July 28, 1953 B. B. BROWN 2,647,216

DISPENSER CATHODE

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Fig. 1

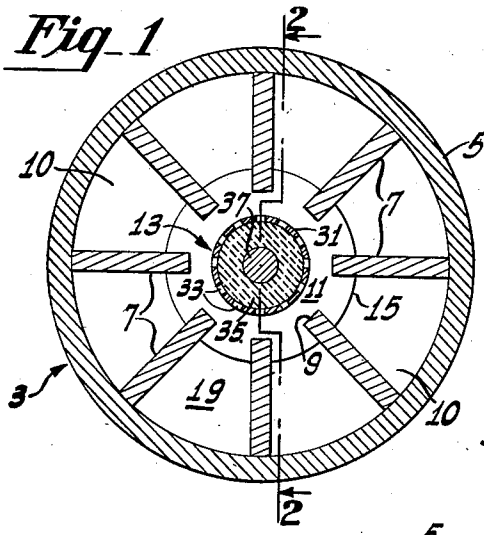


Fig. 4

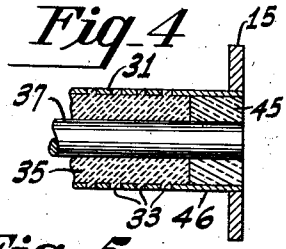
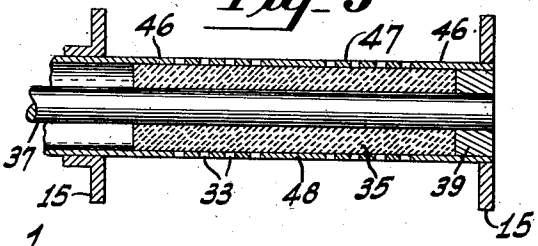


Fig. 5



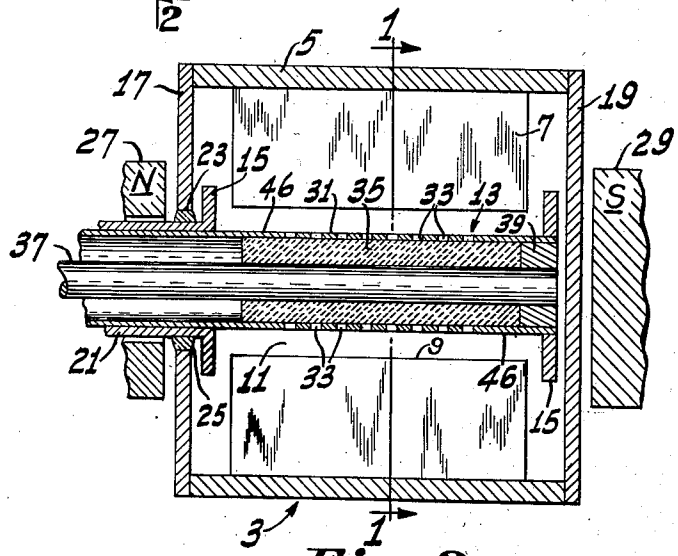


Fig. 2

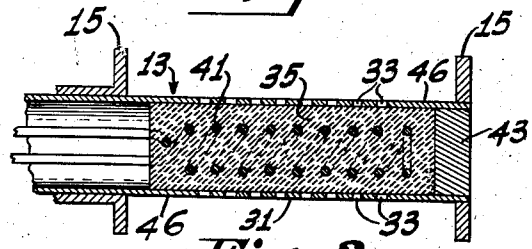


Fig. 3

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DISPENSER CATHODE

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8 Claims. (Cl. 313—157)

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This invention relates to improvements in cathodes for electron discharge devices, and particularly, to a dispenser cathode especially useful in magnetrons.

In a conventional magnetron, a thermionic cylindrical cathode, usually indirectly-heated, is axially mounted within a hollow multi-segment anode. In the multi-cavity type magnetron the anode segments are separated by recesses or cavities which provide internal cavity resonator circuits coupled between adjacent segments. In operation, the anode is maintained at a suitable positive potential relative to the cathode, and a constant magnetic field is maintained parallel to the cathode in the space between the cathode and the anode. Electrons emitted by the cathode and attracted toward the anode are deflected by the transverse magnetic field so that they traverse circular paths. The magnetic field strength is adjusted below "cut-off," so that most of the deflected electrons miss the anode and return to the vicinity of the cathode. The electron space charge sweeping past the anode gaps induce voltages between the anode segments and excite high frequency fields in the cavity resonators. The anode voltages in turn produce velocity modulation in the space charge, thus changing the trajectories of the electrons. A large number of electrons return to and bombard the cathode, producing secondary electrons and also heating up the cathode. Magnetron cathodes, therefore, must be designed to withstand such bombardment without injury.

A good magnetron cathode should:

1. Provide sufficient primary emission for starting and for supplying a part of operating current;
2. Provide sufficient secondary emission to supply the remainder of the operating current;
3. Include sufficient active material to permit satisfactory life;
4. Have means for holding the active material on the cathode surface;
5. Have consistent life;
6. Have sufficiently low electrical resistance to permit large currents without undue local heating;
7. Not exhibit tendency to excessive or repeated sparking;
8. Have the ability to withstand backbombardment without damage;
9. Have satisfactory heat dissipation characteristics;
10. Require low heating current and power and consequent low evaporation;
11. Have low noise; and

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12. Be easy to manufacture.

Conventional oxide-coated cathodes in use in other types of electron discharge devices, not having a magnetic field, have not been found satisfactory in magnetrons. Some cathodes which have been used in magnetrons with varying success are those having: a thoriated tungsten surface, a wire-wound oxide coating; a woven nickel mesh welded or sintered to a nickel base and packed with oxides; a sintered matrix of coarse nickel powder mixed with oxides on a nickel base; and a matrix of sintered thoria with an embedded heater. However, insofar as applicant is aware, none of the cathodes used heretofore has proven ideal for magnetron use.

The present invention is concerned primarily with cathodes utilizing sintered thoria. In the course of tests on known sintered thoria type cathodes in continuous wave (C. W.) magnetrons, the following difficulties have been observed:

(*a*) The constructional difficulties of such cathodes are great, and mechanical strength is low, particularly in small size cathodes;

(*b*) The thermal conductivity of the sintered thoria is so low that relatively low back-bombardment power will raise the cathode surface to operating temperature, even though the thermal conductivity of cathodes can be made sufficiently high when pure metal emitters are used;

(*c*) The cut-off characteristics of magnetrons with such cathodes have been poor, indicating diode emission even in the presence of the magnetic field. There is evidence that this arises from the hats or end shields of the cathode which are initially uncoated, leading to the assumption that there is migration of thoria to the hats.

The principal object of the present invention, therefore, is to provide an improved cathode, especially suited for use in magnetrons.

Another object of the invention is to provide a magnetron cathode which is capable of supplying the desired amount of primary and secondary emission without becoming overheated or damaged by back-bombardment.

Still another object is to provide an improved cathode of the dispenser or reservoir type having satisfactory and consistent life.

Another object is to provide a magnetron cathode requiring low heating current and power.

In accordance with the invention, a perforated sleeve of refractory metal is packed with powdered thoria, or a mixture of thoria and other refractory oxides or some metal powders. The enclosure is then heated to bond and sinter the thoria or thoria mixture within the sleeve.

The foregoing and other objects, features and advantages of the invention will be understood from the following detailed description referring to the accompanying drawing, in which:

Fig. 1 is a transverse sectional view, taken on line 1—1 of Fig. 2, of a cylindrical magnetron embodying the present invention;

Fig. 2 is a longitudinal sectional view on line 2—2 of Fig. 1;

Fig. 3 is a longitudinal sectional view of a modification of the invention;

Fig. 4 is a fragmentary detail view showing another modification; and

Fig. 5 is a longitudinal sectional view of still another modification.

Referring to Figs. 1 and 2, the invention is illustrated, for example, as embodied in a cylindrical magnetron of the multi-cavity type. An anode 3 comprises a hollow cylindrical shell 5 in which are mounted a number, eight as shown, of radial anode vanes 7. The inner edges of vanes 7 constitute electron-receiving anode elements or segments 9. Each pair of adjacent vanes 7 together with the portion of the shell 5 therebetween constitute a cavity resonator circuit 10 coupled between adjacent anode elements 9. The elements 9 define a cylindrical cathode space 11 in which a cylindrical cathode 13 is axially mounted. Conventional electrostatic shields or "hats" 15 may be provided at each end of the cathode to minimize loss of electrons to the end spaces of the magnetron. The envelope of the device is completed by end plates 17 and 19 closing the ends of the shell 5. The cathode 13 and its support 21 extend through an aperture 23 in end plate 17, being supported therein by insulation 25. Suitable means, such as magnets schematically shown as pole pieces 27 and 29 in Fig. 2, are provided to establish an axial magnetic field within the cathode space.

In accordance with the present invention, the cathode 13 comprises an apertured or perforated sleeve 31 of a refractory metal such as molybdenum, tantalum or tungsten. The sleeve may be constructed by boring or punching the desired pattern of holes or apertures 33 in a rectangular sheet of the metal, forming the sheet into a hollow cylinder and welding the edges together. One such cathode sleeve was constructed with a pattern of nine axial rows of eight holes each bored with a #80 drill. As shown in the drawing, the size and spacing of the holes 33 in the sleeve 31 are such that the total area of the holes is an appreciable fraction, considerably less than one-half, of the total sleeve area.

To provide a reservoir of refractory emissive material 35 beneath the holes 33, the sleeve 31 is packed with powdered thoria of the type used for sintered cathodes. Alternatively, a mixture of thoria and other refractory oxides, carbides, nitrides or borides of metals such as thorium, zirconium, titanium and tantalum, or of thoria and some refractory metal powders, such as molybdenum, tantalum or tungsten, may be used.

A preferred method of preparing the cathode is to: (1) make a paste of 200 mesh thoria and a solution of thorium chloride (1 g. in 5 ml. of H_2O); (2) pack the paste into the apertured sleeve; (3) wipe off the outside, avoiding any contact with lint; and inspect for clean, smooth, metal surface, absence of any foreign matter or any bulge in the sleeve.

Some means must be provided for heating the cathode 13 to maintain it at the desired operating temperature. Three alternative heating means

are illustrated in Figs. 2, 3 and 4, respectively. In Fig. 1, a refractory conducting rod 37 of tungsten, molybdenum or tantalum is mounted coaxially within the sleeve 31 and electrically connected at its inner end to the sleeve 31 by a conducting ring 39 (Fig. 2). In operation, heating current is supplied to the rod 37, ring 39 and sleeve 31 in series, heating the enclosure to the desired temperature. In this form of the invention the thoria, or thoria mixture, is packed into the annular space between the sleeve 31 and rod 37.

In Fig. 3, a double-helical, non-inductive heater 41 is embedded in the thoria material 35. Preferably, the inner end of the sleeve 31 is closed by a plug 43, and the thoria mixture is packed into the sleeve from the other end while the heater coil 41 is held in position by suitable means. In operation, the heater is separately energized, so that the sleeve 31 does not form a part of the heater circuit.

Fig. 4 shows a modification of Figs. 1 and 2 wherein the conducting ring 39 is replaced by an insulating ring 45. In this form the thoria material 35 is made conductive, so that it takes the place of the conducting ring 39 in the heater circuit of Figs. 1 and 2.

In each of the forms shown in Figs. 2, 3 and 4 the cathode is processed as follows. After the thoria material has been packed into the sleeve 31, the cathode assembly is mounted in the magnetron which then undergoes normal processing. After the tube is exhausted and baked, the cathode is degassed by slowly raising the heater current to about 35 amperes, or to produce a cathode brightness of 1600 to 1700° C. Upon lowering of the temperature to operating value, full emission is obtained with no apparent activation process occurring. By this normal processing and heating of the cathode, the contained thoria material is fully bonded and sintered within the cathode sleeve. The thoria material may fill the holes 33 as well as the space within the sleeve 31, as shown in Fig. 4.

In operation, electron emission apparently occurs from the thoria beneath the holes and also from the adjacent surfaces of the metal enclosure due to migration of the thoria thereon. It is desirable to prevent migration of thoria to the hats 15, and also to limit direct emission from the parts of the cathode 13 immediately opposite the ends of the anode 3. Therefore, the holes 33 in the cathode sleeve preferably do not extend to the hats 15 but, instead, are spaced substantially therefrom as shown in Figs. 2–4. As shown in Fig. 2, the outermost holes 33 are spaced inwardly from the ends of the anode 3. This leaves a substantial solid or imperforate portion 46 of the cathode sleeve 31 at each end thereof, which restricts primary emission to the central portion of the cathode and also facilitates dissipation of heat generated by back-bombardment of the cathode.

It is also possible to provide other patterns of holes or perforated areas for the purpose of controlling the thermal and electrical conductivity of various portions of the cathode surface. For example, as shown in Fig. 5, a central region 48 of the cathode sleeve 47 may be left imperforate between two perforated regions, because this is the region where maximum back-bombardment power is dissipated.

Tests on the dispenser-type cathodes disclosed herein in C. W. magnetrons have shown them to be far superior to sintered thoria and other cath-

odes tested. The following advantages have been noted:

(1) Because of the bare metal sleeve, the thermal conductivity of the cathode can be made as great as necessary to dissipate back-bombardment power;

(2) The cathode has low sparking characteristics due to the use of the bare metal sleeve;

(3) The operating temperature of a cathode so constructed has been of the order of 1200 to 1300° C. brightness, which is 300 to 400° C. lower than usually encountered in thoriated tungsten and sintered thoria matrix type cathodes under the same test conditions;

(4) The supply of thoria is so great relative to other cathode constructions that emission life is observed to be many times as long as for such other constructions;

(5) The fabrication of cathodes constructed in this manner is very simple as compared to other methods, since it merely involves packing the thoria material into a receptacle, followed by normal tube processing operations;

(6) The thoria material is not required to provide structural support for the cathode assembly and, moreover, is mechanically protected by the metal sleeve;

(7) Emission from the hats is practically nonexistent; and

(8) Cut-off characteristics are equal to or better than that of any other type of cathodes tested in C. W. magnetrons.

Although the invention has been described particularly with reference to magnetron use, it will be understood that the improved dispenser-type cathode is not limited to such use. The cathode is especially suitable for use in electron tubes employing a magnetic field, such as magnetrons, because of its ability to withstand back-bombardment caused by the magnetic field. However, it may also be used in high frequency power triodes or other tubes in which radio frequency currents occur in the cathode.

What is claimed is:

1. A dispenser-type cathode comprising a sleeve of refractory sheet metal having a smooth bare exterior surface and a plurality of apertures therethrough, said sleeve containing a compact mass of electron-emissive material including thoria in contact with its interior surface, and electrostatic shield elements mounted on and surrounding the ends of said sleeve, the perforations of said sleeve being spaced substantially from said shields to prevent migration of thoria to said shields during operation of said cathode.

2. An electron discharge device of the magnetron type including a hollow anode structure defining a cylindrical cathode space, an elongated dispenser-type cathode axially mounted within said space, and means for producing a constant magnetic field in said space axial to said cathode,

said cathode comprising a sleeve of refractory sheet metal having a smooth bare exterior surface and containing a compact mass of electron-emissive material including thoria in contact with its interior surface, a substantial part of said sleeve having apertures therethrough to permit direct emission from said material through said sleeve.

3. An electron discharge device of the magnetron type including a hollow anode structure defining a cylindrical cathode space, an elongated dispenser-type cathode axially mounted within said space, and means for producing a constant magnetic field in said space axial to said cathode, said cathode comprising a sleeve of refractory sheet metal having a smooth bare exterior surface and containing a compact mass of electron-emissive material including thoria in contact with its interior surface, the central portion of said sleeve having apertures therethrough to permit direct emission from said material through said sleeve, a substantial portion of said sleeve within each end of said space being imperforate to restrict primary emission to said central portion and facilitate dissipation of heat generated by back-bombardment of the cathode.

4. An electron discharge device according to claim 2, wherein the total area of said apertures is an appreciable fraction considerably less than one-half of the total area of said surface.

5. An electron discharge device according to claim 2, wherein said mass of electron-emissive material is a sintered mixture of thoria powder and another refractory oxide.

6. An electron discharge device according to claim 2, wherein said mass of electron-emissive material is a sintered mixture of thoria powder and a metal powder.

7. An electron discharge device according to claim 2, wherein said cathode includes a refractory metal rod positioned within said sleeve and electrically connected thereto to form a return conductor for heating current through said sleeve, said electron-emissive material completely filling the space between said rod and said sleeve.

8. An electron discharge device according to claim 2, wherein said cathode includes a heater element embedded in said electron-emissive material.

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