Preparation of Tungsten Matrices of Dispenser Cathodes by Selective Laser Melting

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Abstract: *In this study, the porous tungsten matrices of dispenser cathodes were prepared by a new method of three-dimensional selective laser melting, and the relationship between 3D printing process and porosity of matrix was studied. The emission performance of the cathodes impregnated with barium aluminates with and without addition of Scandia, have been measured. It was found that the emission property of the cathodes with machined and W-coated surface is similar to that of traditional B-type cathodes, and the addition of* Sc_2O_3 *in the impregnations improved the emission capability of cathode significantly.*

Keywords: dispenser cathode; selective laser melting; electron emission.

Introduction

The dispenser cathodes have been widely used in the Vacuum electron devices (VEDs). The impregnated Barium aluminate cathode (B-type cathode) is composed of porous tungsten matrices and the impregnations filled in the pores. Up to now, the matrix of B-type cathode was mainly prepared by powder metallurgy (PM) [1]. However, with the increasing demand for the different shapes of electron beams in modern devices, PM technology showed some limitations in the fabrication of complicated cathode shapes.

In recent years, the selective laser melting (SLM) attracted the attention of many researchers due to its advantages of strong controllability, high precision, easy fabrication, material saving, etc. [2]. In this study, the tungsten matrices were prepared by SLM method. The relationship between the later sintering parameters and the porosity of the matrices was studied. After impregnated with 411 barium aluminates, the electron emission performance of the cathode was investigated. To further improve the emission current density, the surfaces of laser ablated matrices were modified by several methods including surface machining and coating W film by Chemical Vapor Deposition (CVD). In addition, the impregnated scandate cathodes with SLM matrices were also studied.

Experimental

The spherical tungsten powders with particles of 15-20um were selected as starting materials due to its considerable fluidity compared to the fine tungsten powders. The porous tungsten matrices were sintered by selective laser melting with controllable laser speed from 1300 mm/s to 1600 mm/s. Then the porous matrices were impregnated with the traditional 411 $BaO\text{-}CaO\text{-}Al_2O_3$ impregnations and 2.5wt% Scandia added 411 impregnations, respectively. In order to reduce the roughness of the surfaces, the matrices surface were machined or coated by a W film through a CVD process.

Electron emission properties of the cathodes were tested in a closely-spaced diode configuration in a UHV chamber. In the chamber, a water-cooled copper anode was used for emission measurement. Pulsed emission was measured and monitored with pulses of 10μs in width and 50 Hz repetition frequency.

Results

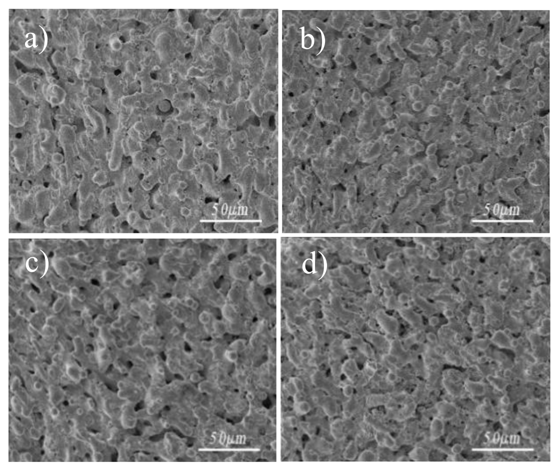

Fig.1. The surface morphologies of the tungsten matrices prepared at different laser speeds
(a) 1300, (b) 1400, (c) 1500 and (d) 1600 mm/s.

Fig.1 shows the SEM images of the matrices sintered at different laser speeds, and the measured densities of matrices were list in Table.1. It can be seen that with the increasing of the speed, the particle size of spherical W decreased slightly and the porosity increased obviously. However, compared to the M3 prepared at the speed of 1500 mm/s, as shown in Fig.1d, many apertures in the M4 (prepared at the speed of 1600 mm/s) were blocked by small tungsten particles, which was mainly attributed to the sputtering of W during fast scanning of high energy laser.

Table 1. The densities of different samples with different laser speeds

Sample	M1	M2	M3	M4
Laser power(W)		160		
Laser speed(mm/s)	1300	1400	1500	1600
Density (g/cm³)	13.47	13.21	12.72	12.68
Porosity (%)	15	19	23	24

Fig.2 shows the morphologies of cathode surface of original cathode, the machined cathode and W deposited cathodes. The original cathode has high roughness (Fig.2a). As shown in Fig.2b, the pores on the surface of the machined cathode were covered with the fragments and the impregnations. While for the W-coated surface in Fig.2c, many nano-sized W stacked on the surface tightly with a large number of grain boundaries.

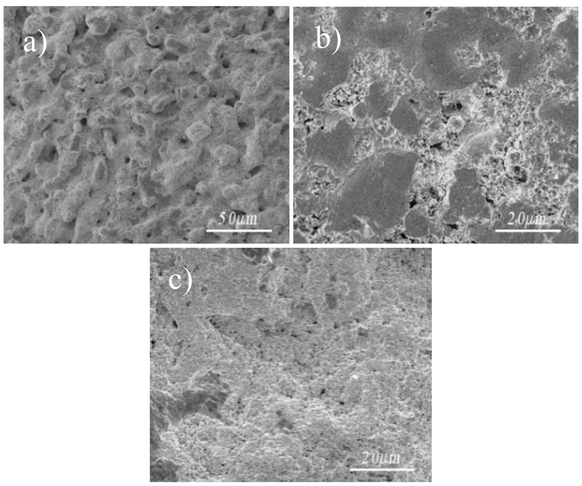

Fig.2. The surface morphologies of the cathodes before and after treatment (a) Orignal impregnated surface, (b) Machined and (c) W-coated

The pulse emission properties of the cathodes were evaluated and the results are shown in Fig.3. Compared with the untreated surface, the Space Charge Limited current density of machined cathode and W-coated cathode increased apparently and reached to 10A/ cm^2 at the temperature of 1050^{o}C, which were close to that of traditional B-type cathodes. On the other hand, the cathode impregnated with the 2.5wt% Scandia added barium aluminates exhibited much higher emission capabilities, about 4 times higher than that without Scandia addition, indicating that Scandia plays an important role in the improvement of thermionic emission. However, compared with the nano-Scandia doped cathode [3], the cathodes with the tungsten matrix prepared by three-dimensional selective laser melting have much lower emission performance probably due to the large tungsten grains and poor distribution uniformity of active substance, which need further investigations.

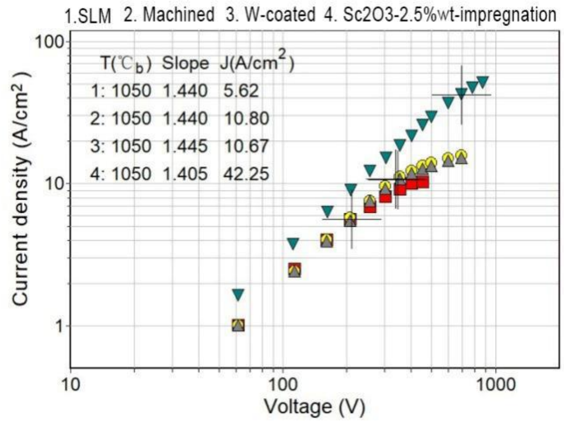

Fig.3. The typical *Lg(V)-Lg(I)* curves of different cathodes

Conclusion

It is a feasible method to prepare dispenser cathode matrices by selective laser melting and the porosities can be controlled by the laser speed. After impregnated the 411 barium aluminates, the pulse emission property of SLM cathodes is similar to that of the traditional B-type disperse cathode. The addition of Scandia can greatly improve the cathode emission capability, about 4 times higher than that of cathode without Scandia addition, although the addition amount of Scandia in the barium aluminates is only 2.5wt%.

Acknowledgments

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References

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