NEG COATING OF PIPES FOR RHIC: AN EXAMPLE OF INDUSTRIALIZATION PROCESS

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Abstract

Non Evaporable Getter (NEG) coated chambers have been used in various accelerators facilities and synchrotrons for several years.

Initially, NEG coated chambers were mounted in small amounts in specific locations, covering a minor fraction of the accelerator surfaces exposed to vacuum. More recently, NEG coated chambers have been adopted to a larger degree in several projects, contributing to a larger extent to the machine performance. LHC, whose commissioning is expected in 2007, will use 6 km of coated pipes, to be the largest machine ever using this technology.

Other examples are the Soleil synchrotron (50% of the ring is NEG coated), ESRF (ongoing replacement of ID with NEG coated chambers) and RHIC (ongoing installation in the machine warm section of 600 m of NEG coated pipes).

Coating a large number of chambers poses challenges in term of process industrialization, product inspection and quality assurance.

In the present paper we report SAES Getters' experience in the NEG coating of the pipes delivered to Brookhaven National Lab for RHIC (120 steel chambers, each 5 m long). Main technological issues faced and procedures adopted to ensure product reproducibility and quality will be presented and discussed.

INTRODUCTION

After being extensively tested at CERN for the LHC project and in several other Laboratories, NEG coating is finding general acceptance as a cost effective technology to improve vacuum performance in high energy machines. A number of synchrotrons and accelerators have started using coated pipes in the last few years and some of them have already implemented this technology on a relatively larger scale, obtaining excellent results. One example is Soleil, where 50% of the ring has been NEG coated, including more than 100 quadrupole and sextupole chambers and several very long, narrow gap ID [1][2]. Commissioning is progressing extremely well and the first beam lines are expected to be operative by the end of the year.

Another example is RHIC at BNL, where more than 450 m NEG coated pipes have been mounted in the warm sections and an additional 150 m are being installed. NEG coated was here selected to suppress electron multi-pacting and the beam-induced pressure rises in RHIC, as well as provide extra linear pumping [3]. Recent results obtained at RHIC show that coated pipes have remarkably reduced the pressure background and help increasing luminosity by significant factor [4]. Considering the advantages this technology can bring in term of machine performance, design improvements and cost reduction, NEG coating is now evaluated as a possible design option in new challenging projects like ILC and MAX IV [5] [6]. The size of these machines and their ambitious design, will pose new and considerable technological difficulties for NEG coating.

In general, coating a large number of chambers is a non trivial task in term of process industrialization, production throughput, product inspection and quality assurance. In the present paper SAES Getters' experience in the NEG coating of the pipes delivered to Brookhaven National Lab for RHIC is reported. Main technological issues faced and procedures adopted to ensure product reproducibility and quality will be presented and discussed.

INDUSTRIALIZATION OF THE NEG COATING PROCESS

More than 120 steel pipes, each 5m long have been coated between 2004 and 2005 using SAES Getters vertical NEG coating facility [7]. Chambers were shipped to SAES Getters in sequential batches, already cleaned and ready to be coated. To ensure a suitable productivity a special magnetron coil was designed with sufficiently large internal diameter to handle three pipes per time.

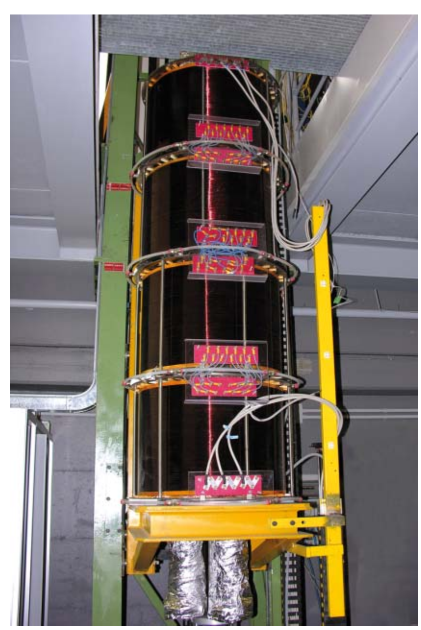

Figure 1: Picture of the vertical coating facility.

The coil was longer than 2 m and special care was taken to ensure a uniform magnetic field all along and within the coil.

The longer and larger coil and its high uniform magnetic field allowed reducing the number of coating steps and achieving the desired throughput.

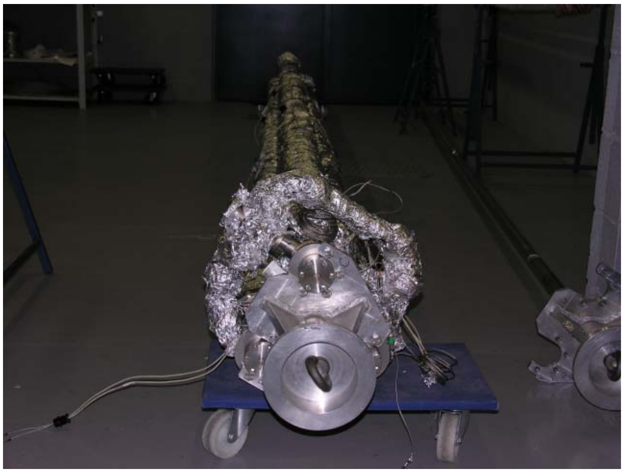

Figure 2: Close up of the mounting system.

A total quality approach, based on checking both the process parameters and the product characteristic was implemented.

Pipes were visual inspected to check for gross contaminant or surface defects, which could cause poor film adhesion. Pipes were then mounted and evacuated in the 10^{-9} mbar range by the UHV group. Before deposition, they were baked overnight and leak tested with helium. An RGA was also carried out by means of a quadrupole mass spectrometer fitted to the coating system to ensure the absence of residue of the cleaning process or possible minor contamination (in particular alkaline ions or hydrocarbons peaks were closely monitored). Even though well known in principle, the sputtering process for thin getter film deposition needs to be optimized to avoid instability and lack of reproducibility which can significantly change the gas sorption and surface properties of the film (e.g. secondary electron yield, ion-electron induced gas de-sorption). As described in another paper at this Conference [8], process instabilities can be originated by a number of factors, including the pipe geometry, the cathodes configuration and the sputtering parameters. During the coating, all relevant process parameters (Plasma gas pressure, substrate temperature, plasma current, magnetic field value) were recorded and suitably adjusted to ensure the stability of the deposition process. After coating, the pipes were cooled to room temperature, exposed to air and left to age for a couple of days before being visually inspected again. Aging is a recommended procedure since it helps in identifying areas where the film adhesion is poor. No single case of peel off was found over more than 120 coated pipes, confirming that the coating process was well set and stable and that the surface cleanliness and morphology of the pipes was adequate.

Film adhesion was checked in some specific cases by thermal cycling several times from room temperature to 250°C the extension chambers attached to the pipes.

Finally, pipes were evacuated and back-filled with dry nitrogen for shipment.

For each coating process, film thickness and chemical composition was measured.

A special type of coupon was inserted inside the pipe assembly in a suitable position, so to expose it to the sputtered material and provide a replica of the process.

The thickness and chemical composition were measured on the coupons with a KLA-Tencor P15 contact profilemeter and an EDX probe, respectively.

The chemical composition of the deposited films is given in Figure 3, along with the average value (dashed lines).

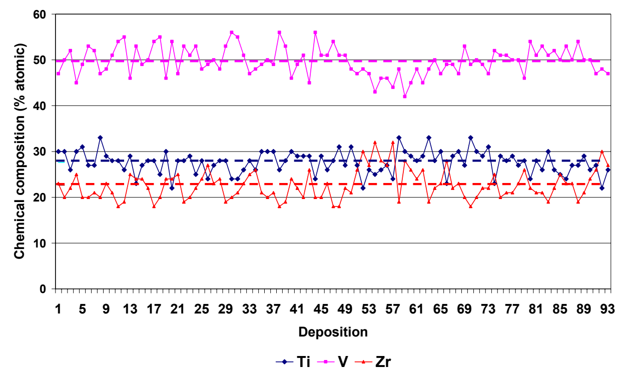

Figure 3: Fluctuation in the chemical composition.

The average atomic composition is Ti_{28} Zr_{23} V_{49}, close to the required specified nominal values ($Ti_{30}Zr_{25}V_{45}$). Fluctuations always remained within the acceptable range as indicated by CERN for the TiZrV getter film [9].

Similar results are showed for the thickness measurement in Figure 4.

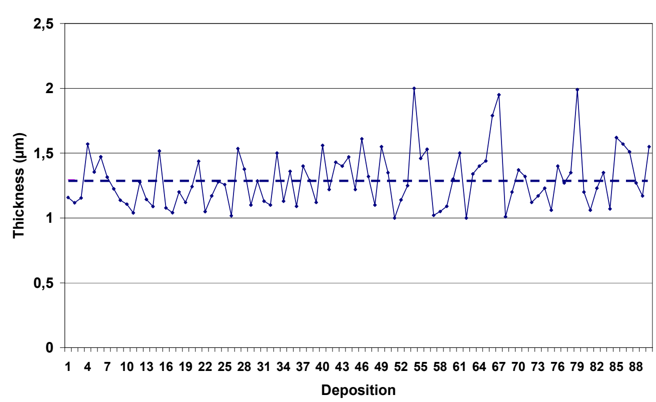

Figure 4: Measurement of the film thickness on various coated pipes.

Average thickness is 1.3 micron. In all cases thickness values are comprised between 1 and 2 microns as requested in the technical specifications.

On a few NEG coated extension chambers the out-gassing rates at room temperature for Kr, H_2O, CO_2 and CH_4 were measured after film activation (250°C x 2 hours). This measurement is particularly delicate, due to the low desorption rates involved which required the use of a dedicated UHV out-gassing bench.
Results are reported in table 1.

Gas species	Ourgassing rate(mbarl/s cm^2)
CO_2	< $3x10^{-16}$
H_2O	< 3x10-^{17}
Kr	< $6x10^{-18}$
CH_4	< $3x\ 10^{-15}$

OPEN ISSUES

Coating the pipes for RHIC has been a formidable opportunity to learn how to transform an R&D activity into an industrialized process, identifying the key critical points in term of process reproducibility, quality control and product quality, and addressing them.
RHIC pipes had a relatively large internal diameter (125 mm). This facilitated the mounting of the cathode assemblies and made the process instabilities easier to control.
The actual trend in high energy machines is to move towards small diameter pipes (e.g. 4-8 mm) to enjoy the benefit of increased beam performance, machine design simplification and cost reduction,
Coating such long narrow pipes increases dramatically the possibility of unstable and uncontrolled coating processes. Cathodes positioning also becomes an issue, since arcing or large local fluctuations in the film thickness can lead to changes in the film composition and local peel off.
SAES Getters has gathered experience in this field working closely with the high energy physics community over the last 5 years. A dedicated internal R&D effort is now ongoing, aimed at deepening the understanding of the basics of the deposition phenomena taking place in long, narrow cavities so to combine stable coating conditions with sound manufacturing cycles which allow high throughput industrial process. Both conditions are required, should the need for large quantity of narrow chambers become real. A first contribution in this direction is provided at this Conference [8].

CONCLUSIONS

Two running accelerators, the Soleil synchrotron and RHIC, are already using NEG coated pipes in a significant portion of the overall vacuum system with good results. LHC, for which this technology has been developed, will be soon the largest benchmark, with 6 km of coated pipes installed. Other large projects like ILC and MAX IV are also considering the adoption of NEG films. Coating large number of pipes, however, poses several challenges and requires tight control of the manufacturing process to ensure reproducibility and reliability of the film properties. This can be accomplished through the adoption of an industrial approach, which delivers consistent quality of the product, as shown by results obtained for RHIC.
In this general frame, an additional challenge is posed by the present trend in reducing the internal diameter of the pipes, which makes it increasingly difficult to maintain a stable and controlled process. Specific activity in this direction has been started at SAES Getters with the aim to provide stable and high throughput manufacturing cycles.

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