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- [21] Appl. No.: 354,808

Apr. 28, 1972 Japan..... 47-42787

- [58] **Field of Search**..... 313/15, 340; 174/138 C,
174/138 N; 219/531; 252/63.2, 63.5

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The cathode device comprises a body consisting of a mixture of electrically insulative and heat resistant substance and a metal and packed in a hollow container, an electron emissive substrate secured to one end of the casing, and a foil heater embedded in the body with its effective surface faced to and spaced from the substrate.

8 Claims, 9 Drawing Figures

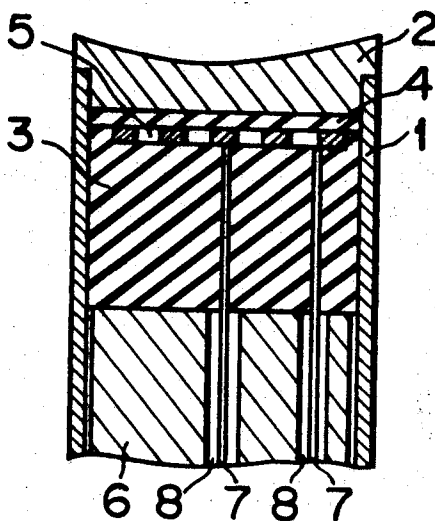


Fig. 1

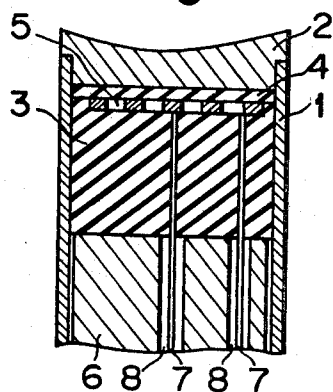


Fig. 2

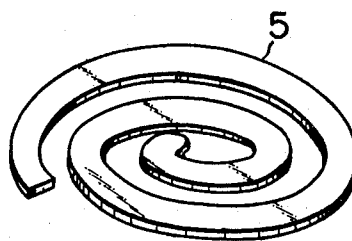


Fig. 4

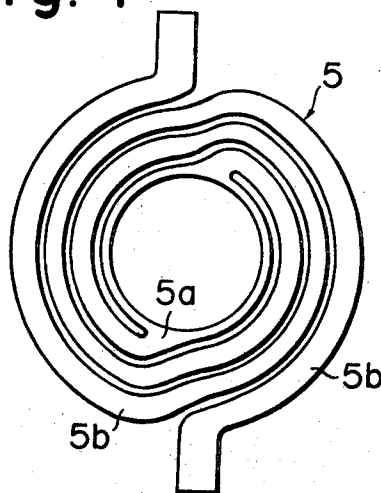


Fig. 3

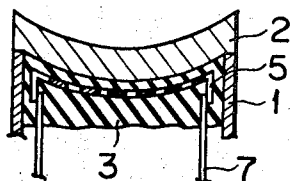


Fig. 5

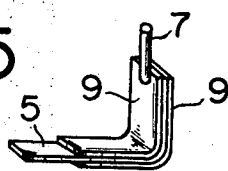


Fig. 6

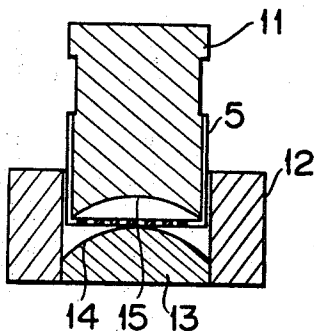


Fig. 7

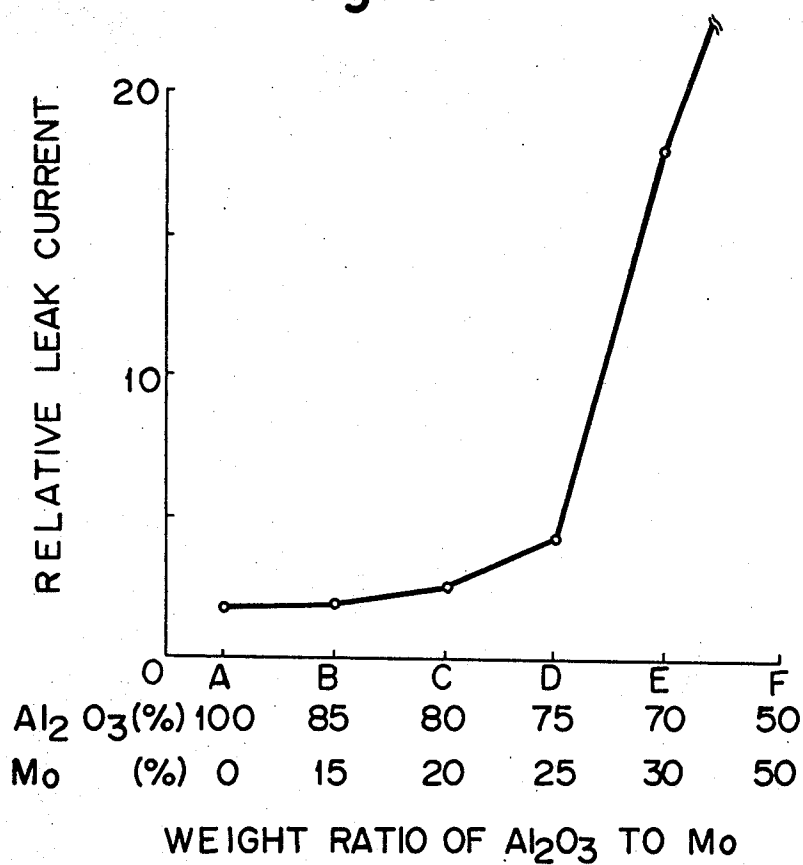


Fig. 8

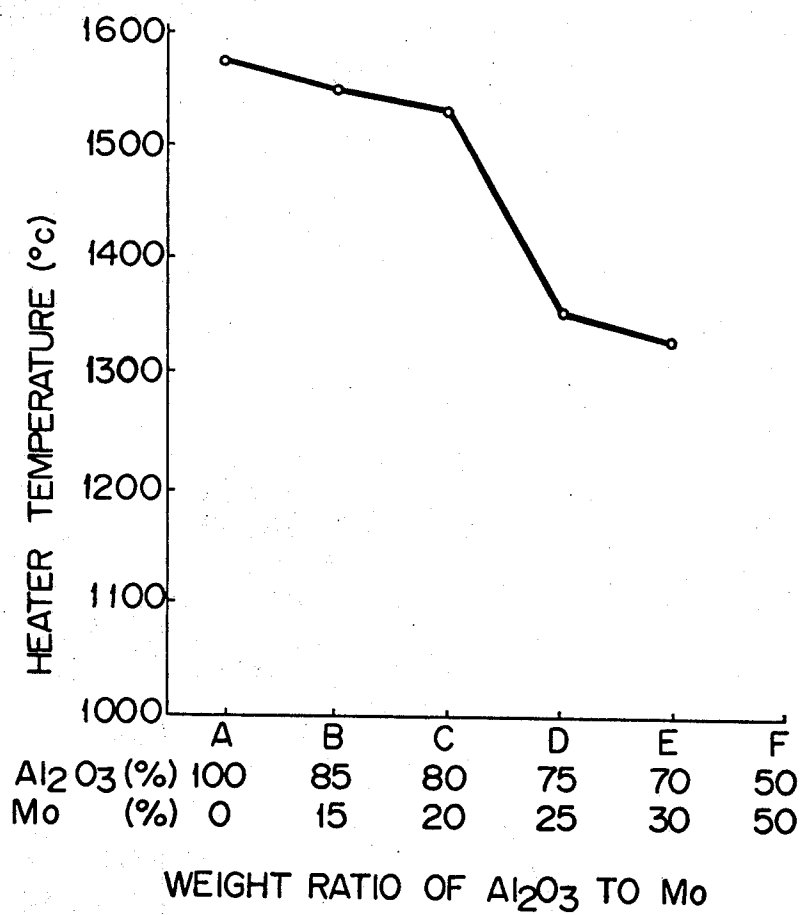
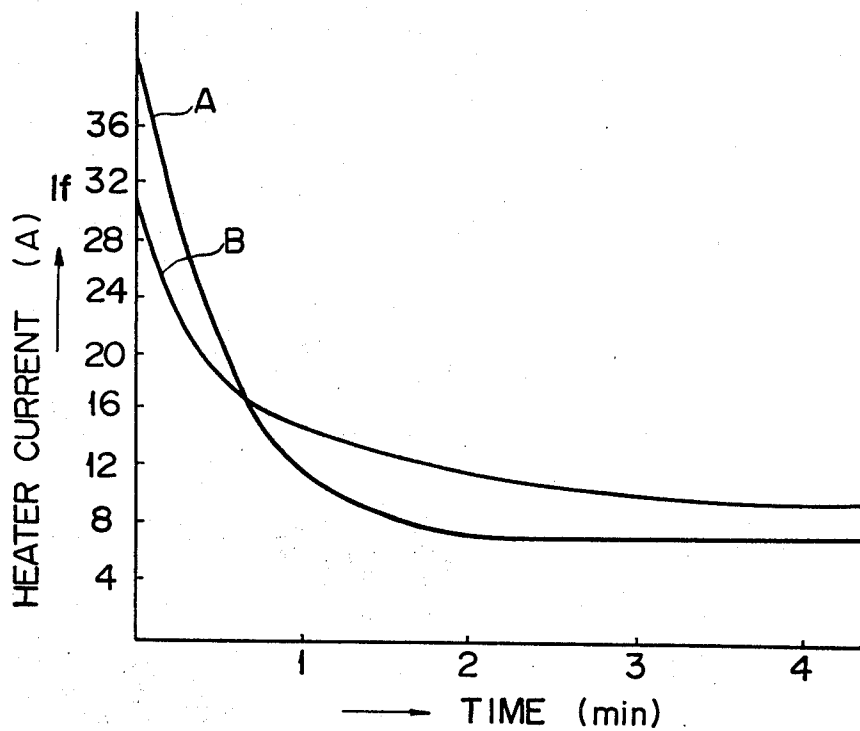


Fig. 9



INDIRECTLY HEATED TYPE CATHODE DEVICES USING FOIL HEATER EMBEDDED IN MIXTURE OF HEAT RESISTANT DIELECTRIC AND A METAL

This invention relates to a cathode structure, more particularly an indirectly heated type cathode device.

In an indirectly heated type cathode structure utilized in electron tubes, klystrons, travelling wave tubes and the like, an electron emissive substance is heated through an intermediate of an electric insulator so as to emanate electrons in the form of a beam. An electric heater utilized in the prior art indirectly heated type cathode device generally comprises a resistance wire wound in the form of a helical coil and embedded in an electric insulator.

The coiled heater is characterized in that the magnetic field formed thereby does not affect in any way the electron beam emanated by the cathode device. On the other hand, the thermal efficiency of the heater is not high because a substantial portion of the heat generated by the heater is radiated to the outside from a metal cylinder containing the coiled heater and the electric insulator. Moreover, the starting time that is the period between the energization of the heater and an instant at which the electron beam is emanated, is long.

Accordingly, it is an object of this invention to provide an improved indirectly heated type cathode device having an improved thermal efficiency and a short starting time.

According to this invention, there is provided an indirectly heated type cathode device comprising a hollow casing, a body consisting of a mixture of an electrically insulative and heat resistant substance and a metal, the body being packed in the casing, an electron emissive substrate mounted on one end of the casing, and a metal foil heater embedded in the body, the effective surface of the metal foil heater facing to the substrate and being spaced apart from the substrate.

In the accompanying drawings:

FIG. 1 is a longitudinal sectional view of one embodiment of an indirectly heated type cathode device embodying the invention;

FIG. 2 shows a spiral foil heater utilized in the cathode device shown in FIG. 1;

FIG. 3 shows a longitudinal section of a modified embodiment of this invention;

FIG. 4 is a plan view of a spiral foil heater utilized in the cathode device shown in FIG. 3;

FIG. 5 is a partial perspective view showing an electrical connection between the foil heater and a lead wire utilized in the cathode device shown in FIG. 3;

FIG. 6 is a sectional view showing dies utilized to form the spiral foil heater shown in FIG. 4;

FIG. 7 is a curve showing the relationship between the composition of a potting mixture which used to form an electrically insulative heat resistant body, and the leak current between the heater and the cylinder;

FIG. 8 is a curve showing the relationship between the composition of potting mixture, and the heater temperature; and

FIG. 9 is a graph comparing the starting times of the cathode device showing in FIG. 3 and a prior art device.

A preferred embodiment of this invention shown in FIGS. 1 and 2 comprises a cylindrical member 1 made of molybdenum, for example, and having an outer diameter of about 20 mm, and disc shaped substrate 2 brazed to one opening end of the cylindrical member 1 thus closing the one end. The purpose of the cathode substrate 2 is to emanate an electron beam when it is heated to a predetermined temperature and the cathode substrate is made of a porous refractory metal disc impregnated with an electron emissive substance in a manner well known in the art. The exposed upper surface of the cathode substrate 2 is concaved inwardly with a predetermined radius of curvature so as to focus the electrons emanated from the upper surface into a beam. A film 4 of an electrically insulative and heat resistant metal oxide is fixed to the lower surface of the cathode substrate 2 within the cylindrical member 1. A spiral foil heater 5 made of a refractory metal, for example, tungsten, is disposed in contact with the lower surface of the film 4. As shown in FIG. 2, the spiral heater 5 is made up of an elongated foil having a thickness of from 25 microns to 0.1 mm, preferably 30 microns. The exposed surfaces of the spiral foil heater 5 and the oxide film 4 are covered with a layer 3 of an electrically insulative and heat resistant potting mixture packed in the cylindrical member 1. In this manner, the spiral foil heater 5 is embedded in the electrically insulative body 3, 4. The electrically insulative and heat resistant potting layer 3 is formed by compressing a 75:25 (weight ratio) mixture of heat resistant electric insulating powder, for example aluminium oxide powder (Al_2O_3), and metal powder, for example molybdenum powder. The inner ends of lead wires 7 are electrically connected to the opposite ends of the spiral foil heater 5. The potting layer 3 is formed by packing a mixture of aluminium oxide powder and molybdenum powder in the cylindrical member 1, compressing and moulding the mixture and then sintering the mixture by heating it to a high temperature. A metal die 6 utilized to compress the mixture is provided with perforations for enabling lead wires 7 to extend therethrough. The potting layer 3 may be formed in the cylindrical member 1 by means of sintering alone and compression is not always necessary. The spiral foil heater 5 may be coated with a thin film of an electrically insulative and heat resistant oxide in which case a slurry of the oxide is coated on the heater 5 and then the coated slurry is sintered to form the thin film.

In a modified indirectly heated cathode device shown in FIGS. 3 and 4, the cathode substrate 2 secured to one end opening of a metal cylindrical member 1 is provided with a reentrant spherical upper surface for producing a focused electron beam and a lower spherical surface substantially in parallel with the upper surface. In the cylindrical member 1 with one end thereof closed by the cathode substrate 2 is formed a layer 3 of electrically insulative and heat resistant potting mixture. The layer 3 is formed by sintering a mixture containing heat resistant metal oxide powder and metal powder at a predetermined ratio as has been described in connection with the previous embodiment. In the upper surface of the oxide layer 3 is embedded a spiral foil heater 5 which is curved into a spherical configuration parallel with the lower surface of the cathode substrate 2, the spiral foil heater 5 being spaced by a predetermined small distance from the lower surface of the cathode substrate 2. The spiral foil heater 5 is

formed by etching a flat tungsten foil and comprises a ring shaped central portion 5a and two interleaved spirals 5b, the radial width of each spiral increasing from the central portion 5a toward the peripheral portion as shown in FIG. 4. The inner ends of the spirals are electrically interconnected and the outer ends are connected to lead wires. The radial width of the peripheral portion 5b is about two times of that of the central portion 5a.

The cathode device of this embodiment has a rating of 10 amperes and has the following dimensions. The outer diameter of the cylindrical member 1 is about 20 mm which is the same as that of the prior art device but the length of the cylindrical member 1 is about 7 mm which is considerably shorter than the length 15 mm of a cylindrical member adapted to contain a helical coil heater of the conventional design. This can be attributed to the use of the flat foil heater. Since the length of the cylindrical member is decreased in this manner, it is possible to proportionally decrease the heat loss caused by the heat dissipation from the outer surface of the cylindrical member. Since shortening of the cylindrical member decreases the heat storage capacity of the cathode device, its starting time can also be reduced. This is also caused by the fact that a concave foil heater 5 is located close to the cathode substrate 2. With this embodiment having dimensions described above, the cathode device becomes operative within about 2 minutes after energization whereas the prior art cathode device has a starting time of more than 3 minutes.

Although the lead wire 7 may be made integral with the spiral foil heater 5, where they are formed separately and connected together later, it is advantageous to use a connecting member 9 shown in FIG. 5. As shown in this figure, the connecting member 9 comprises two conductive pieces which are bent at substantially right angles and connected on the opposite sides of the heater 5. The lead wire 7 is connected to one of the conductive pieces. This construction prevents thermal deformation of extremely thin heater 5.

One example of the method of manufacturing the indirectly heated type cathode device of this invention will be described with reference to FIG. 6.

A photoresist is uniformly applied onto the opposite surfaces of a flat tungsten foil having a thickness of from 25 to 100 microns. A mask perforated with a desired pattern is mounted on the photoresist coating and the coating is exposed to light through the perforation of the mask. Finally the exposed photoresist coating is etched to leave a flat spiral foil of the desired pattern, for example a spiral pattern as shown in FIG. 4. The resulting spiral foil is then shaped with a forming device comprising an upper die 11, a guide cylinder 12, a lower die 13, each made of molybdenum. The lower die 13 has a convex upper surface 14 and the upper die 11 is formed with a complementary concave surface 15 so that when pressed between the upper and lower dies, the flat foil will be deformed into a partial spherical shape having the same radius of curvature as those of the concave and convex surfaces. It is advantageous to subject the foil heater to a suitable heat treatment while pressure is applied thereto. This can be accomplished by heating the assembly of the dies and the foil heater to a temperature of 1,700°C for about 2 hours in a hydrogen containing furnace.

The electrically insulative and heat resistant body in which the spiral foil heater is embedded comprises a mixture of insulator, that is metal oxide, and a suitable quantity of metal powder and not constituted by the metal oxide alone. According to this invention, since the effective surface or the upper surface of the spiral foil heater is located close to the cathode substrate and as it is necessary to position extremely thin peripheral portion of the spiral foil heater close to the inner surface of the metal cylindrical member, it is necessary to limit the quantity of the metal powder below a predetermined limit in order to prevent leak current from flowing across the metal cylindrical member and the spiral foil heater and to decrease the starting time of the cathode device. FIG. 7 shows the relationship between the leak current and the ratio (by weight) of aluminium oxide and molybdenum. The curve shown in FIG. 7 shows a leak current flowing between the metal cylindrical member and the spiral foil heater of the embodiment shown in FIG. 3 when a predetermined voltage is impressed across these members. The weight ratio of aluminium oxide powder and molybdenum powder comprising the electrically insulative and heat resistant layer 3 was varied as follows, 100:0, 85:15, 80:20, 75:25, 70:30 and 50:50. The leak currents measured at respective ratios were plotted, although the magnitude of the leak current varies dependent upon the magnitude of the impressed voltage and the spacing between the spiral foil heater and the cylindrical member. The curve shown in FIG. 7 shows that the ratio within a range of from 100:0 to 75:25 gives a leak current permissible for the cathode devices used in the applications described above. However, in the case of the ratio of 100:0, there is no advantage of the incorporation of the metal powder. It was found that 5 to 30 percent, by weight, of the metal powder incorporated is adequate from the standpoint of minimizing the leak current and maximizing the effect of the metal powder.

As the powder of the heat resistant oxide insulator may be used powders of yttrium oxide (Y_2O_3), zirconium oxide (ZrO), hafnium oxide (HfO_2), beryllium oxide (BeO_2), magnesium oxide (MgO) and oxides of rare earth metals. Among the metal powders utilized in this invention are included powders of tungsten (W), nickel (Ni), rhenium (Re), tantalum (Ta), titanium (Ti), zirconium (Zr), hafnium (Hf), vanadium (V), niobium (Nb), chromium (Cr), elements of the platinum group, and their alloys. These metals and alloys can be used in the range described above.

It is advantageous to provide metallic layers of high melting point, for example an alloy of Ru-Mo, on the inner surface of the metal cylindrical member and the lower surface of the cathode substrate, before packing the mixture of the metal oxide powder and the metal powder in the cylindrical member. When sintered at a temperature of 1,700°C for about one hour, the molybdenum powder and the metallic layer fuse together thereby firmly bonding the resulting electrical insulative and heat conductive body to the metal cylindrical member.

In the cathode device it is possible to decrease the operating temperature of the heater by a suitable selection of the ratio of a powder of the metal oxide to a powder of metal which constitutes the electrically insulative and heat conductive body. FIG. 8 shows the relationship between the heater temperature and the ratio

of aluminium oxide to molybdenum. FIG. 8 shows that when only the powder of aluminium oxide is used it is necessary to rise the operating temperature of the heater to 1,570°C, but as the quantity of the metal powder is increased, the operating temperature decreases, and that at the lower limit of the metal incorporated, that is at a weight ratio of 30 percent, the required operating temperature is decreased to only 1,320°C.

As above described, the cathode device of this invention has a shorter starting time than the prior art cathode device. FIG. 9 shows a comparison of the starting time of the embodiment shown in FIG. 3 and of the prior art construction utilizing a helical coil heater, in which the ordinate shows the heater current and the abscissa shows the time in minutes. Curve A represents the starting characteristic of the present cathode device and curve B that of the prior construction. In both cases, a heater voltage of 6.3V was used. As shown by curve A with the cathode device of this invention, the heater temperature reaches an equilibrium condition within about 2 minutes, whereas curve B, the prior art device, requires a starting time of about 3 minutes.

For the reason described hereunder, the thickness of the metal foil comprising the cathode heater is preferred to lie in a range of from 25 μ to 0.1 mm. More particularly, the foil is made of a metal having a high melting point and is stable at high temperatures, such as tungsten or molybdenum. However, these metals are difficult to roll and the minimum thickness obtainable is about 20 microns. However, a foil having a thickness of about 20 microns varies its thickness in the direction of rolling thus resulting in a local heating and breakage thereat. For this reason, it is necessary to increase the thickness of the foil to a value not causing such variation in the thickness, such minimum thickness being about 25 microns. On the other hand, foils of the desired pattern are usually formed by photoetching technique as above described, and the maximum thickness that can be formed by this technique is about 0.1 mm. Thicknesses exceeding this value decrease the advantage of using thin foils.

What we claim is:

1. An indirectly heated type cathode device compris-

ing a hollow casing, a body consisting of a mixture of an electrically insulative and heat resistant substance and a metal, said body being packed in said casing, an electron emissive substrate mounted on one end of said casing, and a metal foil heater embedded in said body, the effective surface of said metal foil heater facing to said substrate and being spaced apart from said substrate.

2. A cathode device according to claim 1 wherein said casing takes the form of a cylinder with both ends opened, and said electron emissive substrate is secured to said cylinder to close one end opening thereof.

3. A cathode device according to claim 2 wherein the surface of said substrate on the side opposite to said foil heater is reentrant thus forming a partial spherical surface.

4. A cathode device according to claim 1 wherein said foil heater comprises a thin metal strip shaped into a spiral.

5. A cathode device according to claim 1 wherein said foil heater comprises a center ring portion and a pair of interleaved spirals with inner ends connected to the ring portion.

6. A cathode device according to claim 1 wherein said body comprises a mixture of said electrically insulative and heat resistant substance and said metal at a weight ratio of from 95:5 to 70:30.

7. A cathode device according to claim 1 wherein said electrically insulative and heat resistant substance is a member selected from the group consisting of yttrium oxide, zirconium oxide, aluminium oxide, hafnium oxide, beryllium oxide, magnesium oxide and oxides of rare earth metals and said metal is a member selected from the group consisting of tungsten, nickel, rhenium, tantalum, titanium, zirconium, hafnium, vanadium, neobium, chromium, metals of the platinum group and alloys thereof.

8. A cathode device according to claim 1 wherein said foil heater comprises an electrical connector connected to one end thereof and a lead wire electrically connected to said connector.

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