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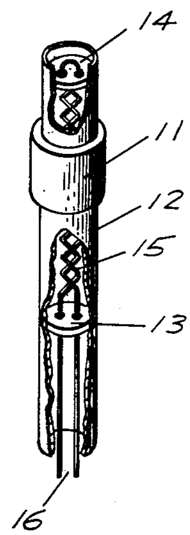

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ELECTRON TUBE CATHODES

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The present invention relates in general to electron tube cathodes and more particularly concerns a cathode assembly for service in a high power tube and the method of manufacture. Cathode assemblies fabricated according to the invention are capable of efficiently emitting high peak currents for long periods of time while withstanding severe mechanical shock with a minimum of undesired electrical effects.

A magnetron is an example of a power tube requiring high peak cathode currents. This tube is basically a diode having a magnetic field perpendicular to a D.-C. electric field established between anode and cathode. Typically, the cathode is cylindrical and concentrically enclosed by an anode so that the D.-C. electric field is essentially radial. The anode has spaced vanes extending radially inward to form resonators whereby tangential A.-C. components of electric field are established between successive vanes as the electrons emitted by the cathode follow a path conforming generally to an epicycloid. This system will oscillate at a frequency primarily controlled by the geometry of the resonant circuit, permitting microwave energy to be withdrawn therefrom at high power levels.

Electrons in the proper phase with the high frequency fields give up energy and move away from the cathode while electrons in an unfavorable phase extract energy from the aforesaid fields and return to the cathode. The latter electrons bombard the cathode with such force that many additional electrons are secondarily emitted. Furthermore, the kinetic energy of the impacting electrons is converted into heat, raising the temperature of the cathode and increasing the number of primarily emitted electrons. In fact, there may be so much heat generated in this manner that filament power may be completely removed, yet the magnetron will continue to operate.

As a practical matter, this type of operation is sometimes undesirable for several reasons. Impacts do not occur uniformly over the cathode surface and hot spots develop on the cathode surface. This reduces the cathode life and causes non-uniform emission from the cathode. Furthermore, external control of bombardment heating is exceedingly difficult and such heating generally varies among production tubes. The production of magnetrons having like characteristics is seriously hampered since a difference of 50° C. at the cathode surface makes a significant difference in the cathode emission.

Typically, a high emission cathode fabricated in accordance with prior art techniques consists of a porous tungsten cylinder impregnated with a substance having the desired electron emissivity, such as barium aluminate. The cathode is slip fitted over a supporting hollow sleeve of highly refractory material and trapped in place. Highly refractory material is material capable of retaining its physical properties at high temperatures. Such material has a low vapor pressure and high melting point. A high temperature filament within the hollow sleeve heats the porous cylinder through the wall of the sleeve to release electrons from the emitting substance for transit under the influence of the electric and magnetic fields. The number of electrons available for emission is related to the temperature of the emitting substance which in turn depends on the heat actually received from the high temperature source and heat due to back bombardment by previously emitted electrons.

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The slip fit results in a poor mechanical and thermal bond between cathode and supporting sleeve. As a result, difficulty is encountered in maintaining the temperature of the emitting surface constant since the excess heat developed at hot spots created by electron bombardment can not be conducted away rapidly enough. Moreover, the temperature at the cathode surface due to heat conducted through the sleeve from the filament will depend upon the thermal conductivity between sleeve and cathode. With a slip fit this varies considerably from tube to tube. Therefore, the filament power required to establish a given cathode surface temperature varies accordingly. Thus, changing a tube frequently requires readjustment of the filament power in order to obtain the desired emission characteristics.

Finally, it is to be noted that slip fitting makes for a poor mechanical bond, and vibrations will displace the cathode causing microphonics. In many applications such microphonics can not be tolerated.

Serious difficulties are presented in attempting to effect a better bond between an impregnated cathode and supporting sleeve without destroying the impregnation because high temperature bonding processes would cause the impregnating substance to flow from the cathode. In a conventional impregnating process, the electron emissive substance is placed in contact with the surface of a porous compact for about a minute at high temperature, the substance flowing into the pores by capillary action. Generally, the surfaces on either side of the compact thickness are exposed to the impregnant. This results in homogeneous impregnation of the cathode, enhancing its life.

The present invention contemplates and has as a primary object the provision of a rugged impregnated cathode assembly with good thermal and mechanical bonding capable of emitting high currents for long periods of time with high efficiency while withstanding severe mechanical shocks without introducing undesired electrical effects.

Another object of the invention is to provide a method of manufacturing an impregnated cathode assembly having the characteristics set forth in the preceding object.

According to the invention, the novel cathode assembly comprises a cathode made of a porous highly refractory material, such as compressed powdered tungsten, impregnated with a substance having high electron emissivity, such as barium aluminate, sintered to a supporting member of highly refractory material, such as molybdenum. This structure is formed by first sintering the porous refractory material to the supporting assembly; thereafter, the porous material is impregnated with the emissive substance.

As a result, excellent thermal and mechanical bonding is obtained between cathode and the supporting member whereby heat due to electron bombardment is uniformly distributed by the member to the entire emitting surface. Similarly, this member serves to uniformly distribute heat from an adjacent high temperature filament to the cathode emitting surface. Consequently, applying a prescribed power to the filament establishes the same temperature on the cathode surface, facilitating the interchangeability of production tubes. Moreover, the improved thermal bonding lessens the warm up time while the better mechanical bonding reduces microphonics.

Other features, objects and advantages will become apparent from the following specification when read in connection with the accompanying drawing, the single figure of which illustrates an exemplary embodiment of the novel cathode assembly.

With reference to the darwing, there is shown a perspective view of a cathode assembly suitable for use in a magnetron, the cathode sleeve being partially cut away to expose the high temperature filament. Electrons are emitted from the surface of cylinder **11** made of porous tungsten impregnated with barium aluminate and sintered to the hollow modybdenum sleeve **12**. Ceramic spacers **13** and **14** fit tightly within sleeve **12** and concentrically support a high temperature tungsten filament **15** energized through outwardly extending leads **16**. Heat is transmitted from filament **15** through sleeve **12** to the electron emitting surface of cylinder **11**. By virtue of the excellent bonding provided by the sintering process, to be described below, heat loss at the interface between cylinder **11** and sleeve **12** is minimized.

The illustrated cathode assembly is preferably formed in the following manner. Fine tungsten powder, for example, of 325 mesh, is compressed at 12.5 tons per square inch in a steel mold to provide a generally cylindrical tungsten matrix or compact intended as cylinder **11**. This compact is heated in an inert or reducing gas atmosphere at 2350° C. for 20 minutes to establish a porosity of approximately 20%. The reducing atmosphere may, for example, consist of hydrogen or a mixture of hydrogen and nitrogen.

The porous compact is then placed in intimate contact with copper wire or powdered copper in a molybdenum or ceramic dish and heated in a reducing atmosphere of hydrogen for 10 minutes at 1600° C. Copper thus infiltrates the pores, resulting in an internal structure which includes copper as a lubricant to facilitate machining. This member is now machined to provide the cylindrical emitter **11** with the desired inner and outer diameters, and then cut to the desired axial length. After machining, the copper is evaporated from cylinder **11** by heating in vacuum for 20 minutes at 1800°–1900° C.

The surface of sleeve **12** is dusted with molybdenum powder and cylinder **11** is assembled thereon in intimate contact with the dusted surface. Thus assembled, the cylinder **11** and sleeve **12** are heated in a reducing atmosphere for 10 to 15 minutes at 2100° C. to create a firm, sintered bond at the common interface.

Cylinder **11** is then impregnated with a substance such as barium aluminate having a high electron emissivity. The powdered barium aluminate, which may be suspended in a suitable binder, is painted onto or otherwise placed in intimate contact, with the exposed surface of cylinder **11** and heated in a non-oxidizing atmosphere, such as a vacuum, a reducing atmosphere, or an inert atmosphere at a temperature somewhat in excess of 1500° C. for a sufficient time to produce impregnation, thereby impregnating cylinder **11** uniformly with electron emitting material.

The excess aluminate may be scraped off, and the outer surface of ring **11** polished with No. 1 emery paper. The filament structure may then be inserted to provide the final cathode assembly illustrated, care being taken in centering the filament on the axis to insure substantialy uniform heating of the electron emitting surface.

Specific materials, temperatures and time intervals have been set forth in connection with a preferred method of practicing the invention.

Various shapes may be used for the impregnated cathode and supporting structure. For example, the cathode may be a solid cylinder supported at one end within a hollow sleeve. The cathode assembly may include a rectangular cathode sintered to supporting rods.

The porous compact and supporting structure are composed of highly refractory materials. The porous compact may be formed by well known powder metallurgy techniques with metals preferably characterized by strength and a low evaporation rate so as not to detract appreciably from the emission characteristics of the electron emitting substance infiltrating its pores. Tungsten compacts exhibit these characteristics but other materials alone or mixed with tungsten, such as rhenium, may be used. The supporting structure may be made of highly

refractory materials other than molybdenum, such as non-porous tungsten and tantalum.

The novel cathode was described with specific reference to a magnetron because of the especially significant results obtained. However, the disclosed techniques are also applicable to impregnated cathode assemblies for other types of electron tubes. It is thus apparent that those skilled in the art may make numerous modifications of and departures from the specific embodiment and techniques disclosed herein without departing from the invention concepts. Consequently, the invention is to be construed as limited only by the spirit and scope of the appended claims.

What is claimed is:

1. A method of forming an electron tube cathode assembly including the steps of placing a compact of porous highly refractory material in contact with a surface of a supporting member of highly refractory material, sintering said porous compact of highly refractory material to said supporting member of highly refractory material while in surface contact by heating at an elevated temperature, placing a substance having high electron-emissivity in contact with said sintered compact, and thereafter impregnating said porous material with said substance of high electron emissivity by heating said compact and said substance to a relatively lower temperature sufficient to cause said substance to flow into said porous material by capillary action.

2. A method of forming an electron tube cathode assembly including the steps of dusting a powder of highly refractory material over a surface of a supporting member of highly refractory material, placing a compact of porous highly refractory material in intimate contact with said dusted surface, heating said compact and said supporting member while in surface contact at high temperature in the presence of a reducing atmosphere, thereby sintering said compact to said supporting member, placing a substance having high electron emissivity in intimate contact with said sintered compact, and heating said compact and said substance while in surface contact at high temperature in a non-oxidizing atmosphere, thereby impregnating said sintered compact with said substance.

3. A method of forming an electron tube cathode assembly including the steps of dusting molybdenum powder on a surface of a molybdenum supporting member, placing a porous tungsten compact in intimate contact with said dusted surface, heating said compact and said member while in surface contact at a first high temperature in the presence of a reducing atmosphere for a first time interval, thereby sintering said compact to said supporting member, placing barium aluminate in intimate contact with said sintered compact, and heating said compact and said barium aluminate while in surface contact at a second high temperature for a second time interval in a non-oxidizing atmosphere, thereby impregnating said sintered compact with said barium aluminate, said first temperature being appreciably greater than said second temperature, said first time interval being much greater than said second time interval.

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