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CATHODE AND METHOD OF PRODUCING SAME

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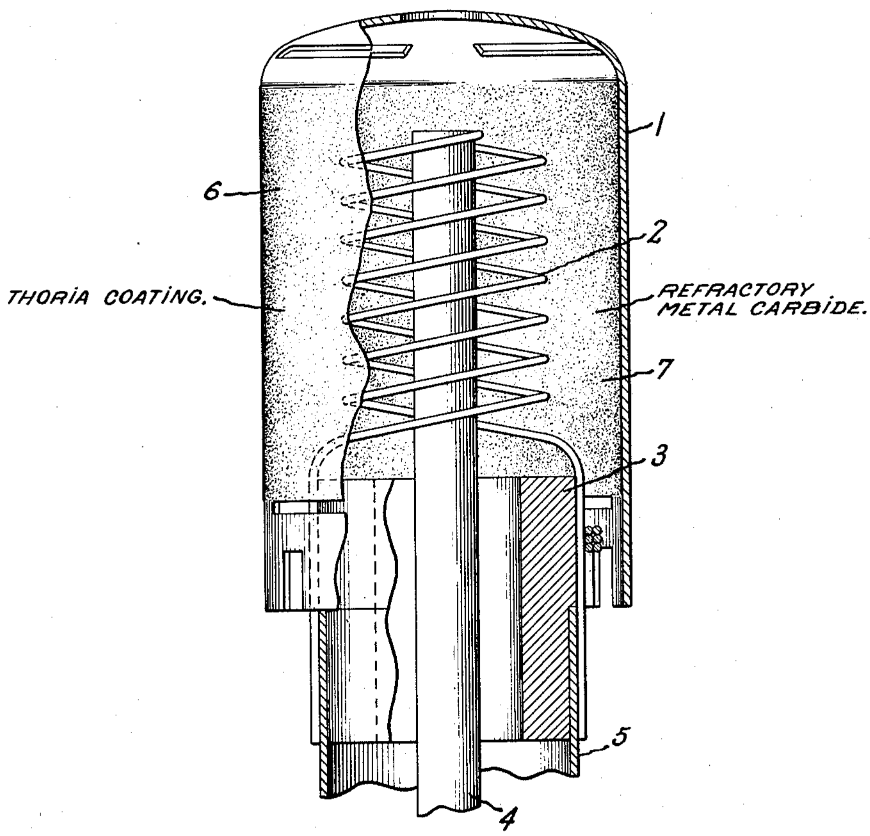

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CATHODE AND METHOD OF PRODUCING SAME

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The present invention relates to improved thermionic cathodes and to methods of making such cathodes.

Thorium oxide coated cathodes have been widely used in electric discharge devices particularly in those having high power ratings such as used in transmitting apparatus. These cathodes have in general been of the filamentary or directly heated type. It is generally accepted that thermionic emission of electrons from such cathodes is attributable to a monolayer of free thorium on the surface of the cathode which is produced by the reduction of the thorium oxide.

As the requirement for higher frequency high power devices has increased, the problem of providing adequate emission in a cathode which is of suitable geometry with respect to the high frequency requirements is greatly increased. Indirectly heated cathodes have definite advantages with respect to high frequency requirements but considerable difficulty was experienced in obtaining such a cathode with satisfactory life and with satisfactory emission.

The present invention provides an improved cathode structure particularly of the indirectly heated type, utilizing a thorium oxide coating and a novel manner of effecting the continued and gradual reduction of the thorium oxide during operating life of the cathode. The invention also provides for a better heat transfer between the heater element and the cathode proper so that the emitting surface of the cathode operates more nearly at the same temperature as the heater. In this way, for a given cathode temperature, the operating temperature of the heater is reduced.

Accordingly, it is an important object of the present invention to provide a new and improved thermionic cathode.

It is another object of the present invention to provide a new improved indirectly heated cathode.

It is a further object of the present invention to improve the heat transfer between the heater and cathode of an indirectly heated cathode.

It is a still further object of the present invention to provide a new and improved method of activating a thorium oxide coated cathode.

Further objects and advantages of the present invention will become apparent as the following description proceeds, reference being had to the drawing in which the single figure is an elevational view partially broken away of an indirectly heated cathode embodying our invention.

Referring now to the drawing, we have shown our invention embodied in a cathode heater assembly including a cathode sleeve **1** surrounding a helical heater element **2**. The ends of the heater are received in suitable recesses extending longitudinally on opposite sides of a cathode supporting collar **3** which is received within the lower end of the hollow cathode sleeve **1**. As illustrated the collar is in the form of an annulus and a central supporting rod **4** for the upper end of the helical heater element is provided. As will be readily understood by those

skilled in the art, the supporting rod **4** and a cathode supporting cylinder **5** provide terminal connections for the heater cathode assembly which may extend through the envelope of a discharge device in which the cathode is used.

In accordance with an important aspect of the present invention, the outer surface of the cathode sleeve **1** is provided with an emissive coating **6**, and the inner surface of the cathode provided with a refractory metal carbide coating **7**. In accordance with the preferred form of our invention, the base metal of the cathode sleeve **1** is of tantalum, the carbide layer **7** is of tungsten carbide and the emissive coating **6** on the exterior of the cathode is thorium oxide. These materials will be referred to in the remainder of the specification although it will be readily appreciated that other refractory metals may be used for the cathode cylinder, such as tungsten and molybdenum, and that the carbide may be tantalum carbide or molybdenum carbide instead of tungsten carbide. The properties of tungsten carbide, however, particularly with respect to the nature of the heat absorbing surface provided on the inner surface of the cathode sleeve is preferred.

The preparation of a cathode embodying our invention may be explained in detail in connection with the following specific example. A tantalum sleeve having a thickness of approximately .005" is first coated on its inner surface with a layer of tungsten carbide. This may be accomplished by suspending the carbide in a suitable binder such as a methyl cellulose binder and painting a uniform layer on the inside wall of the cathode. The cathode thus coated is heated in vacuum at a temperature in the order of 1750° to 1800° C. for approximately 5 minutes. During the initial heating the pressure in the system will be high, in the order of .5 micron but should drop rapidly and be held at about .001 micron.

After the carbide coating has been applied, the thorium oxide coating is applied to the exterior of the cathode sleeve. While this may be accomplished by spraying or painting, it has been found that a superior coating is produced by electrophoretically coating the sleeve to a thickness in the order of .0016" to .0025" for example. The electrophoretic coating produces a very dense adherent coating which provides a cathode of superior characteristics and the thickness is readily controlled.

As an example, the electrophoretic bath may be prepared by dispersing 20 grams of thorium oxide in 25 cubic centimeters of a 2% solution of thorium nitrate. This suspension is stirred into approximately 475 cubic centimeters of methyl alcohol. The bath is operated at room temperature at a potential of 120 volts with the cathode sleeve acting as the cathode of the cell and an aluminum member utilized as the anode. After coating, the cathode is vacuum fired for about 30 minutes under the same conditions as described in connection with the firing of the carbide coating on the inside surface of the cathode, that is a vacuum firing at a temperature in the order of 1750° to 1800° C.

This heating initiates a reaction which supplies carbon to the interface between the tantalum member and the thoria coating so that some of the thoria is reduced and a small amount of free thoria is provided. Activation by further reduction of the thoria coating of the cathode is carried out in the tube during exhaust at a temperature above the normal operating temperature of the cathode, which may be, for example, 1650° C. The activation temperature may accordingly be in the range of 1700° C. to 2200° C. Activation may be carried out, for example, by passing sufficient heater current through the heater to bring the cathode sleeve to a temperature of 2200° C. where it is held for a period of about 10 minutes. A substantial period of time perhaps as long as 90 minutes is required to bring the cathode to this temperature. It will be appreciated that activation may be accomplished at a lower temperature but the time required is longer.

During this activation a breakdown of the tungsten carbide continues and the carbide diffuses into the tantalum and some of the carbon combines with the tantalum to form a tantalum carbide (Ta_2C). As the carbon and carbides diffuse toward the tantalum-thorium oxide interface, carbon becomes available for reducing the thorium oxide to produce the free thorium of the active cathode. While a substantial part of the reduction takes place at the time of activation, there is a gradual and continued supply of carbon available at the interface which effects a continual and gradual reduction of the thorium oxide during life of the cathode.

Thus it will be seen that a cathode constructed in accordance with the present invention provides a novel manner of supplying the reducing agent necessary for activating the cathode in the first instance and for gradually releasing the free thorium during life of the cathode by providing a carbide coating on the opposite surface of the cathode with respect to the thorium oxide coating. At the same time the refractory carbide forms a practically black body type of coating on the interior of the cathode and enhances the transfer of heat from the heater element to the cathode. Furthermore, the back reflection of heat to the filament is reduced to negligible quantity. In this way, it is possible to operate the indirectly heated cathode at a temperature in the order of 1650° C. without subjecting the heater to destructively high temperatures, and thus increase the available thermionic emission current per watt of heater power input.

While we have shown and described particular embodiments of our invention, it will be apparent to those skilled in the art that changes and modifications may be made without departing from our invention in its broader aspect and we aim, therefore, in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of our invention.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A thermionic cathode comprising a base member of a refractory metal selected from the group consisting of tantalum, tungsten and molybdenum, a coating of a refractory metal carbide on one surface of said member and an electron emissive coating on the other surface of said member consisting essentially of thorium oxide.

2. A thermionic cathode comprising a base member of tantalum, a coating of tungsten carbide on one surface of said member and an electron emissive coating on the other surface of said member consisting essentially of thorium oxide.

3. A cathode comprising a base member of a refractory metal selected from the group consisting of tantalum, tungsten and molybdenum, said base member having a thickness of approximately .005″, a coating of a refractory metal carbide on one side of said member and an electron emissive coating on the other side of said member consisting essentially of thorium oxide, said carbide providing a source of carbon for diffusing through said base member and being available at the surface of said base member having said electron emissive coating thereon to reduce said thorium oxide when said cathode is heated to an elevated temperature.

4. A cathode comprising a base member of tantalum, said base member having a thickness of approximately .005″, a coating of tungsten carbide on one side of said member and an electron emissive coating on the other side of said member consisting essentially of thorium oxide, said carbide providing a source of carbon for diffusing through said tantalum member and being available at the tantalum-thorium oxide interface to reduce said thorium oxide gradually when said cathode is heated to an elevated temperature.

5. An indirectly heated cathode comprising a cylindrical sleeve of a refractory metal selected from the group consisting of tantalum, tungsten and molybdenum, a coating of a refractory metal carbide on the inner surface of said sleeve and an electron emissive oxide coating on the outer surface of said sleeve and a heater element positioned within said sleeve.

6. An indirectly heated cathode comprising a cylindrical sleeve of tantalum, a coating of tungsten carbide on the inner surface of said sleeve, an electron emissive coating on the outer surface of said sleeve consisting essentially of thorium oxide and a heater element positioned within said sleeve.

7. An indirectly heated cathode comprising a cylindrical sleeve of tantalum, a coating of tungsten carbide on the inner surface of said sleeve, an electron emissive coating on the outer surface of said sleeve consisting essentially of thorium oxide and a heater element positioned within said sleeve, said carbide coating increasing the heat absorption of said sleeve, minimizing reflection of heat to said heater and thereby increasing the emission current from the cathode sleeve for a given heater power input.

8. A method of making and activating a cathode which comprises coating a refractory metal member on one surface with a refractory metal carbide, the metal of the member and of the carbide being selected from the group consisting of tantalum, tungsten, molybdenum, applying a thorium oxide coating to an opposite surface of said member and heating said member in vacuum to a temperature above 1700° C. to diffuse carbon from said carbide layer through said tantalum member to reduce some of the oxide of said thorium oxide coating and thereby activate the cathode.

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