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3,227,905

ELECTRON TUBE COMPRISING BERYLLIUM OXIDE CERAMIC

Filed Oct. 2, 1961

4 Sheets-Sheet 1

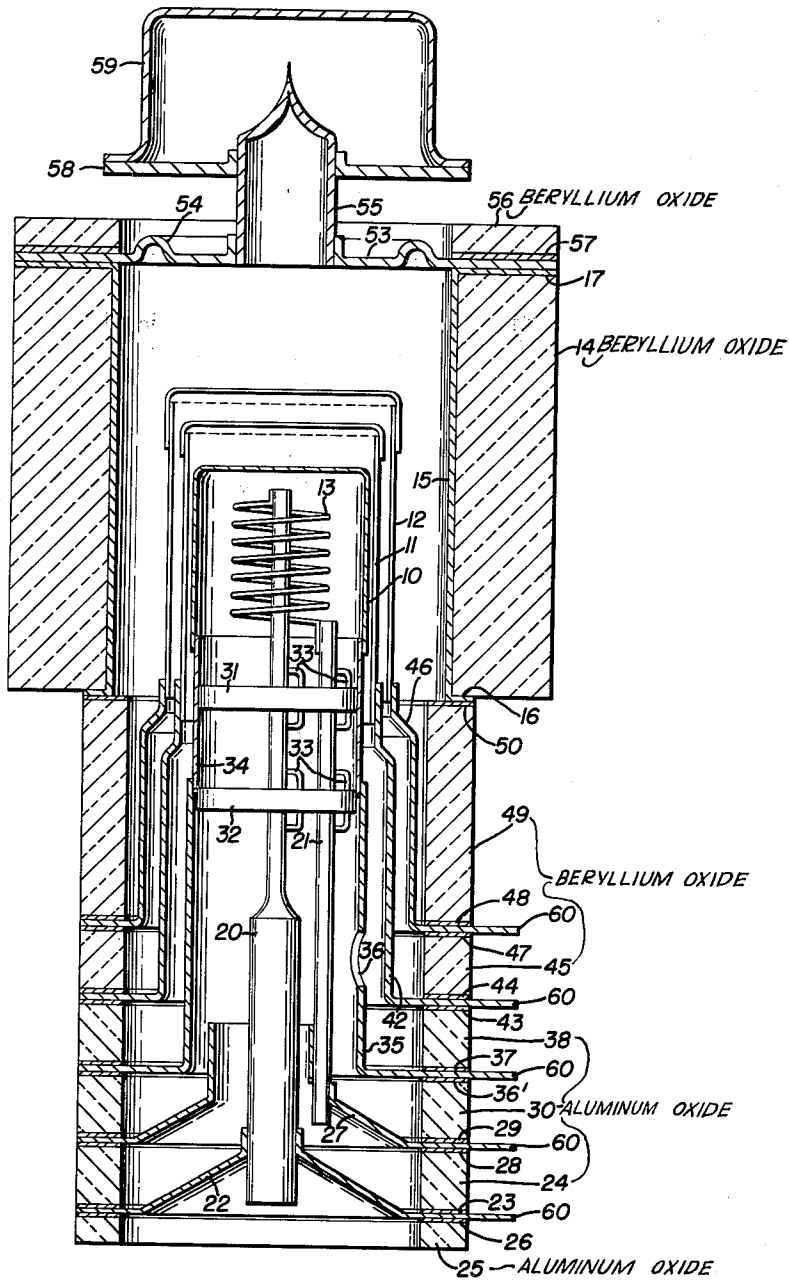


Fig. 1

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4 Sheets-Sheet 2

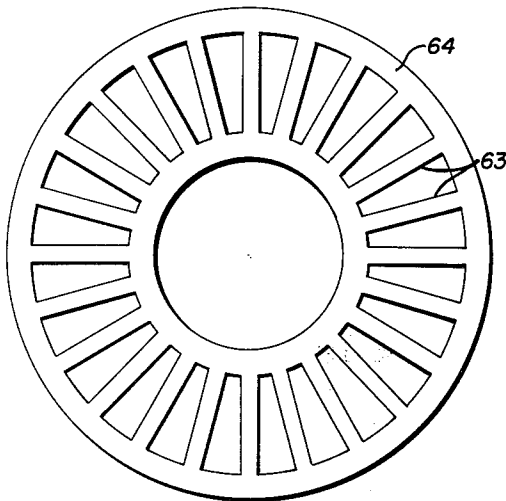


Fig. 3

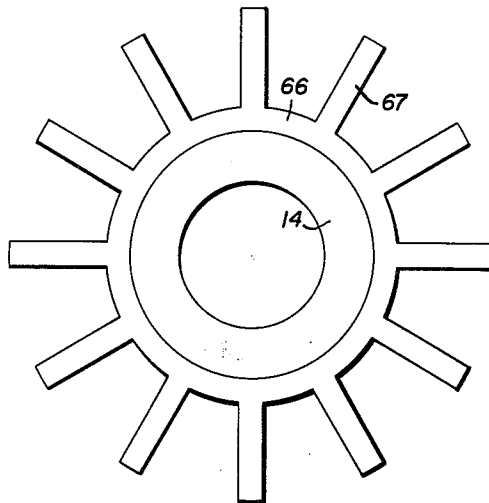


Fig. 5

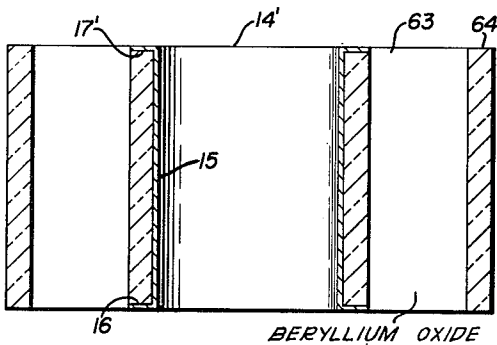


Fig. 2

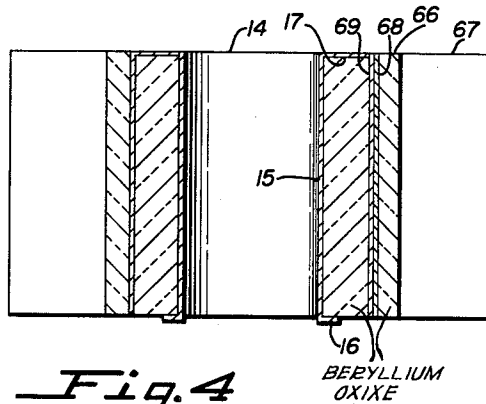


Fig. 4

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4 Sheets-Sheet 3

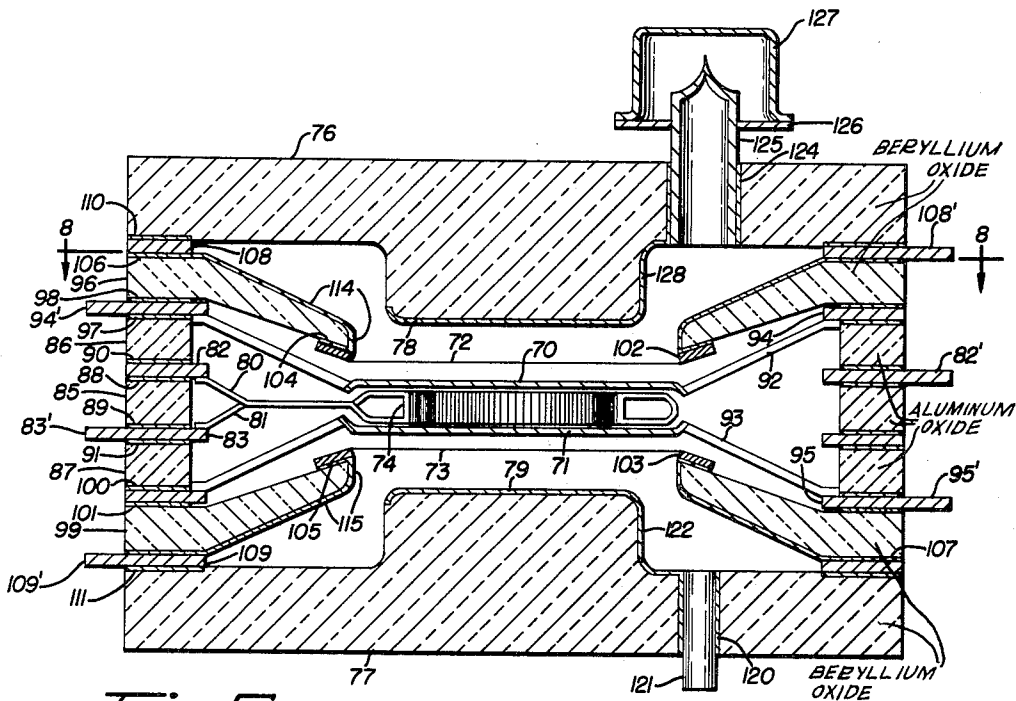


Fig. 6

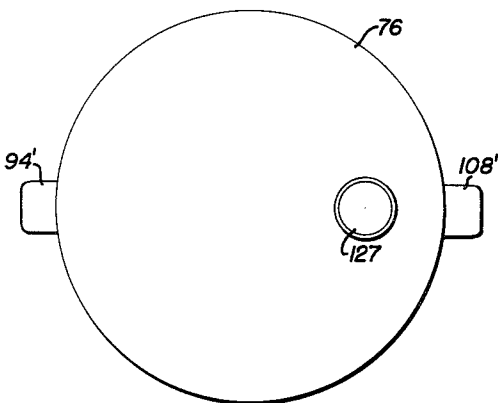


Fig. 7

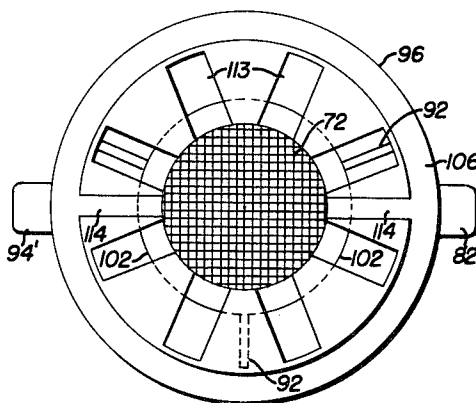


Fig. 8

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4 Sheets-Sheet 4

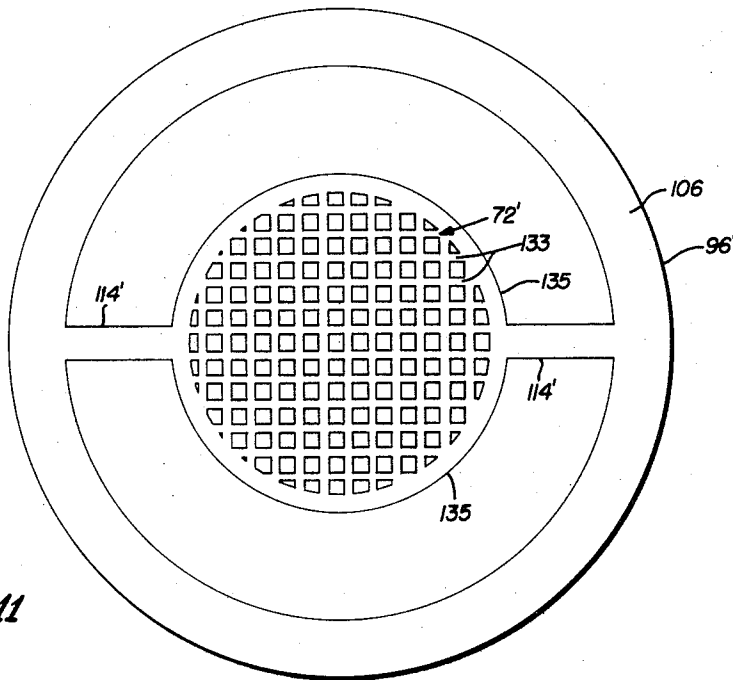


Fig. 11

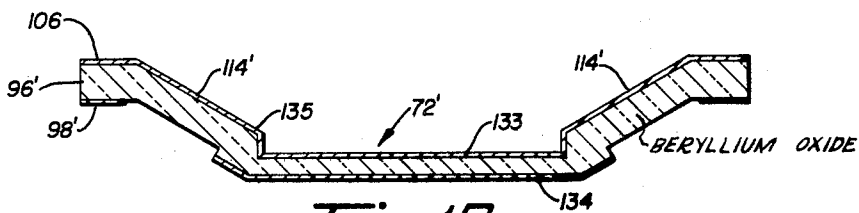


Fig. 10

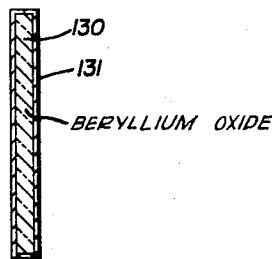


Fig. 9

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ELECTRON TUBE COMPRISING BERYLLIUM OXIDE CERAMIC

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8 Claims. (Cl. 313—39)

This invention relates to electron tubes and more particularly to the problem of improving electron tubes from the standpoint of heat dissipation, number of parts, weight, electrical characteristics and ability to withstand mechanical shock and vibration.

In order to utilize the full capabilities of electron tubes it is often necessary to provide extensive cooling apparatus. The cooling apparatus adds considerable weight and expense to the electrical systems employing the tubes. In some systems, size or cost limitations prohibit the use of adequate cooling apparatus and thus make it impossible to operate at the full capabilities of the tubes.

In order electrically to separate the variously charged electrodes of electron tubes it is customary to provide insulating material such as glass or ceramic between the electrodes. The electrodes are normally carried by metal support members which extend through the tube envelopes. The metal support members serve the triple function of electrical conduction, heat conduction, and physical support. Since the heat conducting capability of a member varies directly with its cross sectional size, the optimum design for temperature considerations requires a relatively large metal support member extending from the electrodes to the outside of the tube. However, large metal support members have a detrimental effect on the size, weight, and electrical characteristics of electron tubes, and cannot be easily joined to the insulating portions of the tube because of difference in coefficient of expansion.

According to its full concept, this invention results in electron tube constructions in which one member provides a quadruple function of electrical conduction, heat conduction, physical support, and electrical insulation. The material which has been found to make this combination possible is beryllium oxide ceramic (BeO). Beryllium oxide has the somewhat anomalous properties of high heat conductivity, high mechanical strength, and high insulating properties. Beryllium oxide even weighs much less than the commonly used metals which it replaces according to the invention and it also retains its shape better than such metals throughout the operating temperature range of electron tubes. Also, its thermal expansion closely matches that of alumina ceramic, so that it can readily be joined to structural or envelope parts made of either aluminum oxide or beryllium oxide.

Beryllium oxide by itself does not provide the electrical conductivity function. However, this fourth function is obtained by metalizing the beryllium oxide. Thus it is possible to have a relatively large cross-section beryllium oxide electrode support which, because of its combined size and physical characteristics, can be designed to result in a well cooled, strong, and well insulated tube. At the same time, relatively limited areas of metalization on the beryllium oxide will provide ample electrical conductivity without introducing the detrimental features of a solid metal electrode support such as high interelectrode capacity, high weight, and the difficulty or impossibility of joining thick metal parts to insulating material.

An object of this invention is to employ beryllium oxide

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to provide improved electron tubes having better heat dissipation, fewer parts, lower weight, better electrical characteristics, and greater ability to withstand mechanical shock and vibration. It should be understood that various ones of these features of advantage can be emphasized at the expense of others depending on which features are most important in a particular type of tube. For example, if heat dissipation and mechanical rigidity are critical the beryllium oxide parts may be made larger and therefore heavier than if weight were the feature of prime importance.

More specifically, an object of this invention is to provide an improved electron tube by making a portion of the envelope wall of beryllium oxide with a metallic coating on its inside surface to provide an electron receiving surface such as an anode or collector.

An associated object of the invention is to provide an improved electron tube by making a metalized beryllium oxide anode or collector which is shaped to have cooling fins or cooling passages, either as an integral structure or as more than one piece of beryllium oxide.

Another object of this invention is to provide an improved electron tube by making certain insulating portions of the envelope of insulating material having low heat conductivity and others of insulating material having high heat conductivity.

An additional object of the invention is to provide an improved electron tube by employing a beryllium oxide insulating envelope ring which is brazed to a metal grid support ring.

A further object of the invention is to provide an improved electron tube by employing a beryllium oxide envelope section which is extended inside the envelope to provide a support for an electrode.

Another object of the invention is to provide an improved electron tube by employing an electrode, other than the anode or collector, which is made of metalized beryllium oxide.

Other objects and features of advantage will be apparent from the following detailed description read in conjunction with the accompanying drawings in which:

FIGURE 1 is a cross section view of a cylindrical electrode tube according to the invention;

FIGURE 2 is a cross sectional view on reduced scale showing a modified anode for the tube of FIGURE 1;

FIGURE 3 is a plan view of FIGURE 2;

FIGURE 4 is a cross sectional view on reduced scale showing the anode of FIGURE 1 with a separate beryllium oxide cooler or radiator brazed on it;

FIGURE 5 is a plan view of FIGURE 4;

FIGURE 6 is a cross sectional view of a planar electrode tube according to the invention;

FIGURE 7 is a plan view of FIGURE 6 on reduced scale;

FIGURE 8 is a view taken on line 8—8 of FIGURE 6 showing the beryllium oxide grid supporting ring of FIGURE 6 on reduced scale;

FIGURE 9 is a cross sectional view of a modified form of grid rod to replace the grid wires of FIGURE 1;

FIGURE 10 is a cross sectional view of a modified form of grid to replace the solid metal grids of FIGURE 6; and FIGURE 11 is a top view of FIGURE 10.

Referring to the drawings in more detail, FIGURE 1 shows an electron tube having a cylindrical cathode 10, a cylindrical control grid 11, a cylindrical screen grid 12, and a heater 13 for the cathode. The anode comprises a

beryllium oxide member 14 which is metalized at 15 to provide an electron receiving surface. The member 14 is also metalized at 16 and 17 for purposes to be herein-after described, and of course, member 14 forms a substantial section of the envelope wall for the tube. In employing the invention it has been found that conventional metalizing processes which are used for aluminum oxide ceramic work also for beryllium oxide ceramic.

The heater 13 is attached at its upper end to a center post 20 and at its lower end to a post 21. Post 20 is attached to a metal support ring 22 which is brazed to a metalized surface 23 on an aluminum oxide envelope ring 24. An aluminum oxide backing ring 25 is metalized at 26 and brazed to the bottom of ring 22. Post 21 is attached to a metal support ring 27 which is brazed to a metalized surface 28 on ceramic ring 24 and to a metalized surface 29 on a second aluminum oxide envelope ring 30. In accordance with conventional construction, posts 20 and 21 pass through aluminum oxide disks 31 and 32 which rigidify the posts and help prevent loss of heat from the heater chamber. U-shaped wires 33 are brazed in holes in the disks 31 and 32 and are spot welded to the posts to hold the disks in place.

Cathode 10 is preferably of the oxide coated type, made in the shape of an inverted metal can and having its side wall coated with a conventional electron emissive composition. The cathode can is attached to a thin cylindrical metal heat dam 34 which is in turn attached to a metal cathode support 35, apertured at 36 for evacuating purposes. Support 35 is brazed to a metalized surface 37 on the aluminum oxide ring 30 and to a metalized surface 37 on a third aluminum oxide envelope ring 38.

The control grid 11 is a conventional cage-type structure made of a plurality of wires spaced circumferentially around the cathode. The lower ends of the wires are attached to a metal grid support 42 which is brazed to a metalized surface 43 on the aluminum oxide ring 38 and to a metalized surface 44 on a first beryllium oxide envelope ring 45. Screen grid 12 is a conventional cage-type structure like grid 11, with the lower end of its grid wires attached to a metal grid support 46. Support 46 is brazed to a metalized surface 47 on the beryllium oxide ring 45 and to a metalized surface 48 on a second beryllium oxide envelope ring 49. The upper end of ring 49 is metalized at 50 and is brazed to the metalized surface 16 on the anode member 14. As will be more fully understood in connection with the later description of FIGURE 6, the metal grid support members 42 and 46, could be beryllium oxide extensions of rings 45 and 49. However, FIGURE 1 discloses a tube in which many of the desirable features of the invention are realized by using beryllium oxide only in the envelope wall and retaining the more conventional metal structures inside the envelope.

The upper end of the tube is closed by a metal ring 53 having an annular inverted U-shaped portion 54 which will relieve the stresses caused by the different coefficients of expansion of metal and beryllium oxide. Ring 53 is brazed to the metalized surface 17 on member 14 and to the lower end of a metal exhaust tubulation 55. Preferably, a beryllium oxide backing ring 56 with a metalized surface 57 is brazed to the upper side of ring 53. A two piece cap 58, 59 is brazed to the tubulation 55 to provide a protective cover as well as a convenient anode terminal. Ring 53 could also be made by beryllium oxide, either as a separate piece or as an integral part of member 14. Each of the metal support rings is provided with a plurality of outwardly projecting terminal tabs 60, only one such tab is shown in FIGURE 1 for each ring. Each ring has a plurality of such tabs spaced around the tube, and the tabs on the several rings are arranged in vertical rows parallel to the axis of the tube.

The embodiment of the invention disclosed in FIGURE 1 contains all of the advantages of the invention except fewer parts; that is, the tube does not have fewer parts than

an equivalent conventional tube having a solid metal anode and ceramic envelope rings all made of aluminum oxide. However, the tube of FIGURE 1 does possess the features of better heat dissipation, lighter weight, better electrical characteristics, and better ability to withstand mechanical shock and vibration. For example, beryllium oxide ceramic having 96% beryllium has the following properties as compared to 96% aluminum oxide and to copper:

	Unit	96% BeO	96% Al ₂ O ₃	Copper
Specific gravity.....	Grams/cu. cm....	2.9	3.7	9.0
Thermal conductivity at 25° C.....	Cul./sec./° C./cm.	.5	.05	.92

Thus it will be understood that the beryllium oxide rings 45 and 49 will conduct heat from the grid support rings 42 and 46 much more efficiently and will weigh less than if they were aluminum oxide. At the same time the aluminum oxide rings 24, 30 and 38 will be relatively efficient in preventing the loss of heat from the heater and cathode support rings 22, 27, and 35. It will be understood by those skilled in the art that just as it is important to dissipate heat from the grids and anode it is also important to prevent the loss of heat from the heater and cathode. As shown by the preceding chart beryllium oxide weighs about one third as much as copper (the usual anode metal) but is much more nearly equivalent in heat conductivity. Therefore, the beryllium oxide anode member 14 weighs less than a copper member of the same total heat dissipation value or has a much greater volume and therefore greater total heat dissipation value than a copper member of equal weight. Also, the lower weight characteristic of the beryllium oxide members 45, 49, and 14 means that the tube can withstand more mechanical shock and vibration before it will break or be torn from its socket. In addition, the fact that the outside of member 14 is a non-conductor improves the electrical characteristics of the tube by reducing the undesirable capacitance problems caused by a solid metal anode.

FIGURES 2 and 3 show a modified form of anode member 14' which can be substituted for anode 14 to even further improve the heat dissipation. Conventional solid metal anodes are usually provided with cooling fins in the form of separate thin metal pieces brazed or clamped to the outside of the solid metal anode. Since beryllium oxide is more easily formed in any desired shape and weighs much less than metal, it is practical to make a beryllium oxide anode member having integral cooling fins 63 and air channel forming ring 64. Since beryllium oxide can be formed in almost any desired shape, an almost endless variety of shapes can be selected for the cooling fins or cooling passages. Sometimes it is desirable to make a standard tube construction without any cooling fins as shown in FIGURE 1, in order to obtain the benefits of mass production. Then the tubes can be completed and sold without cooling fins for some applications and with different types of cooling fins or passage structures for other applications. For this purpose the cooling fins are formed on a separate sleeve-like beryllium oxide member such as member 66 in FIGURES 4 and 5. The cooler or radiator 66 has fins 67 and is metalized at 68. In this embodiment the anode member 14 is metalized at 69 and the two metalized surfaces are brazed together. The fact that the anode and cooler are of the same material eliminates any coefficient of expansion problems, and good thermal contact exists between members 14 and 16 throughout the temperature range of operation of the tube.

FIGURE 6 discloses a planar electrode tube embodying the invention. The tube is a double triode having two oxide coated cathode disks 70 and 71, two control grids 72 and 73, and a common heater coil 74. The tube

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has two anode members 76 and 77 each comprising a beryllium oxide disk metalized at 78 and 79, respectively, to form the electron receiving surfaces.

Heater 74 is made of wire coated with insulating material and wound in a toroidal shape. The coil has two terminal ends 80 and 81 which are attached to metal terminal rings 82 and 83. The terminal rings are brazed to aluminum oxide ceramic rings 85, 86 and 87 which are metalized for this purpose at 88, 89, 90, and 91.

Cathode members 70 and 71 are metal disks, each having an electron emissive oxide coating on its outer surface. The disks 70 and 71 are supported on thin metal spokes 92 and 93, respectively. The spokes are preferably channel shaped in cross section and there are at least three spokes for each disk, two being visible in FIGURE 6. Spokes 92 are attached to a metal terminal ring 94 and spokes 93 are attached to a metal terminal ring 95. Terminal ring 94 is brazed to the aluminum oxide ring 86 and to a beryllium oxide ring 96, these ceramic rings being metalized at 97 and 98 for this purpose. Similarly, terminal ring 95 is brazed to the aluminum oxide ring 87 and to a beryllium oxide ring 99, these ceramic rings being metalized at 100 and 101 for this purpose.

The grids 72 and 73 are conventional wire mesh construction brazed to metal washers 102 and 103. The washers are brazed to metalized surfaces 104 and 105 on the beryllium oxide rings 96 and 99. Rings 96 and 99 are also metalized at 106 and 107 where they are brazed to metal terminal rings 108 and 109. The anode members 76 and 77 are metalized at 110 and 111 where they are brazed to the terminal rings 108 and 109. As shown in FIGURE 8 the beryllium oxide ring 96 (and also ring 99) can be made even lighter in weight by providing cut out portions 113. In order to provide an electrical connection between grids 72, 73, and terminal rings 108, 109, the beryllium oxide members 96 and 99 are metalized at 114 and 115. As shown in FIGURE 8, this connecting metalizing layer can be a relatively small strip to reduce interelectrode capacitance. The terminal rings 108 and 109 are employed for the purpose of maintaining a uniform type of terminals. Obviously, rings 108 and 109 could be eliminated and the grid terminal could be provided by metalizing the peripheral edge of members 76 and 77. It will be noted that the terminal rings are provided with outwardly projecting terminal tabs alternately on opposite sides of the tube as shown in FIGURES 6-8. Such alternate placement further reduces interelectrode capacitance. For identification purposes, the tabs are given primed reference numbers.

The anode member 77 has a bore with a metalized wall 120 to which is brazed a terminal pin 121. The electrical connection between pin 121 and the active anode surface 79 is formed by a strip of metalizing 122 similar in width to strip 114 on member 96 in FIGURE 8. Anode member 76 has a bore with a metalized wall 124 to which is brazed a metal exhaust tubulation 125. A two piece protective cap 126, 127 is brazed to the tubulation and serves also as a convenient anode terminal. The electrical connection between tubulation 125 and the active anode surface 78 is formed by a strip of metalizing 128 like strip 122 on member 77. Obviously, if it is desired to make the tube without tubulation, a terminal pin such as pin 121 could be substituted for tubulation 125.

The tube of FIGURE 6 employs many of the features of the tube in FIGURE 1. For example, in FIGURE 6 the heater 74 and cathodes 70 and 71 are connected to aluminum oxide ceramic, and the anodes are made of metalized beryllium oxide members 76 and 77. It will be noted that the cathode disks are in metallic contact with the beryllium oxide rings 96 and 99 without the intervention of an aluminum oxide ring to serve as a heat dam as in FIGURE 1. However, an effective

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heat dam is provided by reason of the very small total cross sectional area of the spokes 92 and 93. Obviously, if low heater power is more important in a particular tube than is size, weight, and number of parts, an aluminum oxide ring could be added between rings 94 and 96, and also between rings 95 and 99. It should be noted however, that the aluminum oxide members 86 and 87 thermally separate the heater from the beryllium oxide wall sections and that heat which radiates sideways from the hot center of the tube is blocked by the relatively poor conducting aluminum oxide sections 85, 86, and 87.

In addition, the tube of FIGURE 6 employs a further feature of the invention in the form of beryllium oxide members 96 and 99. The peripheral portion of these members form part of the insulating envelope wall and the inwardly projecting portion replaces the conventional grid support ring made of metal. The combined envelope-grid-support rings 96, 99 provide many advantages over the conventional separate aluminum oxide envelope ring and metal grid support ring. For example, the unitary beryllium oxide structure reduces the number of parts. Obviously, if the grid support ring and the anode on each side of the tube were made of metal in the usual manner, one ceramic ring would be required between the cathode terminal ring and the metal grid support ring, and a second ceramic ring would be required between the metal grid support ring and the metal anode. Also, the beryllium grid support and anode members can be made lighter in weight than metal having equivalent strength and total heat dissipating capability. Also, the elimination of solid metal grid supports and anodes maintains more accurate interelectrode spacings throughout operation of the tube. The reasons for this benefit are that beryllium oxide does not have as high a coefficient of expansion as the metals which are usually employed, and that beryllium oxide does not deform under its own weight and internal stresses at tube operating temperature as do metals.

According to a further aspect of the invention, it is desirable to make electrodes such as the grids out of metalized beryllium. For example the metal wires which form grids 11 and 12 in FIGURE 1 could be made of beryllium oxide rods 130 provided with a metallic coating 131 as shown in FIGURE 9. Similarly, the wire mesh 72, 73 in FIGURE 6 could be replaced by metalized beryllium oxide. Thus as shown in FIGURES 10 and 11 the beryllium oxide member 96' is integrally formed to provide the control grid 72'. More specifically member 96' has a center portion of beryllium oxide formed in a grid like shape. The beryllium oxide grid portion can be dipped in metalizing paint so that all of the surfaces of the grid like shape are metalized, as indicated by the metalizing 133 and 134 on the top and bottom horizontal surfaces of the grid portion. The vertical surfaces of the grid portion would of course also be metalized. In order to insure good electrical connection to the grid, a ring of metalizing 135 can be located to connect with metalizing strips 114' (FIGURE 11).

It should be understood that although the invention has been disclosed in connection with specific tubes, the various features and benefits of the invention are applicable to many types of tubes. For example, the use of beryllium oxide member having a metalized electron receiving surface is applicable to the collector of tubes such as klystrons and traveling wave tubes. Similarly, the use of a combined envelope and electrode support ring made of metalized beryllium oxide is applicable to any electrode which requires the heat dissipating and other features previously described.

Having thus described the invention what is claimed as new and desired to be secured by Letters Patent is as follows:

1. An electron tube comprising a hermetically sealed

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envelope and electrodes within the envelope, one of said electrodes being a grid and another of said electrodes being a cathode, said envelope comprising a plurality of ceramic insulating sections, one of said sections being beryllium oxide and another of said sections being a ceramic having substantially lower thermal conductivity than beryllium oxide, said ceramic sections having metalized portions, a metallic connection between said grid and the metalized portion of said beryllium oxide section, and a metallic connection between said cathode and the metalized portion of said other ceramic section.

2. An electron tube comprising a hermetically sealed envelope and electrodes within the envelope, said envelope comprising a beryllium oxide wall section, one of said electrodes being an electron receiving electrode, the inside wall surface of said beryllium oxide section having a metallic coating forming said one electrode, said beryllium oxide section being metalized on its outside surface, a beryllium oxide cooler having a metalized surface, and a braze joint connecting said metalized surface of the cooler to said metalized outside surface of the beryllium oxide wall section.

3. An electron tube comprising a hermetically sealed envelope and electrodes within the envelope, one of said electrodes requiring cooling during operation of the tube and another of said electrodes requiring heating during operation of the tube, said envelope comprising a plurality of ceramic insulating sections, at least one of said sections being beryllium oxide and at least one other of said sections being a ceramic having substantially lower thermal conductivity than beryllium oxide, said beryllium oxide section being attached to said electrode which requires cooling, and said other ceramic section being attached to said electrode which requires heating.

4. An electron tube as claimed in claim 3 in which said beryllium oxide section extends to the inside of said tube, and said electrode which requires cooling is a grid comprising a metallic coating on the beryllium oxide section inside the tube.

5. An electron tube comprising a hermetically sealed envelope and electrodes within the envelope, said envelope comprising a first beryllium oxide wall section, one of

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said electrodes being an electron receiving electrode formed by a metallic coating on the inside surface of said first beryllium oxide wall section, another of said electrodes being a grid comprising a beryllium oxide base having a metallic coating thereon, and said beryllium oxide grid base extending to the exterior of said tube and forming a second beryllium oxide wall section of said envelope.

6. An electron tube comprising a heater, a cathode, a grid, and an electron receiving electrode, a hermetically sealed envelope for said tube comprising beryllium oxide wall sections and aluminum oxide wall sections, one of said beryllium oxide sections being metalized on its inside surface to form said electron receiving electrodes, said grid being attached to another of said beryllium oxide sections, and said heater and cathode being attached to said aluminum oxide sections.

7. An electron tube as claimed in claim 6 in which said cathode and grid are attached to metal support members brazed between certain of said wall sections, the wall section which is brazed between said cathode support member and said grid support member being aluminum oxide.

8. An electron tube as claimed in claim 6 in which said other beryllium oxide wall section projects further into said tube than said aluminum oxide sections for a support for said grid, and a metallic coating on the inwardly projecting portion of said other beryllium oxide section forming an electrical lead for said grid.

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