NEG COATED CHAMBERS AT SOLEIL: TECHNOLOGICAL ISSUES AND EXPERIMENTAL RESULTS

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Abstract

The SOLEIL accelerator complex includes a 100 MeV LINAC pre-injector, a full energy booster synchrotron and a 2.75 GeV electron storage ring with a 354m circumference, which provides synchrotron light to 24 photon beam lines.

SOLEIL is the first synchrotron facility specifically designed to make extensive use of Non Evaporable Getter (NEG) coating technology to improve the vacuum, reduce bremsstrahlung radiation and boost beam performances. In fact, NEG coating of the straight parts of the vacuum system covers more than 50% of the overall storage ring surface and includes 100 q-pole and sextupole chambers as well as several conductance limited narrow insertion devices vacuum vessels. Use of such a large amount of NEG coated chambers has posed several challenges in term of coating technology, chamber testing, installation and machine commissioning.

We report in the present paper main technological issues related to the chambers preparation, film deposition, quality control and characterization. Chambers installation in the main ring, conditioning and activation procedures as well as preliminary vacuum performances will be also discussed.

INTRODUCTION

SOLEIL is the first synchrotron radiation facility to extensively use NEG coating technology [1] [2].

To this purpose, more than 110 q-pole and sextupole aluminum chambers and 26 straight sections vessels were coated by SAES from March 2005 through May 2006. A few others were coated independently at ESRF. Those latest will not be referred to in this article. Coating such a large number of different types of chambers within the tight project schedule has posed several challenges in term of logistics, planning, technical specifications and quality assurance. Due to their special geometry, q-pole chambers were coated using a sputtering system which was specifically designed and built for the project. Straight sections chambers were coated on a separate sputtering facility which can mount chambers as long as 6.5m. The two SAES deposition facilities along with general chamber preparation details were described in previous communications [3][4]. Cleaning of the q-pole chambers (maximum length 1.7m), was carried out by the chamber manufacturer while straight chambers, some of which as long as 5.6m, where cleaned at CERN.

All chambers were fitted with silicon coupons to measure the deposited thickness. To gather more specific information on the chemical composition, roughness and morphology of the film as deposited inside the chamber surface, aluminum test coupons, about 20x20mm, were also added in most of the deposition processes. These coupons were made from the same aluminum raw extruded profile than the chambers and submitted to the same chambers cleaning process.

QUADRUPOLE CHAMBERS COATING

Q-pole chambers have a very peculiar geometry characterized by the presence of one or two pumping ports protruding from the chamber axis, as shown in Fig. 1.

Figure 1: q-pole chamber with two pumping ports.

The chamber section is 30x70 mm with a hippodrome like shape. Cathodes spacing and relative positioning was adjusted by the view factor method [5] in order to maximize the film thickness at the median plane of the profile (where the photons irradiate the vacuum chamber) and to minimize it on the transversal plane, where the impedance matters most. Specified nominal values (± 35%) were 1.5µm on the extremities (median plane) and 0.5µm on the transversal plane. While mitigating the impedance, this arrangement still provides good pumping speed and capacity for gases. In fact, as showed by CERN, negligible differences in sorption properties do exist between 0.5µm and 1.5µm films up to 15 venting/re-activation cycles [6]. Calculated film distribution along the chamber profile is showed in Fig.2

Measured film thickness and composition is showed in Fig. 3 and Fig. 4, respectively.

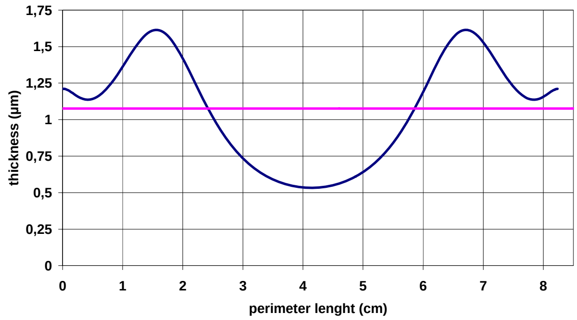

Figure 2: thickness variation along half chamber profile.

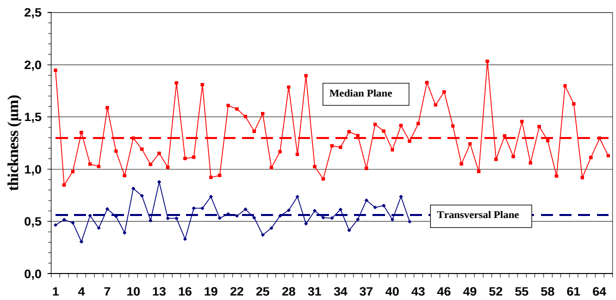

Figure 3: thickness measurement on coupons

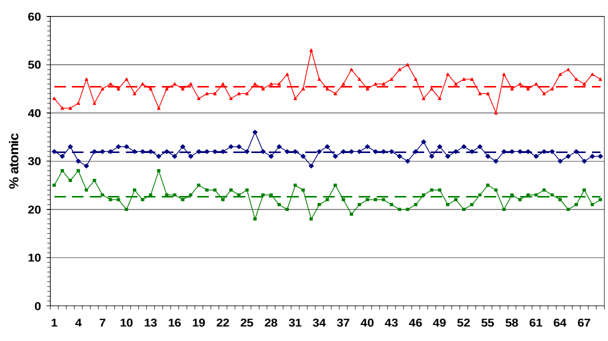

Figure 4: chemical composition on q-pole vessels

STRAIGHT SECTIONS COATING

A total of 26 straight sections were NEG coated. All chambers were T6060 aluminum grade but two (316LN stainless steel). The two longest chambers (10.6m) were coated as two 5.6m separate vacuum chambers, one flange cut-off, and then welded. Special precautions were taken for this operation, including Ar neutralization and cooling of the welded area to avoid NEG coating alteration. Measurements of bremsstrahlung rate in the different straight sections during first beam operations showed that the average vacuum pressure was good along the beam path despite the narrow gap. The measurement did not show any difference between the medium (5.6m) and the long (10.6m) straight sections, yielding an even better result for long straight sections. We then concluded that the welding of aluminum did not degrade the NEG performance on a significant area (no local pressure rise that could increase the mean pressure value).

Tab.1 lists the straight chamber types, length and profile.

Table1: straight chambers, E=Elliptical, H=Hippodrome

Chamber type	N° of chambers	Profile (mm)	Length (meters)
SDL 5011,3	2	E 56x14	5
SDL 5601,3	3	E 56x14	5.6
SDL HU640	2	E 56x14	10.6
CVQ 2378	9	H 70x25	2.4
CVQ 1594	2	H 70x25	1.6
CV 2090,65	2	H 84x25	2.1
HU80	2	E 46x10	5.6
HU256	4	E 46x10	5.6

As for the q-pole chambers, 0.5µm thickness (transversal plane) and 1.5µm (median plane) was specified for straight chambers. The two cathodes approach and the view factor method was applied to find the best configuration. Measured chemical composition and thickness were within specifications.

NEG COATING QUALITY ISSUES

In addition to film thickness and composition, several other checks and process controls were implemented to ensure film quality. Chambers were inspected before mounting with a metrological video probe, to assess surface cleanliness and morphology. Leak tightness and absence of gross contamination was checked by a mass spectrometer before the sputtering process. Process parameters (currents and voltages, magnetic fields, plasma pressure, substrate temperature) were monitored and optimized to avoid instability effects during the deposition [7], this being particularly critical for narrow gap medium straight chambers.

After coating, chambers were inspected again, aged for 1 day, evacuated, closed under nitrogen and shipped. Final close visual inspections of the surface of all chambers were also conducted after deliveries. 100% of the surface was examined for all the q-pole chambers. This most required ultimate control operation was not possible in the middle of the narrow gaps straight section chambers (10mm gap for 5.6m long)

These procedures were effective to provide peel off-free coating on all the straight sections. Some quality issues were faced in the case of the q-pole chambers. Three chambers had peel-off problems and 8 chambers showed surface irregularity, like small flowers, droplets or veils, difficult to precisely evaluate and ascribe. One chamber was rejected due to the presence of stains and another for a blister. On 4 of these chambers, the presence of peaks 20 and 36 (HF and HCl, likely coming from the cleaning) was measured by the RGA during the evacuation. Even though difficult to univocally ascribe, at least some of the adhesion or stains problems seemed to be related to an insufficient chamber surface preparation and/or cleaning, as also confirmed by the excellent coating results obtained on the straight chambers, all cleaned at CERN. All rejected chambers were stripped and recoated. A more focused analysis of the type of defects encountered will be addressed in a specific note.

CHAMBERS INSTALLATION AND VACUUM CONDITIONING

Results of the vacuum conditioning of the NEG coated chambers in the ring will be extensively covered at this Conference [8]. Here we report the results obtained during the conditioning of a single sectors. SOLEIL's storage ring is composed of 48 independent sector isolated by UHV valves. Among them are 16 arcs preceded by 16 long or medium straight sections, each arcs plus straight section is a cell. Half of the cells are in addition divided in two sectors by a short straight section (yielding 8+8 more sectors). Except the straight section for the injection devices and for the RF cavities, the straight sections are mainly composed of a NEG coated vacuum chamber surrounded by bellows, absorber assemblies and beam positioning monitors (BPM). The arcs are composed of NEG coated q-pole vacuum chambers between one or two dipoles, and surrounded by BPM and bellows. A typical mono-sector arc (2 dipoles) is presented in Fig.5. The pumping system is composed of sputter ions pumps (SIP) and titanium sublimation pumps (TSP) distributed along the ring on the q-pole chambers and on absorbers assemblies on both sides of straight sections.

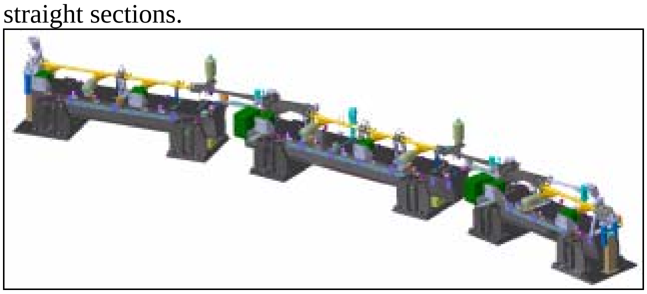

Figure 5: Typical SOLEIL's cell lay-out. NEG coated q-pole chambers are in yellow.

After several trials, the best activation procedure was found to be the following:

- Switch off SIP and pump down with TMP
- Heating all the vessels at 100°C
- Uncoated parts (stainless steel vacuum vessels) are heated at 180°C for at least 48 hrs.
- SIP are flashed (switched on and off)
- Uncoated parts are cooled down to 100°C
- BA gauges, RGA and TSP are degassed
- Switch on SIP and stop heating
- NEG coated chambers are heated to 180°C
- After 4 hrs uncoated vessels are cooled down
- NEG activation continues for additional 8 hrs
- TSPs are regenerated
- NEG coated chambers are cooled down to room temperature.

Results of the process are illustrated in Fig.6 with temperature and total pressure measurements. Main gases evolution is also reported in Fig.7 in the case of a short straight section sector, where NEG surfaces are dominant with respect to uncoated surfaces.

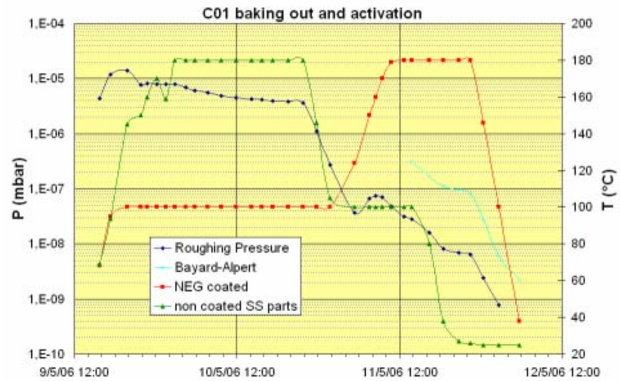

Figure 6: Cell bake-out and activation procedure.

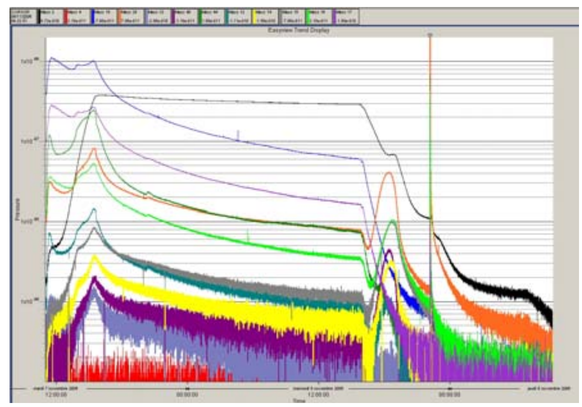

Figure 7: RGA during bake-out and NEG activation.

An activation period of 12 hours appears to be efficient after a "longest possible" baking-out of non NEG deposited parts while keeping NEG warm at 100°C. On Fig.7 the effect of the activation of the NEG coating is clearly seen on residual gas partial pressures with a sudden drop of most species, then yielding after complete cool-down a very clean RGA spectrum showing more than 90% H_2, balanced with only CO, CO_2, N_2 and CH_4.

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