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3,117,249

EMBEDDED HEATER CATHODE

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FIG.1.

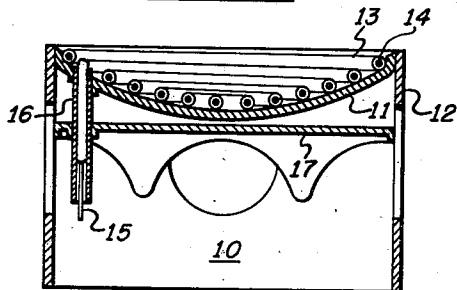


FIG.2.

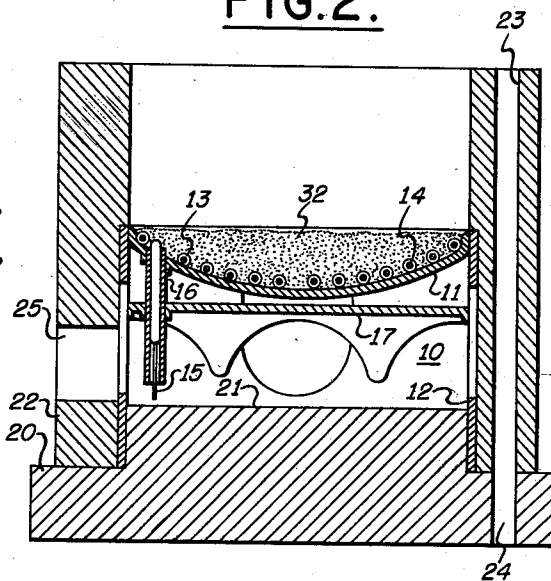


FIG.4.

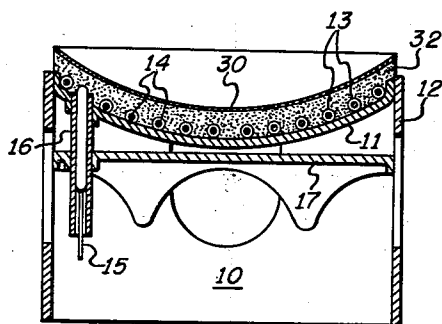
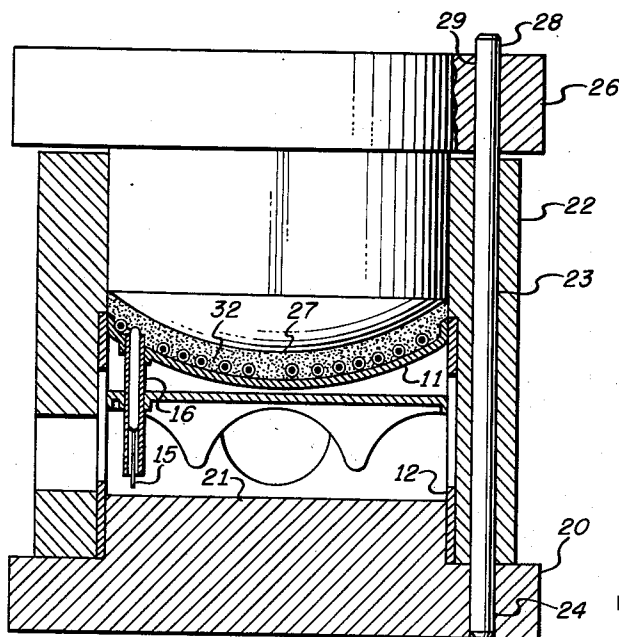


FIG.3.



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EMBEDDED HEATER CATHODE

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This invention relates to a ruggedized cathode structure for electron emissive tubes and to a method for making said cathodes. More particularly, the invention is concerned with potted heater elements wherein the potting material, a nickel matrix, is molded around the heater element in such a manner as to prevent damage to the insulation and to the conductive wire of the heater, while at the same time securely supporting said heater, and additionally providing a shaped surface for the deposition of electron emissive material thereon.

In electronic tube designs, it commonly is desirable that the mechanical construction of the tube be as rugged as possible in order that the tube may operate satisfactorily for extended periods of time in environments where rather severe vibration and mechanical shock are present. Quite often, attempts to ruggedize the cathode structure of a tube have resulted in compromises in the mechanical and electrical properties of the cathode, and additionally, have resulted in added expense and complexity in the construction of the tube.

It is an object of this invention to provide a simple and economical method for producing a ruggedized cathode heater for an electron emitting device.

It is another object of this invention to provide a method for producing an oxide-coated cathode which is more rugged and which has a longer life than known oxide-coated cathodes constructed in the past.

Another object is to provide a ruggedized cathode structure wherein the operating life and emitting qualities of the cathode are improved.

A further object of the invention is to provide a ruggedized heater construction for a cathode of an electron emissive device.

A further object of the invention is to provide a method for embedding a heater element of an electron emissive cathode in a sintered metallic matrix having good heat transmission properties, and for providing a shaped surface on the matrix for the deposition of an electron emissive material thereon.

These and other objects and advantages of the invention, which will become more evident from the specification and claims below, are achieved by placing a cup-shaped cathode receptacle in a jig and inserting a high-temperature electrical insulated heater coil within the receptacle. A nickel powder is poured into the receptacle to surround and cover the heater element. A forming tool which has a desired shaped surface is then positioned into contact with the nickel powder to compress the powder to form a porous, loosely compacted metallic matrix, and to impress a shaped surface into the nickel powder. This arrangement is then heated in a non-oxidizing or reducing atmosphere at a sufficient temperature for a sufficient length of time to bring the metallic powder to an initial sintered state. The forming tool then is removed and the metallic powder and cup-shaped receptacle again are heated in a non-oxidizing or reducing atmosphere to further sinter the metallic powder. The resultant structure within the cathode receptacle is a porous metallic matrix which securely holds the heater element and provides excellent heat transfer from the heater to the shaped surface. The shaped surface of the metallic matrix then is coated with an electron emissive material. Because of the porous nature of the nickel matrix, electron emissive material penetrates into the pores in the shaped sur-

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faces and provides a reservoir of available emissive material in addition to the emissive material deposited on the shaped surface.

The process of the present invention represents a departure from conventional techniques for making molded nickel or tungsten matrices for cathodes having unpotted heaters in that said matrices commonly were formed under extremely high compressive forces of several tons per square inch to produce a compacted substance which then was sintered. I have found, however, that these techniques cannot be employed when the heater element is potted within the cathode receptacle because the high compressive forces will crack the insulation, usually alumina, on the heater wire which will result in the heater shorting-out to the nickel matrix. Additionally, and equally important, if the matrix is tightly compacted, it will not be deformable and likely will cause cracking of the matrix and/or the alumina insulated coating of the heater wire as a result of differential thermal expansion of the heater coil and nickel matrix during warm-up and operation.

The present invention will be described in connection with the accompanying drawings wherein:

FIGS. 1, 2 and 3 illustrate progressive steps in the process of producing a ruggedized, embedded cathode heater according to the present invention; and

FIG. 4 is an illustration of a completed embedded heater cathode constructed according to this invention.

Referring now to FIG. 1, a cathode receptacle 10 is comprised of a spherically concave cathode cup 11 spot-welded to one end of the hollow cylinder 12. A flat, spiraled heater element 13 is positioned within receptacle 10 and is spot-welded at end 14 to cathode cup 11, while the other end 15 passes through an insulated tubing 16 to provide an external connection to the heater element. Heater element 13 is wound from a length of heater wire which has a covering of high-temperature electrical insulation, usually alumina. Other suitable high-temperature electrical insulated wire may be employed if desired. A metallic disc 17 extends across the hollow cylinder 12, beneath cathode cup 11, and serves as a heat shield to reduce thermal radiation from that side of the heater element 13. In some instances it may be found that heat shield 17 is unnecessary and may be eliminated, particularly if the hollow cylinder 12 is short.

In the next step of the process of this invention, illustrated in FIG. 2, the cathode receptacle 10 with the heater element 13 therein is placed on the base portion 20 of a jig. Base 20 has a raised cylindrical portion 21 over which the cylinder 12 of the cathode receptacle fits. The jig further is comprised of an open-ended hollow cylinder 22 which fits over cathode receptacle 10 and rests on base 20. The cylindrical portion 22 of the jig is of greater internal diameter at its bottom to securely engage cathode receptacle 10. Cylindrical portion 22 of the jig has a longitudinal bore 23, and base 20 has a similar bore 24 in alignment therewith. Cylinder 22 has an aperture 25 in its wall to permit the correct alignment of the heater lead 15.

A measured amount of metallic powder 32, nickel powder for example, is poured into the open end of the jig and covers the heater element 13. One type of nickel powder which has been used with great success is known as Special Type I, carbonyl nickel powder, 200–325 mesh (30 microns), manufactured by SKC Research Associates, Paterson, New Jersey. This is an agglomerated powder made by sintering smaller particles of nickel together to attain the required mesh. It is desired that the particle size (agglomerated particle size) be sufficiently large so that after compressed and sintered, as explained below, the resulting sintered nickel matrix is permeated with

enough voids to permit plastic deformation of the matrix when the heater element and nickel matrix expand by different amounts during initial heating and during operation. If too small a particle size is used, the voids will be small and the nickel matrix will be compact and non-deformable. This gives rise to cracking of the nickel matrix and/or breaking of the alumina insulation, and possibly breaking of the wire of the heater element. The heater element will very likely short-out to the nickel matrix under these conditions. If too wide a range of particle sizes is used in the agglomerated powder, the desirable voids will be filled with the smaller particles and the above-mentioned deleterious results will occur. If the particle sizes are too large, the thermal conductivity of the nickel matrix will be poor, requiring greater heater power to operate the heater element at a higher temperature. To obtain acceptable and repeatable results, the agglomerate powder particle sizes should be within the range of 10 to 100 microns. Although I presently prefer the above-mentioned type of agglomerated nickel powder, other types of metallic powders may be used. Ordinary unsintered nickel powder, cobalt or cobalt-nickel alloy powders, as well as molybdenum or molybdenum-nickel powders, for example, also could be used, the particle sizes being within the above-mentioned range. Whatever metallic powder is used it should be suitable for use in a cathode of an evacuated electron discharge device operating at a temperature as high as approximately 1000° C.

The next step of the process is illustrated in FIG. 3. A forming tool 26 having a spherically convex shaped surface 27 is inserted into the open end of the jig and into contact with the metallic powder 32. A rod 28 is passed through a bore 29 in forming tool 26, and through aligned bores 23 and 24 in the jig to hold the respective pieces in alignment. The weight of forming tool 26 is chosen to provide the desired compressing force per unit area on the surface of the metallic powder. Within the limits of the particle sizes stated above, a compressive force within the limits of 1 to 10 pounds per square inch should be applied to the nickel powder. The higher compressive forces within the stated limits should be used with the larger particle sizes, and the lower compressive forces should be used with the smaller particle sizes. I use a low pressure to compress the nickel powder rather than the high pressures employed in the prior art in order not to crack the alumina insulating coating on the heater wire, and to assure that the powder is not too tightly compacted to eliminate the previously mentioned necessary voids in the nickel matrix.

The entire fixture illustrated in FIG. 3 then is placed in an oven and heated in a non-oxidizing or reducing atmosphere at a sufficiently high temperature and for a sufficient length of time to bring the nickel powder to an initial sintered condition. In this initial stage of heating it is desired that the nickel powder be sintered only enough to insure that the particles will cohere to form the shaped surface. Any further sintering at this stage will likely cause the forming tool 26 to stick to the nickel matrix and will make it difficult to remove said tool from the jig. In attempting to remove a stuck forming tool, the shaped surface of the loosely compacted nickel matrix likely will be damaged. In constructing potted cathodes as described herein, I heated the fixture at a temperature of 900° C. for twenty minutes. Upon removing the fixture from the oven, the forming tool 26 is removed. The exterior surface of the nickel powder now has the shape imparted to it by the shaped surface 27 of forming tool 26. The shaped surface 27 of forming tool 26 is made of a stainless steel, or a similar material, so that it will not contaminate the shaped surface of the nickel powder by diffusion.

The cathode receptacle 10 then is completely removed from the jig and is reheated in an inert atmosphere to complete the sintering of the nickel powder. I have found

that heating to a temperature of 1200° C. for 20 minutes is sufficient for this purpose.

It is to be understood that the times and temperatures recited above are examples which I have found to be suitable, and I do not intend to imply that the practice of my invention is limited to the particular given examples of time and temperature. However, it is believed that the ranges cited offer the best combination of features.

The cathode receptacle with the heater element embedded in the nickel matrix next is removed from the oven and allowed to cool. Following this, an electron-emissive material 30 is applied to the shaped surface of the sintered nickel matrix. Any known emissive material such as barium oxide, strontium oxide or calcium carbonate, for example, may be used. The material may be sprayed on the shaped surface of the nickel matrix. Thus, a ruggedized oxide-coated cathode is produced.

An advantageous feature of this type of cathode is that the emissive material will penetrate into the porous shaped surface and will, in effect, provide a reservoir of emissive material in addition to the emissive material deposited on the shaped surface itself. In one spherically shaped cathode button having a diameter of 1.277 inches, 6.3 grams of the above-mentioned Special Type I carbonyl nickel powder was used. This cathode had a small central aperture .128 inch in diameter for the passage of ions therethrough.

A further advantage of the cathode constructed in accordance with this invention is that the emissive material is deposited directly on the nickel matrix. This greatly simplifies the construction of the cathode. As a result of the heater element being embedded in the nickel matrix and the emissive material being deposited directly on the nickel matrix, the heat transfer qualities of this cathode are excellent. I have found that the heater element may be operated at a lower temperature, which results in a longer heater life. I also have found that the emitting surface of the cathode reaches operating temperature in a relatively short length of time, i.e., three minutes, and is quite uniformly heated, thereby producing uniform electron emission from all areas of the emitting surface.

While the invention has been described in its preferred embodiments, it is understood that the words which have been used are words of description rather than of limitation and that changes within the purview of the appended claims may be made without departing from the true scope and spirit of the invention in its broader aspects.

What is claimed is:

1. A method for producing an embedded-heater cathode structure for an electron discharge device comprising the steps of inserting into an open-ended cathode receptacle an electrical heater element having a high-temperature electrical insulated covering thereon, providing external access to the leads of said electrical heater, depositing within said cathode receptacle a measured amount of metallic powder to embed said heater element therein, said metallic powder having particle sizes within the limits of 10 to 100 microns and being of the type suitable for use in a cathode of an evacuated electron discharge device operating at a temperature as high as approximately 1000° C., positioning a shaped tool into contact with said metallic powder and compressing said powder with a force within the limits of one and ten pounds per square inch to form a shaped surface in said metallic powder and to loosely compact said powder, heating said cathode receptacle and metallic powder with said shaping tool in position in a non-oxidizing atmosphere to a sufficient temperature and for a sufficient length of time to cause the particles of said powder to cohere but not to stick to said forming tool, removing said shaping tool from contact with said powder and further heating said powder in a non-oxidizing atmosphere to a sufficient temperature for a sufficient length of time to substantially completely sinter said powder, and applying a coating of electron

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emissive material to said shaped surface of said powder, whereby said coherent metallic powder rigidly supports said heater element and provides a shaped emitting surface for the emission of electrons therefrom.

2. A method for producing a potted-heater cathode structure for an electron discharge device comprising the steps of placing an open-ended cup-shaped cathode receptacle in a jig, inserting into said receptacle an electrical heater element having a high-temperature insulated covering thereon, providing external access to the leads of said electrical heater, pouring into said receptacle a measured amount of nickel powder to embed said heater element therein, said nickel powder having particle sizes within the limits of 10 to 100 microns, positioning a spherically convex shaping tool into contact with said nickel powder at the open end of said receptacle and compressing said powder with a force between the limits of one and ten pounds per square inch to form a spherically concave surface in said nickel powder, heating said cathode receptacle and nickel powder with said shaping tool in position in a non-oxidizing atmosphere to a temperature within the range of 800-900 degrees centigrade for a period of time between 15 and 25 minutes to bring said nickel powder to an initial sintered condition, removing said shaping tool from contact with said nickel powder and further heating said nickel powder in a non-oxidizing atmosphere to a temperature of between 1100 and 1300 degrees centigrade for a period of time between 15 and 60 minutes to substantially completely sinter said nickel powder to form a sintered loosely-compacted nickel matrix, and applying a coating of electron emissive material to said spherically shaped surface of said matrix, whereby said sintered nickel matrix rigidly supports said heater element and additionally provides a shaped porous surface for the deposition of said electron emissive material.

3. A method for producing a potted-heater cathode structure for an electron discharge device comprising the steps of inserting into an open-ended cathode receptacle an electrical heater element having a high-temperature electrical insulated covering thereon, providing external access to the leads of said electrical heater, pouring into the open end of said cathode receptacle a measured amount of nickel powder to embed said heater element therein, said nickel powder having particle sizes within the limits of 10 to 100 microns, positioning a shaped tool into contact with said nickel powder and compressing said powder with a force within the limits of one and ten pounds per square inch to form a shaped surface in said nickel powder and to loosely compact said powder, heating said cathode receptacle and nickel powder with said shaping tool in position in a non-oxidizing atmosphere to a sufficient temperature and for a sufficient length of time to bring said nickel powder to an initial sintered condition without contaminating said shaped surface of the nickel powder by excess diffusion of material from said shaping tool, removing said shaping tool from contact with said nickel powder and further heating said nickel powder in a non-oxidizing atmosphere to a sufficient temperature for a sufficient length of time to further sinter said nickel powder, and applying a coating of electron emissive material to the shaped surface formed in said nickel powder, whereby said sintered nickel rigidly

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supports said heater element and provides a shaped porous emitting surface for the emission of electrons.

4. A potted heater cathode structure comprising a cup-shaped receptacle having an open end, an electrical heater element disposed within said receptacle and having a high-temperature electrical insulated covering, a porous sintered metallic matrix molded within said receptacle and embedding said heater element to rigidly support said heater element, said metallic matrix having a given shaped surface across the open end of said receptacle, and an electron emissive material disposed on and penetrating within the pores of the shaped surface of said porous metallic matrix.

5. A ruggedized cathode structure for an electron discharge device comprising a cup-shaped receptacle having an open end, an electrical heater element disposed within said receptacle and having a high-temperature electrical insulated covering thereon, a porous sintered nickel matrix within said receptacle embedding said heater element therein, said nickel matrix being comprised of a sintered, loosely-compacted nickel powder whose particle sizes are within the range of 10 to 100 microns to provide a porous, deformable nickel matrix permitting relative thermal expansion between said heater and said nickel matrix, said sintered nickel matrix having a given shaped surface at the open end of said receptacle, and an electron emissive material disposed on and penetrating within pores of said shaped surface, whereby said nickel matrix surrounds and encloses said heater element within said receptacle and provides an emitting surface for the emission of electrons therefrom.

6. A method for producing an embedded-heater cathode structure for an electron discharge device comprising the steps of inserting into an open-ended cathode receptacle an electrical heater element having a high-temperature electrical insulated covering thereon, providing external access to the leads of said electrical heater, depositing within said cathode receptacle a measured amount of metallic powder to embed said heater element therein, said metallic powder having particle sizes within the limits of 10 to 100 microns and being of the type suitable for use in a cathode of an evacuated electron discharge device, compressing said powder with a shaping tool to loosely compact said powder and impart a shaped surface thereto, heating said cathode receptacle and metallic powder in a non-oxidizing atmosphere to a sufficient temperature for a sufficient length of time to substantially completely sinter said powder to form a sintered loosely-compacted nickel matrix, and applying a coating of electron emissive material to said shaped surface of said matrix, whereby said sintered metallic matrix rigidly supports said heater element and additionally provides a shaped porous surface for the deposition of said electron emissive material.

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