

DEPOSITION OF NON EVAPORABLE GETTER (NEG) FILMS ON VACUUM CHAMBERS FOR HIGH ENERGY MACHINES AND SYNCHROTRON RADIATION SOURCES

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Abstract

Non Evaporable Getter (NEG) films, sputter deposited onto the internal surfaces of vacuum chambers reduce thermal out-gassing and provide conductance-free distributed pumping ability, allowing the achievement of very low pressure inside narrow and conductance limited chambers, like Insertion Devices.

NEG films do show additional interesting features, like low secondary electron yield and low gas desorption rates under ions, electrons and photons bombardment.

They seem therefore ideal to reduce electron multi-pacting and dynamic gas desorption induced beam instabilities in high energy machines.

This paper presents SAES Getters' experience in the NEG coating of chambers of different geometries and sizes for a variety of projects related to high energy machines and synchrotron radiation facilities. Examples of applications, as well as most common issues related to chambers preparation, film deposition, characterization and quality control, are given. Areas where further work is still necessary to fully take advantage of NEG film properties will be also discussed.

INTRODUCTION

Non Evaporable Getters (NEG) are widely used to effectively capture molecules impinging on their active surface and achieve UHV-XHV conditions in vacuum systems [1]. NEG elements, either sintered bodies or laminated getter strips, are generally assembled into highly efficient cartridge pumps to provide large pumping speed for active gases [2]. NEG coating in the form of sputtered films have been proposed by CERN [3] as a way to further improve ultimate vacuum. Being a barrier for gases, NEG films reduce thermal out-gassing while providing in-situ conductance-free pumping speed. These features are ideal for conductance limited narrow-gap chambers, like Insertion Devices (IDs), otherwise difficult to evacuate by ordinary means. NEG films can be fully activated at modest temperature, like 250°Cx2 hrs. Milder activation (e.g. 180°Cx24 hrs), have been successfully applied, this condition being better suited for aluminium chambers which cannot withstand high temperature bake-out. Benefits in using NEG coatings are not limited to sorption performances. Several studies showed that they reduce Bremsstrahlung radiation and allow faster vacuum recovery after maintenance or shut downs in synchrotrons [4,5], which in turn means more machine time for the users. Gas desorption under photon, ion and electron bombardment, as well as secondary electron yield (SEY)

have also reported to be lower than for uncoated surfaces [6,8]. All these features contribute to remarkable reduction of the dynamic out-gassing during machine operation, and a mitigation of the electron cloud effect. Interest for NEG coatings in synchrotrons, colliders and high energy machines has therefore increased in the last years. ESRF has now 20 NEG coated chambers installed and has upgrading plans to add more [9]. Soleil project has adopted NEG coatings in all straight vacuum vessels of the storage ring (56% of the total circumference) and represents the largest application of NEG coating in synchrotrons so far.

Several others facilities like ELETTRA, MAX II-III, SLS and Diamond have NEG coated chambers already installed or being installed. Synchrotrons are not the only machines taking advantage of NEG coating, though.

Installation of 430m of NEG coated pipes in the warm straight sections of RHIC has proved beneficial to reduce pressure instabilities and to remarkably increase machine luminosity [10,11]. More NEG coated pipes will be installed in 2006 at RHIC.

CERN will use 6 km of coated chambers in the straight warm sections of LHC [12,13], while GSI has decided to use NEG in substantial amount in the FAIR project [14]. An extensive, updated review of NEG coating technology can be found in [15] which collects the talks given at the recent 45th IUVESTA Workshop on NEG Coating for Particle Accelerators and Vacuum Systems, held in Catania, Italy, April 2006.

THE FILM DEPOSITION PROCESS

NEG films with typical atomic composition of $Ti_{30}V_{40}Zr_{30}$ are deposited on the inner chamber surface by magnetron sputtering. Cathodes are prepared by twisting together Ti, Zr and V metal wires. Pre-cleaning of the chamber surface before sputtering is essential to ensure adequate adhesion of the film to the substrate. Suitable cleaning treatments have been developed at CERN for various materials, like steel, aluminium and copper [16].

Kr is used as the sputtering gas: being less efficiently trapped by the growing film than Ar, less out-gassing is generated when the film is under vacuum. Depending on the chamber section, one or more sputtering cathodes can be used. One single cathode, placed along the chamber axis, provides the required deposition uniformity for cylindrical pipes. For elliptically shaped chambers like narrow-gap IDs, 2 or even 3 cathodes are necessary.

Cathodes spacing and relative positioning can be adjusted to achieve a given thickness distribution profile

along the perimeter. Calculations using the view factor method [17,18] are currently used by SAES Getters to this purpose. Film thickness generally varies from 0,5 to 2 micron. Film roughness can be modified to some extent adjusting the plasma parameters, substrate temperature and surface finishing [13].

SAES GETTERS COATING FACILITIES

SAES getters acquired in 2000 the license from CERN for NEG coating of vacuum chambers for particle accelerators. Since then, large investments were progressively made for coating facilities, infrastructures and test equipment to achieve production capabilities and coating flexibility required by the particle accelerators community. One coating facility is showed in Fig.1.



Figure 1: Vertical coating facility. Various cylindrical pipes (5.5m long) are here coated simultaneously. The magnetic coil is visible at the bottom.

It is a vertical tower which can handle long chambers, up to 6.5 m. Chambers are mounted vertically to the manifold, evacuated and baked before coating. A RGA is used to measure gas background and for leak testing. Sputtering is carried out at constant Kr pressure (about 0.015 mbar). Kr is injected by a leak valve electronically driven by a capacitance manometer. A 2m long magnetic coil (generating fields up to 700 gauss) can be moved sequentially upward/downward to coat by steps all the chamber length. A variety of narrow-gap (down to 10 mm) and very long IDs (up to 5.5 m) for Soleil, MAX II-III, ELETTRA, NSRRC and Diamond have been coated using this facility. ID chambers require very careful handling and positioning of the cathodes and only one chamber per time can be generally coated.

For cylindrical chambers (e.g. RHIC warm straight sections), cathodes positioning is less critical and more chambers can be coated simultaneously using suitable holding fixtures. This increases process productivity.

To get uniform coating up to the very end of the chambers, extension nipples having the same chamber cross section are flanged to the chamber extremities. On request, test coupons, are mounted inside the extension chambers and analyzed to determine film composition (SEM-EDX probe) and thickness (profilometer). Silicon pieces are particularly suited as test coupons, due to their very smooth and flat surface.

Another NEG coating facility available at SAES getters to process very large, more complex chambers, like those used by Soleil in the quadrupole and sextupole magnets of the storage ring [19] is showed in Fig.2.



Figure 2: Large coil coating facility.

Soleil chambers have lateral pumping ports protruding perpendicularly to the chamber axis, as showed in Fig. 3.



Figure 3: Soleil chamber with lateral pumping ports.

A very large coil (internal diameter 600 mm) is here necessary to coat these chambers.

Also, suitable mounting/handling systems have been designed to mount and connect to the vacuum system more vessels at a time. Two independent vacuum groups and associated equipment (i.e. mass spectrometers, power supplies, data acquisition systems) have been realized, which allow simultaneous coating of multiple vessels speeding-up the whole process.

QUALITY ASSURANCE AND COATING CHARACTERIZATION

A number of checks and process controls are implemented in the manufacturing cycle to ensure film quality. Chambers are visually inspected before mounting, also with the aid of a metrological video probe, to assess surface cleanliness and morphology. Stains can be indication of contamination or poor surface cleaning which can cause peel-off of the NEG coating. Leak tightness and absence of gross contamination is measured with the mass spectrometer before injecting Kr and starting the film deposition. Process parameters (cathodes currents and voltages, magnetic fields, plasma pressure, substrate temperature) are fully monitored to keep control during the deposition process. After coating, the chamber is inspected again, aged for one day and then evacuated, filled with nitrogen and closed for shipment.

On request, chemical composition and thickness can be measured on test coupons. Film adhesion was checked in some specific cases by thermal cycling the extension chambers from room temperature to 250°C several times.

Extension chambers can also be connected to a UHV system to measure NEG film sorption performances.

OPEN ISSUES AND FUTURE TRENDS

Areas where NEG coating technology needs further improvements do exist. One is the optimisation of the experimental set-up to get finer control of the overall coating process. With this regard, the ability to precisely monitor the plasma discharge and to detect the presence of anomalies during the sputter deposition is one key factor to ensure optimal film properties, reproducibility and a good match between desired calculated profiles and actual NEG film thickness distribution. This latter aspect is particularly relevant for narrow-gap chambers where good sorption properties have to be coupled with acceptable impedance values. In these cases, film thickness has to be carefully controlled in such a way to be as low as possible in the critical area and sufficiently large elsewhere. An optimised coating process can ensure the deposition of thin films (e.g. 0,5 microns or less) in areas where the impedance is critical and thicker films (e.g. 1-2 micron) where sorption properties are more relevant. Another interesting area of investigation is related to the evaluation of the very limits of NEG coating technology. Innovative high energy machines, using narrow gap IDs with internal diameter of 4-6 mm,

have been proposed recently, which can take advantage of the properties of NEG films [19]. Coating such chambers, however, is at the very limit of presently available NEG coating technology and new concepts and developments are likely necessary to ensure this target can be met. SAES Getters has recently started an internal R&D project to address this topic, taking advantage of the experience so far accumulated in the past 6 years of coating activity. Several challenges have already been identified in term of cathodes positioning, plasma ignition, monitoring and adjustment, as well as NEG film thickness control.

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