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METHOD OF MAKING CYLINDRICAL MESH ELECTRODE FOR ELECTRON TUBES

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FIG.1

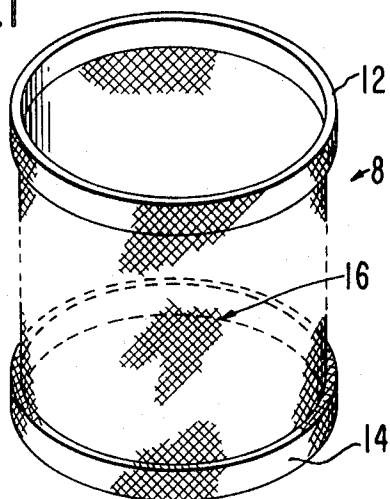


FIG.2

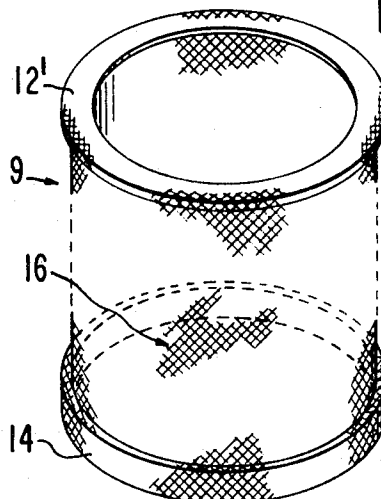


FIG.4

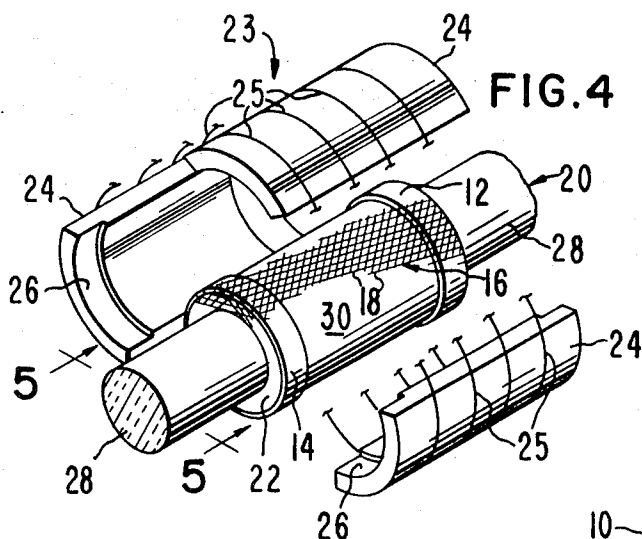


FIG.3

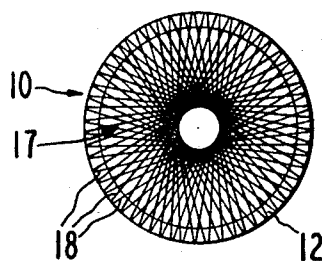
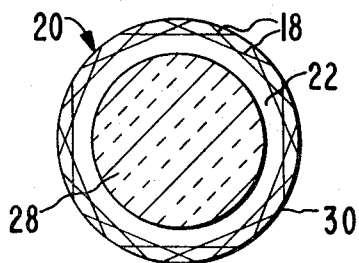


FIG.5



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METHOD OF MAKING CYLINDRICAL MESH ELECTRODE FOR ELECTRON TUBES

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ABSTRACT OF THE DISCLOSURE

A method of making a cylindrical electrode of wire mesh having fused wire intersections suitable for use in an electrode tube, in which method a refractory metal wire coated with a soft metal is wound about a mandrel made of a material having a higher coefficient of expansion than the refractory metal and the assembly is heated to cause the mandrel to expand against the wire resulting in fusion of the soft metal coating at the wire intersections at a temperature below the melting point thereof under the influence of pressure and temperature.

Background of the invention

This invention relates to an improved method of making cylindrical cathode and grid electrodes for use in electron tubes and particularly to an improved method of making wire mesh cathodes and grids.

Cathode and grid electrodes of conventional high power electron tubes commonly comprises cylindrical arrays of wires. In the prior art, it has been proposed that such arrays of wires be made in the form of a cylindrical mesh, and that for structural reasons the individual wires of the cylindrical mesh electrodes be joined together at their crossing points. Heretofore this has been done by spot-welding or brazing the wires together. However, such electrodes have often had hundreds of crossing points. Methods which separately unite each of such points are obviously cumbersome and impractical, and produce non-uniform structures. Furthermore, the heat of spot-welding, and the alloying resulting from brazing embrittles the wires or introduces other non-uniformities in the mechanical characteristics of the electrode. Accordingly, an object of the present invention is the provision of a method of making cylindrical wire mesh electrodes wherein all intersecting wires are joined together in one single operation and at a temperature below that which would embrittle the wires or introduce other non-uniformities in the mechanical characteristics of the electrodes.

Even if great care is exercised in spot-welding the intersecting wires to avoid the introduction of non-uniform mechanical characteristics, the resulting structure will have certain non-uniformities in mechanical characteristics due to stresses inherently present in metal members as a result of prior fabrication processes. One of the advantages of the method of the present invention is a forming action which results from the method and which relieves the stresses present in the wire thus decreasing if not eliminating the "memory" of the wire and the attendant warping or distortion of the electrode when it is heated during subsequent operation of the electron tube. This is accomplished by the present method without an accompanying embrittlement and weakening of the wires at their intersections.

A directly-heated cathode comprising wires which will both emit electrodes and exhibit high electrical resistance is inherently the fastest heating cathode structure available. However, directly-heated cathodes constructed in accordance with the prior art are not capable of as much total electron emission at operating temperature as indirectly-heated cathodes, even if the wires of the directly-

heated cathode structures are coated with a material capable of high electron emission. This is due to the limited surface area afforded by the wires to act as a supporting base for the emissive material. Such surface area may be increased by increasing the number of wires but the cross-sectional area of each wire must then be reduced in order to maintain the required high electrical resistance, and the resulting structure would comprise a greatly increased number of wires of much smaller cross-sectional dimensions. Although a cylindrical mesh of a large number of extremely fine wires coated with a highly emissive material would produce an extremely quick-heating cathode having total electron emission capability approaching that of an indirectly-heated cathode, such a structure could not be made according to the teaching of the prior art for the reasons set forth above. The method of the present invention is uniquely suitable for use in making a quick heat cathode for an electron tube.

Summary of the invention

Briefly described the present invention comprises the steps of forming a cylindrical mesh by winding a wire of refractory metal such as tungsten or molybdenum which may be coated with a soft metal such as nickel or gold about a mandrel having a higher coefficient of thermal expansion than the refractory metal, heating the wire and mandrel to a temperature below the melting point of the wire including the coating, but high enough to produce sufficient pressure to cause the wire-to-wire contacts to fuse, cooling and removing the bonded mesh structure from the mandrel. Where the electrode is used as a cathode, nickel is preferred as the wire coating; where the electrode is used as a grid, gold is preferred as the wire coating. Electrode mounting rings, made of a refractory metal such as molybdenum and coated with the soft metal with which the refractory wires are coated, may be placed on the mandrel in spaced relation to each other prior to the winding. The cylindrical mesh is then formed between the two rings when the wire is wound onto the mandrel over the rings. Upon heating all wire-to-wire contacts fuse together simultaneously with the fusing of the wire-to-wire contacts. Sectional cylindrical clamps may be placed over and held tightly to the wire-wound mandrel. Upon heating the clamps produce more pressure at the wire-to-wire and wire-to-ring contacts, and distribute the pressure more evenly over the mesh.

The invention possesses other features which will become apparent from the following detailed description and the accompanying drawing. It should be understood, however, that the invention is not limited to the embodiment of the method or the means described and illustrated, for numerous embodiments fall within the scope of the claims.

Brief description of the drawings

FIGURE 1 is a perspective view of one electrode made in accordance with the method of the present invention.

FIGURE 2 is a perspective view of another electrode made in accordance with this invention.

FIGURE 3 is an end view in elevation of a modified version of the electrode shown in FIGURE 1.

FIGURE 4 is a perspective view of a mandrel about which an electrode is supported and shows disassembled clamping means which may be used in practicing the invention.

FIGURE 5 is a sectional view taken along line 5—5 in FIGURE 4.

Description of the preferred embodiments

Referring now in more detail to the drawing in which like reference characters designate like or corresponding parts throughout the several views, there is illustrated in FIGURE 1 an electrode 8 made in accordance with the

present invention. An upper cylindrical ring 12 is joined to a lower cylindrical ring 14 by a wire mesh 16 forming a hollow right circular cylindrical electrode. Where the electrode is to be employed as a cathode, rings 12 and 14 are preferably made of nickel-plated molybdenum and the wire mesh 16 of nickel-plated tungsten. Where the electrode is to be used as a grid, gold is used in lieu of nickel and the wire is preferably gold-plated molybdenum. All individual wire-to-wire and wire-to-ring junctions are fused together resulting in a rigid structure.

FIGURE 2 illustrates an electrode 9 similar to that shown in FIGURE 1 except that ring 12' is in the form of a centrally apertured disk. This configuration results in less end cooling where the electrode is used as an oxide cathode.

FIGURE 3 illustrates an electrode 10 in plan view which is electrode 8 of FIGURE 1 modified to have a planar wire mesh screen 17 partially closing one end. Such screens are typically used for electron shielding purposes. As in electrodes 8 and 9, all wire-to-wire junctions are fused together. If desired, electrode 9 may be similarly modified.

FIGURE 4 depicts the apparatus and parts used to fabricate electrode 8. A cylindrical mandrel 20 is shown having an enlarged portion 30 forming shoulders 22 with unenlarged portions 28 thereof. The mandrel is made of a material which is stable in form, which will not contaminate or fuse to soft metal-clad wires subsequently wound about it, and which has a suitable higher coefficient of thermal expansion than such wire. Although there are several materials which satisfy these requirements, a high alumina ceramic has been found to be quite suitable. Where electrodes 9 or 10 are to be fabricated, each of which have one end partially obstructed either by ring 12' or screen 17, mandrel 20 terminates at one of shoulders 22. This modified version of the mandrel, not shown, is further designed to axially receive a screw at this terminus. The screw is used either to secure a centrally-apertured disk-shaped clamp to the end of the mandrel for purposes which will be hereafter explained, or to hold ring 12' to the mandrel while mesh 16 is being formed. In fabricating either electrodes 8, 9 or 10 one unenlarged portion 28 of the mandrel is connected to a wire-winding machine whenever mesh 16 is not to be formed by hand. In FIGURE 4 rings 12 and 14 are shown mounted at each end of enlarged portion 30 of the mandrel adjacent shoulders 22. This is their disposition for the fabrication of either electrode 8 or 10. Where electrode 9 is to be formed, ring 12' is placed upon, and held by the aforementioned screw means to shoulder 22. Rings 12, 12' and 14 are preferably made of nickel-clad molybdenum, but may also be gold-clad molybdenum.

A continuous wire 18 is shown helically wound about enlarged portion 30 of mandrel 20 in FIGURE 4 forming mesh 16. Where electrode 8, 9 or 10 is to be used as a cathode, wire 18 is made of tungsten having a diameter of approximately .0005 inch. Tungsten is preferred because of its electrical resistance, structural strength, and expansion properties. The tungsten wire is clad with approximately .0001 inch of nickel which provides a good base for electron emissive materials. The nickel coatings of intersecting wires will also fuse together without melting at a temperature below that at which tungsten embrittles. Where electrode 8, 9 or 10 is to be used as a grid, gold-coated molybdenum is used in lieu of nickel-clad tungsten. Gold is preferred as the soft metal for its electron suppression properties and molybdenum is preferred because of its strength and lower electrical resistance.

Also shown in FIGURE 4 is clamping means 23 comprising at least three semi-cylindrical sections 24 preferably made of ceramic, and tying wire 25. The radius of sections 24 is made greater than the radius of enlarged portion 30 of the mandrel by an amount corresponding to the size of the wire wound on the mandrel. The sum

of the angles subtended by the arcs of sections 24 should be slightly less than 360°. Such dimensional relationships between the mandrel and clamps will allow for the semi-cylindrical sections to fit closely about the surface of the mandrel while allowing room between adjoining sections for concentric compression caused by a subsequent tightening of tying wire 25. The tying wire is made of a refractory material having a lower coefficient of thermal expansion than the mandrel such as molybdenum.

Finally in FIGURE 4 there is also shown indentures 26 along the inside edges of semi-cylindrical sections 24 dimensioned to receive and house rings 12 and 14 when clamping means 23 are affixed about mandrel 20. Indentures 26 serve the purpose of distributing the pressure caused by a tightening of clamping means 23 about the mandrel evenly upon both mesh 16 and rings 12 and 14 which lie between the mandrel and clamps.

Referring now to FIGURE 5 there is shown, in plan view, one shoulder 22 of mandrel 20 with several sections of continuous wire 18 shown looped over the shoulder in chordal fashion. This shoulder is used to support the wire while mesh 16 of electrode 8 is being wound and before the mesh and rings are fused into an integral structure. Shoulder 22 serves this same purpose during the formation of electrode 9 of FIGURE 2. In this latter case, however, ring 12' is laid directly upon and held to shoulder 22. Wire 18 is then looped over the ring in a chordal manner. Thus for the fabrication of the embodiment shown in FIGURE 2, reference numeral 12' should be substituted for reference numeral 22 in FIGURE 5.

Having fully described the embodiments shown in the drawing and the apparatus used in fabricating them, the actual steps of fabrication will now be explained.

Rings 12, 14 and wire 18 may be formed by electro-etching the refractory metal base to clean and size it, and then electroplating the nickel or gold thereon. Such rings and wires are also available commercially. For the fabrication of electrode 8 rings 12 and 14 are placed on enlarged portion 30 of mandrel 20. Wire 18 is then helically wound about enlarged portion 30 of the mandrel and over rings 12 and 14, preferably by a wire winding machine. Where the wire reaches an end of enlarged portion 30 it is brought across shoulder 22 in a chordal manner before again crossing enlarged portion 30. This continuous winding of wire over enlarged portion 30 and shoulders 22 is repeated until mesh 16 is completely formed. During the formation of the mesh shoulders 22 hold wire 18 taut thereby preventing slippage of the wire along the surface of enlarged portion 30 of the mandrel. In this manner, the configuration of mesh 16 is maintained while it is being formed and before it is fused into an integral structure.

When mesh 16 has been formed the mandrel is removed from the wire winding machine, if one has been used. Clamping means 23 are then placed over rings 12, 14 and mesh 16, and secured about enlarged portion 30 of the mandrel. In this manner all wire-to-wire and wire-to-ring contacts of the mesh electrode are squeezed together. The clamped mandrel is then placed in a furnace having a wet hydrogen atmosphere. The hydrogen atmosphere serves to prevent oxidation during heating while the water vapor serves to keep the structure clean by removing carbon which would hamper fusion of the intersecting wires and rings. The clamped mandrel is then heated to approximately 1030° C. for some 20 minutes. Due to this increase in temperature all materials in the assembly expand. The mandrel, however, expands more than mesh 16 or rings 12 and 14 due to the differential in their coefficients of thermal expansion. The mesh and rings, trapped between the expanding mandrel and the clamping means which expand to a lesser degree than the mandrel because of the lower coefficient of thermal expansion of its tying wire, are subjected to substantial pressure. This pressure would, of course, occur even with-

out use of the clamps for as the mesh is an integral structure consisting of one continuous wire having a coefficient of thermal expansion less than the mandrel, it must resist enlargement under the force of the expanding mandrel about which it is wound. This resistance places all wire-to-wire and wire-to-ring contacts under pressure. As the mandrel expands both radially and longitudinally in the furnace, both those sections of continuous wire 18 which lie over the enlarged portion of mandrel 30 and over shoulders 22 are also stressed. However, ceramic sections 24, held against the expansion of the mandrel by the highly refractory tying wire 25, apply still more force against the mesh and rings, and more importantly, distributes the pressure evenly. As a result of this combination of time, temperature and pressure, the elastic limit of wire 18 is surpassed. All the nickel wire-to-wire and wire-to-ring contacts fuse together. Following this the assembly is cooled and removed from the furnace. The clamping means and the excess wire extending beyond the rings and lying across shoulders 22 are removed. The structure can then be easily slipped off the mandrel since it has been permanently stretched in the furnace. If the electrode is to be used as a cathode, it is then sprayed with an electron emissive coating such as barium, strontium or calcium carbonate, or a combination thereof, which, upon subsequent heating, is converted to an electron emissive oxide. The electrode is now ready for assembly into an electron tube.

As the electrode has been stretched beyond its elastic limit in the furnace, it has lost its "memory" of prior forms. This results in a sound, symmetrical structure which will retain its shape when later heated in an electron tube, and which has not been embrittled during fabrication. As all intersecting wires have been fused together in a single operation, the number of wires comprising the mesh can be greatly increased over prior art method in which each individual intersection was separately joined. This increase in number enhances the strength of the mesh structure, and increases the electron emissive material base area. Several thousand wire intersections may quite easily be fused in the use of this invention.

Electrode 9 is made in the same manner as described above except that ring 12' is placed on shoulder 22 in lieu of ring 12 being placed on enlarged portion 30 of the mandrel. After wire 18 has been wound onto the mandrel, a centrally-aperture disk-shaped clamp may be placed over ring 12' and secured to the terminal end of enlarged portion 30 of the mandrel by screw means. Upon subsequent heating in the furnace the wires overlapping ring 12' fuse thereto. Upon cooling electrode 9 is slipped off enlarged portion 30 which, in the apparatus used to form this embodiment, terminates at one shoulder 22.

Electrode 10 may also be made using the method by which electrode 8 is made. For this embodiment however the modified mandrel used in fabricating electrode 9 is again employed. The variation in procedure consists of lengthening the chords formed by wire 18 which form screen 17. A comparison between FIGURES 3 and 5 will reveal this increase in length.

In summary, the above-described steps provide a simple, economical method of producing a rugged, symmetrically cylindrical mesh electrode having hundreds of wires fused together at several thousand junctions. The electrode may be used as either a cathode or a grid in low or high power electron tubes. It is particularly useful as an instant heat cathode for use in tubes which must become operative quickly as, for example, those used in "push-to-talk" transmitters.

Those skilled in the art will appreciate the fact that materials other than those specifically recommended above may be used in practicing this invention, and that numerous combinations of the time, temperature and pressure variables may be employed without deviating

from the scope of the invention or from the spirit of the following claims.

What is claimed is:

1. The method of making a cylindrical electrode of refractory wire mesh having fused intersecting wires for use in an electron tube comprising the following steps:

(A) forming a hollow, cylindrical mesh structure by winding a refractory wire about a mandrel, said wire having a coefficient of thermal expansion less than that of said mandrel,

(B) heating the mesh and mandrel to a temperature in the range above that at which sufficient pressure is exerted by the expanding mandrel against the mesh structure to cause the wire-to-wire contacts of the mesh to fuse, and below that at which the wire melts,

(C) cooling and removing the fused mesh structure from the mandrel.

2. The method according to claim 1 wherein said refractory wire is coated with a soft metal prior to winding on the mandrel and said heating is to a temperature below the melting point of said soft metal.

3. The method of claim 2 wherein said electrode is a cathode and wherein said coating step comprises the coating of nickel on a tungsten wire.

4. The method of claim 3 wherein said tungsten wire is drawn to approximately .0005 inch in diameter and coated with nickel to a depth of approximately .0001 inch.

5. The method of claim 3 wherein said electrode is coated with an electron emissive material after removal from the mandrel.

6. The method of claim 5 wherein said electrode is coated with an emissive material selected from the group consisting of barium carbonate, strontium carbonate, calcium carbonate, and combinations thereof.

7. The method of claim 3 wherein two spacially-separated nickel-coated molybdenum rings are placed on said mandrel prior to step A, and wherein the heating of step B causes the wire-to-ring contacts to fuse.

8. The method of claim 2 wherein said electrode is a grid and wherein said coating step comprises the coating of gold on a molybdenum wire.

9. The method of claim 1 wherein said wire is wound over one end of said mandrel.

10. The method of claim 1 wherein following step A clamping means are placed about and held tightly to said mesh against the thermal expansion of said mandrel.

11. The method of claim 4 wherein said heating is conducted in a wet hydrogen furnace at a temperature of approximately 1030° C. for approximately 20 minutes.

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