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[54] FAST WARM-UP INDIRECTLY HEATED CATHODE STRUCTURE

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[52] **U.S. Cl.** **313/337,** 29/25.15, 29/25.17, 29/473.1, 29/494, 29/498, 29/504

[51] **Int. Cl.** **H01j 1/20,** H01j 19/14

[58] **Field of Search** 29/473.1, 25.15, 504, 494, 29/498, 472.9, 472.7, 25.17; 313/337

[56] **References Cited**

UNITED STATES PATENTS

2,835,967	5/1958	Umblis	29/473.1 X
2,945,295	7/1960	Feaster	29/494
3,175,118	3/1965	Ney	313/337 X
3,495,122	2/1970	Hübner et al.	313/337 X
3,528,156	9/1970	Kling	313/337
3,117,249	1/1964	Winters	29/25.17 X

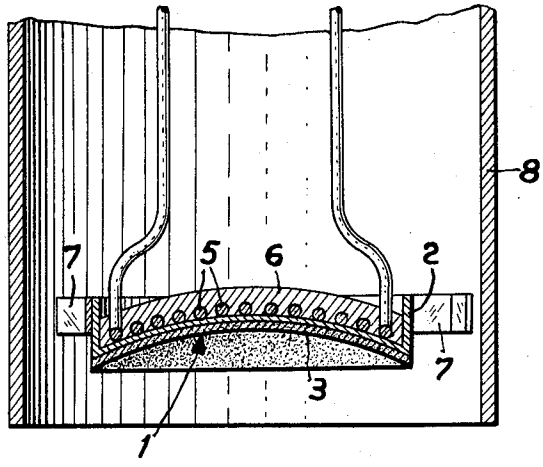
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[57] **ABSTRACT**

A tungsten heater, covered with a thin alumina layer (about 1 mil), is potted inside a molybdenum cathode cup in a sintered mass formed from a mixture of fine particles (of the order of 1–5 microns) of molybdenum and nickel in the weight ratio of at least 40 percent molybdenum, but preferably about 90 percent moly. The emissive surface of the cup has a matrix of sintered nickel carbonyl filled with alkaline earth metal emissive oxides. The cup is supported by invar struts.

The processing includes: (1) preparing a sintered nickel carbonyl matrix layer for the emissive surface of the cup; (2) ball-milling molybdenum-nickel mix with butyl carbitol, and after covering the heater therewith, inserting the heater in the cup, firing the assembly in hydrogen at between 1,150° to 1,350° C until sintered; and (3) impregnating the nickel carbonyl matrix with a mix of alkaline earth carbonates in methyl alcohol and using heat and ultrasonic vibration to compete impregnation. After assembly in tubes, activation and aging follows.

8 Claims, 3 Drawing Figures



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Fig. 1

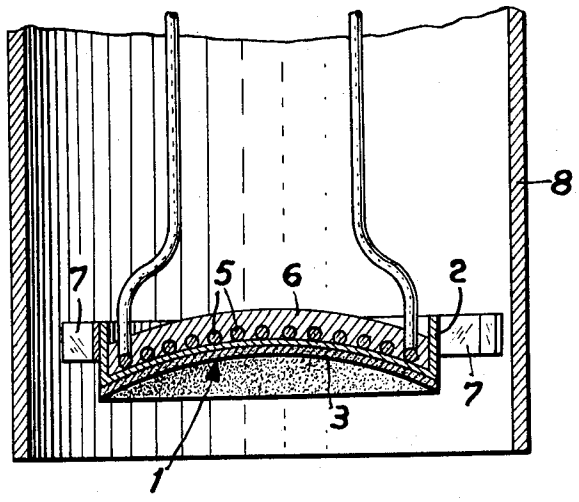


Fig. 2

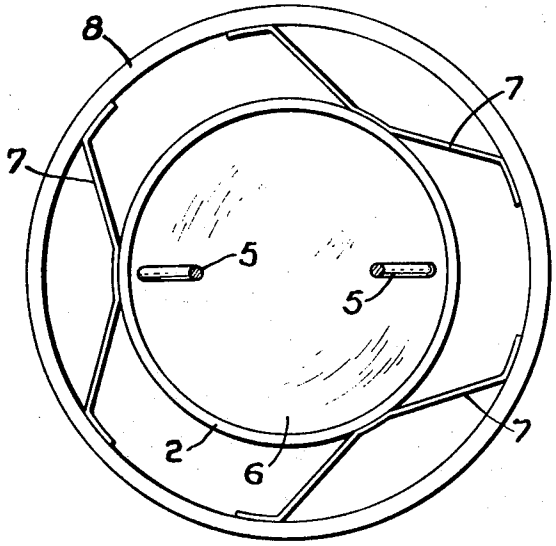
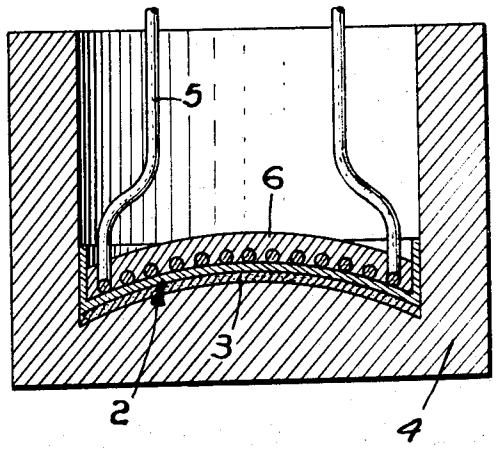


Fig. 3



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FAST WARM-UP INDIRECTLY HEATED CATHODE STRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to indirectly heated cathode structures, including their supports, whose cathodes are adapted to warm up rapidly. This invention also relates to processes for making same.

For brevity, the term "cathode" is used hereinafter to include the cathode and its associated structure including supports, unless the context indicates otherwise.

2. Description of the Prior Art

For certain application, cathodes, such as those used in klystrons or traveling wave tubes intended for airborne or missile systems, must meet a number of different requirements. For example, with the development of lightweight radars for airborne systems, a need has evolved for cathode structures which will deliver high current densities and which are also efficient. Cathodes, specifically those of missile borne traveling tubes, should be extremely rugged so as to withstand severe shock and vibration, and provide high levels of emission during launch without any drooping of the current during long pulses. Fast warm-up is an important requisite of such cathodes.

One type of indirectly heated cathode which meets some of the above requirements consists of nickel as a base material with a mounting sleeve for holding the cathode in position, the heater being mounted inside the cathode and attached to the cathode with aluminum oxide, the heater being potted inside the cathode by the aluminum oxide. This type of structure while providing a high degree of rigidity does not provide either high efficiency or fast warm-up for the cathode.

SUMMARY OF THE INVENTION

An object of the present invention is the provision of an indirectly heated cathode which is adapted to warm up rapidly; and of processes for making same.

In accordance with the present invention there is provided an indirectly heated cathode assembly comprising a cathode element of refractory metal, a heater adjacent said cathode element, and sintered refractory metals binding said cathode element to said heater, said metals comprising 40 to 90 percent molybdenum.

Other and further objects of this invention will become apparent and the foregoing will be best understood with reference to the following description of the invention, reference being had to the drawings in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram showing a cathode assembly according to the present invention;

FIG. 2 is a schematic plan view showing the arrangement of the mounting struts which support the cathode assembly on its support member; and

FIG. 3 is a schematic diagram used in explaining one step in the process of manufacturing said assembly.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings the cathode assembly or structure 1 consists of a cup 2 made of a refractory material that will not contaminate or overactivate the cathode, having a low coefficient of expansion and high strength at the opening temperature of about 800° C. Another desirable feature of the cathode cup 2 is that it have high thermal conductivity so as not to impede transfer of heat from the heater to the emitting surface. Further desirable properties for fast heating of the cathode assembly are that the cathode cup have low specific heat and low density. Of the readily available refractory materials, molybdenum is the ideal material. Tungsten is the second best material, although the material used does not necessarily have to be limited to these two.

The concave surface, or face of the cathode cup is covered with a layer 3 which will provide the primary emission. There are several alternatives for achieving this emitting layer. This layer may be prepared by carefully weighing and sintering a layer of very pure metallic nickel carbonyl of particle size 9 to 15 microns to the cathode cup. The weight is calculated and measured to give a matrix layer of 0.003 to 0.005 inches thick.

The uniformity of this layer 3 is very critical for uniform emission and better tube operation. The preferred emitting layers are smooth, compact and of uniform appearance. The cathode layer 3 is formed by placing the nickel carbonyl in the forming fixture 4 as depicted in FIG. 3. The forming fixture may be made, for example, of 99 percent alumina. To the nickel carbonyl there may be added a lubricant to aid in forming a uniform surface; such a lubricant may be any binder that escapes during sintering. A satisfactory binder has been butyl carbitol.

The cathode cup 2 is then placed on top of the nickel carbonyl and the alumina coated heater 5 is then placed inside (on the convex surface) the cathode cup. The heater is made of pure tungsten and is wound in a bifilar pancake design to minimize sensitivity of the electron beam caused by magnetic field effects from the heater current. The heater is made of pure tungsten because of the high ratio of hot to cold resistance. For voltage regulated heater supplies, with high surge current capabilities, it can be shown that pure tungsten will permit faster warm-up than most other materials. It is covered by a layer of alumina about 1 mil thick. Beryllia also may be used, but it requires caution in handling.

The next step in the preparation of a fast warm-up cathode is the preparation of a mixture to intimately bond and pot the heater 5 inside of and to the cathode cup 2. Powders suitable for this should meet most of the requirements for the cathode cup because their primary function is to provide the lowest possible thermal impedance between the heater and the cathode cup. Powders for this purpose should be of fine particle size of the order of 1 to 5 microns. A suitable mixture is prepared by mixing molybdenum and nickel in the weight ratio of 90 percent molybdenum and 10 percent nickel. Other potting mixes have been made in which the percentage of molybdenum has varied down to 40 percent by weight. However, it has been found that the 90 percent molybdenum material has resulted in fastest warm-up and the most dense potting.

The mixture is prepared by placing the metal powders, in the proper weight ratio, in a ball mill along with sufficient butyl carbitol to cover the particles and then milling for 48 hours or more to insure homogeneity.

The heater 5 is then covered with this potting material 6 and the assembled cathode is fired in a dry atmosphere of reducing gas such as hydrogen. The temperature range of the firing is from 1,150° to 1,350° C, the lower limit being set by the temperature necessary to have a good bond between the cathode cup and the face. Increasing the temperature may increase the density of the emitting surface such that it may not be possible to place sufficient alkaline earth carbonates in the face, and thus results in a reduced life. A porous matrix enhances emission because of the increased surface contact between the nickel carbonyl powder and the alkaline earth mixture. Heating continues until the sintering of the potting mass is completed.

The face of the cathode is then impregnated with an emitting material which will decompose to produce a low work function material such as barium oxide. Suitable materials include barium-strontium-calcium carbonate or mixtures thereof.

The impregnation is accomplished by mixing the desired carbonate with methyl alcohol and applying to the face of the cathode. Thorough impregnation is readily accomplished under the influence of heat and ultrasonic vibration.

To obtain higher heater efficiency it is necessary to minimize both conduction and radiation losses from the cathode. An analysis of supporting structures has been made

and an invar strut system, as shown in FIGS. 1 and 2, meets all the requirements for severe environment. The low thermal conductivity of invar makes it an ideal material for thermally isolating the cathode assembly from the other parts of the tubes. Also invar has a very low coefficient of thermal expansion, thereby reducing the likelihood of failure resulting from thermal stress. While there are other low thermal conductivity materials, such as kovar, stainless steel, nichrome, care must be taken with these to prevent poisoning of the emissive layer.

The struts 7 are fastened at their ends to a suitable support structure such as molybdenum cylinder 8. The middle of the struts are fastened to the perimeter of the cup 2 at widely spaced intervals thereon. Fastening may be accomplished by spot welding. The design of the invar struts is such as to provide maximum mechanical strength with minimum conduction loss, and because of the small surface area of the struts the thermal radiation loss is held to a minimum and thus the heater efficiency is higher than that for conventional designs where the cathode is supported by a thin walled cylinder. Where the cathode is part of an electron gun, the supporting cylinder 8 may have a focusing electrode mounted coaxially on the forward end thereof.

Cathode assemblies made in the above manner were placed in diodes and traveling wave tubes. The tubes were then placed on an exhaust station and were baked for 24 hours. At the end of 18 hours the cathode temperature was increased to 1,100° C to activate the cathode. The tubes were then removed from the station and tested. The resultant tubes were aged and processed as normal tubes. Operation was comparable with other traveling-wave tubes with no signs of reduced gain or output power.

The warm-up time was measured, and with normal operating voltage placed on the heater the warm-up time was 5 seconds, where warm-up time has been defined as the time required to reach 90 percent of the final value of beam current. In many systems it is permissible to double the heater voltage until the final beam current is obtained. When tested in this manner the final beam current was attained with 2 seconds. Several diodes and tubes were cycled over 100 cycles and showed no significant gas evolution or degradation of warm-up time.

I claim:

1. An indirectly heated cathode assembly comprising:
- a cathode element of refractory metal having inner and outer opposite surfaces;
- said outer surface of said cathode element having a uniform sintered porous emissive coating;
- a heater adjacent said inner surface of said cathode element; and
- a sintered mass of a mixture of refractory metals of high thermal conductivity covering said heater and intimately bonding said inner surface of said cathode element to said heater, said metals comprising between 40 to 90 percent of molybdenum.

2. An indirectly heated cathode assembly according to claim 1, wherein
- said metals consist essentially of 90 percent molybdenum and 10 percent nickel.

3. An indirectly heated cathode assembly according to claim 1, wherein
- said cathode element is in the form of a cup of molybdenum having an outer concave curved surface and an inner curved surface, said emissive coating being of nickel carbonyl impregnated with an alkaline earth material and being on said outer surface, said heater being a planar winding potted in said mixture on said inner surface and having a curvature conforming to said inner surface.

4. An indirectly heated cathode assembly according to claim 1, further including
- a supporting member; and
- at least one strut of low thermal conductivity metal extending between and fastened to said supporting member and said cathode for mounting said cathode.

5. An indirectly heated cathode assembly according to claim 4, wherein
- said strut is formed of a material taken from the group consisting of invar and nichrome.

6. An indirectly heated cathode assembly according to claim 4, in which said supporting member is of molybdenum.

7. An indirectly heated cathode assembly according to claim 1, wherein
- said heater is of tungsten covered by a thin layer of alumina; and
- said cathode element is molybdenum.

8. In the process of manufacturing an indirectly heated cathode the steps comprising mounting a heater against the inner surface of a cathode element,
- preparing a homogeneous mixture of fine particles of the order of 1 to 5 microns of molybdenum and other refractory metal, said mixture consisting of 40 to 90 percent molybdenum;
- covering at least a portion of said heater mounted against said cathode with said mixture; and
- firing the assembly in a dry atmosphere of reducing gas at a temperature of between 1,150° to 1,350° C to sinter the metal and bond the heater to the cathode.

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