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3,176,180

DISPENSER CATHODE

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FIG. 1.

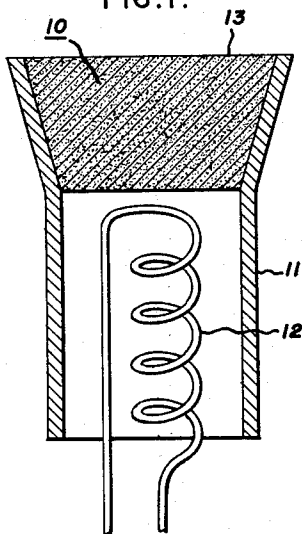


FIG. 2.

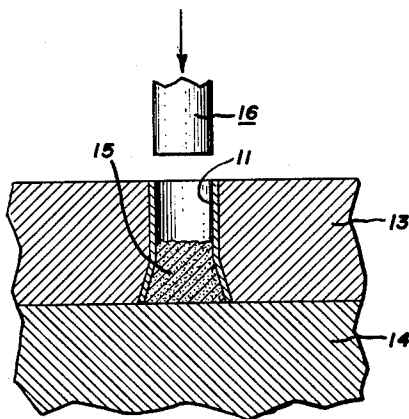


FIG. 3.

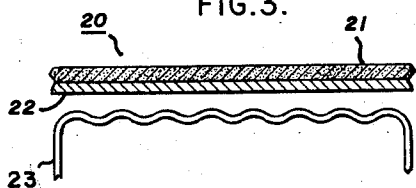
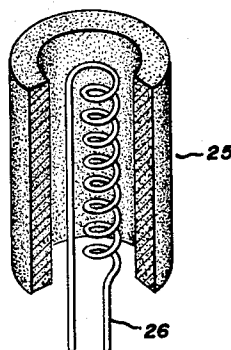


FIG. 4



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DISPENSER CATHODE

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My invention relates to electron emitters and pertains more particularly to a new and improved thermionic emitter of the dispenser type and a new and improved method of making same.

Dispenser-type emitters usually consist of a porous metal matrix impregnated with an activator, or electron source, such as an alkaline earth metal, or a potentially active compound, such as an alkaline earth carbonate, and a reducing agent adapted upon heating to reduce the compound chemically and thereby provide an elemental activator in the matrix. Much of the effort heretofore devoted to the development of dispenser-type emitters has been directed toward providing systems characterized by a low effective work function and, therefore, adapted for high density electron emission within a given operating temperature range. Also, it has been a general object in the art to provide an emitter wherein the activator material is characterized by a satisfactorily low evaporation rate within the mentioned operating temperature range, thereby to provide for prolonged operating life. Additionally, it has been heretofore recognized that when a compound and a reducing agent are jointly employed to provide the elemental activator in the manufacture of a dispenser cathode, undesired gaseous ingredients such as oxygen can be released, an occurrence which usually necessitates special processing, or, which can have adverse effects on the emission surface of the cathode as well as on the operation of any electric discharge device into which the cathode may subsequently be incorporated. Further, in many prior art dispenser-type emitters the activator is not uniformly present at the active surface with the undesirable results of non-uniform and reduced electron emission.

Accordingly, one object of my invention is to provide a new and improved thermionic emitter of the dispenser type.

Another object of my invention is to provide a new and improved dispenser-type emitter characterized by a satisfactorily low effective work function and activator evaporation rate.

Another object of my invention is to provide a new and improved thermionic emitter comprising an improved activator constituent and which does not require the employment of a reducing agent and is not subject to the evolution of undesirable gases.

Another object of my invention is to provide a new and improved thermionic emitter of the dispenser type which is particularly adapted for high, uniform current density over the entire active surface thereof.

Another object of my invention is to provide a new and improved method of manufacturing a dispenser-type cathode.

Another object of my invention is to provide a dispenser-type cathode which can take any one of several different forms depending upon the application involved.

Further objects and advantages of my invention will become apparent as the following description proceeds and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming part of this specification.

Briefly, my invention contemplates a new and improved thermionic emitter of the dispenser type comprising a

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compressed fused mixture of powders consisting essentially of (1) a refractory matrix material selected from the group consisting of tungsten, tantalum and molybdenum, the silicides, borides and carbides of such metals and combinations thereof; and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and adapted for thermal dissociation of the barium from the compound upon heating. The emitter is preferably manufactured by admixing uniformly the powdered refractory matrix material and activator compound constituents and then compressing the resultant admixture with a predetermined pressure effective for fusing the powdered constituents into a compressed coherent body having a consistency and internal structure whereby the body is adapted for the uniform migration to the surface thereof of elemental activator upon thermal dissociation of the barium from the activator compound.

For a better understanding of my invention, reference may be had to the accompanying drawing wherein:

FIGURE 1 is a sectional view of a dispenser-type emitter constructed in accordance with an embodiment of my invention.

FIGURE 2 is a fragmentary somewhat schematic illustration of apparatus employable in manufacturing my improved emitter;

FIGURE 3 is a fragmentary sectional view illustrating a modified form of my invention; and

FIGURE 4 is a fragmentary perspective view illustrating another modified form of my invention.

Referring to FIGURE 1, there is illustrated a thermionic emitter of the dispenser type generally designated 10 and constructed according to an embodiment of my invention. The emitter 10 is in a plug-like form and is supported in a flared end of a cathode holder 11 which is tubular and is preferably formed of a refractory metal such as molybdenum, tungsten or tantalum. It is to be understood that the cathode holder 11 need not be flared and can comprise a straight-walled cylindrical or tubular member of any desired cross-sectional configuration. A heating element 12 is contained in the holder 11 for heating the emitter, thereby to effect electron emission from the transverse active outer end surface 13.

The emitter 10 is a compressed densely packed fused body of powdered constituents of approximately 325 mesh and consists essentially of (1) a refractory matrix material selected from the group consisting of tungsten, tantalum and molybdenum, the silicides, borides and carbides of tungsten, tantalum and molybdenum and combinations thereof; and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof. More specifically, the emitter 10 is preferably formed of a generally uniform powdered densely packed and fused mixture of one of the mentioned refractory metals or refractory metal compounds and one of the mentioned activator compounds. However, it is to be understood that combinations of the refractory metal and refractory metal compounds as well as combinations of the activator compounds can be employed in practicing my invention. This mixture is compressed at between approximately 70 to 80 tons per square inch to a desired shape and whereby the metal particles constituting the powdered constituents are fused together to provide a coherent unitary body. In the present disclosure the term "fused" is used to mean that the particles constituting the body are blended or joined as a result of the pressure applied to the mixture much in the same sense as metal members are cold welded or fused together by application of pressure thereto. Such

a process which uses essentially pressure only is denoted as cold pressing, i.e., pressing in the absence of applied elevated temperatures where fusing is directly related to the temperature.

Illustrated in FIGURE 2 is apparatus whereby the structure of FIGURE 1 can be constructed. This apparatus comprises a female die construction adapted for holding the cathode holder 11 firmly in an inverted position against a smooth surface die 14 while a quantity of the above-discussed powdered mixture designated 15 is compressed by the actuation of a ramrod 16. The ramrod 16 is actuated with a force effective for compressing the mixture at the above-mentioned pressure of between approximately 70 to 80 tons per square inch. In this manner the desired form of the emitter illustrated in FIGURE 1 is obtained and the emitter is formed as a compressed fused body having a desired consistency and porosity which contributes to the effectiveness of the emitter in providing a desired low effective work function and insuring uniform complete coverage of the active or emissive surface 13 with barium during energization of the heater 12. Upon heating of the emitter 10 in a vacuum atmosphere, as by energization of the heater 12 with the emitter incorporated in an electric discharge device, the barium of the activator compound is thermally dissociated and diffuses through the body and migrates uniformly to and over the exposed planar active surface 13. Thus is provided an emitter having a refractory substrate bearing an active surface 14 uniformly covered with elemental barium for providing a high density source of electrons and characterized by a substantially reduced effective work function. Additionally, in this structure the activator compound is continuously subject to thermal dissociation of the barium therefrom upon energization of the heater 12. Thus, the active surface 13 is continuously replenished with elemental barium during operation of the device to maintain the reduced effective work function of the system and to insure the complete uniform coverage of the active surface for maximizing uniform high current density of the system.

Illustrated in FIGURE 3 is a modified form of my invention. In this embodiment the emitter is generally designated 20 and can be formed to include a compressed fused body 21 formed of the same material as the member 10 in FIGURE 1 but constituting a coating on a base member 22. In this embodiment the base member 22 can be formed of a refractory metal such as tantalum, tungsten or molybdenum and the coating-like body 21 can be fused to the base member 22 in much the same manner as the individual particles making up the coating 21 are mutually fused. Provided for rendering the emitter 20 emissive is a heating element 23. Apparatus generally similar to that illustrated in FIGURE 2 can be employed for providing the pressure necessary to form the coating materials as a compressed fused body fused to the base 22. This embodiment of my invention can be planar as illustrated or can assume any desired configuration, such as a cylinder.

Illustrated in FIGURE 4 is another modified form of my invention. In this embodiment the emitter generally designated 25 is formed of the same material as the emitter 10 in FIGURE 1 and the coating 21 in FIGURE 3. However, in this embodiment the mixture is compressed to provide a generally cylindrical or tubular coherent and self-sustaining body adapted for containing a heating element 26. This embodiment of my invention can also be formed by means generally similar to that illustrated in FIGURE 2 and adapted for applying appropriate pressure to effect the predetermined fusing of the constituent particles.

A number of emitters constructed according to my invention as described above have been prepared and tested for the purpose of demonstrating the effective work functions and activator evaporation rates attainable therewith. The following chart lists some of the emitter sys-

tems tested at a given operating temperature of 1250° K. and the emission and evaporation properties observed:

	System in Weight Percentages	Effective Work Function at 1,250° K., ev.	Evaporation Rate in Grams per cm. ² per sec.
5	Tungsten and Barium Silicide, 90% W +10% BaSi ₃	2.40	1.16×10 ⁻⁴
	-----	2.39	1.45×10 ⁻⁴
10	Tungsten Carbide and Barium Silicide, 90% WC+10% BaSi ₃	2.28	3.0×10 ⁻⁷
	-----	2.28	1.3×10 ⁻⁸
	Tungsten Silicide and Barium Silicide, 90% WSi ₂ +10% BaSi ₃	2.39	6.8×10 ⁻⁸
	-----	3.00	4.2×10 ⁻⁹
15	Tungsten Boride and Barium Silicide, 90% W ₂ B ₃ +10% BaSi ₃	2.05	8.5×10 ⁻⁶
	-----	2.23	2.6×10 ⁻⁷
	Tantalum Silicide and Barium Silicide, 90% TaSi ₂ +10% BaSi ₃	2.42	4.6×10 ⁻⁷
	-----	2.61	4.2×10 ⁻⁸
20	Tantalum Boride and Barium Silicide, 90% TaB ₂ +10% BaSi ₃	2.72	-----
	-----	2.73	2.3×10 ⁻⁸
	Molybdenum Carbide and Barium Silicide, 90% Mo ₂ C+10% BaSi ₃	2.61	1.5×10 ⁻⁶
	-----	2.61	-----
25	Molybdenum Silicide and Barium Silicide, 90% MoSi ₂ +10% BaSi ₃	3.44	-----
	-----	2.50	3×10 ⁻⁸
	Molybdenum Boride and Barium Silicide, 90% Mo ₂ B+10% BaSi ₃	2.52	2.8×10 ⁻⁸
	-----	2.66	1.4×10 ⁻⁶
30	Tungsten and Barium Aluminide, 90% W+10% BaAl ₃	2.75	1.5×10 ⁻⁸
	-----	2.37	5.5×10 ⁻⁷
	Tungsten Carbide and Barium Aluminide, 90% WC+10% BaAl ₃	2.33	1×10 ⁻⁹
	-----	-----	-----
	Tungsten Silicide and Barium Aluminide, 90% WSi ₂ +10% BaAl ₃	-----	-----
	-----	-----	-----
	Tungsten and Barium Iodide, 90% W+10% BaI ₂	-----	-----

It is to be understood that while I have not listed in the above chart all of the systems falling within the purview of my invention, the other systems which are encompassed by my invention, including, for example, those involving the admixture of barium iodide with tantalum and molybdenum, the carbides, silicides, and borides of tungsten, tantalum and molybdenum and the admixture of barium aluminide with tantalum and molybdenum, the carbides, silicides and borides of tantalum and molybdenum and the mixtures of combinations of various noted constituents, are equally effective in providing a low effective work function and low evaporation rate emitter having properties comparable to those indicated in the chart above.

Also, while the activator compound was in each case in the systems included in the above chart, approximately 10% of the composition of the system under test, it is to be understood that the percentage composition of the systems can vary substantially and still be characterized by a desirably low effective work function and evaporation rate. For example, the benefits of my invention are obtainable when the barium silicide, barium iodide and barium aluminide constitute more than zero and less than 100 percent of the composition of the mixture of which the emitter is formed. However, the use of a composition including approximately 10% of either barium silicide, barium iodide or barium aluminide or combinations thereof with the remainder one or more refractory matrix materials is considered preferable.

Actually, in conducting the tests whereby the above-listed information was obtained, the temperature 1250° K. was arbitrarily selected for test purposes and the effective work functions and activator evaporation rates indicated are those calculated for this temperature. This, however, is not to be construed as indicating that the disclosed emitters are operative only at the temperature indicated, but is intended to demonstrate that desired low work functions and satisfactory evaporation rates are obtainable at that temperature. Additionally, it is to be noted that the above chart shows no evaporation rate data for two of the systems indicated. It is expected that such

data would not be substantially different from that noted in respect to the other systems indicated.

Further, the effective work functions and evaporation rates will vary, of course, with different temperatures and can be determined by use of calculations well known to those skilled in the art. However, it can be seen from the data included in the above chart that the described systems are adapted for effective work functions which are considerably lower than the work functions of most metals. Additionally, the effective work functions approach closely the work functions of alkaline earth oxide cathodes. These latter types of cathodes have low work functions but are limited in applications inasmuch as they cannot withstand high operating temperatures and back bombardment experienced in some devices such as magnetrons. The presently disclosed dispenser cathodes are particularly adapted for high temperature operation and for withstanding electron bombardment while having desirably low effective work functions.

Additionally, the presently disclosed dispenser cathodes are adapted for reducing evaporation of the activator which serves to insure more uniform high density emission across the active surface and longer cathode operating life. This evaporation rate is reduced further when the cathode is operated in a gaseous atmosphere or at operating temperatures substantially lower than that indicated above.

While I have shown and described specific embodiments of my invention, I do not desire my invention to be limited to the particular forms shown and described, and I intend by the appended claims to cover all modifications within the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A thermionic cathode comprising a densely packed fused mixture of powders consisting essentially of (1) a refractory matrix material and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof.

2. A thermionic cathode comprising a refractory metal sleeve, a densely packed fused mixture of powders positioned in one end of said sleeve, said powders consisting essentially of (1) a refractory matrix material and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof, and means contained in said sleeve for heating said mixture to effect thermal dissociation of the barium from the activator compound therein for migration to the outer end of said mixture.

3. A thermionic cathode comprising a densely packed fused mixture of powders comprising a coating fused to and supported on a refractory metal base member, said mixture consisting essentially of (1) a refractory matrix material and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof, and means for heating said base member to heat said coating thereby to effect thermal dissociation of the barium from said

activator compound for migration to the surface of said coating.

4. A thermionic cathode comprising a densely packed fused mixture of powders in cylindrical form, said powders consisting essentially of (1) a refractory matrix material and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof, and means for effecting heating of said mixture to effect thermal dissociation of the barium from the activator compound therein for migration to the exterior surface of said mixture.

5. A thermionic cathode comprising a body of compressed fused powdered constituents consisting essentially of (1) a refractory matrix material selected from the group consisting of tungsten, tantalum and molybdenum, the silicides, borides and carbides of tungsten, tantalum and molybdenum and combinations thereof; and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof.

6. A thermionic cathode according to claim 5, wherein the activator compound constitutes approximately 10% of said mixture.

7. A method of manufacturing a thermionic cathode comprising the steps of providing a powdered mixture consisting essentially of (1) a refractory matrix material and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof, and compressing said mixture at a pressure effective for forming said mixture as a densely packed coherent body.

8. The method of manufacturing a thermionic converter according to claim 7, wherein the pressure exerted on said mixture is in the range of between approximately 70 and 80 tons per square inch.

9. The method of manufacturing a thermionic cathode comprising the steps of providing a powdered mixture consisting essentially of (1) a refractory matrix material selected from the group consisting of tungsten, tantalum and molybdenum, the silicides, borides and carbides of tungsten, tantalum and molybdenum and combinations thereof; and (2) an activator compound selected from the group consisting of barium silicide, barium iodide and barium aluminide and combinations thereof, and compressing said mixture at a pressure of between approximately 70 and 80 tons per square inch for effecting a densely packed coherent body wherein the particles of said constituents are fused.

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