STUDY OF THE PRESSURE PROFILE INSIDE THE NEG COATED CHAMBERS OF THE SIS 18

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Abstract

In the context of the technical developments for the construction of FAIR at GSI, an intensive programme for the vacuum upgrade of the existing SIS 18 was started in 2005, with the aim to improve the beam lifetime and intensity. To reach these purposes also the installation of NEG coated dipole and quadrupole chambers was foreseen. During the upgrade shutdowns performed between 2006 and 2009 the vacuum chambers of approximately 65% of the SIS 18 circumference were replaced by NEG coated pipes. To evaluate in detail the pressure profile inside the coated chambers mounted into the accelerator a dedicated experimental set-up, which reproduces a vacuum environment similar to the one of the SIS 18, was built. Using three gauges, mounted in different positions of a coated chamber, it was possible to measure the pressure in the range of 10^{-12} mbar inside the activated NEG pipe and 10^{-11} mbar outside the pipe at the pumping posts. Additionally, a modelling of a SIS 18 vacuum sector was realised and the pressure variation values obtained by simulations were compared with those measured. In this paper the experimental results and the vacuum simulations are described and discussed.

NEG COATING PRODUCTION AND CHARACTERISATION

Three cylindrical magnetron sputtering facilities designed and commissioned at GSI were used to deposit Ti-Zr-V coatings from cathodes of 2 mm diameter intertwisted elemental wires. The three systems are described in details in Ref. [1] and [2]. Essentially they consist of vacuum pumping units, equipped with a gas injection line, gauges, and residual gas analysers, a manifold, and horizontal solenoids. The coils are individually powered to obtain the generation of inhomogeneous magnetic fields if needed for the coating of vacuum chambers with a non constant aperture.

Deposition rates between 0.04 and 0.1 μm/h were obtained in the set-ups applying a discharge current of 0.12 A/m of cathode (fed by 1.5 kW power supplies) and a voltage of -500V respectively in the case of the coating of the dipole and of the quadrupole chambers.

The magnetic field applied in both cases was about 180 G. Krypton was chosen as discharge gas because it is less prone compared to Argon to be trapped into the film during the deposition process [3] and consequently its outgassing is lower. Additionally during the sputtering process the residual gas composition was continuously monitored to be sure that no leaks were occurring.

The surface chemical composition and the activation behaviour of the produced thin films (≈ 1 μm thick) were studied analysing small samples coated together with each vacuum pipes by means of X-Ray Photoelectron Spectroscopy (XPS) performed initially at CERN and then at the Magdeburg University [4, 5, 6]. Two additional techniques were improved at GSI for the NEG sample investigation: the Rutherford Backscattering Spectroscopy (RBS) [7] and the Elastic Recoil Detection Analysis (ERDA) [8]. Both were used to study the chemical composition and the thickness of the coated samples. Considering that the vacuum chambers mounted in accelerators undergo several venting-activation cycles, a deep investigation on the NEG ageing was performed, and the ERDA techniques resulted to be an excellent means also for that study [8]. In picture 1is shown the magnetron sputtering facility used to perform the NEG coating of the dipole magnet chamber of the SIS 18.

Figure 1: Magnetron sputtering facility designed and commissioned at GSI to perform the NEG coating of the dipole magnet chambers of the SIS 18.

VACUUM UPGRADE ACHIEVEMENT IN THE SIS 18

During the upgrade shutdowns from 2006 and 2009 24 dipole magnet chambers, 11 long and 5 short quadrupole chambers, 10 collimator systems and 13 straight standard vacuum chambers were replaced by NEG-coated UHV chambers. The bakeout and activation programme for the getter coated pipes, inserted in the different vacuum sectors, was accomplished at the beginning of 2010.

The vacuum upgrade achievement was tested during a machine experiment campaign [9, 10]. The increased pumping speed, due to the NEG coatings, the collimations systems, equipped with the Au thin film absorbers [11,12], and some additional upgrade works carried out during the shutdowns of the accelerator [13] allowed accelerating and extracting $2x10^{10}$ U^{28+} ions, which is an intensity increase by a factor of 100 compared to that reached before the upgrade programme. In addition the achievable U^{28+} beam lifetime (t) was strongly improved, from t < 1s before the UHV upgrade, reaching about t=11s after the upgrade (see Figure 2). During the measurements no increase of pressure was recorded [9].

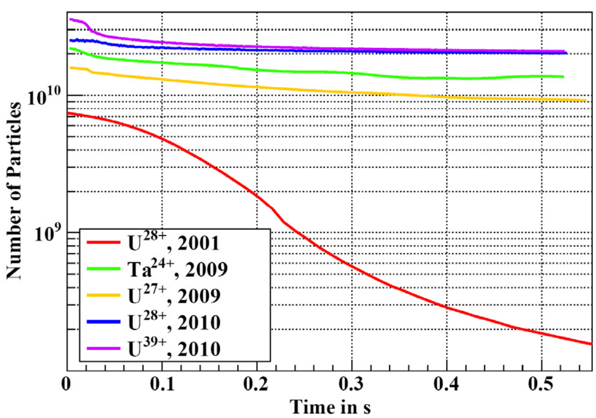


Figure 2: Measurement of the U^{28+} ions lifetime. From the data acquired in 2001 and those of 2010, a clear improvement is visible.

ANALISYS OF THE PRESSURE PROFILE IN THE NEG COATED DIPOLE CHAMBERS

The contribution of the NEG thin film on the vacuum improvement of the SIS 18 could be defined only if the pressure profile inside the coated chamber would be known. Due to lack of space, especially in the magnets, it was not possible to perform that measurement directly in the accelerator. Therefore an experimental set-up to carry out that study was designed to be comparable with the SIS 18 vacuum environment, and commissioned, as shown in Figure 3. The experimental system consists of two pumping posts, equipped with a combination of a titanium sublimation pump (TSP), and ion sputter pump (IP). An extractor ionization gauge is mounted on both sides of the vacuum test chamber [14].

The vacuum pipe built has an the identical gas flow conductance of the dipole magnet chambers, but thicker walls so to make possible the insertion of vacuum gauges.

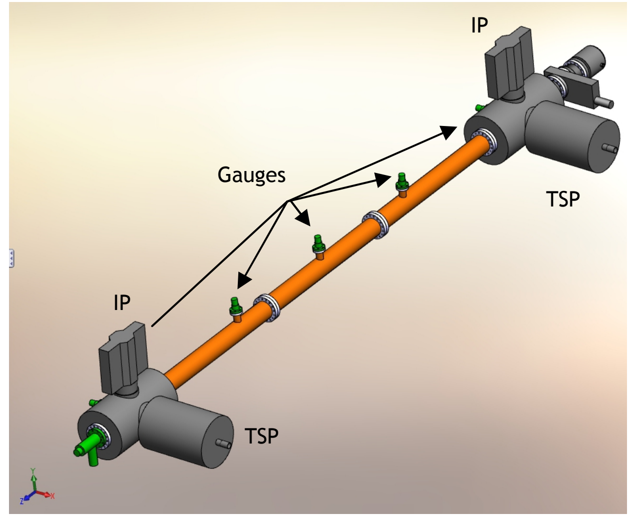


Figure 3: Experimental set-up built to determine the pressure profile into a NEG coated dipole chamber.

The bakeout and activation procedure used in the experiment was carefully following the one adopted in the SIS 18. After heating the uncoated components at 250 °C for 160 hours, and after the degassing of all instrumentations and pumps, the temperature of the coated pipe was raised from 120°C to 220°C, and kept at that temperature for 24 hours to perform the NEG activation. While increasing the temperature of the coated chamber, the uncoated components were kept at 150°C. At the end of the activation a new degassing was carried out. The pressure values read were of the order of 10^{-11} mbar at the pumping posts, while inside the NEG activated pipe of the order of 10^{-12}mbar.

The experimental results obtained were compared with those calculated by means of two different simulation methods: the Vaktrak code [15] and the Molflow+ [16]. In both cases a good agreement between experimental results and simulations was found.

The values obtained by calculations and compared with those measured are shown in Figure 4 and 5.

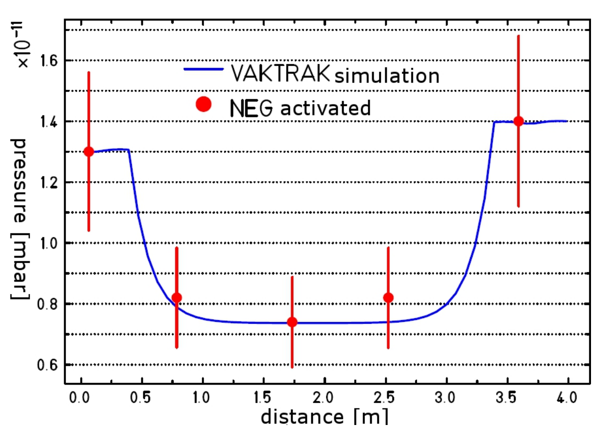
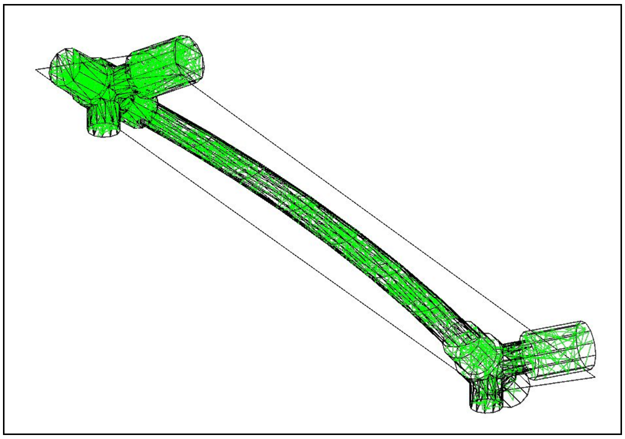


Figure 4: Pressure profile measured and simulated by Vaktrak code in the test chamber.



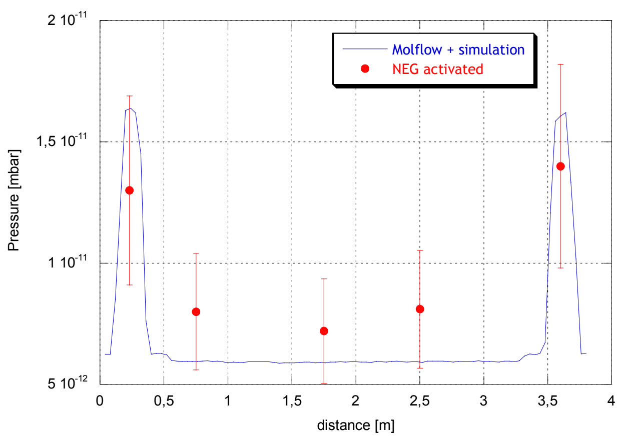


Figure 5: Top: modelling and mesh of the experimental system carried out to perform the Molflow+ simulation. Bottom: pressure profile into the dipole chamber simulated by Molflow+.

Additionally, the effect of the sublimation of the titanium pumps on the activated NEG film was analysed [14].

As shown in Figure 6, even after 12 sublimation cycles the pressure in the coated chamber is still lower than at the pumping posts.

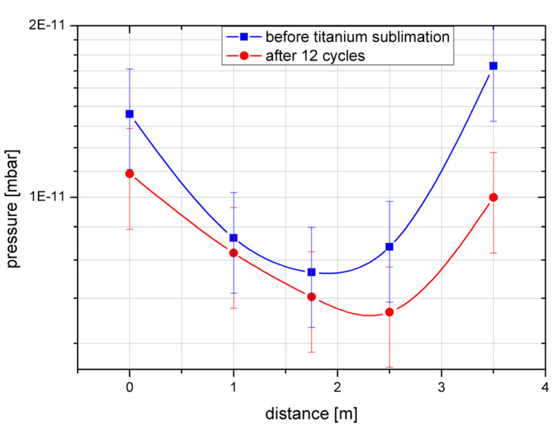


Figure 6: Effect of the Ti sublimation on the activated NEG thin film.

CONCLUSION

During the upgrade shutdowns from 2006 and 2009 24 dipole magnet chambers, 11 long and 5 short quadrupole chambers, 10 collimator systems and 13 straight standard vacuum chambers were coated or replaced by new NEG coated chambers. The bakeout and activation programme for the getter thin film coated pipes, inserted in the different vacuum sectors, was accomplished at the beginning of 2010.

A machine performance was tested after the vacuum system upgrade in a series of experiments. The acceleration and extraction of $2x10^{10}$ U^{28+} ions, which is an intensity increase by a factor of 100 compared to the intensity before the upgrade was performed. In addition the achievable U^{28+} beam lifetime (t) was strongly improved, from t < 1s to about t=11s.

The NEG contribution to the vacuum improvement was studied using an experimental set-up which reproduces a vacuum environment similar to the one of the SIS 18. It was proved that the pressure in the pumping post is limited to 10^{-11}mbar, value observed also in the accelerator, even if inside the coated pipes the pressure can reach 10^{-12} mbar.

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