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METHOD OF FORMING AN EXTRUDED CATHODE

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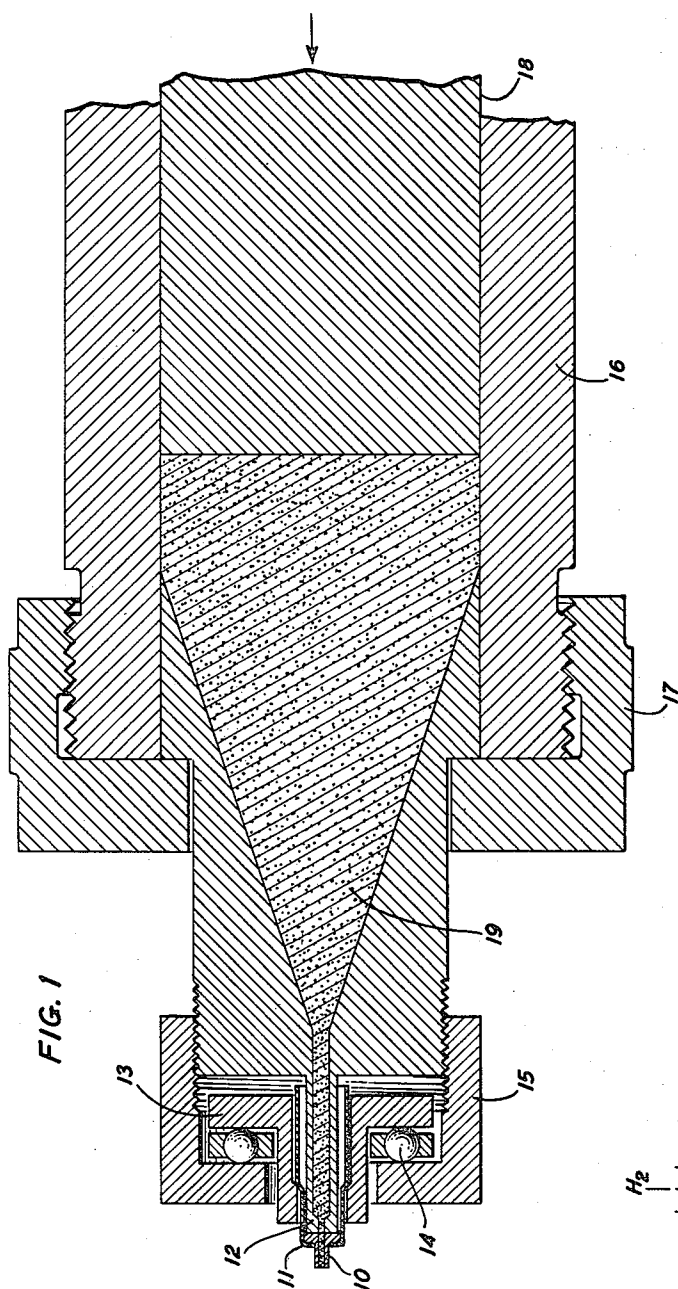


FIG. 3

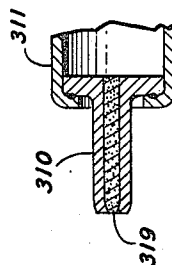
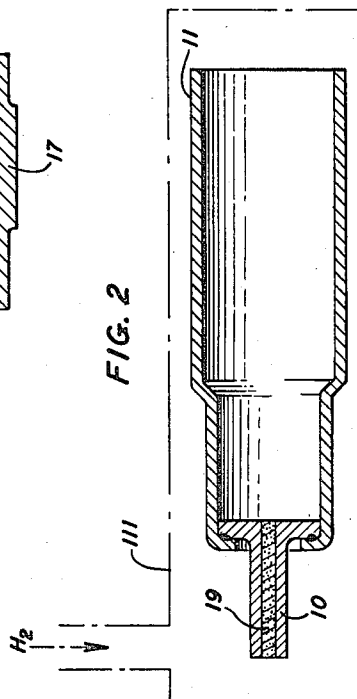


FIG. 2



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METHOD OF FORMING AN EXTRUDED CATHODE

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1 Claim. (Cl. 75—208)

The present invention relates to an electron-emissive cathode for use in an electron discharge device, such as a high frequency traveling wave tube, and more particularly to an extrusion process for making such a cathode.

In a traveling wave tube an electromagnetic wave is propagated along a suitable wave transmission circuit and an electron beam is projected along a path in coupling relation with the transmission circuit for amplifying the propagating wave. Typically, the transmission circuit is a conductive helix and the beam is projected along the axis thereof. For operation at very high frequencies, the dimensions of the transmission circuit necessarily are small and consequently the beam dimensions must likewise be small so that the beam may pass along the helix and avoid collision therewith. Moreover, at such very high frequencies a finely dimensioned beam is essential for good signal-to-noise operation. For obtaining suitable finely dimensioned beams, electron-emissive surfaces of the order of 10 circular mils or less are sometimes required. It is important that the cathodes having such small emissive surfaces not only have high mechanical strength but be readily reproducible so that the electron emission characteristics do not vary from cathode to cathode.

Serious problems exist in the construction of cathodes capable of emitting a finely dimensioned electron beam of rigidly prescribed characteristics. A variation as small as one mil in the diameter of the small circular emissive surfaces used may result in a change of the order of twenty-five percent in the total current of the beam, and a corresponding change in the power characteristics of the tube. Known techniques of cathode construction have not proved completely satisfactory in producing such small accurately dimensioned cathodes.

An object of the present invention is to construct cathodes having emissive surfaces whose dimensions are accurately defined and readily reproducible.

A feature of the present invention is the extrusion of a paste containing emissive material and suitable metallic powder particles through an elongated tubular metallic sleeve and the appropriate heating of the sleeve and the paste remaining therein. The heating is preferably performed in a hydrogen atmosphere for reducing oxide formations on the metallic surfaces. Such heating serves to sinter the metallic particles together and advantageously also to the tubular metallic sleeve, thereby forming a mechanically strong matrix. Sintering of the particles to the metallic sleeve is insured in the preferred embodiment of the present invention by making the particles and sleeve of like metal. Electron emission of the cathode thus formed is from the emissive surface at one end of the metallic sleeve.

In one illustrative embodiment of the present invention, a mixture is prepared of nickel powder, zirconium powder, and an alkaline earth double-carbonate powder, such as barium strontium carbonate. To this mixture is added a suitable lubricant binder, such as polyvinyl alcohol, for

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forming an extrudable paste. The paste thus formed is extruded through a nickel tubular sleeve until some of the paste protrudes from the end of the sleeve. The protruding paste is then severed at the end surface of the sleeve. The sleeve with the paste therein is next heated in a hydrogen atmosphere. This reduces the nickel oxide coating which forms on the surface of the nickel powder particles and on the surface of the nickel tube and ensures an effective sintering of the nickel powder particles to each other and to the nickel sleeve. The matrix structure formed by sintering the particles to each other and to the sleeve provides rugged structural support and, in operation as a cathode, allows barium to migrate through the interstices of the matrix to the surface at the end of the sleeve for electron emission from that surface.

The metallic sleeve through which the emissive material is extruded (and in which the emissive material is contained to form the final cathode) can be very accurately machined and is readily reproducible. The inner periphery of the sleeve, which is readily machinable accurately to any desired dimension, serves as the outer periphery of the emissive surface, thereby accurately defining the area of the emissive surface. The extrusion step is designed to compress the extruded paste, thereby enhancing the emissive properties of the cathode. The matrix formed by the sintered metallic particles within, and advantageously also sintered to, the metal sleeve results in a rugged structure. Moreover, in operation the emissive material contained within this matrix tends to migrate to the emissive surface at the end of the sleeve so as to replace any emissive material expended at the surface, whereby long life is obtained. Accordingly, advantages of the process of the present invention are ease of manufacture, accuracy of dimensions of the emissive surface, convenient reproducibility, good emissive properties, mechanical strength, and long cathode life.

The above and other objects, features and advantages of the invention will be understood by referring to the following description taken in connection with the accompanying drawing, in which:

Fig. 1 shows as one stage of the process of the invention a sleeve, through which emissive material is to be extruded and which will form the outer shell of the cathode, inserted in a jig suitable for carrying out the extrusion step;

Fig. 2 is an enlarged view of the sleeve-like cathode shell of Fig. 1 being heated in a hydrogen atmosphere as is characteristic of a subsequent step of the preferred embodiment of the invention; and

Fig. 3 shows a modification of the cathode shell of Fig. 2.

Before discussing in detail Fig. 1, which illustrates apparatus for extruding an electron emissive paste through a finely dimensioned tubular shell for forming a cathode, it will be helpful to consider the properties of a paste suitable for the purposes of the invention. It is important that the cathode formed be structurally sound and have good emissive properties. To these ends, a mixture is made of particles of nickel and zirconium powders, .1 to 2 percent by weight zirconium and the rest nickel. To this mixture is added an alkaline earth double-carbonate, such as barium strontium carbonate to form a new mixture which is 10 to 50 percent by weight barium strontium. Typically, the resultant mixture includes by weight 59 percent nickel, 1 percent zirconium, and 40 percent barium strontium carbonate. To facilitate the extrusion of the mixture of these powders, they are combined with a lubricant binder, such as polyvinyl alcohol 20 to 30 percent by weight, to form an extrudable paste. It is not feasible to extrude the powders without forming a paste since techniques for extruding powders require pressures so high as to deform or break the usual form of cathode shell.

The paste so formed is now suited for use in apparatus, such as is shown in Fig. 1, for extrusion through the cathode shell. In the apparatus of Fig. 1, cathode shell 10 is of nickel to have the same metal base as the mixture to facilitate sintering the particles of the mixture to the shell for forming a unitary structure. The cathode shell 10 is joined by spot welding or the like to a tubular member 11 which serves as a housing for a heater element when the cathode is assembled in an electron discharge device. Housing member 11 is advantageously made of molybdenum for mechanical strength. The cathode shell and housing are maintained in place by an extrusion die 12 and pressure plate 13. The extrusion die and pressure plate are suitably dimensioned and the pressure plate provided with shoulders for maintaining the cathode shell and housing secure. Thrust bearing 14 and cap 15 serve to force the extrusion die and pressure plate into contact with shell 10 and housing 11, respectively, without setting up any localized stress in the shell. Cylinder 16 is positioned to surround the extrusion die near its right-hand end and is attached thereto by collar 17 for enclosing a reservoir of paste to be extruded through cathode shell 10.

In operation, ram 18 is moved to the left, by hand or suitable automatic mechanical driving force, and forces paste 19 through cathode shell 10 until a stream of the paste protrudes from the left-hand or ejection end of the cathode shell. The motion of the ram is then ceased and the protruding stream of paste is severed, preferably by a sharp-edged cutting blade, close to shell 10 to form a surface flush with the left-hand end of the shell. To ensure an accurate flush surface, the protruding stream should be severed immediately after extrusion. The stream of paste upon exposure to the atmosphere for even a short period of time becomes brittle and cannot be cut without cracking. Such cracking generally precludes obtaining an emissive surface flush with the end of the cathode shell. For the paste described above, cutting should take place within one minute after extrusion ceases.

Following the extrusion, cap 15 is unscrewed from extrusion die 12, and the cathode shell and housing assembly, with the emissive paste contained therein, is removed. It is understood that for mass production the extrusion apparatus of Fig. 1 can be modified to facilitate rapid removal of the cathode assembly. After removal, the cathode is heated, preferably in a hydrogen atmosphere, as is shown schematically in Fig. 2. In this figure an enlarged view of the cathode is shown in a hydrogen atmosphere within furnace 111, shown in phantom view. The cathode comprises shell 10, housing 11, and emissive paste 19. As explained above, the cathode shell and housing member are jointed at their abutting surfaces by spot welding or the like. Also as explained above, the shell 10 is preferably of nickel for sintering, whereas housing member 11 is of molybdenum for mechanical strength. During heating the nickel particles of the emissive paste become sintered to each other and to the nickel shell to form a rugged matrix-like structure. The inside diameter of shell 10 is typically 10 mils or less and its wall thickness is advantageously of the order of 2 mils or less. Such thin wall thicknesses are advantageous since it is desirable to position beam forming electrodes exceedingly close to the emissive surface at the left-hand end of the cathode. The atmosphere in furnace 111 is advantageously maintained at a temperature between 650° C. and 700° C., such as 675° C., and each cathode is heated therein from five to ten minutes, for example eight minutes. The high temperature hydrogen atmosphere vaporizes the lubricant binder from paste 19, reduces the nickel oxide which has formed on the surface of the nickel shell and on the nickel particles in the paste, and sinters the nickel particles to each other and to the nickel shell. A portion of the barium strontium carbonate in paste 19 is reduced to barium oxide and strontium oxide in the high temperature hydrogen atmosphere. Care should be taken that the cathode is not subsequently heated in air. This would result

in the formation of barium hydroxide which inhibits activation of the cathode emissive material. For this reason, after sintering the cathode is advantageously allowed to cool down to room temperature in the hydrogen atmosphere or in an inert atmosphere before being exposed to air. The cathode is then removed from the hydrogen atmosphere and is stored, preferably in a dry atmosphere, in this state until needed for use for incorporation in an electron discharge device.

After incorporation within the evacuated envelope of an electron discharge device, the cathode is heated to a temperature of 900 to 1100° C., typically 1000° C., in the vacuum of the envelope until the remaining barium strontium carbonate is completely reduced to barium and strontium oxide. Such heating is accomplished by passing an electric current through the heater coil of the cathode which will be positioned within housing member 11. The time required to achieve complete reduction is from 15 minutes to one hour, and is typically 20 minutes at 1000° C. During such heating an activation process takes place in which the zirconium in material 19 displaces the oxygen in barium oxide to form free barium which is important for good electron emission properties. After activation and during operation of the tube, the left-hand end of material 19 serves as the electron emissive surface, the area of the surface being accurately defined by the inside diameter of shell 10. As the emission properties of the material 19 near its left-hand surface tend to fall off with age, free barium migrates to that surface so that it maintains good emission properties. Such migration is believed to occur through the interstices in the matrix formed by the sintered nickel particles.

Fig. 3 shows a modification of the cathode of Fig. 2. The cathode of Fig. 3 comprises a shell 310, housing 311, and paste 319. Paste 319 is formed in the manner previously discussed and then extruded through cathode shell 310 in the manner discussed. Unlike the previously discussed cathode, however, cathode shell 319 is tapered at its left-hand end so that the paste extruded there-through becomes compressed. Such compression acts to enhance the emissive properties of the cathode. The left-hand or ejection end of tapered shell 310 is made flat so that the extruded paste can be severed flush with that end of the shell. Cathodes with emissive surfaces having various sizes can be produced by the use of such tapered cathode shells of a single size. After the cathode has been constructed in accordance with the teachings of the present invention, a larger size emissive surface can be obtained if desired by machining off an appropriate amount from the left-hand end of the shell and emissive material.

It is understood that the specific embodiments described are merely illustrative of the general principles of the invention. Various other arrangements may be devised by one skilled in the art without departing from the spirit and scope of the invention. In particular, the nickel particles forming the base metal of the paste may be replaced by another suitable sinterable metal powder, such as tungsten powder. In such a case the cathode shell surrounding the paste is advantageously also made of tungsten so that the particles of base metal become sintered to the shell as well as to each other for forming a unitary structure. Furthermore, the zirconium powder in the paste can be replaced by another suitable cathode activating metal such as titanium. Likewise the polyvinyl alcohol of the paste can be replaced by another suitable lubricant binder.

What is claimed is:

The method of manufacturing a minute electron emissive cathode for use in evacuated electron discharge devices comprising the steps of preparing a paste of a sinterable metal powder, an alkaline earth carbonate powder, and a suitable lubricant binder; extruding said paste through the bore of an accurately machined cathode-shell of said sinterable metal, a portion of the paste project-

ing out of the ejection end of said cathode-shell; sever-
ing said projecting portion flush with said ejection end
before the projected paste can become brittle, the inner
periphery of said cathode-shell thereby defining the outer
periphery of the emissive surface area; and heating the
paste in said cathode-shell in a hydrogen atmosphere to
vaporize the lubricant binder and sinter said metal powder
together and to said cathode-shell, thereby forming a rigid

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matrix in which at least a portion of said alkaline earth
carbonates are reduced to their oxides.

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