SUMMARY ON TITANIUM NITRIDE COATING OF SNS RING VACUUM CHAMBERS*

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Abstract

The inner surfaces of the 248 m Spallation Neutron Source (SNS) accumulator ring vacuum chambers are coated with ~100nm of titanium nitride (TiN) to reduce the secondary electron yield (SEY) of the chamber walls. There are approximately 135 chambers and kicker modules, some up to 5m in length and 36cm in diameter, coated with TiN. The coating is deposited by means of reactive DC magnetron sputtering using a cylindrical cathode with internal permanent magnets. This cathode configuration generates a deposition rate sufficient to meet the required production schedule and produces stoichiometric films with good adhesion, low SEY and acceptable outgassing. Moreover, the cathode magnet configuration allows for simple changes in length and has been adapted to coat the wide variety of chambers and components contained within the arcs, injection, extraction, collimation and RF straight sections. Chamber types and quantities as well as the cathode configurations are presented herein. The unique coating requirements of the injection kicker ceramic chambers and the extraction kicker ferrite surface will be emphasized. A brief summary of the salient coating properties is given including the interdependence of SEY as a function of surface roughness and its effect on outgassing.

INTRODUCTION

On April 26, 2005, Brookhaven coated the final SNS accumulator ring vacuum chamber with TiN. A total of 135 discrete vacuum components (including spares) and over 300m in length were coated. These chambers range from 20 to 36cm in diameter and from < 0.5m to 5m in lengths.

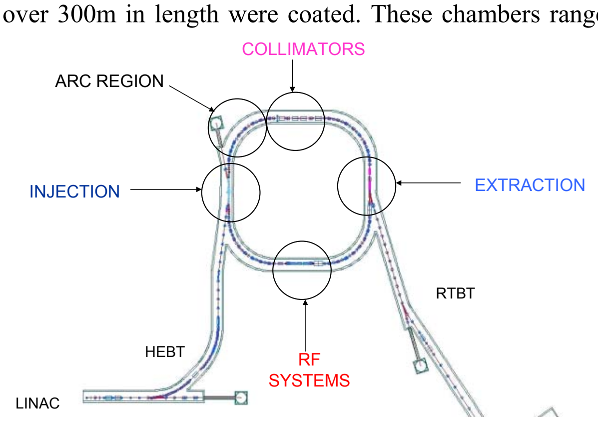

Figure 1. SNS accumulator ring layout.

The accumulator ring, shown in Figure 1, consists of four arc regions and four straight sections; injection, collimation, extraction and RF. A summary of the types and quantities of coated chambers from each region is given in Table 1.

Table 1: Chamber types and quantities for each region of the accumulator ring including coated spares

ARC	INJECTION
Half-Cell A (9)	ceramic pipe (10)
Half-Cell B (9)	pump tee (2)
Half-Cell C (9)	bellows (6)
Half-Cell D (9)	quad doublet (3)
Half-Cell E (5)	chicane chambers (4)

COLLIMATION	EXTRACTION	RF
primary coll (1)	K1 modules (7)	cavity chamber (15)
coll 2 & 3 (2)	K2 modules (7)	quad doublet (3)
quad doublet (3)	quad doublet (4)	IPM (2)
bellows (3)	lambertson (1)	bellows (3)
drift chamber (2)	bellows (1)	beam cur mon (1)
pump tee (1)	beam in gap kick (1)	wall cur mon (1)
tune pickup (1)	drift chamber (1)	tune kicker (1)
QMM pickup (1)	pump tee/spool (3)	QMM pickup (1)
damper kick (2)		spool piece (1)

COATING METHOD

Reactive DC magnetron sputtering, with its high deposition rate, was chosen over diode sputtering to facilitate the coating of these vacuum chambers [1]. The cathode configuration used is similar to the one reported by Hosokawa *et al* [2]. A schematic of this cathode configuration and BNL's cathode is shown in Figure 2. A deposition rate of ~100 nm /hr at a cathode power density of 0.625 watts/cm^2 was achieved during development with a 20cm diameter chamber. For production coating, discharge power was varied linearly with the chamber length (i.e. magnet string length), and the deposition time varied with the diameter. Increasing the power density above 1 watt/cm^2 level would cause heat damage to the nitrogen distribution tube, which was not well thermal anchored with the water cooled cathode. Without that concern much higher deposition rates could be achieved.

*SNS is managed by UT-Battelle, LLC, under contract DE-AC05-00OR22725 for the U.S. Department of Energy. SNS is a partnership of six national laboratories: Argonne, Brookhaven, Jefferson, Lawrence Berkeley, Los Alamos, and Oak Ridge. This work is performed under the auspices of the U.S. Department of Energy.
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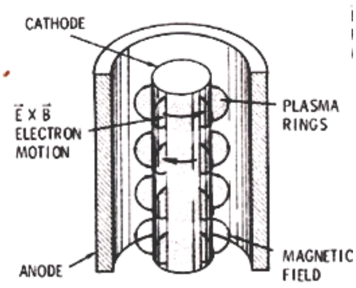

a

b

c

Figure 2: (a) Schematic of the cathode configuration reported by Thornton [3]. (b) Ti tubing and *Alnico* magnets used to construct BNL cathode. (c) Cathode leveling and isolation.

CATHODE CONFIGURATIONS

This magnetron cathode could be easily adapted to a wide range of chamber sizes and geometries. Adjustments in length could be made by simply adding or removing magnets. There were four major configurations required to coat all the SNS ring chambers: *Arc half-cell chambers*; *Straight section metal chambers*; *Injection ceramic chambers*; and *Extraction kicker modules.* In all configurations, the cathode was isolated from the chamber using ceramic breaks. Bellows were also used for alignment and centering of the cathode (Figure 2(c)). Cathode deflection can be reduced by applying a bending moment to the cathode.

Arc Half-Cell Chambers

Due to the Half-cell chamber geometry, a cathode was constructed with a sagitta equal to the dipole arc section. Due to the difference in nitrogen consumption rate resulting from the difference in cathode-to-chamber spacing between the dipole half and quadrupole half, independent flow control was required. A schematic of the coating setup for arc half-cell chambers is shown in Figure 3.

Straight Section Metal Chambers

The coating of straight chambers was much like the half-cell chambers. In the case of short chambers sharing like flanges, they could be joined together and coated in batches. Three cathodes were constructed which would coat chambers 2m, 3.5m and 5m in length. In certain cases, spool pieces would be installed to make up the differences in length.

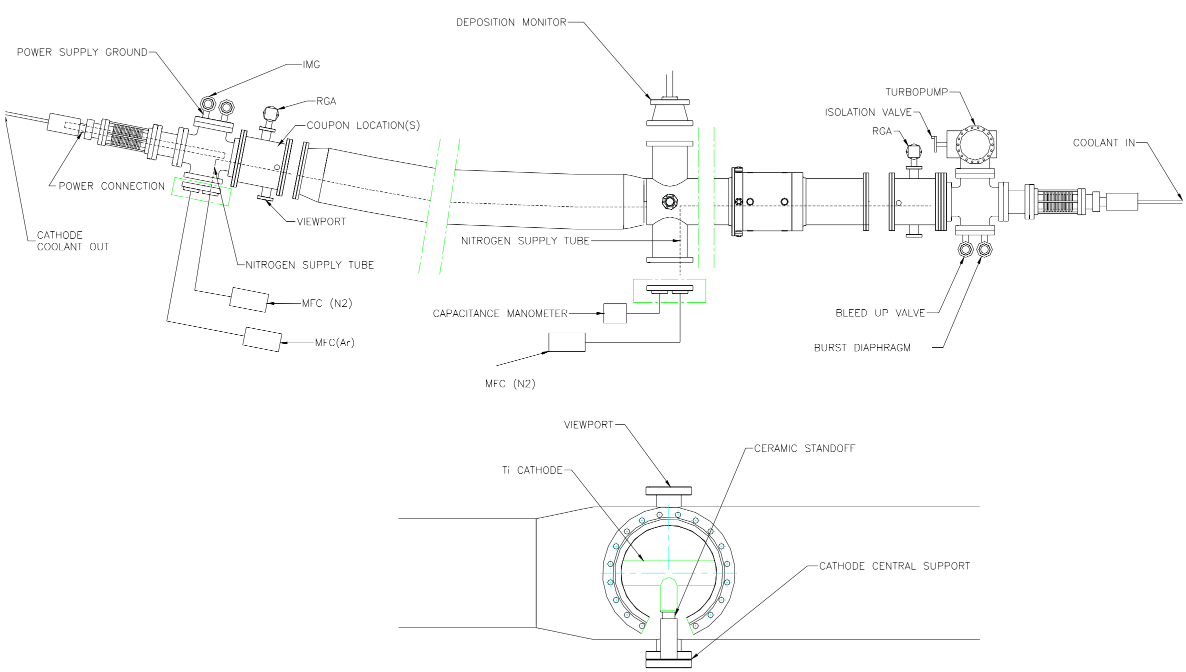

Figure 3: Schematic of magnetron sputtering setup for arc half-cell chambers. The lower portion showing the central cathode support. (IMG: inverted magnetron gauge, RGA: Residual gas analyzer, MFC: Mass flow controller)

The cathode used to coat the 5m injection and RF doublet chambers, was made from thick wall 1.25" diameter schedule 40 Ti pipe. This stiffer cathode reduced the deflection by a factor of 2. Special collars were fabricated to transfer the increased bending moment stress applied to the ceramic break end cuffs when leveling the cathode. Two independent nitrogen tubes were also used to help better control the process.

Injection Kicker Ceramic Chambers

The coating of the injection kicker ceramic chambers posed a unique set of problems [4]. Because the ceramic chambers could not couple the discharge to the cathode, a stainless steel anode screen was placed between the cathode and ceramic chamber. The screen allowed uniform discharge along the cathode but created a non-uniform coating due to shadowing. This shadowing was a form of destructive interference between the discharge ring spacing on the cathode and the screen. Several tests were conducted with various screen sizes and countered intuitively, a smaller screen size yielded the best result. The OFHC Cu cathode, anode screen and magnet string are shown in Figure 4. The coating system isolated the ceramic chamber with additional ceramic breaks so *in-situ* resistance measurements could be taken during the coating.

a

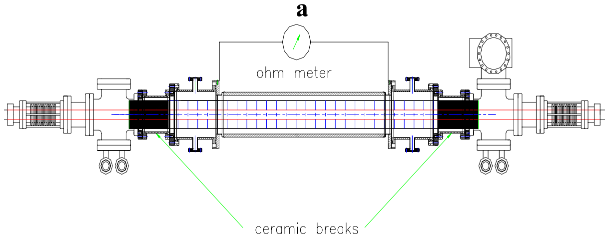

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Figure 4: (a) Copper cathode, anode screen and magnet string. (b) Schematic of set up showing electrical isolation of ceramic pipe for *in-situ* resistance measurements.

Extraction Kicker Modules

The coating on the ferrite surface of the extraction kicker modules needs to have low SEY and minimum induced eddy current heating [4]. An estimate of the coating uniformity was made based on a cosine approximation (Figure 5). The results raised concern that the uniformity of the TiN coating on the vertical ferrite walls would be unacceptable. However, testing showed only a 4x difference in thickness from the midplane to the corner.

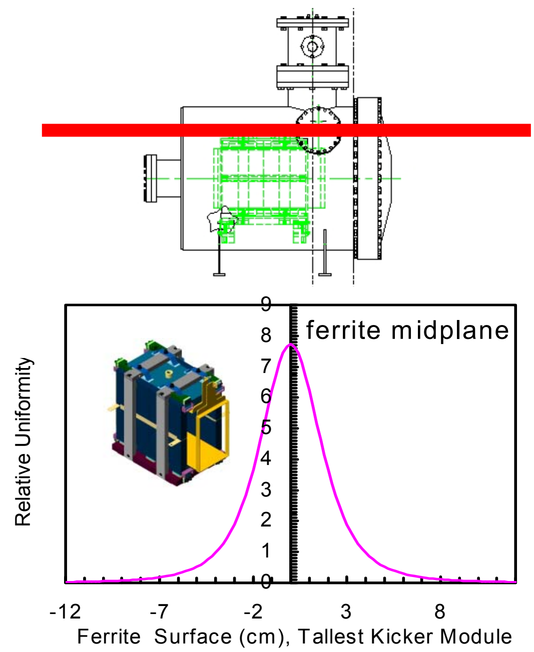

Figure 5: Coating schematic for extraction kicker modules and uniformity approximation.

SEY AND OUTGASSING

The measured SEY of coated chambers was found to be dependent on surface roughness [5]. A rougher surface yields lower SEY values, however these coatings were found to have a higher outgassing rate than coatings produced at lower pressure [6]. For SNS chambers, low SEY was of primary importance. Consequently, rougher coating surfaces were produced at a higher sputtering pressures (i.e. ~5 mTorr), which yielded SEY values in the 1.6 to 1.8 range.

ACKNOWLEDGEMENTS

The authors would like to thank the Collider-Accelerator Vacuum Group for their tireless effort in meeting the SNS coating production schedule.

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