A PHOTODESORPTION STUDY OF A TiZrV COATED STAINLESS STEEL VACUUM CHAMBER

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Abstract

An optimised method to measure the photodesorption yields and sticking probabilities from a room temperature vacuum chamber with a non-evaporable getter (NEG) coating is used to study a stainless steel test chamber coated with about 3 microns of TiZrV getter material. The desorption yields from the as-received and activated coating are determined.

After saturation with CO and during a continuous CO injection the effect of the irradiation is to reduce the pressure, contrary to the normal dynamic behaviour of a conventional vacuum system.

The results are extrapolated to the 'standard' LHC room temperature vacuum system.

1 INTRODUCTION

The coating of vacuum chambers with NEG materials, developed at CERN [1], is an attractive pumping technology with potentially many UHV/XHV applications. One such application is in the field of vacuum technology for particle accelerators. Of paramount importance for such an application is its performance when exposed to Synchrotron Radiation (SR), present in most accelerators or storage rings. The NEG coating, once activated, is an attractive material since apart from providing a distributed pumping, it may inhibit the desorption of gas from the vast reservoir of the industrially prepared substrate material. The net result would therefore be a far superior vacuum performance over conventional materials.

Photodesorption experiments from NEG coated vacuum chambers, using the three-gauge method [2] are presented here. This method permits to separate the main two NEG parameters such as the photodesorption yield and sticking probability.

2 EXPERIMENTAL SET-UP

The experiments were performed on SR beam line on the VEPP-3 electron-positron storage ring at the BINP in Novosibirsk, Russia. In order to have the maximum sensitivity for these experiments VEPP-3 was operated at 2 GeV with its maximum beam current of 120 mA (average 80 mA) resulting in a maximum photon intensity of about $5 \cdot 10^{16}$ photons/(s·m) with a photon critical energy of 4.5 keV. The beam line includes both fixed and movable collimators to define the SR beam and to limit scattered SR entering the experiment. The luminescent screens (LD1 and LD2), in Figfure 1, are used to align the test chamber for the SR to be incident at about 10 mrad, under which the experiments were performed, or pass directly to the collector (C) to determine the forward scattered reflectivity of the test chamber. The extremities of the test chamber are pumped with 150 l/s (N_2) sputter ion pump (SIP). The pressures in the pumping stations are measured with RGA1 and IG1 at one end and RGA3 and IG3 from the other. The *ex-situ* calibrated Bayard-Albert gauges, IG1 and IG3, were used as a reference for RGAs. The pressure in the centre of the chamber was measured with RGA2 *via* a 10 mm diameter hole. In order to limit parasitic desorption in the measuring port a cone was placed over this hole. A filament was incorporated into the cone to permit an independent conditioning by electrons of its surface. High purity gas could be injected at either end of the test chamber *via* leak valves.

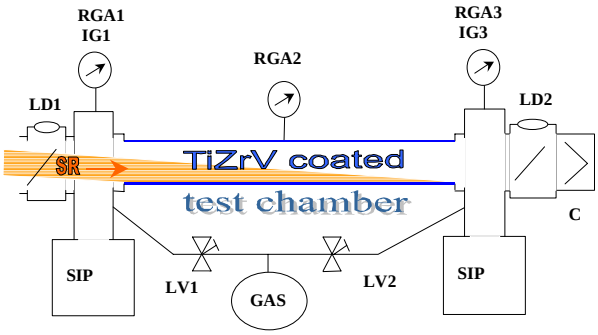

Figure 1. Experimental set-up for photodesorption measurements.

3 TEST CHAMBER PREPARATION

A 1.5 m long 316L stainless steel test chamber, with an inner/outer diameter of 24/28 mm, was coated with approximately 3 microns of TiZrV getter material with the central hole closed, thereby avoiding coating of the measuring port with NEG material.

The TiZrV test chamber was mounted on the experimental set-up and pumped out to a pressure of less than 1E-6 Torr. The system was baked to 300°C for 24 hours whilst the TiZrV test chamber was held at 80°C. For NEG activation the system was maintained at 150°C whilst the TiZrV coated test chamber was activated at 190 ± 5°C for 24 hours. Experiments began 12 hours after reaching room temperature.

4 RESULTS

TiZrV coated test chamber

The intensity of the forward-reflected photons was measured on the end collector and was found to be 10% of the incident photon intensity. The majority of the incident photons are therefore adsorbed on the TiZrV test chamber and the reflected component may be neglected. The pressure rise in the centre of the test chamber, normalised to the SR flux of $4 \cdot 10^{16}$ photon/s, is shown in Figure 2 for the as-received NEG coating and after activation.

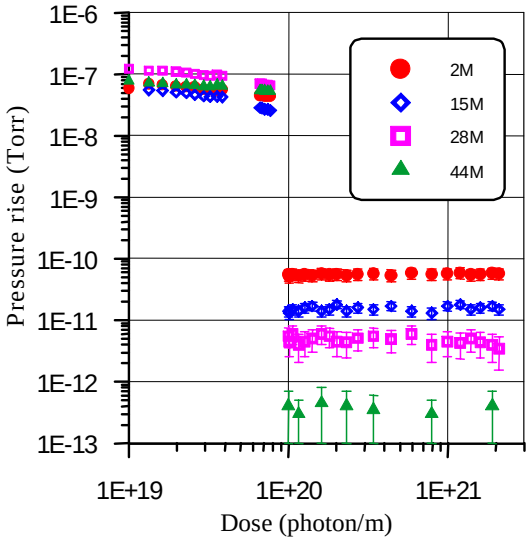

Figure 2: Pressure rise measured in the centre of the TiZrV coated test chamber before activation ($<1 \cdot 10^{20}$ photons/m) and after activation ($>1 \cdot 10^{20}$ photons/m).

Before activation the pressure rises at the centre of the chamber were of the order of $1 \cdot 10^{-7}$ Torr, reducing by about a factor of two with the relatively small photon dose of $8 \cdot 10^{19}$ photons/m. After activation these pressure rises reduced by at least three to five orders of magnitude, depending on the gas species. The pressures rises remained constant as a function of photon dose up to $2 \cdot 10^{21}$ photons/m, indicating neither additional conditioning with photons nor a saturation of the NEG. Results at higher activation temperatures (300°C) were found to be consistent with those presented in Figure 2. The estimated desorption yields for the non-activated and activated test chambers are presented in Table 1 and Table 2.

Table 1: Summary of results from the non-activated test chamber

Gas	Sticking probability	Photodesorption yield (molecules/photon)
H_2	0	$1 \cdot 10^{-3}$
CH_4	0	$2.5 \cdot 10^{-4}$
CO	0	$5 \cdot 10^{-4}$
CO_2	0	$3 \cdot 10^{-4}$

Table 2: Summary of results from the activated test chamber

Gas	Sticking probability	Photodesorption yield (molecules/photon)
H_2	~0.007	$\sim 1.5 \cdot 10^{-5}$
CH_4	0	$2 \cdot 10^{-7}$
CO (28)	0.5	$<1 \cdot 10^{-5}$
C_xH_y(28)	0	$<3 \cdot 10^{-8}$
CO_2	0.5	$<2 \cdot 10^{-6}$

The measured mass 28 can be separated into the contribution from CO and hydrocarbons by using the cracking patterns around mass 28. For the activated coating the pressure rise in the centre of the chamber is only greater than the sensitivity limit for H_2 and CH_4. Therefore only an upper limit for the desorption yields for CO, C_xH_y(28), and CO_2 are given. The sensitivity limit for CO, C_xH_y(28) is given by the relative calibration between RGAs at such low pressures and that for CO_2 is given by the absolute sensitivity of RGA2.

Dynamic behaviour during CO injection

In a separate experiment the activated coating was first saturated by injecting CO from both ends. The pressure at the centre was equal to that at the ends due to the zero sticking probability. The pressure at the ends was maintained at $2 \cdot 10^{-9}$ Torr with a small but continuous CO injection flux during irradiation. During each exposure to SR the pressure at the centre decreased, as can be seen in Figure 3.

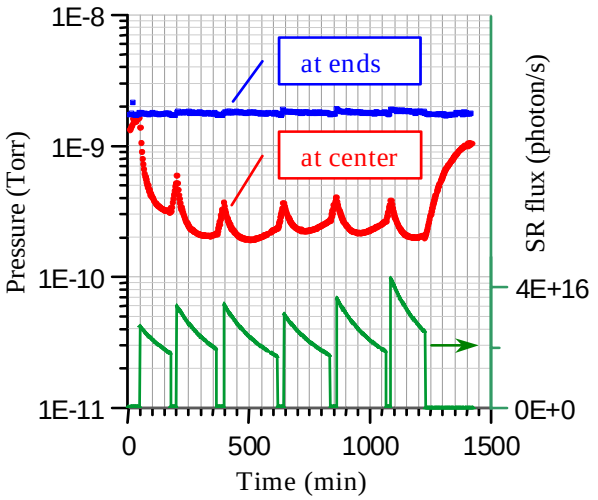

Figure 3: Dynamic CO pressure during SR exposure and continuous CO injection.

Contrary, switching off the SR resulted in an increase of the pressure. These observations are remarkable since they are contrary to the normal dynamic behaviour of a conventional vacuum system where the pressure would increase under irradiation and recover when the radiation is stopped. The interpretation of this observation is that the SR causes photon induced pumping of CO into the

bulk of the NEG. This result is very interesting for the application of the getter film to accelerators since it indicates that the film can improve after saturation with CO and thus the performance of the machine may not be limited by CO contamination.

5 IMPLICATION TO THE LHC

From the deduced desorption yields and sticking probabilities one may now scale the results to a real vacuum chamber, such as proposed for the LHC. It should be noted that such a scaling is rather artificial since stainless steel is neither a candidate vacuum chamber material nor a bare substrate material for the TiZrV coating due to its relatively poor electrical conductivity. In addition the 44.1eV critical energy in the LHC is quite different to that used here (4.5 keV). The difference in critical energy can be accounted for by comparing the estimated pressures, or more precisely a H_2 equivalent average gas density for a conventional stainless steel and the TiZrV test chambers. The H_2 equivalent average gas density is estimated by scaling the gas densities by their relative nuclear scattering cross sections with respect to H_2, σ_i/σ_{H2} at 7 TeV [3]. The average gas density is an important quantity to gauge the quality of the vacuum in an accelerator since it defines the beam lifetime. In addition for the LHC it also defines the beam induced heat load to the 1.9 K cryogenic circuit, the background to the experiments, the activation of equipment due to proton losses.

As an example, the proposed standard circular drift vacuum chamber in the long straight sections of the LHC of inner dimension 80 mm and 7 m long with end lumped pumps is used. The parameters for the estimation are shown in Table 3.

Table 3. The parameters used to estimate the relative H_2 equivalent average gas density for a standard LHC drift vacuum chamber.

Gas	σ_i/σ_{H2}	End lumped pumping speed (l/s)	TiZrV sticking probability
H_2	1	400	0.007
CH_4	5.4	250	0
CO	7.8	200	0.5
CO_2	12.2	160	0.5

In the case of a stainless steel chamber CO and CO_2 would dominate the H_2 equivalent average gas density due to their lower effective pumping speeds and their higher proton gas scattering factors. The stainless steel baked at 300°C for 24 hours has desorption yields of $4\cdot10^{-5}$, $8\cdot10^{-7}$, $2\cdot10^{-5}$, $1\cdot10^{-5}$ for H_2, CH_4, CO and CO_2 after a photon dose of $1\cdot10^{21}$ photons/m [4]. In the case of a TiZrV coated chamber the average gas densities would be dominated by CH_4 and H_2. The H_2 equivalent average gas density for a TiZrV coated vacuum chamber is estimated to be at least two orders of magnitude lower than an un-coated stainless steel vacuum chamber, mainly due to the lower net desorption yields for CO_2 and CO.

6 CONCLUSIONS

The photon stimulated gas desorption from a TiZrV coated stainless steel test chamber was measured in an optimised geometry as a function of photon dose. The recorded H_2, CH_4, CO and CO_2 pressure rises in the centre of the activated TiZrV coated test chamber are found to be at least three to five orders of magnitude lower than that from the un-activated coating. The dynamic pressure rises for CO_2 are below the sensitivity limit of the mass spectrometer. Neither photon conditioning nor saturation of the NEG film was observed up to a photon dose of $3\cdot10^{21}$ photons/m. The hydrogen sticking probability was measured to be about 0.007. The measured desorption yields for H_2, CH_4, CO, $C_xH_y(28)$ and CO_2 are ~$1.5\cdot10^{-5}$, $2\cdot10^{-7}$, $<1\cdot10^{-5}$, $<3\cdot10^{-8}$ and $<2\cdot10^{-6}$ molecules/photon, respectively.

The pressure in the centre of the test chamber, once saturated with CO and during a continuous CO injection, decreases during SR irradiation. This observation is contrary to a conventional vacuum system where the pressure increases during SR irradiation. This observation is explained in terms of photon stimulated pumping. This result is very interesting for the application of the getter film to accelerator since it indicates that the film can improve after saturation with CO and thus may not be limited by CO contamination.

Scaling these results to the proposed 7m long ID 80mm drift chambers in the long straight sections of the LHC, the H_2 equivalent average gas density is estimated to be a factor of at least two orders of magnitude less for the TiZrV coated drift chamber as compared with an un-coated stainless steel drift chamber. This factor is mainly due to the reduced net desorption yield of CO_2 and CO.

7 REFERENCES

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[4] Measured in the same geometry under identical conditions, to be published.