Thermionic Emission of a Novel $Y_2Hf_2O_7$ Ceramic Cathode Applied in High-Power Magnetron Tubes

Shikai Qi[1) a)], Xiaoxia Wang[2)], Xingqi Wang[2)], Mingwei Hu[3)], Wei Zeng[1)], Li Liu[1)]

[1] Institute of Electronics Engineering, Jiujiang University, Jiujiang 332005, P.R. China

[2] Key Laboratory of High Power Microwave Sources and Technologies, Institute of Electronics, Chinese Academy of Sciences, Beijing 100190,P.R. China

[3] School of Physics and Optoelectronics Engineering, Xidian University, Xi'an 710071, P.R. China

a) Email: kaishiqi@126.com

Phone: 086-0792-8314446; Fax: 086-0792-8314446

Abstract: *In order to enhance output power and prolong lifetime of the high-power magnetron tubes, a novel $Y_2Hf_2O_7$ Ceramic cathode had been developed. The thermionic emission and lifetime characteristics of the $Y_2Hf_2O_7$ cathode had been measured. The results show that the cathode can provide 0.15A/cm^2, 3.5A/cm^2 current density for the space charge limitation at 1300℃br, 1600℃ br respectively under 300V anode voltage. The lifetime of the cathode is more than 4100 h with an initial load of 0.5A/cm^2 at 1400℃br.*

Keywords: Magnetron; cathode; thermionic emission; lifetime; $Y_2Hf_2O_7$

Introduction

Nowadays, there are two technical bottlenecks in the large-scale industrial application of microwave energy, one is that it is difficult to really realize the efficient, safe and reliable application of high-power microwave sources; the other is the lack of high-power and long-life industrial microwave sources [1]. As a kind of vacuum electronic device, the magnetron had been proven to be the most efficient and economical industrial microwave generator [2]. At present, the output power and lifetime of a single magnetron are far from meeting the requirements of industrial applications. New materials and methods are urgently needed to increase the output power and prolong the lifetime of the magnetron.

As the heart of a magnetron, cathode, whose quality directly affects the output power and lifetime of the magnetron, plays an important role [3]. In order to enhance the output power, prolong the lifetime of the high power magnetron, it is very urgent and necessary to develop high current density and long-life cathode applied in continuous wave magnetron.

During our previous researches [4-5], we enhance the thermionic emission and secondary electron emission of the cathode by using Re-W, Sc-W, carbonized Th-W alloy materials. Especially, the lifetime of the novel carbonized Th-W alloy cathode that actually applied in the magnetron tube is more than 5000 h among those materials above. Consideration of the radioactive hazard of the Th element, we need the substitutions for the Th-W cathode. So, in this abstract, our researches mainly focus on the thermionic emission of a novel $Y_2Hf_2O_7$ ceramic cathode which possibly has good resistive electron and ion bombing, high secondary electron emission coefficient and thermostability.

Experimental Process

Firstly, the diameter of 0.26mm, length of 10-15mm pure W filaments were chosen, and treated with a series of cleaning process. After that, the surface of the W filaments was sprayed with a layer of W powders. Then, the W filaments were taken to the high hydrogen furnace, and sintered at 1600±50℃ for 3 to 5min. Finally, the W filaments were taken out from the furnace and sprayed with the refractory $Y_2Hf_2O_7$ electron emission active substances. Then the treated W filaments above were taken to the high hydrogen furnace once again and sintered at 1500±50℃ for 3 to 5min.

Experimental Result

Figure 1 shows the schematic of the novel $Y_2Hf_2O_7$ ceramic cathode. It is made up of three parts: W filament base, W sponge layer, and $Y_2Hf_2O_7$ ceramic layer.

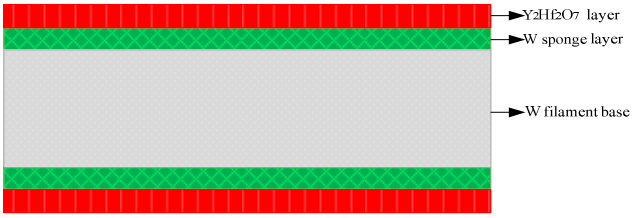

Figure 1 Schematic of the Novel $Y_2Hf_2O_7$ ceramic cathode

Figure 2 shows the I-V dc emission characteristic curves of the novel $Y_2Hf_2O_7$ ceramic cathode at different temperature. From the figure 2, it can be seen that the dc emission density of the novel $Y_2Hf_2O_7$ ceramic cathode is 0.15A/cm^2 at 1300℃br, 0.2A/cm^2 at 1350℃br, 0.5A/cm^2 at 1400℃br, 1.1A/cm^2 at 1450℃br, 1.8A/cm^2 at 1500℃br, 2.5A/cm^2 at 1550 ℃ br, 3.5A/cm^2 at 1600 ℃ br. However, the dc emission density of the pure W filament cathode is 0.4A/cm^2 at 2250℃br by contrast. The novel $Y_2Hf_2O_7$ ceramic cathode can provide the same emission density

with at least 850℃br lower than that of the pure W filament cathode.

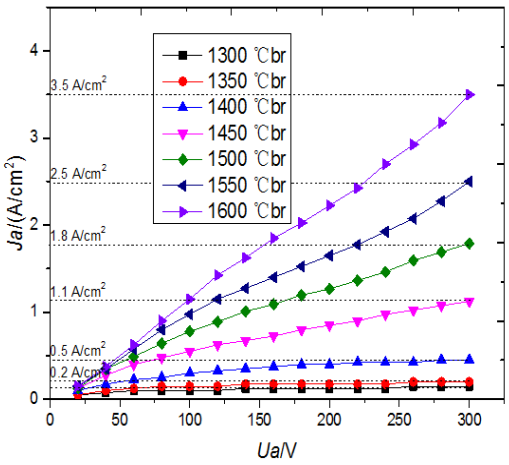

Figure 2 I–V dc emission characteristics curves of the novel $Y_2Hf_2O_7$ ceramic cathode at different temperatures

The lifetime of the novel $Y_2Hf_2O_7$ ceramic cathode was tested in the lifetime testing vehicle, it is shown as figure 3. From the figure 3, it can be seen that the lifetime testing vehicle is made up of seven parts: high vacuum interface, getter, $Y_2Hf_2O_7$ ceramic cathode, shield, Mo tube anode, temperature measuring hole, and conductive core. Through a series of degassing, activation and aging of the cathode, then the lifetime of the cathode began to be tested.

From the Figure 4, it can be seen that with the dc load of 0.5A/cm^2, operating temperature of 1400℃, the lifetime of the cathode has reach to 4100h, and is still continuous until now. The inner surface of the experimental evacuated glass diode has not seriously covered by vapor depositions.

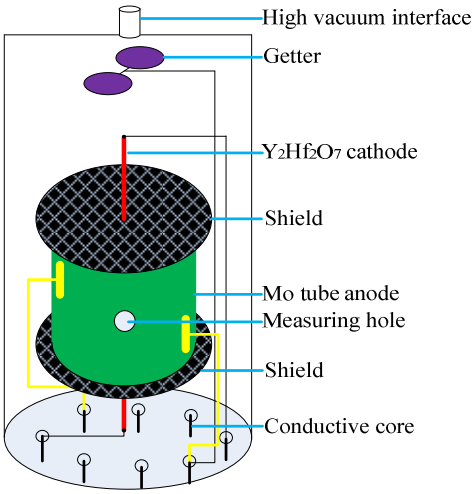

Figure 3 Schematic of lifetime testing vehicle for the $Y_2Hf_2O_7$ ceramic cathode

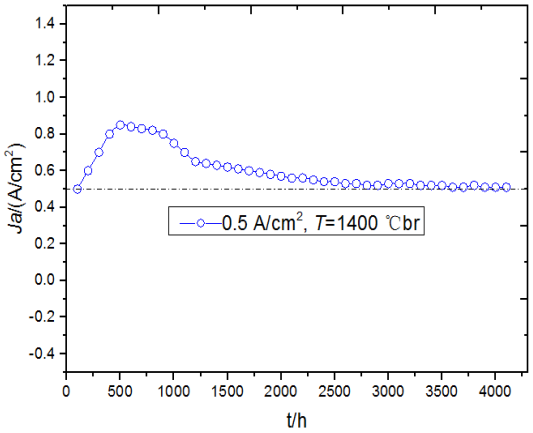

Figure 4 Lifetime curve of the novel $Y_2Hf_2O_7$ ceramic cathode versus temperature

Conclusions

In this abstract, a novel $Y_2Hf_2O_7$ ceramic cathode had been adopted to enhance the thermionic emission. The experimental results show that the cathode can provide 3.5A/cm^2 current density for the space charge limitation at 1600℃br under 300V anode voltage. The cathode can provide the same thermionic emission with at least 850℃br operating temperature lower than that of the pure W filament cathode. The lifetime of the cathode has reach to 4100h, and is still continuous until now.

Acknowledgements

The present work is supported by the Natural Science Foundation of China under Grant No.61841105, 61771454, National Natural Science Foundation of Jiangxi under Grant No.20192BAB217001, Education Department Science and Technology Project of Jiangxi Province under Grant No.180912 and Health department of Jiangxi Province under Grant No.20195631. The authors would like to Prof. Y. W. Liu and Prof. S. Y. Yin for helpful discussions about the emission mechanism of the cathode.

References

1. Bélanger, M. R. B. Jacqueline, J. R. J. Paré, et al. Journal of Microwave Power and Electromagnetic, Vol. 42, No. 4, pp. 24-44, 2007.
2. Electronic tube design handbook editorial Committee. Beijing: National Defence Industry Press, 1979, pp211.
3. S. K. Qi, X. X. Wang, J. R. Luo, et al. International Vacuum Electron Conference, Beijing, China, April 27-29, 2015, pp. 898-899.
4. S. K. Qi, X. X. Wang, J. R. Luo, et al. International Vacuum Electron Source Conference, St Petersburg, Russia, July 1-3, 2014, pp. 1-2.
5. X. X. Wang, Y. W. Liu, et al, IEEE Transactions on Electron Devices, Vol. 61, No. 2, pp. 605-610, 2014.