THIN FILM COATING FOR THE UPGRADE OF THE ION SYNCHROTRON SIS18 AT GSI*

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Abstract

For the future FAIR facility intensities up to 10^{12} U^{28+} ions per second are required. For this purpose the existing heavy ion synchrotron SIS18, which will serve as injector, has to be upgraded. Since the required base pressure is 10^{-10} Pa, among the different measures undertaken to improve the existing UHV system, the installation of NEG coated magnet chambers is foreseen. Two magnetron sputtering facilities were designed and commissioned at GSI to perform the coating. The characterization of the thin films has been carried out by RBS and XPS. Considering that the vacuum chambers mounted in accelerators undergo several venting-activation cycles, a deep investigation on the NEG ageing was performed by ERDA. Fourteen dipole and one quadrupole chambers were coated and installed in the SIS18, and the replacement of the remaining magnet pipes will follow in the next years. Additionally to overcome the dynamic vacuum instability a collimation system equipped with thin film coated absorbers was successfully tested in 2008.

The coating facilities, their operating mode, the results achieved on the thin film characterisation, and the ones obtained in the SIS18 are presented.

EXPERIMENTAL SET-UP

The two cylindrical magnetron sputtering facilities are described in details in Ref. [1]. Essentially they consist of a vacuum pumping unit, manifold and horizontal solenoids. The vacuum pumping unit is equipped with an injection line for Kr, used to generate the plasma, wide-range gauges, and a residual gas analyser. The electrical feedthrough for the cathode (made by intertwisted 2 mm diameter Ti, Zr, V wires) is located on top of the manifold for the coating of the quadrupole chambers. Due to the elliptical aperture of the dipole chambers, instead, two cathodes are used, mounted at about 40 mm from the centre of the pipe respectively, and for this reason located opposite to each other at the lateral side of the manifold.

The coating procedure foresees to bake the chamber for at least 24 hours at 200°C and to maintain it at 100°C while coating. After coating the chambers are vented with dry air, dismounted from the sputtering system, visually inspected, to observe if scratches are present or peel off occurs, and stored.

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THIN FILM CHARACTERISATION

To ascertain the quality of the NEG thin film, two small samples were coated together with each chamber; one used to analyse the chemical composition and the thickness by Rutherford Backscattering Spectroscopy (RBS) [2] and the second to evaluate the activation behaviour by XPS [3, 4].

To perform the RBS measurement the NEG coated sample was bombarded perpendicularly by a 16.8 MeV C^{2+} beam. The backscattered projectile ions were energy analysed by a semiconductor detector mounted with an angle of about 170° above the incoming beam in backward direction. The use of the carbon beam allows being very sensitive to the high Z components of the thin film surface. A typical RBS energy spectrum obtained during the analysis of the Ti-Zr-V thin film is shown in figure 1. A well defined Zr peak is observable, while the Ti and V peaks are not well distinguishable since they have comparable mass.

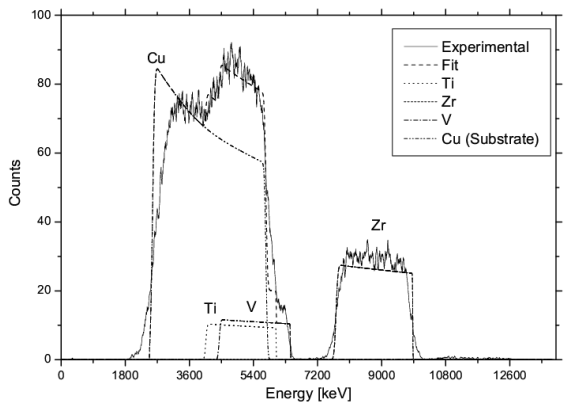

Figure 1: Measured and fitted RBS data of a getter coated copper sample. The film thickness is little below one micrometer, and the film composition is Ti 35, Zr 36 and V 29 at %.

The film element concentration and the film thickness could be, nevertheless, calculated performing peak fit by means of the SIMNRA code [5].

The activation behaviour of the produced Ti-Zr-V thin films is stated by the reduction of the oxygen and carbon peaks area as a function of the temperature as proven from the XPS analysis [1].

NEG AGEING

Considering that the vacuum chambers mounted in accelerators undergo several venting-activation cycles, a deep investigation on the NEG ageing was performed, and for this purpose a dedicated setup was built (see Fig. 2). It consists of a gas inlet system, a NEG coated test chamber, where 50 Ti-Zr-V coated samples are placed, and a pumping post. The surface gas capacity and the NEG pumping speed can be calculated knowing the conductance of the gas inlet and of the pumping post and the pressure in all three chambers.

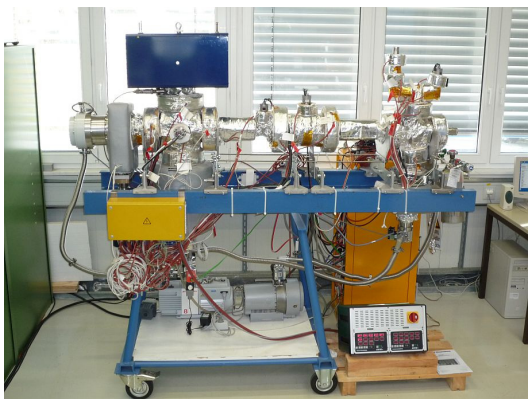

Figure 2: Picture of the experimental set up built to study the NEG ageing.

The quality of the injected gas (CO) was checked by a residual gas analyzer (RGA) mounted in the gas inlet system. In figure 3 the pumping speed and thin film surface capacity reduction as a function of the venting cycles is shown. The first four measurements were carried out after activating the thin film at 200°C. To compensate for the decrease of pumping speed and capacity the activation temperature was then increased to 250°C. The last two measurements were performed after a heating cycle at 300°C.

One of the small samples was removed from the testing chamber and investigated by Elastic Recoil Detection Analysis (ERDA) after each CO saturation.

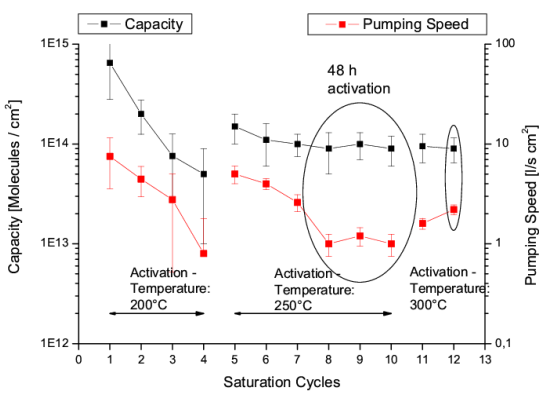

Figure 3: Ageing of the NEG performance for different activation temperatures. The activation was performed for 24 h if not differently indicated.

ERDA is a well elaborated technique, which allows achieving depth concentration profiles of a material [6]. The first four samples were already investigated as shown in figure 4. The number of activation cycles is plotted from light to dark colour, carbon in red and oxygen in blue. The oxygen diffusion in the bulk of the Ti-Zr-V film and the C (surface peak at channel 450) surface increase after each activation cycle is clearly demonstrated.

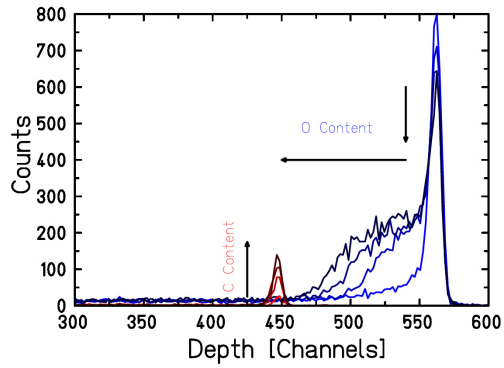

Figure 4: C and O profiles from ERDA raw data for the first four samples. The C and O surface energies are at channels 450 and 560 respectively.

THE SIS18 PILOT SECTOR

By the end of 2007 the first coated dipole chambers were mounted in the SIS18. The gauge S01 in the vacuum sector VII (see Fig. 5) was chosen to follow the evolution of the pressure during the bakeout and activation procedure.

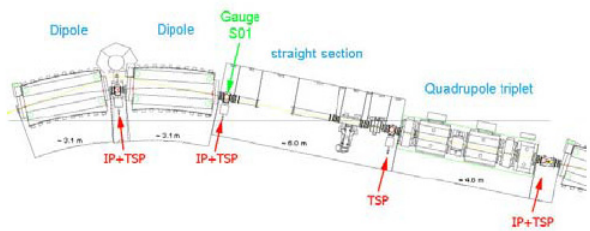

Figure 5: Schematic drawing of the sector VII. The gauge S01 is located between the dipole chamber and a straight sector.

After the bakeout of the uncoated parts of the accelerator at 220°C for 160 hours, the temperature of the coated pipes is raised from 120°C to 210°C, and kept at that temperature for 24 hours to perform the NEG activation.

In figure 6 the variation of the pressure recorded during the heating cycle is shown and compared with the pressure value measured before venting the vacuum sector.

The final pressure recorded by the gauge S01 was about 3×10^{-12} mbar, 5 times lower that the one reached before the installation of the coated chambers ($\approx 1{,}6 \times 10^{-11}$ mbar).

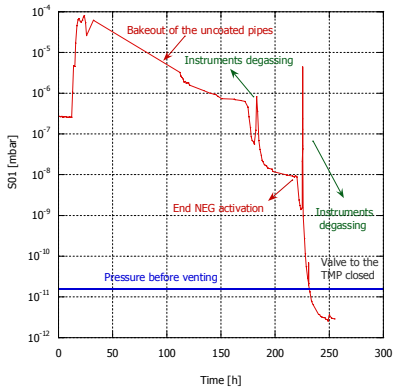

Figure 6: Variation of the pressure during the bake-out/activation cycle recorded by the gauge S01.

VACUUM INSTABILITY AND ION CATCHER SYSTEM

To reach the required beam intensities in SIS18, low charge state ions are used in order to avoid stripping losses and to shift the limitation by space charge to higher particle numbers. For the FAIR injector mode U^{28+} will be used. The disadvantage of the low charge state is the comparable high cross section for projectile ionization [7].

During test operation of SIS18 with high intensity low charge state heavy ions, strong intensity dependent beam losses have been observed in coincidence with pressure fluctuations inside the accelerator beam pipe. Due to charge exchange, in case of U^{28+} dominantly ionization, beam particles get lost after the dipole chambers and hit the beam pipe under grazing incident. In this ion-surface collision huge amounts of adsorbed gas are released from the stainless steel surface. For grazing incident angles desorption yields of 10^3 to 10^5 molecules per incident ion are reported. Experiment have also shown, that the desorption yield for grazing incident is higher compared to perpendicular incident [8]. In order to find low desorbing materials and to overcome the problem of ion-induced desorption due to charge exchanged beam particles in the SIS18, *in-situ* desorption yield and ERDA measurements were performed [9]. In parallel an ion catcher system was built to guarantee that the loss of the charge exchanged particles behind the dipole chambers occurs on a low desorbing material and in a high pumping environment. Lowest desorption was observed for gold coated copper targets, where a thin nickel film between copper and gold avoid diffusion of the materials into each other during the standard UHV bakeout. For this purpose a Ni film thickness around 200 nm is sufficient.

Figure 7 shows the ion catcher prototype as implemented in the period 2 and 3 of the SIS18. Two geometries were realized: a wedge and a block shaped absorber. The first one, which separates the region where the losses occur from the circulating beam, has the disadvantage that the particles hit the absorber under grazing incident causing high desorption. The second one, which can be placed in the correct position by a linear motion feedthrough guarantees instead perpendicular incident with the disadvantage of an open geometry. Experiments have shown that the block shaped absorber has, as expected, lower desorption yield on the level of 25 molecules per incident ion. Therefore it represents the favourite solution for the next ion catcher system.

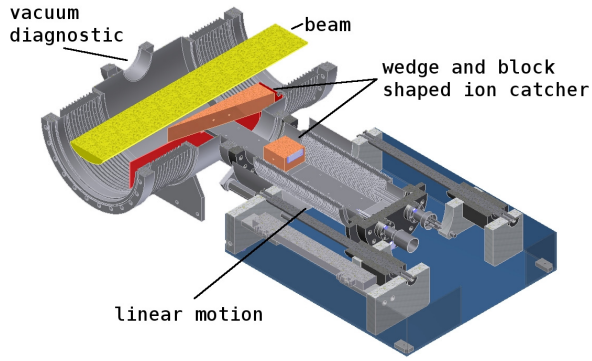

Figure 7: Schematic drawing of the ion catcher prototype with wedge and block shaped loss regions.

CONCLUSION

In the last three years two magnetron sputtering facilities were designed and commissioned at GSI. The performances of the thin films getter produced were analysed with different techniques and the good activation and pumping behaviour were proven. The first promising results after the installation of the coated chambers were already obtained. Additionally the ion catcher system commissioned at GSI represents a good solution to reduce the desorption caused by charge exchange which mainly occurs after the dipole chambers.

At present 14 coated dipole chambers, one quadrupole chambers and two ion catcher systems have been mounted in the accelerator. For the accomplishment of the SIS18 upgrade it is foreseen to mount the remaining coated dipole, quadrupole chambers and ion catchers in the next shutdowns.

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