

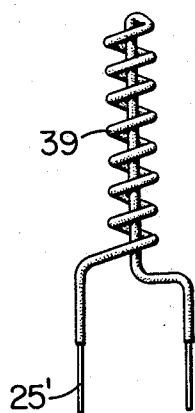
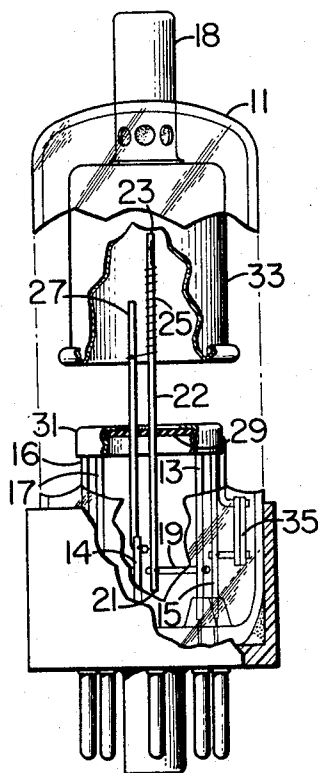
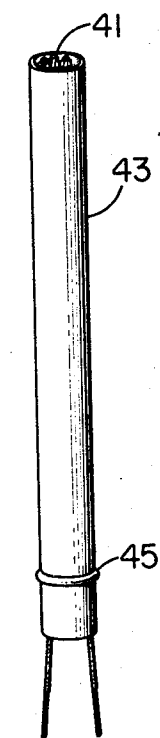
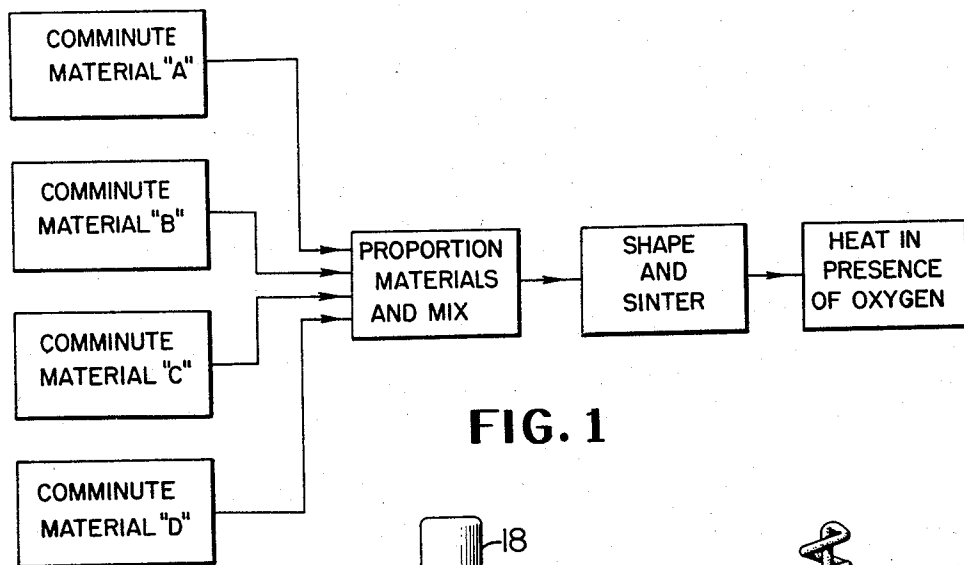
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ELECTRON TUBES AND METHOD OF MAKING SAME

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ELECTRON TUBES AND METHOD OF MAKING SAME

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The invention pertains to electron tubes and particularly to electric insulating members therefor and methods of fabricating such members.

The problem of electrically insulating various elements within electron tubes has concerned the industry for many years. However, the stringent requirements of electron tubes tend to render solution of the problem very difficult. For example, satisfactory materials must be capable of withstanding relatively high operating temperatures without breaking down or affecting the characteristics of the tube in any way. As a result, only a certain few materials, such as the oxides of aluminum, magnesium or silicon, have been used successfully in practice. Such materials are very good electric insulators and are inert throughout the temperature range encountered in practice.

Although different ways of applying oxides to tube elements have been tried, the two most common ways have been by cataphoresis or by drag coating. Prior art methods result in a more or less thin, even coating of the oxide being affixed to the part being insulated. While such a coating is satisfactory for many applications, its brittleness makes the forming of elements from drag coated wire or other stock difficult. As an alternative, the coating may be applied, as by cataphoresis, after the elements are shaped, but only at the obvious expense inherent in handling finished elements.

If the coating be so thick that it does not chip, difficulty is encountered in attaching the coated element to other tube elements. As is well-known, oxides do not lend themselves to operations such as soldering, welding or clamping, so it is necessary to strip certain portions of the coating, or to mask certain portions of the element in the coating process, to provide an uncoated area on the element to facilitate soldering, welding or clamping. Regardless of which method of ready connection is adopted, it is evident that complexity is added to the fabrication of the element without improving it to any degree.

The known methods of applying insulating materials to electron tube elements present other problems in practice. For example, in drag coating mentioned hereinbefore, it is very difficult to apply an even coating of insulating material. It is conventional practice to dip-coat formed elements, but drippings are almost certain to collect in any sharp turns or bights. Relatively complicated parts, such as filamentary cathodes and heater wires are especially subject to this difficulty. The drippings occasionally cling to the convolutions of the part and build up to such size that the part cannot be used.

While cataphoresis is not subject to the aforementioned shortcomings, it has other deficiencies that make it a less-than-ideal process. For example, the materials in the solution in which the process is carried out must be maintained at certain rather critical proportions in order to attain efficiency, and frequently, high voltages must be used.

Although both of the enumerated methods of applying

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insulating coatings have been commonly used in the past, a better method is highly desirable in many cases. For example, when a filamentary cathode for a high voltage rectifier is desired, design considerations may dictate that the cathode be helical in shape and supported on an insulated rod. With such a design, best results are obtained if the insulated rod is fabricated of molybdenum and if a refractory material such as aluminum oxide is used as the insulating material. Molybdenum is used since it is the least expensive of known materials having properties which permit its use at high temperatures. However, molybdenum is not easily welded to other metals. As a result, special care must be taken to ensure a satisfactory connection between the filamentary cathode and the support rod. To ensure a satisfactory connection, a portion of the molybdenum support rod is plated with nickel and then the tungsten filament is welded to the plated portion of the rod. Such an expedient is obviously not to be desired since the nickel plating is not a functional part of the tube.

Other components in electron tubes are almost as difficult to insulate. In tubes having an indirectly heated cathode, it is highly desirable that the heater wire be insulated from the cathode to allow sufficiently great flexibility in use, as when a number of tubes are operated in so-called "series string" circuits. The potential difference between the heater and the cathode of tubes so operated is often in the order of several hundred volts. Unless almost perfect insulation is provided, breakdown is almost certain to occur. The problem is complicated by the fact that thermal considerations in this application make it desirable that the insulation between the heater and the cathode interfere as little as possible with heat transfer. Since almost every known insulating material is also a refractory material, it is evident that the mass of the insulating material should be kept to a minimum consistent with good insulation in order to improve the heat transfer between the heater and cathode.

The problem of insulation is not necessarily restricted to applications in which very high temperatures are encountered. In the electron tube, for example, flat sheets of mica are commonly used to space the elements. However, a material having a greater strength than mica would be more desirable. In the past, attempts have been made to provide a stronger material by using aluminum spacers having an oxide coating, but known oxide coatings have been too fragile to be practical. Cracking of the oxide coating, of course, completely destroys the insulating qualities of the anodized material.

An object of the invention is to provide a method of permanently insulating elements in an electron tube.

Another object of the invention is to provide a method of electrically insulating raw material for elements of any desired shape.

Still another object of the invention is to provide an electrically insulated element for electron tubes that may be easily welded to other elements.

Yet a further object of the invention is to provide an element for an electron tube having an electrically insulating coating and an electrically conducting core.

According to the invention, support rods and other tube elements are made by sintering a metal mixture containing a small amount of a metal that forms a non-conducting oxide, such as aluminum, or magnesium, in the configuration of the desired element and thereafter heating it in the presence of oxygen, resulting in an electrically conducting metallic core thinly coated overall with a non-conducting oxide. The metals making up the mixture are so selected that the metal forming a non-conducting coating has the lowest melting point. During the heating step the temperature of the entire mixture is brought above the melting point of the oxide-forming

metal, but below the melting point of the metal having the next lowest melting point. As a result, at least part of the oxide-forming metal passes into its liquid phase while the remaining metal remains solid. The liquid metal forms a thin film on the surface of the element and is there converted to its oxide form after exposure to oxygen. By this method of making the support rod or other tube element, the oxide is so tightly bonded to the core that there is little chance of its being dislodged.

The thickness of the oxide coating that is obtained according to the invention is sufficient in almost all cases to provide insulation, yet it is not so thick that it interferes with welding. It has been found that the welding characteristics of the core material predominate; it is then a matter of choice to determine the proper metals for the core material so that the optimum performance under high temperature and weldability is obtained.

Express embodiments of the invention, given by way of example, are described hereinafter with reference to the drawing in which:

Fig. 1 is a flow diagram of a method of utilizing the concepts of the invention in fabricating elements for electron tubes;

Fig. 2 is a perspective drawing of an electron tube embodying the invention, partially cut away, to show the critical parts thereof;

Fig. 3 is a perspective view of an alternative form of the filamentary cathode electrode assembly shown in Fig. 2; and

Fig. 4 is a perspective view, partially cut away, of an indirectly heated cathode electrode assembly made according to the invention.

Referring now to Fig. 1, a practical method of making an insulated member is diagrammed. The oxide-forming material and the desired metals are comminuted, proportioned, mixed, sintered in the desired shape and the sintered mass is heated in the presence of oxygen to bring the oxide-forming material to the surface to provide a thin coating of oxide. The number of and the particular metals used are not critical to the invention, there being many that are practicable. It is necessary only that the oxide-forming metal have the lowest melting point. For example, in Fig. 1, metal "A" may be aluminum, metal "B" may be iron, metal "C" may be chromium and metal "D" may be nickel. Further, the exact size of the individual grains of each constituent obtained by comminution is not critical, it merely being desirable that a relatively fine powder be formed to facilitate the mixing and sintering steps described hereinafter.

After the constituents have been comminuted, they are thoroughly mixed to form a homogeneous charge. The proportions of each of the metals may be varied over wide limits. However, it is desirable in any event to keep the amount of oxide-forming material in the charge below approximately 2%, by weight, thereof. As an example only, the proportions of the homogeneous charge may be iron 60%, chromium 29%, nickel 10% and aluminum 1%. It should also be noted that the metals need only be commercially pure, since trace impurities normally found in the aforementioned metals have no discernible adverse effect on the insulator made according to the invention.

The charge is then placed in a mold and sintered according to known practice. During the sintering step, a combination of heat and pressure operates to weld the individual particles in the charge together so that a unitary structure is obtained. Any unwanted projections or burrs resulting from the sintering step may be removed by known methods. However, if care has been exercised in the design of the mold and in the operation, it will be found that the product of the sintering step is a completely electrically conductive part with the dimensions of the desired tube element that may be processed further without dressing.

The completely conducting part is then transformed

into the desired insulated tube element by heating it in the presence of oxygen. Two ways have been found practicable to accomplish the transformation, although there are undoubtedly other ways that are equally efficacious. The first of the mentioned ways consists of heating the part, as produced by the sintering step, in air, by flame or in an electric furnace at a temperature above the melting point of the oxide-forming material and below that of the other constituents for a relatively short time. With the aforementioned materials, for example, the heating process may be carried out efficiently at approximately 1000° C. for about 15 minutes. The second way is to pass enough current through the part to bring its temperature up to the required level for a shorter time. Again, with the aforementioned materials, for example, the part is raised to about 1000° C. for about five minutes in air. In any event, the result of this step is that a thin, adherent and dense coating of substantially pure aluminum oxide is formed on the surface of the part.

The formation of the oxide coating is due to the difference in melting points of the metals in the sintered part. Thus, in the example given above, the aluminum passes into its liquid phase when the temperature is raised to 1000° C. At the same time, the other metals do not change state so the part becomes a solid-liquid mixture without changing shape. The liquid aluminum migrates to the surface of the part and there reacts with the oxygen in the air to form aluminum oxide. The oxidation of the aluminum need not be carried to completion. In fact, it is preferable that oxidation not be carried to completion in order that the oxide be formed on a zone of relatively pure aluminum contained in the interstices of the solid metals.

As may be observed from the foregoing discussion, the materials used are not critical. In general, any mixture may be used, the only requirement being that at least one of the minor constituents have the characteristics of aluminum in the illustrated embodiment; i.e., be capable of sintering with the other materials, have a lower melting point than the other materials, and be capable of forming a non-conductive oxide when heated in air above its melting point. For example, magnesium could be substituted for aluminum in the present case. In effect, this means that the practical limitation on the kinds of material and the proportions thereof in the mixture may be varied within large limits depending on the use to which the final product is to be put. However, as far as use in electron tubes is concerned, it is preferred that the percentage of iron be kept rather high (above 50%) in order that the part may be easily welded to other parts in the tube.

While the illustrated method has been described using a sintering step to form the desired shape, other ways of forming shapes may be employed. For example, a support rod may advantageously be fabricated from a long wire by cutting desired lengths therefrom in any known manner. In such a case, it is only necessary that the wire contain a small amount of uncombined oxide-forming material, such as aluminum, in order that the heating and oxidizing step be effective in causing the oxide-forming material to migrate to the surface and oxidize. Uncombined oxidizing material, such as aluminum or magnesium, may be introduced into many alloys capable of being drawn into wire by incorporating to the melt of the desired alloy an amount of the oxidizing material above that amount which will remain in solid solution.

Referring now to Fig. 2, a tube embodying the invention may be seen. The particular tube illustrated is a high voltage rectifier tube for use with peak inverse voltages in the order of more than 20,000 volts. The tube consists of an envelope 11 having a plurality of lead-in wires 13 to 17 sealed therethrough. The lead-in wire 13 is connected through a cross-member 19 to the lower end 21 of a support rod 22. The support rod 22 is fabricated

either according to the method described in connection with Fig. 1, or from a wire having uncombined aluminum therein, so that it has an electrically conductive core and an electrically insulating coating. Connected to the upper end 23 of the support rod 22 is an end of a filamentary cathode 25 that may advantageously be formed into a helical shape and disposed around the support rod 22 in close proximity thereto as shown. The lower end of the filamentary cathode 25 is connected to a connecting member 27 that is, in turn, connected to the lead-in wire 14. The filamentary cathode 25 may advantageously be fabricated from tungsten wire coated with one of the known electron-emissive earth carbonates (not shown) to make it more efficient in operation. A spacer 29 is positioned around the support rod 22 and the connecting member 27 to hold the members in fixed spatial relationship to each other and to a corona shield 31. Spacer 29 may be fabricated either from mica or from a metallic disc treated to produce an insulating coating thereon as described hereinbefore. Spacing of the support rod 22 and the connecting member 27 from the corona shield 31 is attained by press fitting the spacer 29 into the corona shield 31 as shown. At the same time, the spacer 29 renders the parts more resistant to movement under conditions of vibration.

In passing, it should be noted that the lead-in wires 15, 16, 17 are not all essential to the invention, but are desirable in order to position the corona shield 31 more accurately and firmly. An anode 33 is connected to the cap 18 and is positioned around the filamentary cathode 25 as shown to complete the functional parts of the tube. A getter assembly 35 may be positioned as shown for well-known reasons. All connections between metallic parts are preferably made by welding to ensure satisfactory results in operation.

In operation, the filamentary cathode 25 is connected to a source of power through the lead-in wires 13, 14 to energize the electron-emissive coating thereon. The insulating coating on the support rod 22 prevents short-circuiting of the individual turns of the filamentary cathode 25 through the support rod 22. The high voltage being rectified is connected to the anode 33 through the lead-in wire 18 and to one side of the filamentary cathode 25 through one lead-in wire connected thereto, say the lead-in wire 14. A much greater potential difference exists on occasion between adjacent turns of the filamentary cathode 25 in this case than the potential difference due to the filament energizing potential previously mentioned, but the thin, dense insulating coating still prevents short-circuiting.

An unexpected advantage accrues from the use of the described insulating coating. Whereas, in the past, the insulating coating was so thick that interference with proper welding was always experienced unless portions of the coating were stripped away from the base metal, the coating contemplated by the present invention is so thin that it does not interfere with welding. It has been found possible to weld, for example, a tungsten wire directly to a support rod, made as previously described herein, without stripping or treating the coating in any way. In addition, it has been found that the welding characteristics of support rods are substantially the same as the major constituent of the core, yet the ability of the core to retain its stiffness at high temperature is substantially improved by the presence of the other metals in the core. This fact means that the support rod may be easily welded by known techniques, yet is as satisfactory for the particular use as other less easily welded rods such as those made of molybdenum.

Other vacuum tube elements that may incorporate the invention to advantage are shown in Figs. 3 and 4. In Fig. 3, a filamentary cathode assembly that may be substituted for the support rod 22 and the filamentary cathode 25 of the tube illustrated in Fig. 2 is shown. The filamentary cathode 25', however, differs in that its base

material is not tungsten, but rather is the same as the material of the support rod 22 described in connection with Fig. 2. It is advantageous in this case, however, to fabricate the filamentary cathode 25' from wire having aluminum as the minor constituent as previously described, as by winding on a mandrel, and then heating it to about 1000° C. to cause the excess aluminum in the wire to be converted into a coating of aluminum oxide. An electron-emissive coating 39, composed of any of the known materials used for that purpose, may be deposited on the surface of the filamentary cathode 25' as shown. One end of the filamentary cathode 25' is doubled back through the coiled portion thereof to take the place of the support rod 22 of Fig. 2. The two free ends may be connected to appropriate lead-in wires to complete the necessary electrical circuit.

Still another structure in which the principles of the invention may be incorporated is shown in Fig. 4. In this embodiment, an indirectly heated cathode electrode is shown. Again, the illustrated electrode may be substituted in place of the support rod 22 and filamentary cathode shown in Fig. 2. In this embodiment, heater wire 41 is disposed within a cathode cylinder 43. A positioning ring 45 may be disposed on outer surface of the cathode cylinder 43 as shown to permit location of the cathode cylinder 43 with respect to the spacer 29 of Fig. 2. The material of either the heater wire 41 or the cathode cylinder 43, or both, may be insulated in the same manner as described hereinbefore in connection with the filamentary cathode 25' and the support rod 22 of Fig. 3; i.e., by oxidizing aluminum or other material that has been brought to the surface of the elements. In other words, both elements are formed from a material having aluminum or other oxidizing material in excess of the amount that will remain in solid solution in any of the ways previously described. The assembly is completed, of course, by depositing any known electron-emissive material (not shown) on the outer surface of the cathode cylinder 43.

In operation, the electron sources described in both Figs. 3 and 4 are equally well insulated. All surfaces of both the filamentary cathode or heater and the support rod or cathode cylinder have even continuous coatings of insulating material firmly attached thereto. This prevents, to a large degree, voltage breakdown between the elements and makes a tube in which such parts are used more flexible in application.

While the invention has been described in connection with elements that are subjected to high temperatures, the invention may be applied to other elements to advantage. Thus, well-known support rods for elements, such as grids and anodes, may be fabricated in the same manner as disclosed herein to improve the leakage resistance between various parts of an electron tube and so on.

The invention claimed is:

1. An electron tube comprising, a helical coil of tungsten wire as the base material for a filamentary cathode, a support and insulating assembly adapted to position said helical coil within said tube, said assembly comprising a first and a second support rod, said first support rod being rigidly affixed at one end thereof to the envelope of said tube, passing centrally of said helical coil, the free end portion of said first supporting rod projecting a predetermined distance beyond the end of said helical coil, the material of said first support rod being a sintered mass of iron, chromium and nickel having a thin coating of aluminum oxide anchored in the interstices between the grains of said sintered mass and intimately affixed to the surface thereof, one end of said helical coil being welded to said support rod at a point on said free end portion, said second support rod being disposed parallel to said first portion adjacent thereto, the material of said second support rod being nickel-plated steel, and the second end of said helical coil being welded to said second support rod at a predetermined point thereon.

2. A filamentary cathode assembly for an electron tube, comprising a tungsten wire and an electron-emissive material, said tungsten wire being centrally formed to a helical shape, the ends of said wire being bent to form end portions at predetermined angles to the axis of said helical shape, said electron-emissive material being disposed as a film on the surface of said helically shaped wire, a first support rod being fixed at one end and passing centrally of said helically shaped portions of said wire, said first support rod having a predetermined portion thereof projecting beyond said helically shaped portion of said wire, said first support rod comprising a sintered mass of iron, chromium and nickel having a thin film of aluminum oxide anchored in the interstices between the grains of said sintered mass and intimately affixed to the surface thereof, the first of said end portions being welded to

said predetermined portion of said support rod at a point thereon, a second support rod being fixed at one end and disposed substantially parallel to said first support rod, the second of said end portions being welded to said second support rod at a predetermined point thereon.

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