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ELECTRON TUBE HAVING CLOSE SPACED ELECTRODES AND A BIMETALLIC CATHODE

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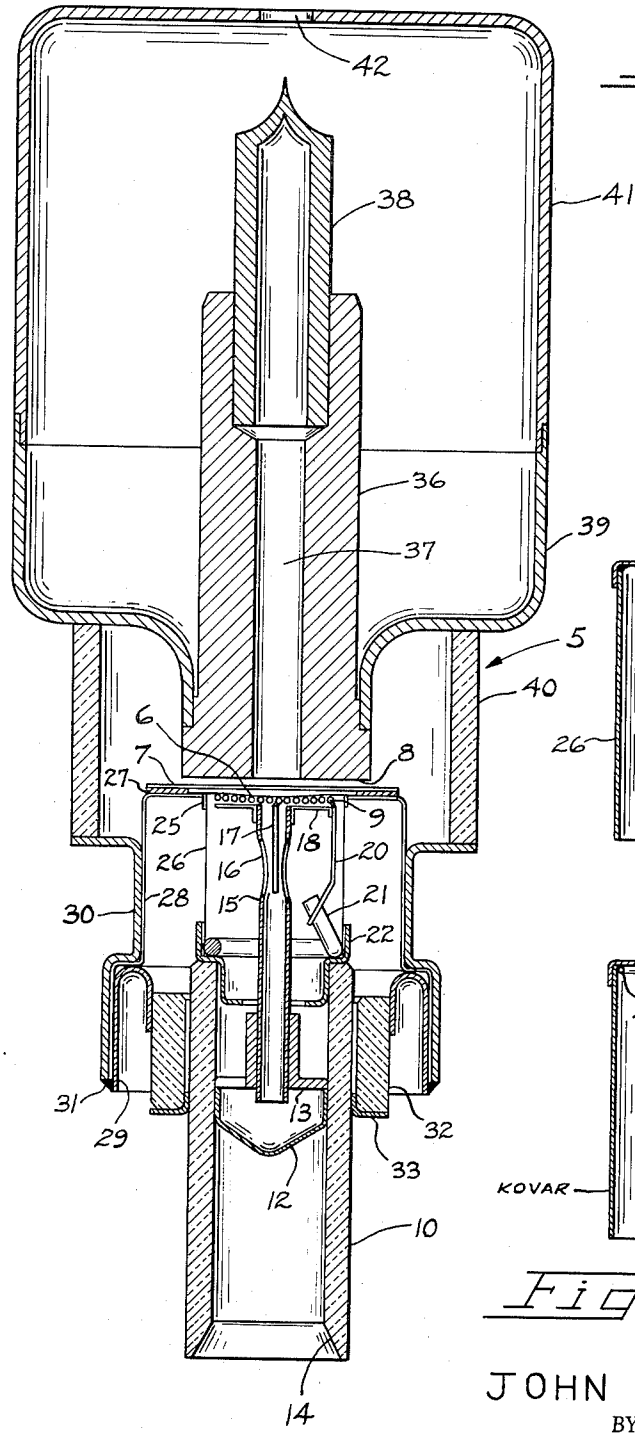


Fig. 1

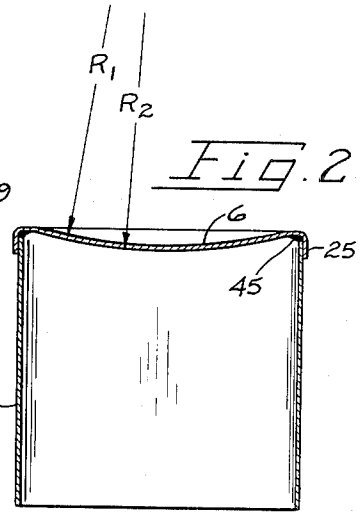


Fig. 2

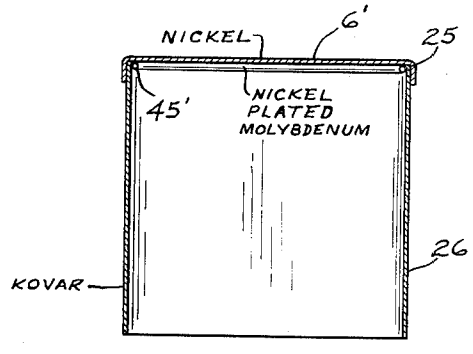


Fig. 3

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ELECTRON TUBE HAVING CLOSE SPACED ELECTRODES AND A BIMETALLIC CATHODE

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This invention relates to electron tubes, and more particularly to electron tubes having extremely close spaced electrodes.

In order to meet the demand for electron tubes which operate at higher frequencies, it has been necessary to place electrodes closer together. Not only is it necessary to build tubes having very minute interelectrode spacing, but in addition such spacings must be maintained within very close tolerances during operation of the tube. As a specific example, one tube made according to this invention has a cathode-to-grid spacing of .0045 of an inch, measured when the tube is not in operation.

Tubes having close spaced electrodes are plagued by the fact that even a slight deformation of the electrodes causes interelectrode shorts, or at least a change in electrode spacing which detrimentally affects the electrical characteristics of the tube. This problem is aggravated when in addition to having close spaced electrodes it is also necessary to make the electrodes of very thin metal. For example, it is necessary to make a cathode very thin in order to achieve quick warm-up time. Generally, thin members tend to deform more than thick members. Electrodes are normally positioned in the tube by means of support members, and often the material of the support is necessarily different from the material of the electrode. Sometimes the different coefficients of expansion of the different materials cause deformation as the electrodes are brought up to operating temperature.

Differing materials are not the only cause of electrode deformation. For example, a disk-shaped planar cathode is known to deform even if its support member is made of the same material as the cathode. This deformation is caused by the fact that when the cathode is at operating temperature, its center operates at a higher temperature than its rim portion. Thus, the center portion expands more than the rim portion, and being thus constrained by the rim, "oil cans," that is, bows to assume a slightly dished shape.

It has been found by this invention that the problem of detrimental electrode deformation can be solved by properly employing the coefficient of expansion characteristics of alloys formed during a brazing operation. In other words, when a brazing alloy cools down through the eutectic temperature, it solidifies and thereafter has a coefficient of expansion which is normally quite different from the coefficient or coefficients of the type of metal or metals joined by the braze. Thus, as the brazed assembly cools down from brazing temperature to room temperature, the brazed parts contract at a different rate from the brazing alloy and thus the parts are deformed or at least prestressed by the alloy, depending upon the relative size and strength of the alloy and the parts. Since the coefficients of expansion of the metal parts and various alloys formed by brazing can be readily determined, the proper type and location of brazing material can be selected to provide deformation or prestressing in the desired direction.

By way of example, one application of the teaching of this invention is in connection with disk-type planar cathodes. Such cathodes are conventionally made of nickel and have a short downturned cylindrical rim to which a thin "Kovar" support cylinder is spot welded.

When this type of cathode is heated to operating temperature, it "oil cans" as previously described. This "oil canning" would not impair tube operation if the center of the cathode disk bowed toward the support cylinder; that is, away from the adjacent electrode. However, it has been determined by numerous tests that such a conventional cathode always bows toward the adjacent electrode. This sample problem is solved according to the invention by employing a brazing material to deform or prestress the cathode disk so that its tendency is to bend away from the adjacent electrode, as will be hereinafter described in more detail.

Thus, the object of this invention is to provide improved electron tubes having close spaced electrodes.

More specifically, the object of the invention is to prevent detrimental deformation of close spaced electrodes by employing the coefficient of expansion characteristics of an alloy formed by brazing to deform or prestress electrodes in a non-detrimental direction.

Another object of the invention is to provide a tube having a very thin and therefore quick heating cathode which does not experience detrimental deformation during operation.

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

FIGURE 1 is a cross-sectional view of a close spaced planar electrode tube embodying the invention;

FIGURE 2 is an enlarged cross-sectional view of the cathode of FIGURE 1; and

FIGURE 3 is a view similar to FIGURE 2 but showing the parts in position prior to brazing.

Referring to the drawings in more detail, FIGURE 1 shows a triode tube **5** having planar electrodes including a cathode **6**, a grid **7** and an anode **8**. The cathode is indirectly heated by an insulated wire coil **9**.

The lower end of the tube comprises a ceramic cylinder **10**. A metal closure member **12** and a metal heater support sleeve **13** are brazed to the inside of cylinder **10**. The inside of cylinder **10** is metalized from the upper edge of its tapered end surface **14** up to the rim of sleeve **13**. The metalizing makes it possible to braze members **12** and **13** to the ceramic cylinder and also provides an electrical terminal for one end of the heater **9**. The heater is supported on a metal tube **15** which is attached to sleeve **13**. Tube **15** has a hole **16** therethrough, and one end **17** of the heater is spot welded to the inside of the tube, hole **16** permitting insertion of one of the spot welding electrodes. The heater **9** is supported on a flange **18** attached to tube **15**. The other end **20** of the heater is attached to a metal ring **21** which is in turn attached to a cup-shaped metal member **22**. The outside surface and upper edge of ceramic cylinder **10** are metalized, and the member **22** is brazed to the upper edge of the cylinder. Thus the inner and outer surfaces of the ceramic member **10** provide the two terminals for the heater, and the non-metalized surface **14** insulates the terminals from each other.

The cathode disk **6** is made of nickel coated with an emissive oxide layer on its upper surface. The disk **6** is provided with a downturned rim **25** which fits over a thin "Kovar" support cylinder **26**. Rim **25** and cylinder **26** are secured together in a manner which will be hereinafter described in detail. The lower end of cylinder **26** is attached to the cup-shaped member **22** so that the cathode shares with the heater the terminal formed by the metalized outer surface of the ceramic cylinder **10**. In one class of tubes made as shown in FIGURE 1 it was desirable to have a very short warm-up time, and for that class the cathode **6** was made with a thickness of .0015 of an inch.

The grid 7 is of conventional construction comprising a thin wire mesh attached to a metal washer 27 which is in turn attached to a metal support cylinder 28. Cylinder 28 is supported between two metal envelope rings 29 and 30; braze 31 joins these three members together in a hermetic seal. Metal ring 29 is brazed to a ceramic ring 32 which is in turn brazed to ceramic cylinder 10 by means of a metal ring 33. The ceramic ring 32 is metalized only in the areas where it is brazed to the metal rings 29 and 33 so that it insulates the cathode terminal from the grid terminal, rings 29 and 30. In a particular class of tubes made as shown in FIGURE 1, the cathode-to-grid spacing was .0045 of an inch, plus or minus .0005 of an inch, measured when the tube was not in operation.

The anode 8 comprises a metal rod 36 having an exhaust bore 37 and brazed to a pinched-off metal exhaust tubulation 38. A metal anode support member 39 is brazed to the anode rod 36 and to the metalized upper end of a ceramic envelope cylinder 40. Cylinder 40 is also metalized at its lower end and brazed to the ring 30. A protective metal cap 41 is attached to member 39 and provides a convenient terminal for the anode. Cap 41 has an aperture 42 to prevent the build-up of high gas pressures therein.

From the preceding description it will be apparent that an electron tube is provided which has a hermetically sealed envelope enclosing closely spaced electrodes. In such tubes made prior to the invention, the cathode rim 25 was spot welded to the Kovar cylinder 26. When such tubes were operated, the cathode disk 6 bowed upwardly toward the grid 7, resulting in undesirable changes in electrical characteristics and even cathode-to-grid shorts. The reason for the bowing is that when the cathode is heated to operating temperature, around 900° C., by the heating coil 9, the center of disk 6 runs hotter than the peripheral portion which is cooled by having heat conducted away by the support cylinder 26. As a result, the center portion of the disk cannot expand radially because of the restraining effect of the peripheral portion, and the expansion of the center portion is accommodated by axial movement, or bowing. As previously stated, it has been found that the disk 6 always bows upward, and it may be the presence of the rim 25 and cylinder 26 which causes the bowing to occur always in an upward direction, that is, toward the grid 7.

According to the invention, the problem is solved by placing a brazing ring around the peripheral undersurface of disk 6. In order to make double use of the brazing ring, it is employed to join the rim 25 and the support cylinder 26 as well as to correct the bowing problem. When the invention is applied to a cathode, the selection of brazing material is fairly limited. In view of the high (900° C.) operating temperature of the cathode, the eutectic point of the alloy formed by brazing must be well above 900° C. Also, the alloy must not release vapor at the high temperature it experiences in operation. In addition, the alloy must have a strength and a coefficient of expansion which is properly related to the strength and coefficient of expansion of the electrode material or materials. One alloy which has been found to meet these requirements is molybdenum-nickel.

Referring now to the enlarged view of the cathode (FIGURE 2), the completed braze is indicated at 45. FIGURE 3 shows the cathode parts in assembled position prior to making the braze. The cathode disk is designated 6′ in FIGURE 3 because at this stage it is perfectly flat. Similarly, the brazing ring is designated 45′ because at this stage its composition is somewhat different from the alloy composition after being heated to brazing temperature. In the specific example, the cathode 6′ is made of .0015 inch nickel and the support 26 is made of .0005 inch "Kovar." The brazing ring 45′ is made of .002 inch diameter molybdenum wire with a .0005 inch nickel plate. Since molybdenum and nickel alloy very readily and since cathode 6′ is nickel, the nickel plating could be eliminated if disk 6′ were of thicker material. However, with the indicated thickness of disk 6′ too much nickel from the disk would go into alloy with the molybdenum if some nickel were not supplied by a plating on the molybdenum wire. The result without the plating would be to weaken and even make holes in disk 6′. Of course if too much nickel is plated on the molybdenum wire, it will supply all of the nickel proportion of the eutectic alloy and thus would not form a good bond with the nickel disk 6′.

After the parts are assembled as shown in FIGURE 3, they are placed in an oven and heated to the eutectic temperature, about 1320° C., in a protective atmosphere such as dry hydrogen. As the eutectic temperature is reached, an alloy of molybdenum and nickel is formed and a small amount of "Kovar" also goes into alloy to form a good bond between disk 6′ and the "Kovar" support 26. Thus, a brazing alloy 45 is formed which has a lower coefficient of expansion than the nickel of disk 6′. As the parts cool below brazing temperature, the alloy solidifies. Thereafter, as the parts cool down to room temperature, the nickel disk 6′ tends to contract more than the alloy 45. In effect then, the top of disk 6′ is relatively free to contract whereas the undersurface is restrained, or in relative terms pulled radially outward by the relatively non-contracting alloy 45. This means that the upper surface of disk 6, which is relatively free to contract, adopts the relatively short length, or short radius curvature R_1, in FIGURE 2, whereas the lower surface, which is in effect being stretched, adopts the relatively longer length or longer radius of curvature R_2. In other words, the disk 6′ is forced to bow away from grid 7 into the shape of disk 6. When the cathode which has thus been deformed is heated to operating temperature in the tube, it cannot "oil can" in the direction of the grid. If the temperature gradient between the center and rim of the disk 6 causes any further bowing, it will necessarily be in the preformed or prestressed direction. If the cathode disk 6 were substantially thicker, the brazing alloy might not be strong enough to cause a visible deformation. Nevertheless, the alloy will prestress the disk so that as it starts to "oil can" it will start to bow in the direction away from the grid 7. Obviously, when the cathode disk 6 bows away from grid 7 there is no possibility of an interelectrode short. Also, as will be understood by those skilled in the electron tube art, the electrical characteristics of the tube are materially altered when disk 6 bows toward the grid (even if not severe enough to cause shorting), whereas substantial bowing away from the grid can be tolerated without any detrimental effect on the electrical characteristics of the tube.

In actual practice, the preferred composition of nickel disk 6 is 96% nickel and 4% tungsten. However, other metal or other alloys can be employed within the scope of the invention. The important feature is that the material of the electrode must have a different coefficient of expansion from the alloy formed by the brazing operation. In addition, it is of course necessary to place the brazing material on the electrode in a position which will prestress the electrode in the described direction.

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 envelope and at least two electrodes within said envelope, one of said electrodes being a disk-shaped cathode having an electron emitting surface positioned close to another of said electrodes, said other electrode being a planar electrode, a ring of brazing material brazed to said cathode outwardly of the center of the cathode, said brazing ring being made of a material which forms an alloy with the material of said cathode, said alloy having a coefficient of expansion different from that of said cathode and a melting point above the operating temperature of said cathode, and the center portion of said cathode being

deformed relative to the periphery of the cathode by said alloy in a direction away from said other electrode.

2. An electron tube comprising a hermetically sealed envelope and at least two electrodes within said envelope, one of said electrodes being a cathode having an electron emitting surface positioned close to another of said electrodes, a support for said cathode, material forming an alloy with and connecting said cathode to said support, said alloy having a coefficient of expansion different from that of said cathode and a melting temperature above the operating temperature of said cathode, and a portion of said cathode being forced relative to the remainder of the cathode by said connecting alloy in a direction away from said other electrode.

3. An electron tube comprising a hermetically sealed envelope and at least two closely spaced electrodes within said envelope, a support for one of said electrodes, material forming an alloy with and connecting said one electrode to said support, said alloy having a coefficient of expansion different from that of said one electrode and a melting temperature above the operating temperature of said one electrode, and a portion of said electrode being stressed relative to the remainder of the electrode by said alloy in a direction away from said adjacent electrode.

4. An electron tube comprising a hermetically sealed envelope and at least two planar electrodes within said envelope, one of said electrodes being a disk-shaped cathode having on one side an electron emitting surface positioned close to another of said electrodes, said other electrode being a planar electrode, a ring of brazing material brazed to the other side of said cathode adjacent the periphery of said disk, said brazing ring forming with said cathode an alloy having a coefficient of expansion less than that of said cathode and a melting point above the operating temperature of said cathode, and the center of said cathode being deformed relative to the periphery of the cathode by said alloy in a direction away from said other electrode.

5. An electron tube comprising a hermetically sealed envelope and at least two planar electrodes within said envelope, one of said electrodes being a disk-shaped cathode having an electron emitting surface positioned close to another of said electrodes, said other electrode being a planar electrode, a support cylinder for said cathode, a cylindrical rim on the periphery of said cathode disk and fitting over the end of said support cylinder, a ring of brazing material forming an alloy with and joining the other surface of said cathode disk and the end of said support cylinder, said alloy having a melting temperature above the operating temperature of said cathode, and the center of said cathode being deformed relative to the periphery of the cathode by said alloy in a direction away from said other electrode.

6. A disk-shaped nickel cathode having an electron emissive surface, a cylindrical support for said cathode, and a brazing alloy comprising molybdenum and nickel joining the other surface of said cathode disk to the end of said cylindrical support.

7. A disk-shaped nickel cathode having an electron emissive surface, a cylindrical "Kovar" support for said cathode, and a brazing alloy comprising molybdenum and nickel joining the other surface of said cathode disk to the end of said cylindrical support.

8. A disk-shaped nickel cathode having an electron emissive surface, a cylindrical support for said cathode, and a brazing alloy comprising molybdenum and nickel joining the other surface of said cathode disk to the end of said cylindrical support, said cathode disk having a thickness of about .0015 of an inch.

9. A disk-shaped nickel cathode having an electron emissive surface, a cylindrical support for said cathode, and a brazing alloy comprising molybdenum and nickel joining the other surface of said cathode disk to the end of said cylindrical support, said cathode disk having a thickness of about .0015 of an inch, and said support cylinder having a wall thickness of about .0005 of an inch.

10. The method of making a cathode assembly having a disk with an electron emissive surface on one face and mounted on a cylinder, said method comprising the steps of forming said disk with a thickness of about .0015 of an inch nickel, forming a brazing ring of molybdenum wire having a thickness of about .002 of an inch in diameter and coated with nickel having a thickness of about .0005 of an inch, assembling said disk and support cylinder with said brazing wire at the juncture of the support cylinder and the other face of said disk, heating said assembly to at least the eutectic melting temperature of the brazing alloy, and then cooling the assembly.

11. An electron tube comprising a disk shaped first electrode, a planar second electrode positioned closely adjacent said first electrode, said first electrode comprising a center portion having a given coefficient of expansion and an outer ring of material having a different coefficient of expansion, said outer ring of material being secured to one face of said disk shaped first electrode, and said coefficients of expansion being so related that when said first electrode is heated said center portion does not become convex toward said second electrode.

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