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PRELIMINARY MECHANICAL DESIGN OF CERAMIC PIPE FILM COATING EQUIPMENT AT HEFEI LIGHT SOURCE II *

Jie Wang†, Yanhui Xu, Bo Zhang, Wei Wei, Le Fan, Xiangtao Pei, Yuanzhi Hong, Yong Wang#,
National Synchrotron Radiation Laboratory，University of Science and Technology of China, HeFei, AnHui 230029 China
Jiadong Lu†, School of Automation, Northwestern Polytechnical University, Xi'an, Shanxi 710072 China

Abstract

Ceramic vacuum chambers are important components of the injection chamber at Hefei Light Source II (HLS II). The length of each Ceramic vacuum chamber is 350 mm and their inner surface is coated with TiN thin film whose properties are low secondary electron yield (SEY), good electrical conductivity, stability of performance, ability to block hydrogen permeation. Considering that the cross section of Ceramic pipe is racetrack structure, Ti plate was chose as the cathode to improve TiN thin film deposition rate. Meanwhile, the authors designed a motor drive magnetron sputtering film coating equipment to obtain uniform TiN film.

INTRODUCTION

Ten years ago, ceramic chambers and ferrite kicker magnets were developed in HLS injection system and the inner surface of the ceramic chambers was coated with 0.1 ohm/square metallic Mo layers to meet the requirements of both the penetration of pulse magnetic field and small beam coupling impedance [1]. Now TiN or Ti are chosen as the metal coating material of the ceramic vacuum chamber in HLS II [2-6]. Furthermore, for the purpose of improvement of the deformation and uniformity of the thickness, Ling-Hui Wu et al. designed and fabricated a ceramic chamber using Ti films [7]. However, for some irregular type ducts, such as the racetrack type (Fig. 1) ceramic chamber in accelerators, the shape of the ceramic pipe will induce new and considerable technological difficulties for the uniformity of TiN coating which is important for the vacuum and beam stability in the pipes of storage ring.

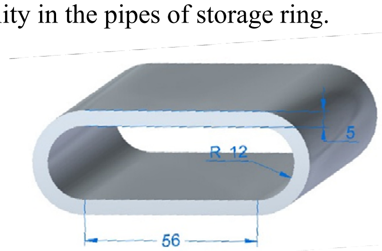

Figure1: A diagram of a ceramic vacuum pipe.

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†These authors contributed equally to this work. They are co-first author.
#ywang@ustc.edu.cn

APPARATUS AND METHODS

Coating System

The TiN films are deposited onto the interior wall of ceramic vacuum pipe which is described in Fig. 1. The cross-section of shaped ceramic vacuum chambers in the system is a special type of racetrack with a small aperture. The schematic diagram of DC magnetron sputtering coating system which mainly consisted of vacuum gauge, solenoid, cathode, gas flow control system, power supply, 300 l/s turbo molecular pump and ceramic pipe, was shown in Fig. 2.

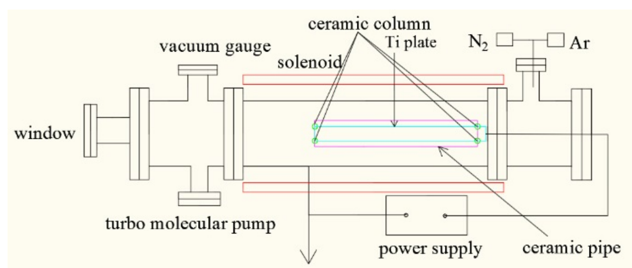

Figure 2: Schematic diagram of DC magnetron sputtering coating system.

The Uniformity of TiN Film and Electric Field Distribution

The electrostatic solver of CST software was used to simulate the electric field distribution in the case of ceramic pillars as cathode brace, during glow discharge. In this simulation, the voltage of the cathode plate and ceramic pillars was -680 V and 0 V respectively. In Fig. 3, the location of green arrow is the position of the ceramic pillars. According to the scale on the right side of Fig. 3, the electric displacement vector on the position of four ceramic pillars is two times higher than that on both ends of Ti cathode plate and also higher than other parts of the ceramic pipe. The electric field distortion caused that film thickness near the ceramic pillars is greater than the one on other parts, which also can be seen from Fig. 4. Therefore, the results of the simulation basically matched experimental results.

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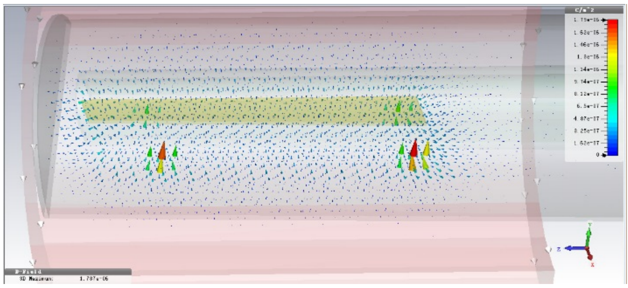

Figure 3: The electric displacement vector distribution in the case of ceramic pillars as cathode brace, during glow discharge.

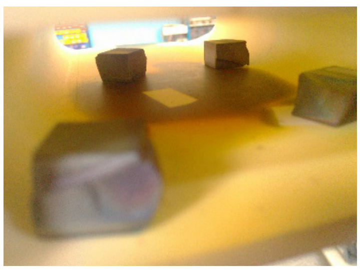

Figure 4: The non-uniformity of TiN film which was caused by ceramic pillars in DC magnetron sputtering film coating experiments.

Single Motor Drive

In order to avoid the electric field distortion caused by ceramic pillars, single motor drive method was developed. The single motor drive system mainly includes fixed clamp, gear, bracket, motor and the transmission pole, as shown in Fig. 5. The transmission pole was driven out the chamber to fix Ti plate cathode expediently. Then adjust the position of the transmission pole according to the length of ceramic pipe.

CST software was used to simulate the electric field distribution in the case of single motor drive. In this simulation, the voltage of cathode plate and vacuum wall was -680 V and 0 V respectively. Fig. 6 shows that besides the electric field intensity is higher than the edge of Ti plate, other parts of the electric field intensity are uniform. The cathode plate which was fixed in this way, can make the electric field distribution almost the same along the axial of ceramic pipe, so as to improve the uniformity of TiN film.

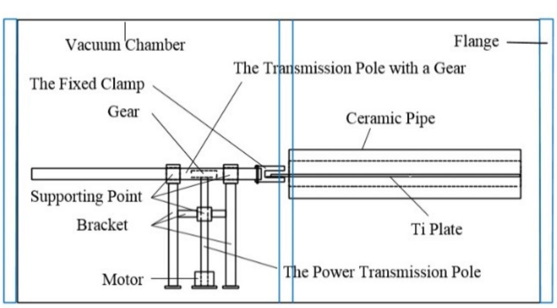

Figure 5: Schematic diagram of single motor drive.

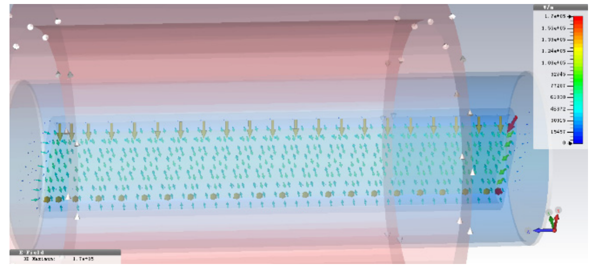

Figure 6: The electric field distribution in the case of single motor drive.

Motor Parameters

The movement of cathode plate is driven by stepping motor with the whole step driver control method, so it doesn't need a separate position detection device. If the cathode plate need to move the distance s, the step number D which motor need steps forward is shown as below:

$$D = \frac{s \times 360^0}{l \times \alpha}$$

where s is the distance which cathode plate need to move, α is the step angle of stepping motors, namely, the angle by each step, l is the forward distance of worm at one revolution of the turbine. The perimeter of the gear is equal to the forward distance of transmission mechanism at one revolution of the motor.

Long Ceramic Pipe

For long ceramic pipe which need long TiN cathode plate, it is difficult for the single clamp to insure that Ti cathode plate is located in the central axis of the ceramic pipe, due to the effect of gravity. Two cantilever supports were installed near the both ends of ceramic pipe, to ensure that Ti plate cathode was located in the central axis of the ceramic pipe, as shown in Fig. 7.

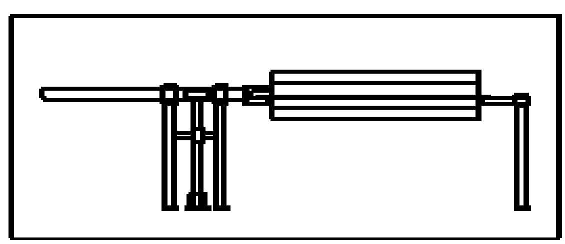

Figure 7: Schematic diagram of the installation of two cantilever supports for long ceramic pipe.

CONCLUSION

Preliminary mechanical design of ceramic pipe film coating equipment was discussed above. For the new film coating equipment, the optimization of the parameters such as gas flow, discharge voltage, discharge current and so on, need more experiment and research.

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FUTURE PERSPECTIVES

Based on the preliminary mechanical design, film coating device will be built and the relevant coating experiments will be carried out to get uniform TiN thin film in the future.

REFERENCES

[1] L. Shang et al., "Study of Ceramic Vacuum Chambers in HLS New Injection System", Proceedings of PAC 2001, Chicago.
[2] K. Shibata et al., "Study of Ceramic Vacuum Chambers in HLS New Injection System", MO6RFP015, Proceedings of PAC09, Vancouver, Canada.
[3] K. Shibata et al., "Development of TiN Coating System for Beam Ducts of KEK B-Factory", TUPP071, Proceedings of EPAC08, Genoa, Italy.
[4] Saito, K. et al., "TiN thin Film on Stainless Steel for Extremely High Vacuum Material", J. Vac. Sci. Technol. A Vac. Surf. Films, 1995, 556-561.
[5] Yong Wang et al., "Deposition of Titanium-Zirconium-Vanadium Films by DC Magnrtron Sputtering. National Synchrotron Radiation Laboratory", MO6RFP024, Proceedings of PAC09, Vancouver, BC, Canada.
[6] J. Lorkiewicz, et al., "Surface TiN Coating of TESLA Couplers at DESY as an Antimultipactor Remedy", The 10th Workshop on RF Superconductivity, 2001, Tsukuba, Japan.
[7] Wu Ling-Hui et al., "Design and Fabrication of the Novel-type Ceramic Chamber", Proceedings of IPAC2014, Dresden, Germany.