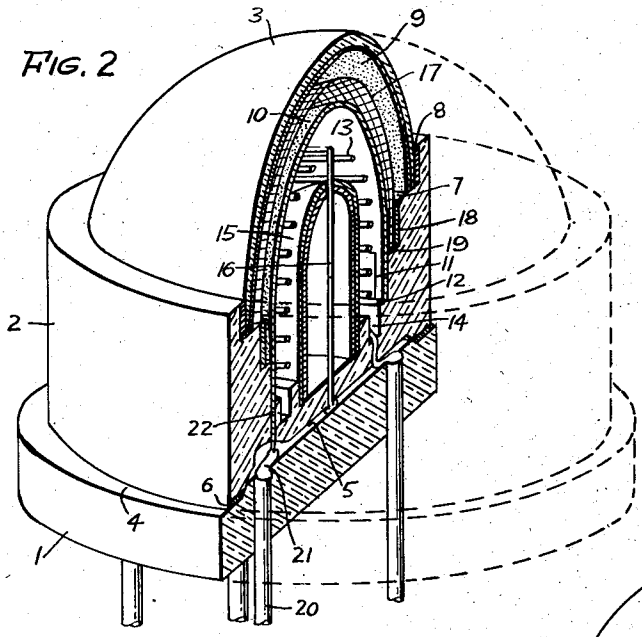
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ELECTRON TUBE

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FIG. 2



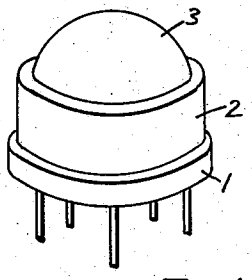


FIG. 1

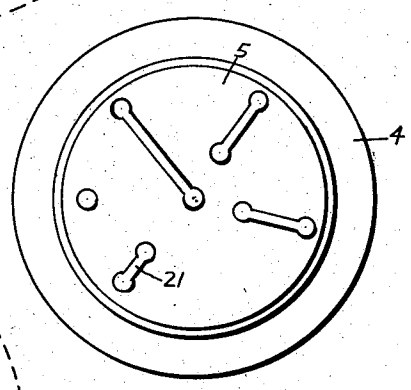


FIG. 3

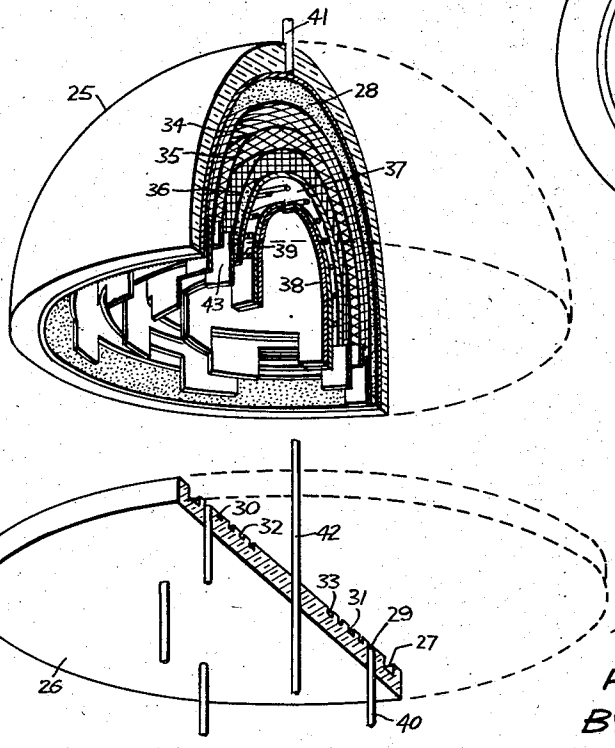


FIG. 4

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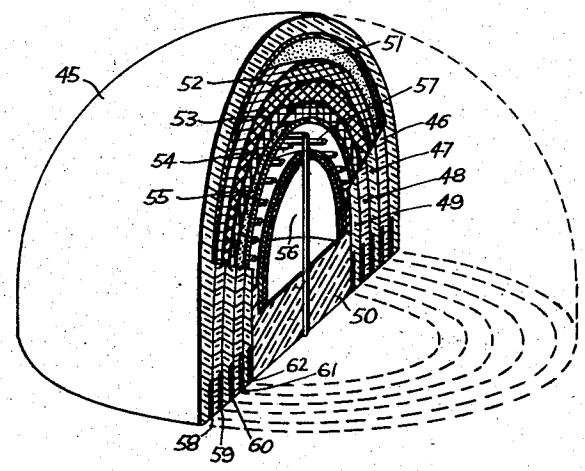


FIG. 5

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2,883,575

ELECTRON TUBE

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Application March 28, 1957, Serial No. 649,253

4 Claims. (Cl. 313—247)

This invention relates generally to electron tubes and more particularly pertains to vacuum tube constructions employing hemispherical electrodes housed within an envelope which may be constituted partially or entirely of a ceramic material.

Presently known ceramic envelope vacuum tubes are difficult to produce by automatic processes because of the multiplicity of parts employed and their design. The rate of rejection in the production of such ceramic tubes is inordinately high because their multiple vacuum seals increase the likelihood of leakage. In addition, the performance of those ceramic tubes suffers from excessive interelectrode capacities, resulting from closely spaced ring seals, and from appreciable microphonics attributable to flat electrodes which tend to vibrate when shocked. Due to thermal expansion, flat electrodes, moreover, have a tendency to buckle during operation of the tube, forming either concave or convex surfaces. The direction and extent of this buckling is unpredictable and results in altered tube characteristics which is, indeed, highly undesirable where an objective is the production of a uniformly performing item.

The invention resides in the manner in which hemispherical electrodes are mounted in an envelope to produce a vacuum tube which is compact, extremely rugged, relatively free from microphonics, has fewer components than the conventional vacuum tube, and which lends itself to automatic production. The novel tube is greatly superior to conventional vacuum tubes in its ability to operate satisfactorily and survive under severe shock and vibration and, by discriminating selection of ceramic and metallic materials, the tube can be made to withstand ambient temperatures as high as 600° C.

The invention contemplates the employment of hemispherical electrodes to provide structural rigidity. Since a sphere is fundamentally a strong structure, the hemispherical electrode surface exhibits inappreciable movement when operated under conditions of shock and vibration. A nest of electrodes may be easily formed by utilizing hemispheres of progressively increasing diameter, and because of the symmetry of the surfaces, orientation requirements may be eliminated. As is well known, the sphere provides maximum surface area for a given enclosed volume, and by securing the hemiphere by its peripheral edge to a support structure, practically the entire hemispherical surface can be active.

The invention, together with its advantages and various modes of construction, may be apprehended by reference to the following description when considered in connection with the drawings wherein:

Fig. 1 is a perspective view illustrating the external features of a ceramic envelope;

Fig. 2 is a sectional view depicting the internal structure of the preferred embodiment of the invention;

Fig. 3 is a top plan view illustrating printed wiring on the ceramic base of the embodiment of Fig. 2;

Fig. 4 illustrates the internal structure of a species of the invention; and

Fig. 5 depicts the internal structure of another species embodying the invention.

The ceramic employed in the envelope of the tube may be of the alumina or zirconia type, or of any other type of material having suitable electrical insulating and mechanical properties, such as Forsterite, which has the chemical composition Mg_2SiO_4. The term "ceramic" as used here denotes products produced by mixing and shaping to a desired form various oxides, such as aluminum oxide, silicon oxide, magnesium oxide, sodium oxide, calcium oxide, etc., which are subjected to a firing treatment to produce a final refractory product composed of very coherent particles. A "ceramic" is understood to be predominantly crystalline with a minor proportion of glassy bond. The ceramic sections constituting the envelope are united by hermetic vacuum seals. Sealing methods are known to the bonding art which permit the formation of satisfactory vacuum-tight joints. Two such methods are the molybdenum metallizing process and the titanium hydride process. The former is carried out in a protective hydrogen atmosphere and the latter in a vacuum. Both processes result in metallic coatings integrally fused to the ceramic. The metallically coated ceramic is bonded readily to similarly prepared ceramics, or to metals, by brazing with silver solder or suitable alloy solders, such as silver-copper. In the molybdenum metallizing process, that portion of the ceramic surface which is to be bonded is covered with a finely divided powdered mixture of molybdenum and manganese and fired to an elevated temperature which is dependent upon the ceramic material, e.g., for high alumina ceramic, about 1350° C. The metallized area is subsequently electroplated with nickel to produce a uniform metallic surface. In the titanium hydride process, the ceramic area to be bonded is painted with powdered titanium hydride and fired, where the ceramic is a high alumina type, to a temperature of about 1200° C. Other ceramic bonding methods are presently being developed in an effort to produce a bond which is electrically non-conductive. The invention, however, does not reside in the bonding method nor in the type of ceramic employed, and the foregoing discussion of bonding methods and suitable ceramics is not intended as a delineation of the invention but rather as supplemental information.

Referring now to Fig. 1 which illustrates the external shape of the preferred embodiment of the invention, there is shown a tube having a ceramic envelope constituted by a circular base **1**, a hollow cylindrical body **2**, and a hemispherical cap **3**. A number of pins depend from the base and are electrically connected to the elements of the tube housed within the envelope. The manner in which the three ceramic sections are united is depicted in Fig. 2. In order to promote alignment of the body **2** with respect to the base **1**, a depressed circular shelf **4** is provided on the base, defining a central boss **5** having a chamfered edge. The lower portion of the cylindrical body **2** is formed as an annulus having an interior chamfer, and the annulus is proportioned to fit closely about central boss **5** on the base. In joining the body **2** to the base, a ring of solder is plated or placed upon the shelf **4** between the two ceramic sections, and the parts are heated to brazing temperature in a manner to be described later. It is to be understood that all surfaces indicated as bonded herein have previously been treated to promote an effective union. Where the chamfered edges are not in contact, solder will, during the brazing operation, be drawn by capillary action into those spaces, further insuring a satisfactory hermetic seal. The lower edge of the body **2** is joined to the base **1**, in this manner, by the bond **6**. The hemispherical cap **3** rests upon a step **7** formed in the interior of the body **2** and is united to

the upper portion of the body by a vacuum seal 8. The interior surface of the ceramic cap 3 is metallically coated and the coating 9 serves as the anode. Since certain of the ceramics (e.g., alumina ceramics) are fair thermal conductors, adequate heat dissipation can be obtained for tubes having low anode dissipation ratings by selection of the appropriate ceramic material. The triode tube depicted in Fig. 2 employs an indirectly heated hemispherical cathode 10. The cathode may be of nickel and can be fabricated by stamping or electroforming. In accordance with conventional practice, the cathode may be coated with substances, such as the oxides of barium or strontium, which copiously emit electrons when heated. In order to minimize heat losses to the supporting ceramic structure, the cathode is formed with legs 11. The legs rest upon step 12 in the body 2 and are soldered to the adjacent vertical surface. A coiled heater 13 shaped to conform to the configuration of the cathode is disposed adjacent to the cathode's inside surface. An annular groove 14 is provided in the body 2 and the lowermost coil of the heater is disposed therein. To help direct all radiant heat energy towards the cathode, a heat shield 15, preferably consisting of nickel laminates, is utilized. Heat shield 15 is of generally hemispherical shape and is fixed by a brazed joint within an interior recess of the body 2. The uppermost coil of heater 13 is secured to a vertical support 16 embedded in the lower portion of body 2. The heater may be embedded in, or coated with, an electrical insulative material, if desired. It is apparent that heater 13 need not be of the form described, and heaters which are capable of uniformly heating the cathode may be employed, though they be of a different configuration.

A hemispherical mesh grid is disposed between cathode 10 and anode 9. The peripheral edge of grid 17 is bonded to a ceramic annulus 18. The annulus, in turn, rests upon step 19 and is bonded to the adjacent vertical surface of body 2. The grid may be fabricated by electrolytically etching the desired mesh, or a fine wire flat mesh may be given the desired curvature by mechanical working.

A number of pins are set into the base to provide external electrical connections to the heater and electrodes within the tube. In order to allow placing the pins in convenient positions, the surface of boss 5 serves as a printed wiring area as shown in Fig. 3. Each of the pins is united to its own printed wire. Electrical connection between a printed wire and an electrode is made by a lead attached to the electrode which extends through a hole in the body and is soldered to one terminus of the printed wire. For example, cathode 10 may be connected to pin 20 through printed wire 21 by means of a lead 22 soldered to the grid, the lead extending downward into contact with the printed wire to which it is soldered. Electrical connections from the pins to the other electrodes and to the heater are made in analogous fashion.

In assembling the tube, the heat shield and cathode are brazed to the body and jointure is established by the cathode and the heater with their respective leads. The grid 17 is secured to annulus 18 by brazing. The various sections of the tube are now placed upon a fixture which holds the sections in spaced positions. A bell jar is placed about the fixture and the interior of the bell jar is exhausted to create a hard vacuum. The tube assembly in the evacuated bell jar is now heated to outgas the tube parts. Since the tube sections are in spaced positions, the gases may be rapidly removed, thereby increasing the effectiveness of this outgassing procedure. Subsequently, the cathode 10 is heated by energizing heater 13 to activate the electron-emissive coating. Since the grid and anode at this time are a relatively large distance away from the cathode, activation of the coating is accomplished without contamination of other tube elements by volatile substances emanating from the emissive coating. Upon concluding activation of the emissive coating, the fixture is caused to deposit the grid subassembly in its proper position, and that sub-assembly is brazed to unite it with the body 2. The fixture then brings base, body and cap together to close the envelope and the ceramic sections are sealed by heating to brazing temperature. In each of these brazing operations the surfaces to be bonded may be plated with solder or a ring of solder may be placed between the parts.

The invention has been illustrated in Fig. 2 in the form of a triode, but that embodiment can be modified readily to provide any desired number of electrode elements within the envelope. Where more electrodes are desired, the housing 2 is modified to provide an additional step for each added electrode, and the electrode is mounted upon the step in a manner analogous to that of grid 17. The use of ascending steps, it should be noted, facilitates assembly of the tube, since each electrode is automatically properly positioned when it is deposited upon its step. In addition, the metallic bonds which secure the electrodes to the vertical risers of the steps are in an ascending spaced relation, thereby minimizing interelectrode capacities.

The grid 17 has previously been described as bonded to a ceramic annulus 18, which, in turn, is bonded to the vertical riser of step 19. While this is the preferred construction, it is manifest that grid 17 may be bonded directly to the riser of step 19 thereby eliminating the annulus 18. The elimination of annulus 18 requires that grid 17 be bonded to the body prior to activating the cathode-emissive coating and hence this construction is less desirable than the preferred form.

The embodiment of the invention depicted in Fig. 2 may be modified, where it is desirable or necessary to increase the heat dissipation of anode 9, by replacing ceramic cap 3 with a hemispherical cap made of copper or some other suitable metal. The metallic cap functions as the anode. The envelope then is constituted by ceramic base 1, ceramic body 2, and a hemispheric metallic cap. Copper has a thermal conductivity which is in the order of one hundred times higher than the thermal conductivity of high alumina ceramics and hence can more efficiently dissipate heat. In addition, the heat dissipation efficiency of a copper anode cap can be enhanced by providing external fins about the exterior of the hemispherical surface.

Fig. 4 illustrates a species of the invention embodied as a pentode tube. The envelope comprises a hemispherical ceramic cap 25 and a circular ceramic base 26 having a circular groove 27 dimensioned to receive the peripheral edge of the cap. A hermetic seal is established by bonding the edge of cap 25 to the base. The interior surface of cap 25 is metalized to provide anode 28 of the tube. The surface of base 26 is provided with five concentric circular grooves 29, 30, 31, 32 and 33. Grids 34, 35, 36, cathode 37 and heat shield 38 are hemispheres, and are of such dimensions that those elements may be superposed in a concentric spaced relation to form a nest with the heat shield 38 disposed in the interior. Each of the grids 34, 35, 36 is secured at its peripheral edge to a metallic annulus having small feet which fit into a groove in base 26 and thereby align the grid. For example, grid 36 is bonded to an annulus 43 provided with feet adapted to fit into groove 31. Cathode 37 and heat shield 38 are formed with dependent feet. In assembling the tube, the feet of heat shield 38 are positioned in groove 33, the feet of cathode 37 are fitted into groove 32, and in a similar manner the feet depending from grids 34, 35, 36 are fitted into grooves 29, 30, 31, respectively. Each groove preferably is metalized and the metalized surface is plated with solder. The heat shield, cathode and grids are secured in position by brazing. During the assembly operation a heater coil 39 is positioned between the heat shield and the cathode. After the nested elements have been bonded to the ceramic base, a hermetic vacuum seal is established by bonding the edge of cap 25 to the base. Electrical connections to the grids and to the cathode are

accomplished by pins set into the base so that they contact the metalized coatings in the grooves, as exemplified by pin **40** extending into groove **29**. In order to reduce interelectrode capacities, the legs of the various electrodes are angularly offset with respect to the legs of adjacent electrodes. An external electrical connection to the anode may be accomplished by bringing a pin **41** out through the cap **25**. Pin **42** provides a support and electrical connection to one end of heater **39**.

The species of the invention depicted in Fig. 5 employs a hemispherical ceramic envelope constituted by a hemispherical cap **45**, a number of truncated hemispherical supports **46**, **47**, **48**, **49** nested within the cap, and a base **50** disposed within support **49**. The interior surface of the cap is metalized to provide the anode **51**. Grids **52**, **53**, **54**, cathode **55** and heat shield **56** are generally of hemispherical form. The base **50** is provided with a circular flange within which heat shield **56** is positioned and to which the shield is bonded. Cathode **55** is secured, as by solder, to the rim of support **49**. Grids **52**, **53**, **54** are similarly secured to their respective supports. A heater **57** of suitable form is positioned between heat shield **56** and cathode **55**. The cathode is preferably coated with an electron-emissive substance. The lower facing surfaces of adjacent ceramic sections of the tube envelope are hermetically sealed by brazes **58**, **59**, **60**, **61**, **62**. Each of the electrodes is electrically connected to a different one of said brazes by a lead positioned between the ceramic sections and extending from the electrode to the braze.

The electrodes in the preceding exposition have been uniformly described as hemispherical because that geometry is deemed the most suitable in carrying forward the invention. It is, however, manifest that other geometric shapes, such as parabolic or elliptic surfaces, may be employed. The configuration of the electrodes will be governed somewhat by the method employed in their fabrication. For example, where the electrodes are fabricated by mechanical working, such as drawing, a departure from the hemispherical shape may be required.

In the drawings, the brazed joints, for illustrative purposes, have been exaggerated in thickness. These joints are, in actuality, thin films several thousandths of an inch thick.

This invention is not limited to the precise details of construction, materials, and processes described, as equivalents will most certainly suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given an interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. An electron tube comprising a hollow hemispherical cap providing an anode, a cylindrical ceramic body having an interior structure providing steps ascending from the interior toward the periphery thereof, a ceramic base having multiple dependent pins, hermetic seals bonding said cap to said body and said body to said base forming a sealed enclosure, a hemispherical cathode disposed within said enclosure concentric with said anode and secured at its peripheral edge to an interior one of said steps, a hemispherical grid interposed between and spaced from said cathode and anode and concentric therewith, said grid being secured at its peripheral edge to another of said steps, and means electrically connecting said cathode, and grid, individually to different ones of said pins.

2. An electron tube comprising a hermetically sealed evacuated ceramic envelope, a portion of said envelope being constituted by a ceramic cap having an interior hemispherical metallic surface providing an anode, said envelope including a ceramic base having wires secured upon an interior surface thereof, multiple pins depending from said base, each of said pins being connected to one of said wires, said envelope having an interior structure providing steps ascending from the interior toward the periphery thereof, a hemispherical cathode within said envelope disposed concentrically with said anode and secured at its peripheral edge to one of said steps, a hemispherical grid interposed between and spaced from said cathode and said anode, said grid being secured at its peripheral edge to another of said steps, and means electrically connecting said cathode and grid individually to different wires on said base.

3. An electron tube comprising a hermetically sealed ceramic evacuated envelope, said envelope including a hemispherical cap and a plurality of truncated hemispherical ceramic sections nesting within said cap, a plurality of spaced concentric hemispherical electrodes within said envelope, each of said sections being bonded to the peripheral edge of a different one of said electrodes, and means providing external electrical connections to each of said electrodes.

4. An electron tube comprising a hermetically sealed ceramic evacuated envelope, said envelope including a hemispherical cap and a plurality of truncated hemispherical ceramic sections nesting within said cap, a metallic coating secured to the interior surface of said cap forming a hemispherical anode, a plurality of spaced concentric hemispherical electrodes within said envelope, each of said electrodes having its peripheral edge secured to a different one of said ceramic sections, and means providing an external electrical connection to each of said electrodes and to said anode.

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