Long Lifetime Oxide Cathode for HIRFL-CSR Electron Cooler

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Abstract: *In this paper the characteristic of a type of oxide cathode for HIRFL-CSR electron cooler is discussed, which includes the measurement of the DC emission current density and the lifetime of the cathode. The results show that the cathode has good emission uniformity with 0.5 A/cm² at 700℃~800℃ and its actual service lifetime is over 25000 hours.*

Key words: Oxide cathode; Electron cooling; Emission performance; Lifetime;

Introduction

HIRFL-CSR [1] is an ion cooler-storage-ring system in IMP China. It consists of a main ring (CSRm) and an experimental ring (CSRe). The two existing cyclotrons SFC and SSC of the Heavy Ion Research Facility in Lanzhou(HIRFL) are used as its injected system. The heavy ion beams form HIRFL is injected into CSRm, then accumulated, e-cooled and accelerated, finally extracted to CSRe for internal-target experiment and other physics experiments.

The electron cooling device plays an important role in HIRFL-CSR experimental ring for heavy ion beam. Continuous electron cooling is applied to the stored ion beam for compensation of the heating by various scattering. The most important is the ability to cool ion beams to highest quality for physics experiment with highly charged ions [2].

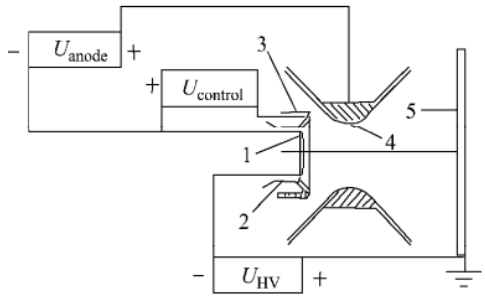

Figure1. The electron gun structure of the electron cooling device, 1.cathode, 2.haped electrode, 3.controlling electrode, 4.anode, 5.speedup tube

The electron gun is one of the key components for the electron cooling device. Figure 1 is the electron gun structure[3]. It consists of cathode, haped electrode, controlling electrode, anode and speedup tube cathode. As the heart of the electron gun, the cathode plays a very important role in the device.

As electron cooling gun, the operating temperature of the cathode is required to be as low as possible in order to reduce the influence of the heat of the electron itself on the ion cooling effect. Oxide cathode has lower operating temperature compare to other thermionic cathodes that is from 500℃ to 850℃. Improved oxide cathodes have high emission current density and long lifetime and widely used in all kinds of electronic devices [4,5].

In this paper, we mainly describe a long lifetime Ni sponge reservoir oxide and its application in the HIRFL-CSR electron cooler.

Preparation of the Ni sponge reservoir oxide cathode

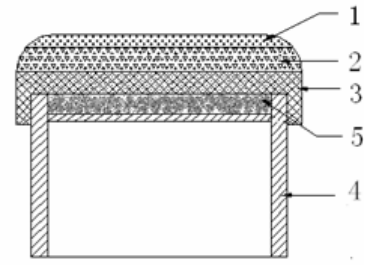

Figure2. The cathode structure 1.carbonates, 2.Ni sponge, 3.Ni net, 4.Ni sleeve, 5.reservoir emission material

The basic structure of the Ni sponge reservoir oxide cathode is shown in Figure 2. The reservoir emission material is stored in the cell of a nickel sleeve and there is a cap formed with a pure nickel net over the top. On the top of the cap, a layer Ni sponge is sintered. The carbonates are impregnated into the Ni sponge using a brush and then sprayed onto the Ni sponge surface with a conventional spray gun.

Based on our former research we believe excess Ba in the reservoir oxide cathode comes from the reservoir emission material in a cell of the cathode. Therefore, in this type of reservoir cathode emission material in reservoir is composed of barium calcium aluminates and activators. The characteristics of the cathode, such as emission capability, reliability and lifetime directly depend on the quality of the aluminates and the proper proportion of aluminates to activators.

Emission Characteristics of the cathode

A diode test is done for detecting the characteristics of

cathode 3mm in diameter. A Mo anode with diameter of 30mm and thickness of 0.4 mm is used in the test. The operating temperature of the cathode is measured by a Ni-Mo thermocouple spot-welded on the cathode cap, which is 0.5mm away from the cathode emission surface. After decomposing, activating and aging of the cathode for 30 hours, we tested its emission current and lifetime.

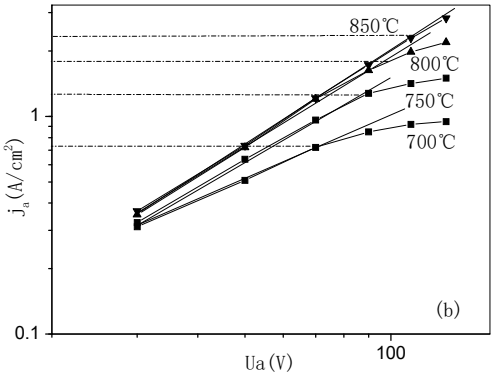

Figure3. I–V DC emission characteristics of the cathode, the knee-point emitted current density is listed for different operating temperature.

The dc emission characteristic curves of the cathode at different temperatures are shown in figure 3. It can be seen that the knee-point emitted current density of the cathode is 2.3 A/cm^2 at 850℃, 1.8 A/cm^2 at 800℃，1.27 A/cm^2 at 750℃ and 0.72 A/cm^2 at 700℃. So this kind of cathode meets 0.5 A/cm^2 using requirements for HIRFL-CSR electron cooler.

Accelerated lifetime test of the cathode

There are two kinds of methods for accelerated lifetime test of the cathode. One is temperature accelerated lifetime test and anther is emission current accelerated lifetime test. We used emission current accelerated lifetime test method, in which the relationship between lifetime and emission current density is as follows [5]:

$$\ln t = a - b \ln j_a \qquad (1)$$

where t is the lifetime, j_a is the emission current density, a and b is constant respectively. The lifetime is 3504h with 1.0 A/cm^2 emission current and 6504 with 1.50 A/cm^2 respectively at 800℃. Substituting (1A/cm^2,6504h) and (1.5A/cm^2,3504h) into equation (1)，calculated a is 6504h，b is1.5253. The current acceleration lifetime of the cathode at 800℃ is obtained, which shows as follows:

$$\ln t = \ln 6504 - 1.5253 \ln j_a \qquad (2)$$

The lifetime expectancy of the cathode is 18722 with a 0.5A/cm^2 DC load at 800℃ operating temperate form equation (2).

When the cathode is operated in space charge limitation region, the logarithm of the cathode lifetime is inversely proportional to temperature with a constant emission current density [6]. So the lifetime of this kind of Ni sponge reservoir oxide cathode is over 18722h with a 0.5A/cm^2 DC load under below 800℃ temperature during 700℃～800℃ range.

Application in HIRFL-CSR electron cooler

The main characteristics of the cathode for HIRFL-CSR electron cooler: the dc emission current density of the cathode is 0.5A/cm^2 and total current is 3A, the heating power is 36W～50W. The cathode has been serviced in HIRFL-CSR electron cooler over 25000 hours under 700℃～720℃ operating temperature from 2009 to now.

Acknowledgements

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