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INCANDESCIBLE CATHODES

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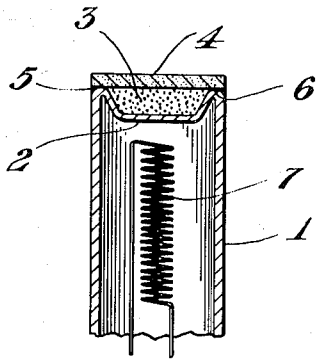


FIG. 1.

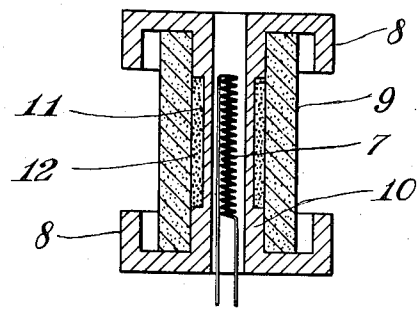


FIG. 2.

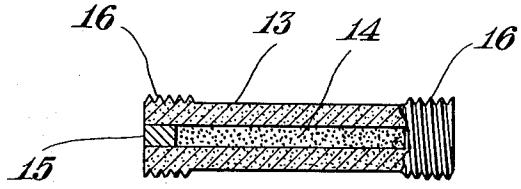


FIG. 3.

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INCANDESCIBLE CATHODES

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2 Claims. (Cl. 29—25.18)

My invention relates to a method of making incandescent cathodes and to incandescent type cathodes made by this method. More particularly, the invention relates to a method of manufacturing cathodes of the dispenser type.

In U. S. Patent 2,543,728 to H. J. Lemmen et al., a dispenser type cathode is described in which a reservoir of electron emitting material is contained within a cavity in a tightly closed body of refractory metal having a porous wall portion, the pores of which form the largest passageways connecting the electron emissive material with the outside of the cathode. In the specific examples described and illustrated in this patent a sintered body provided with a cavity is partially filled with electron emissive material arranged within the cavity, the cavity tightly closed by fitting a member of refractory material over the open end of the body and the latter member sealed to the sintered body.

In the manufacture of such cathodes an important consideration in determining the satisfactory operation of the cathode is the porosity of the sintered body since the pores of the sintered body form the largest connecting passageway between the cavity containing the emissive material and the outer surface of the cathode. Accordingly, the body is usually sintered to an extent at which the required degree of porosity results only after the body has been mechanically worked into its approximate shape and dimensions.

If the body is first sintered to the extent necessary to obtain the required degree of porosity and then machined, the pores of the body are closed and in the case of tungsten, such sintering makes it extremely difficult to even machine the body. Consequently, the body is pre-sintered at a lower temperature, machined, and then sintered to the required porosity. As a result of further heating at higher temperatures, the pre-sintered, machined body is subject to considerable shrinkage and warpage making it difficult to hold cathode structures of this type to close dimensional limitations.

The main object of my invention is to provide an improved method of manufacturing a cathode of the dispenser type.

A further object of my invention is to provide a cathode of the dispenser type which can be held to closer dimensional limitations.

Another object of my invention is to provide a method of making a dispenser type cathode having particular desired shape and dimensions.

And another object of my invention is to provide a cathode of the dispenser type employing a novel means for sealing a refractory metal to the sintered body.

These and further objects of my invention will appear as the specification progresses.

Briefly stated the method of manufacturing a cathode according to my invention comprises forming a body of particles of a heat refractory metal such as tungsten or molybdenum sintered into a coherent mass of predetermined porosity. The sintered body is then impregnated

with a filler metal to make the body machinable, i. e. workable by machine tools, and to prevent closing of the pores in the body during machining and then mechanically shaped into a structure adapted to receive the emissive material. After the machining operation and before introducing the emissive material, the filler metal is evaporated out of the machined sintered body thus leaving a porous shaped body of refractory metal having a predetermined porosity and shape.

More specifically, the invention envisages the manufacture of cathodes of the dispenser type in which the porosity of at least a portion of the wall surrounding a cavity which contains the emissive material is porous to an extent such that the pores form the largest connecting passageways between the cavity and the outer surface of the cathode. Consequently, it is essential that the body be sintered in such manner that satisfactory cohesion of the particles is obtained for mechanical strength while maintaining a required degree of porosity in the body.

The final porosity of the body depends upon the particle size, the pressure employed to shape the body and the temperature at which the shaped body is heated. Since these factors are interrelated, a choice of any two of the factors will usually determine the third for a given product of predetermined porosity. In general, a coarse particle size and low shaping pressures will require a high sintering temperature while a relatively fine particle size and large shaping pressures will materially reduce the required heating temperature. In general, however, the sintering temperature must be chosen higher than the normal activating and operating temperatures, whichever is higher, of the cathode when used in an electron discharge tube, and lower than the melting point of the refractory metal. Activation and operating temperatures are usually around 1250° C. although in some cases the cathode may be activated at lower temperatures over a very long period of time.

In regard to the filler metal, I have found that metals which practically do not alloy with the refractory metal in the metallographic sense and which exhibit some lubricating properties are to be preferred. In addition, the filler metal should be inert to a non-oxidizing and preferably a completely or partly reducing atmosphere which does not react with the refractory metal such as hydrogen or hydrogen-nitrogen mixtures, it should have a relatively high vapor pressure at temperatures below the temperatures at which the refractory metal is sintered, and it should have a melting point lower than the temperature at which the refractory metal is sintered. Among the metals suitable for this purpose are copper, gold, silver and their alloys in any combination.

Impregnation of the sintered refractory metal is conveniently accomplished by placing the body of sintered refractory metal in contact with the molten filler metal in a non-oxidizing and preferably a completely or partly reducing atmosphere which does not react with the refractory metal so that the filler metal penetrates into the pores of the sintered body by capillary attraction.

The impregnated body can be mechanically worked into a body of any desired shape and dimensions without closing the surface pores by cutting, turning, boring, drilling, lapping or milling. Threads may be cut on the body, if desired, by dies, a tab, or by a screw cutting machine.

After machining to desired shape and dimensions, the body is then heated in a suitable protective atmosphere, preferably in a vacuum to a temperature at which the filler metal volatilizes and lower than the temperature at which the body was sintered for a time sufficient to remove substantially all the filler metal thus leaving a porous body of refractory metal of predetermined porosity, shape and dimensions. It is important to choose the temperature of volatilization lower than the temperature

of sintering since otherwise the body would be subject to further shrinkage and warping. Consequently, the duration of volatilization and the nature of the protective atmosphere must be carefully chosen to permit volatilization of the filler metal at a temperature lower than the sintering temperature.

The invention will, for convenience, be illustrated and described in connection with dispenser type cathodes having porous tungsten walls. However, it is to be understood that instead of tungsten, molybdenum, tantalum, hafnium, niobium, rhenium and any other refractory metals which may be fabricated into a dispenser type cathode could be substituted for the tungsten by varying only the details of my process and not varying its basic concept. I have chosen tungsten as my example because it illustrates the superior advantages of my invention with a metal which heretofore was considered very difficult to machine when prepared to have a high apparent density approaching that of the theoretical density of tungsten.

The invention will be described with reference to the accompanying drawing in which:

Fig. 1 is a sectional view of a dispenser cathode of the indirectly heated type;

Fig. 2 is a sectional view of another dispenser cathode of the indirectly heated type; and

Fig. 3 is a sectional view of a directly heated dispenser type cathode.

Referring to Fig. 1, the cathode comprises a tubular cylinder of refractory metal, such as molybdenum closed at one end by a portion **2** forming a cup-shaped recess in which emissive material **3** such as a mixture of barium and strontium oxides or carbonates are arranged. A porous sintered tungsten disc **4** manufactured in accordance with the method hereinafter described is welded to the edges **5** and **6** of the refractory metal cylinder and tightly closes the cup-shaped recess in which the emissive material is arranged. The cathode is heated by a filament **7** which results in the liberation of emissive material through the porous tungsten disc and the formation of a monomolecular layer of barium on the outer surface of the disc.

Fig. 2 shows another form of an indirectly heated cathode of the dispenser type employing a porous hollow tungsten cylinder **9** manufactured in the manner described hereinbelow. The porous tungsten cylinder is tightly fitted between the U-shaped ends **8** of a molybdenum tube **10** provided with a shallow dish-shaped recess **1** containing the emissive material **12**. The filament **7** is arranged within the molybdenum tube.

Fig. 3 shows a directly heated type of dispenser cathode in which the emissive material is contained in a central reservoir of the cathode and the cathode directly heated by the passage of an electric current through the cathode body. The cathode comprises a cylindrical body **13** of porous tungsten having a central bore extending partially through the body and filled with emissive material **14**. The bore is sealed with a molybdenum plug **15** force-fitted into the open end of the bore. The ends of the porous tungsten body are provided with threads **16** for securing terminals to the cathode in a convenient manner.

The sintered porous tungsten parts are made in accordance with the following method which is in accordance with my invention. It will be understood that the following example is representative only of one way of making one form of cathode structure and that the details of the method may be varied to make the same and other forms of the cathode or to use other refractory metals instead of tungsten. For example, different powder sizes, shaping pressures, sintering temperatures and machining operations can be employed to obtain a cathode of desired porosity, shape and dimensions.

A tungsten body was made by sintering tungsten particles into the form of a bar of predetermined porosity by shaping tungsten powder having an approximate density of 54 gms./in.^{3} and comprising the following fractions in the following proportions as determined by the elutriation test:

Fraction	Radius	Proportion by Weight, Percent
I	over 6.1/μ	30.9
II	between 6.1–3.6/μ	30.6
III	between 3.6–2.9/μ	13.3
IV	between 2.9–2.2/μ	7.6
V	between 2.2–1.5/μ	17.6

at a forming pressure of about 2000 kilograms/cm.^{2} and presintering the shaped tungsten mass for 20 minutes at 1100° C. in a hydrogen atmosphere to obtain a bar-shaped tungsten body which has some mechanical strength. The pre-sintered bar-shaped tungsten body was then heated in a hydrogen atmosphere by conduction in a suitable furnace by attaching electrodes to the tungsten bar and passing a current through the tungsten to raise its temperature to 2150° C. (optical temperature) for about 20 minutes. The ends of the bar which had not reached the required temperature and thus were not fully sintered were broken off and discarded.

The bar had a density of about 16 gms./cm.^{3} corresponding to 83% of the theoretical density of tungsten.

The bar was then impregnated with copper as a filler metal by placing it in contact with molten copper in an atmosphere of hydrogen at a temperature of 1350° C., the copper being absorbed into the tungsten mass by capillary attraction. About 7% by weight of copper was absorbed by this process which was uniformly distributed throughout the tungsten bar.

The bar-shaped tungsten body impregnated with copper was then machinable into any desired shape such as a disc, a hollow cylinder and the like. In the construction shown in Fig. 3, the bar was turned down into a cylindrical rod having an external diameter equal to the outer diameter of the threads and then threaded throughout its entire length. The threaded rod was drilled to the required depth and the center portion of the threads under-cut leaving a smooth tungsten surface over the emitting area.

The remaining step of removing the copper from the machined and threaded tungsten body prior to its assembly with molybdenum terminals forming the cathode was accomplished by heating the machined rod in a vacuum (about 10^{-5} Hg) to about 1500° C. for approximately 60 minutes. At this temperature, it was found that substantially all the copper was removed in this period of time.

The volatilization temperature for the removal of the filler metail and the duration of the volatilization depends upon the degree of vacuum, porosity, thickness of the tungsten body, and the filler metal. The temperature and time of heating the tungsten body should, however, be chosen to remove substantially all the filler metal and should be below the temperature at which the tungsten was sintered in order to avoid further shrinkage and warping.

The method according to the invention permits the manufacture of a dispenser cathode of any desired shape and dimensions and eliminates the problem of shrinkage and warping common in the manufacture of such bodies. Moreover, the porosity which is an important consideration in cathodes of the dispenser type in order to obtain the best results therefrom remains unaltered because the pores of the sintered body are filled with filler metal which is evaporated out after machining and thus are not closed in this operation.

While I have thus described my invention with specific examples and applications other modifications thereof will be readily apparent to those skilled in the art without departing from the spirit and scope of my invention as defined in the claims appended hereinbelow.

What is claimed is:

1. A method of manufacturing a dispenser type of cathode which comprises forming tungsten powder into a body, sintering said body at a temperature above 1000° C. and higher than the volatilization temperature of a filler metal selected from the group consisting of copper, gold, silver, and alloys thereof with which the body is subsequently impregnated to form a coherent body having a predetermined density and porosity, the thus-formed tungsten body being substantially in its final sintered state, impregnating said body with said filler metal, machining said body to form the same into a body of desired shape and dimensions and having an emissive surface, volatilizing all of said impregnant metal from said body in a protective atmosphere which will not react with tungsten at a temperature substantially less than said sintering temperature to leave a sintered body free of said impregnant metal without substantially altering the porosity and density thereof, and disposing at a point connected to said surface only through pores of the body a supply of alkaline earth compounds capable of furnishing free alkaline earth metal to said surface.

2. A method of manufacturing a dispenser type of cathode which comprises forming tungsten powder into a body, sintering said body at a temperature above 1250° C. and higher than the volatilization temperature of copper with which the body is subsequently impregnated to form a coherent body having a predetermined porosity and a density of the order of 80%, the thus-formed tungsten body being substantially in its final sintered state, impregnating said body with copper in a non-oxidizing atmosphere, machining said body to form the same into a body of desired shape and dimensions and having an emissive surface, volatilizing all of said copper from said body in a vacuum at a temperature substantially less than said sintering temperature to leave a sintered body free of copper without substantially altering its porosity and density, and disposing at a point connected to said surface only through pores of the body a supply of alkaline earth compounds capable of furnishing free alkaline earth metal to said surface.

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