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OPTIMIZATION DESIGN OF Ti CATHODE IN CERAMIC PIPE FILM COATING BASED ON THE SIMULATION RESULTS OF CST*

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Abstract

The injection chamber at Hefei Light Source II (HLS II) consists of four ceramic vacuum chambers whose inner surface were coated with TiN thin film. The cross section of ceramic pipes is special racetrack structure. In order to improve the uniformity of the film, the structure of the cathode Ti plate needed to be optimized. In this article, CST PARTICLE STUDIO™ software had been used to simulate the influence of different target structure on discharge electric field distribution and electrons trajectories. Furthermore, the reliability of the simulation were analysed compared with the experimental results. Also, we put forward the optimization design of Ti cathode structure which could satisfy the requirement of uniformity of the thin film.

INTRODUCTION

TiN thin film causes great interest because of its low secondary electron yield (SEY), good electrical conductivity, stability of performance, ability to block hydrogen permeation, etc. [1-3]. TiN film deposition methods include DC magnetron sputtering, DC sputtering, hollow cathode discharge ion plating (HCD-IP) [4], RF sputtering et al. In general, the substrates are mainly flat plates, stainless steel cylindrical pipe [5], and ceramic vacuum chamber [6]. 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 vacuum performance and beam stability in the pipe.

Ceramic vacuum chamber is the key equipment of the electron storage ring injection system which was made of 99.9% pure alumina. The electrons injection chamber at Hefei Light Source II (HLS II) consists of four ceramic vacuum chambers whose inner surface are coated with thin conductive metal film, and the length of each vacuum chamber was 350 mm. Typically TiN or Ti are chosen while the sheet resistance of the film should be 0.3-0.8 Ω/sq. It was an extremely valuable research that how to get uniform TiN film which has high quality and meets the requirements of the physical design of the storage ring, such as mitigating the electron cloud instability [7]. This article mainly focuses on optimization design of Ti cathode in ceramic pipe which based on the simulation results of CST.

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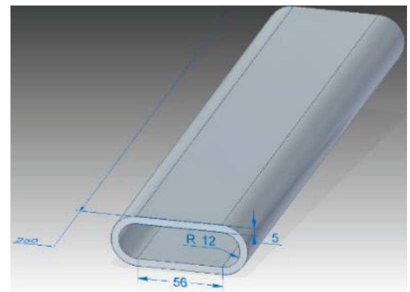

Figure1: A diagram of a ceramic vacuum pipe.

APPARATUS AND METHODS

Coating System

The TiN films are deposited onto the interior wall of ceramic vacuum pipe which is shown in Fig. 1, using DC magnetron sputtering method. The deposition system which is shown in Fig. 2 consists of observation window, 300 l/s turbo molecular pump, DC power supply, vacuum gauge, vacuum chamber and gas flow control system. Argon gas and nitrogen are introduced into the sputtering system through an adjustable leak valve. The typical sputtering parameters are: ~ -600 V cathode voltage, 5×10^{-1} torr gas pressure, 2:1 nitrogen and argon gas flow ratio, 200 Gauss magnetic field strength and 0.5 A sputtering current.

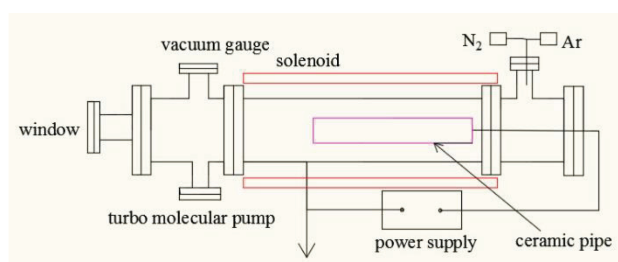

Figure 2: Schematic diagram of DC sputtering coating system.

TiN Coatings

Thickness was measured by use of a Sirion 200 Schottky field scanning electron microscope (SEM). Fig. 3 shows the cross-sectional and surface SEM morphology of specimen TiN film. It can be seen that the TiN film has a columnar structure which are mostly perpendicular to the film surface.

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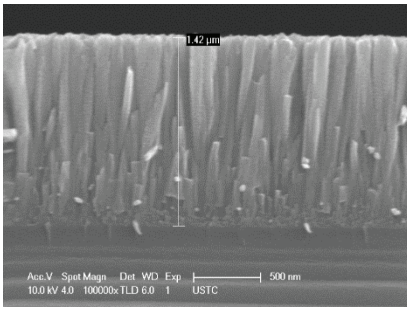
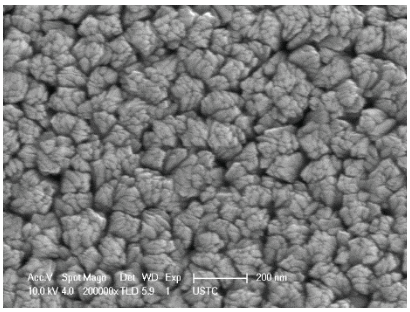


(a)



(b)

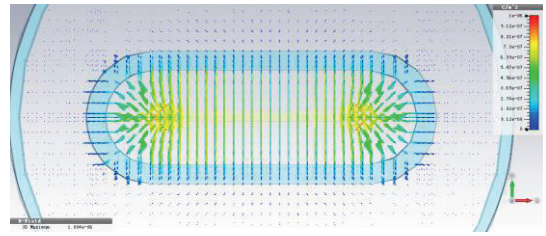
Figure 3: SEM micrographs of (a) the fracture sections and (b) surface of TiN coatings deposited onto ceramic substrates by DC magnetron sputtering. Target current, 0.5 A; pressure, 1.3×10^{-1} mbar; gas flow ratio: 5 Sccm nitrogen and 2.5 Sccm argon; working voltage ~-530V; deposition rate 473nm/s.

CST SIMULATIONS

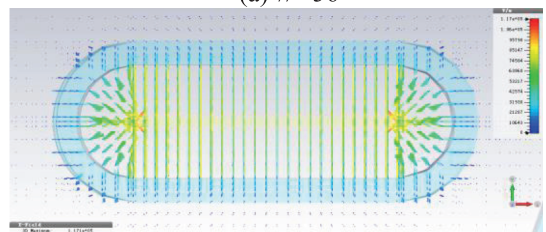
Cubic Ti Plate

In order to improve the deposition rate of TiN film, titanium plate was horizontally mounted as cathode target in the experiment. At the same time, considering the uniformity of TiN film, it needed to choose a suitable size for Ti plate. Using CST software, the effect of different cathode Ti plate size on the distribution of electric field was simulated. In the figures below, different colours represent different potential.

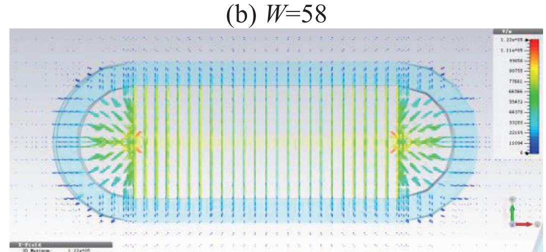
As shown in Fig. 4, the electric field distributions were simulated in the case of W=58, 60, 62, 64, 66. In the case of W=56mm, it is clearly that the potential in the circular arc is lower than in the plate segment. So, this led to the film thickness on circular arc was far less than that in the plate, which is shown in Fig. 5. The potential on arc segment increased slowly with the increasing of width. In the case of W = 66, the potential on arc segment was basically the same with the electric potential on plate segment. The electrons trajectories in the case of W=66, 200 Gauss magnetic field are shown in Fig. 6 which illustrates that the electrons density on circular arc was less than that on plate segment and the energy of electrons on circular arc is lower than that on plate segment. Therefore, the surface area of Ti plate near arc segment need to be enlarged. Consequently, cylindrical-cubic Ti plate was proposed in the next section.



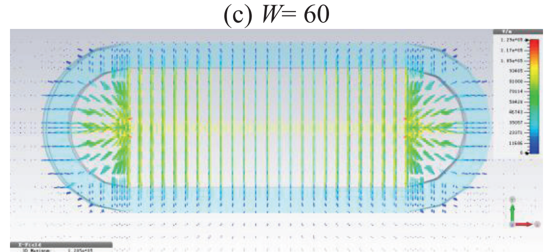
(a) W=56



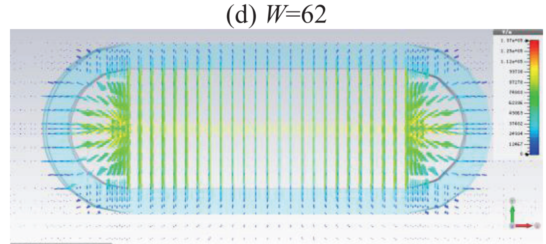
(b) W=58



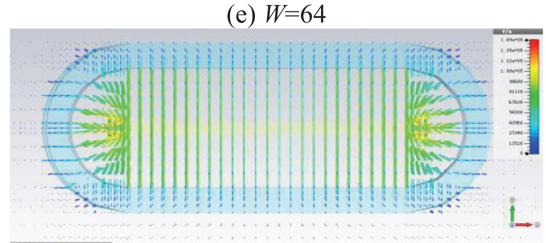
(c) W= 60



(d) W=62



(e) W=64



(f) W=66

Figure 4: The influence of different Ti plate cathode size on the distribution of electric field. The dimensions of titanium plate were 2*30*W mm, W was the width of Ti plate.

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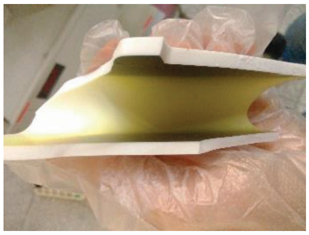

Figure 5: In the case of *W*=56, TiN coated ceramic chamber samples.

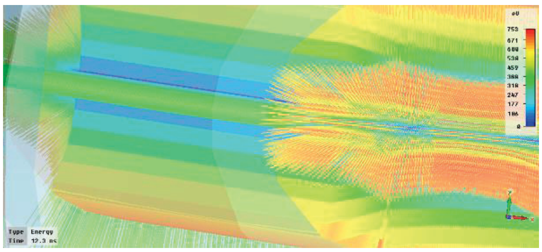

Figure 6: The electrons trajectories in the case of *W*=66, 200 Gauss magnetic field.

Cylindrical-cubic Ti Plate

When the side of the rectangle Ti plate was changed to 1 mm radius half cylinder, the electrons trajectories was shown in Fig. 7. Apparently, electrons density on the arc segment is relatively low. Moreover, in the case of 2 mm radius half cylinder, electrons densities on arc segment and plate segment are basically the same.

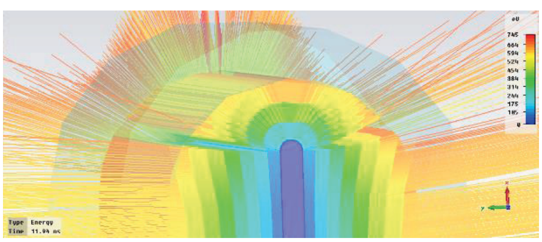

Figure 7：Electrons trajectories in the case of the side of the rectangle Ti plate was changed to 1 mm radius half cylinder, 200 Gauss magnetic field strength, *W*=66 mm.

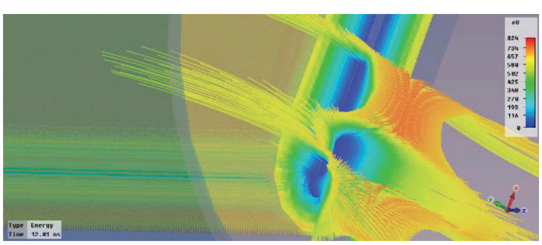

Figure 8：The electrons trajectories in the case of the side of the rectangle Ti plate was changed to 2 mm radius half cylinder, 200 Gauss magnetic field, *W*=62 mm.

CONCLUSION

In short, electric field distributions and the effect of magnetic and electric fields on electrons trajectories in the process of TiN film coating under various Ti plates' size were simulated using CST software. Based on the experimental results, the size of Ti cathode was optimized to obtain uniform film and improve the TiN average deposition rate.

FUTURE PERSPECTIVES

In order to verify our simulated results, we will carry on the experiment according to the optimization of Ti plate size in the future.

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