ID beamlines; rates are normalised to 300 mA and the same slits aperture.

ID No.	Pressure (pbar)	Rate (mGy/h)	Rate/Pressure (mGy/h pbar)
1 (Al)	1.8	12.3	6.8
2 (Al)	6.2	33.8	5.5
3 (SS)	1.4	1.1	0.8
4 (SS)	0.42	0.48	1.1
6 (SS)	0.29	0.17	0.6

The aluminium chambers installed until now approach a minimum bremsstrahlung emission after about 150-200 Ah of conditioning. Even then however the bremsstrahlung rate is significantly higher than in the case of previous stainless steel ID chambers. A comparison of bremsstrahlung rates measured in the radiation hutch, outside the shielding wall, on a number of active beamlines [7] has given the results shown in Table 1.

The results show that on the section with a well conditioned aluminium ID vessel (ID_S1), the rate is 25.6 times higher than for the SS ID vessel with no lateral pumping (ID_S4). Part of this difference can be explained by the difference in pressure (x 4.3). When normalised to the same pressure value however the bremsstrahlung rate remains 6.0 times higher for the Al chamber compared to the SS one. A similar discrepancy (4.8) is observed also for the ID_S2 Al chamber.

4 DISCUSSION AND CONCLUSIONS

Aluminium vacuum chambers require a longer conditioning time with respect to the chambers manufactured from stainless steel. In the case of the BM vessels about 80 Ah seems to be required to reach low desorption rates (10^{-11} mbar/mA). In the case of ID vessels however, although beam lifetime recovers after about 100 Ah, the local pressure and bremsstrahlung rates remain higher even after much larger doses.

The difference in pressure, and consequently part of the increased bremsstrahlung rate, could be caused by the different molecular desorption rate of aluminium and stainless steel; a factor of 5-6 (for CO) for a dose of 10^{23} photons/m, corresponding to about 100 Ah in the present case, has been reported [8]. Whether there are any differences between machined and extruded Al surfaces is not clear. The further increase in bremsstrahlung, even after pressure differences are included, must be due either to a different ratio of average pressure to pressure at the extremities, or a higher mass component. Recent experiments with gas injection seem consistent with the latter hypothesis [9].

The higher bremsstrahlung rates have required that extra measures be taken, both temporary and permanent, to reduce the dose rates to the required levels. Depending on the beamline this has involved a combination of installing extra shielding blocks, increasing the area and thickness of the lead shielding around the first optical elements, and also extension of the hutches to include more optical elements. In the longer term different solutions for future ID vessels will be explored.

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