A Directly Heated High Emission Density Low-Temperature Cathode

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In order to enhance output power and prolong lifetime of the high-power continuous wave magnetron tubes, a novel Y_2O_3-Gd_2O_3-ZrO_2 impregnate W sponge layer directly heated cathode is researched. The testing results show that the DC emission density of the cathode can reach 3.58A/cm^2 at a temperature of 1750℃. Lifetime experiment results show that the thermionic emission current density is still above 1.5A/cm^2 after 2600h operation.

I. INTRODUCTION

When the high-power continuous wave magnetron tubes operate in normal output power, the temperature of its cathode is more than 2000℃, and the barium tungsten cathode and oxide-coated cathode [1-2] will be damaged at this temperature. The traditional pure W filament cathodes have good emission stability, thermo-stability, resistive electron and ion bombing, anti-poisoning which are mainly applied to high-power continuous wave magnetron tubes.

However, the W filament cathodes have low thermionic emission and secondary emission [3] which result in the magnetron cathode operating at a high temperature to guarantee normal output power. Due to the high operating temperature which leads to the accelerating evaporation of surface of the cathode, the magnetron tubes will reach its end of the life after the diameter of W filament degrades to 90% of the original value.

In order to enhance the output power and prolong lifetime of the magnetron tubes, we need to enhance the anode currents which constituted of thermionic emission current and secondary emission current. Therefore, a novel Y_2O_3-Gd_2O_3-ZrO_2 impregnate W sponge layer directly heated cathode which operates under lower temperature is researched.

In this abstract, our research mainly focuses on thermionic emission of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated sponge layer directly heated cathode.

II. RESULTS

The diameter of 0.26mm, length of 6mm and smooth surface of W filaments are chosen, then through a series of cleaning, degasing process of W filament. After that, the surface of W filaments are sprayed with a layer of W powder, then the W filaments are sintered in the high temperature hydrogen furnace at 1600 ℃ for 5mins, finally, the Y_2O_3-Gd_2O_3-ZrO_2 active material are impregnated into the sintered W sponge layer.

Figure 1 shows the schematic of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W filament cathode which consists of three parts: W filament base (3), W powder sintering layer (2), and Y_2O_3-Gd_2O_3-ZrO_2 impregnated layer (1).

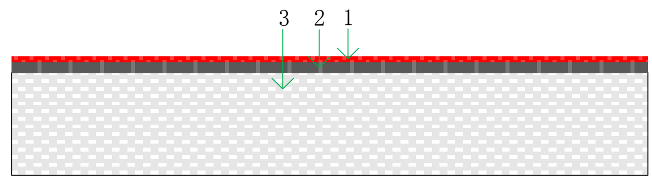

Fig.1. Schematic of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W filament cathode cathode, 1: Y_2O_3-Gd_2O_3-ZrO_2 impregnated coating 2: W powder sinter coating 3: W filament base

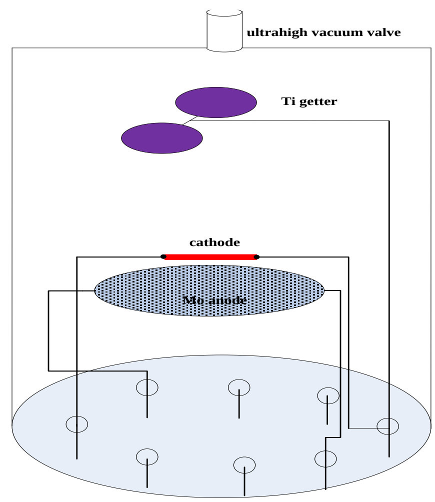

Fig.2. Schematic of the closely-spaced diode test vehicle showing the arrangement of the W sheet cathode and Mo anode inside the evacuated glass tube.

Figure 2 shows the schematic of the closely-spaced diode (CSD) test vehicle [4-5] which is used for measuring the thermionic electron capacity of the cathode. Common Ba-W cathode and Oxide cathode operates in low temperature between the 800℃ and 1100℃ which are tested with indirectly heated cathode device. But the cathode of this abstract operates in the temperature above 1500℃, We need a new measurement apparatus to satisfy the evacuated temperature environment operating demand. Figure 2 shows the new directly heated cathode testing structure. The diameter of the Mo anode is close to 30mm. In order to keep parallel to the Mo anode, and measure the thermionic emission current density of the cathode accurately, W sheet base is a good substitute for W filament base. As the figure 1 shows that the structure of the W sheet cathode is the same as the W filament cathode. The length of the W sheet cathode is 5mm, and the width of the W sheet cathode is 0.3mm. Compared with the area of the Mo anode, the area of the W sheet cathode is small enough. The distance between the cathode and the anode is 2mm.

Figure 3 shows the I–V dc emission characteristics curves of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode at different temperature, respectively, it indicates that the dc emission density of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W powder layer directly heated cathode is 0.37A/cm^2 at 1400℃, 1.79A/cm^2 at 1500 ℃, 2.45A/cm^2 at 1600 ℃, 3.36A/cm^2 at 1700, 3.58A/cm^2 at 1750℃. However, the traditional pure W filament cathodes can only provide 0.13A/cm^2 at 1900℃ by contrast.

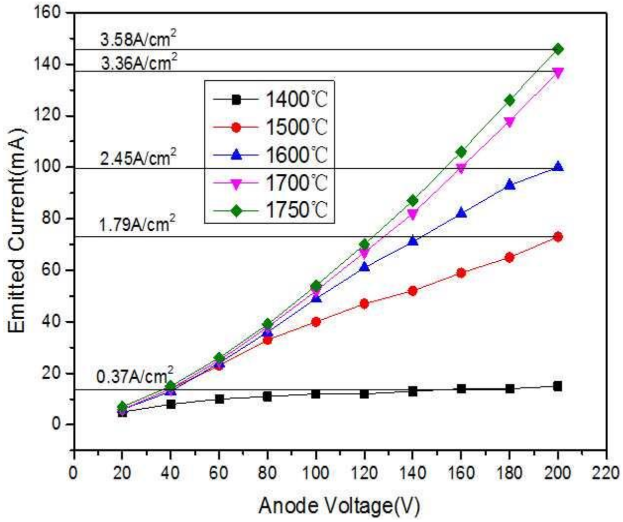

Fig.3. I–V dc emission characteristics curves of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode at different temperatures respectively. The dc emission density of the cathode is 3.58A/cm^{2}at a temperature of 1750℃, 3.36A/cm^2 at a temperature of 1700℃, 2.45A/cm^2 at a temperature of 1600℃,1.79A/cm^2 at a temperature of 1500℃,0.37A/cm^2 at a temperature of 1400℃.

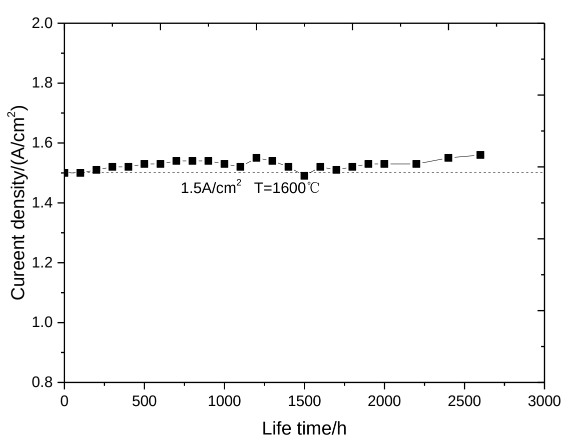

Fig.4. DC emission for the life-tested Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode for the first 2600h of operation. The life-tested emission current density of the cathode is 1.5A/cm^2 loading at 1600℃.

It is consideration of that the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode will be applied to high-power continuous wave magnetron tubes. So, the W filament cathode is applied to test the lifetime which will never end up with exhaustion of the activation material (Y_2O_3-Gd_2O_3-ZrO_2) in theory, but in fact, the pure W filament will also provide effect emission when the operation temperature reaches to 2000℃. The cathode will reach its end of the life after the diameter of W filament degrades to 90% of the original value. Through increasing the operation temperature of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode, we can get enough lifetime.

Compared with the lifetime standard of the common Ba-W and oxide cathode, the Ba-W and oxide cathode will cease to operate when the activation material barium has been low enough. The lifetime of the Ba-W and oxide cathode will depend on the storage quantity of the barium. But the lifetime of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode will not only depend on activation material Y_2O_3-Gd_2O_3-ZrO_2, but also depend on the pure W filament base.

On the basis of the lifetime standard of the Ba-W and oxide cathode, we get the life time curve of the Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode.

The lifetime of the cathode were tested in the CSD test vehicle which is shown in figure 2. The operating temperature of the cathode is measured using an optical pyrometer. The vacuum level is held below 2.5×10^{-4}Pa during the diode baking and degassing process at a temperature 500 ℃br for 1.5h. The vacuum level was held below 3×10^{-6}Pa during the cathode activation process at a temperature of 1700 ℃ for 30min. After degassing, activation and aging of the cathodes for 24h, the lifetime was tested.

From the Figure 4, we can know that with the dc load of 1.5A/cm^2, operating temperature of 1600℃, the lifetime of the cathode has reach to 2600h. Up to now, the lifetime of the cathode is still continuous, and the inner surface of the experimental evacuated glass tube is not seriously coated caused by vapor deposition.

III. SUMMARY

In this abstract, a novel Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode is adopted to enhance thermionic emission. Experimental results show that this cathode can provide the same thermionic emission with 500℃ lower than that of the W cathode. The lifetime of the cathode has reach to 2600h, and is still continuous. During the following research, we will further measure the secondary electron emission, electron and ion bombing ability, thermo-stability, et al performance of this Y_2O_3-Gd_2O_3-ZrO_2 impregnated W sponge layer directly heated cathode.

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