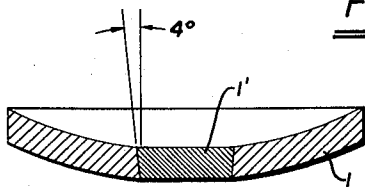
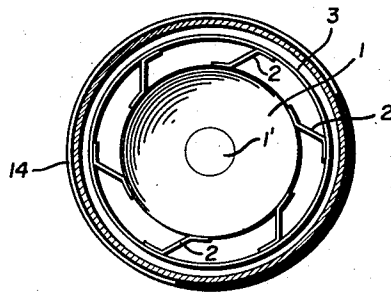
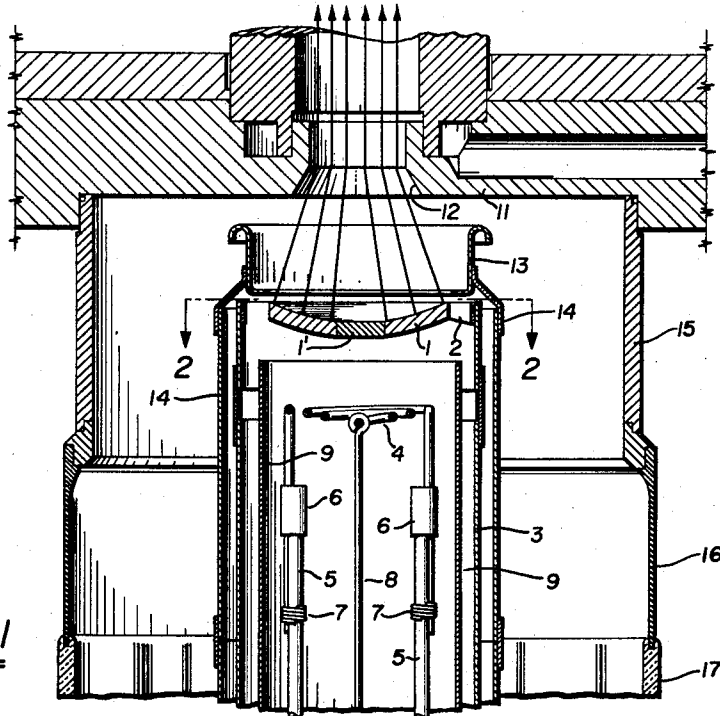


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CHARGED PARTICLE EMITTER APPARATUS

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CHARGED PARTICLE EMITTER APPARATUS

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The present invention relates in general to charged particle emitters and more specifically to a novel improved electron emitter or cathode useful, for example, in obtaining high permeance electron beams utilized in velocity modulation type vacuum tubes and the like.

The present invention relates to improvements in bombarded cathodes which are especially suitable for continuous, high current density emission wherein, in addition, the emitter is subjected to high accelerating voltages. An exemplary application of such a bombarded cathode is the emitter utilized in high power klystron amplifiers presently utilized for the high power amplification of television signals. A klystron amplifier embodying such a cathode is taught in a copending U.S. patent application entitled "High Frequency Tube," S.N. 370,568, invented by Wayne G. Abraham et al., filed July 7, 1953, now U.S. 2,879,440.

In emitter applications where the emitter must provide continuous, high current density emission into a high accelerating electric field, standard high current density emitters such as, for example, oxide emitters are found to be unsatisfactory. These standard cathodes are unsatisfactory because positive ions that are created by the collisions between the accelerated electrons of the beam and residual gas molecules in the tube cause ions to form in the center of the beam. Then because the ions have a positive charge and a strong continuous electric field exists between the center of the beam and the cathode the positive ions will be accelerated toward the cathode. During their flight from beam to cathode the positive ions will pick up a considerable amount of kinetic energy. This energy will be imparted to the cathode emitter upon collision therewith. The effect of the positive ion bombardment upon the oxide cathodes is to strip the oxide coating from the cathode surface and thereby render the cathode inoperative.

A pure metallic emitter is much more immune than oxide cathodes to the effects of ion bombardment. Examples of such pure metallic emitters are tantalum and tungsten. The operating temperature of a pure metallic emitter is much higher than the operating temperature of oxide coated cathodes. For example, oxide coated cathodes can operate at temperatures of approximately 850° C. whereas a pure metallic emitter such as, for example, tantalum must be operated at approximately 2000° C.

The radiation method of heating the cathode emitter, which is generally quite satisfactory for heating oxide coated cathodes, is generally not satisfactory for heating pure metallic emitters. The reason for this is that the hot body from which the heat must flow has to be considerably hotter than the cathode which it is heating or else heat will not radiate from the heater to the emitter. When the emitter operates at a relatively low temperature such as, for example, 850° C. it is easy to obtain a filament or heater which may operate at a substantially higher temperature such as, for example, 1400° C. However, when the emitter is made of a pure metallic substance

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such as, for example, tantalum having an operating temperature of 2000° C. it is difficult if not impossible to find a heater capable of withstanding the temperature differential necessary to obtain good radiation heating.

Direct heating methods for heating the cathodes may sometimes be employed. The direct heating method consists of running an electrical current through the cathode emitter itself thereby heating the emitter due to the I²R losses of the emitter material. Utilizing this technique it is easy to heat the emitter to the required operating temperature of 2000° C. or higher. It will be noted that an electrical potential gradient is obtained along the length of the cathode emitter when it is heated utilizing the direct method. This small potential gradient arises from the IR drop per unit length of the cathode emitter.

In many applications a gradient cathode is generally considered to be unsatisfactory. For example, in velocity modulation type tubes such as, for example, klystrons and traveling wave tubes a unipotential cathode is normally specified to minimize the electron gun design complexity and to minimize perturbations in the electron beam. Therefore, in such applications the direct heating method for heating the cathode emitter is not utilized.

A bombarding heating method is the one found most satisfactory for heating pure metallic emitters. The bombarding heating method utilizes a first electron emitter which emits the electrons into a relatively strong accelerating field. The electrons thus emitted are accelerated into a beam and focused upon the back surface of a second cathode emitter. The heat generated by the collision of the first electron beam with the back side of the cathode emitter furnishes the necessary heat to heat the second cathode emitter.

Utilizing the bombarding technique emitter temperatures of 2000° C. are easily obtained. In general, this method of heating the cathode has been found satisfactory providing that the electrons bombarding the cathode emitter are properly focused onto the back side of the emitter to yield a uniform temperature and therefore a uniform emission from the front side.

Although the positive ion bombardment difficulties were minimized by the use of a pure metallic emitter it was found that holes were still appearing in the center of tantalum emitters. The cause of these holes in the cathode emitter is most probably three fold. Undoubtedly, one cause is the bombardment of the cathode emitter by high energy positive ions. A second cause is believed to be the effect of imperfect focusing of the bombarding electron beams, which results in the concentration of heat at the center of the button. Thirdly, the button temperature is made even cooler at the edges due to the mechanics of physically supporting it, and the consequent conductive cooling to the support members. Thus, the center of the cathode emitter operates at a higher temperature and therefore evaporates at a faster rate than the rest of the cathode emitter.

When a hole appears in the cathode emitter the bombarding electrons are allowed to pass therethrough and enter the main pencil-like beam of the velocity modulation tube. When this takes place and A.C. hum due to the A.C. filament current appears on the main electron beam and manifests itself as hum on the amplified R.F. signal. In addition, as the tube continues to operate the hole in the emitter will continue to grow in size thereby decreasing the total emission. Decreasing the emission decreases the power output of the tube thereby shortening its useful life.

In the present invention portions of the cathode emitter which are likely to burn through or melt are replaced by a material having a more refractory characteristic and lower vapor pressure thereby preventing the positive

ions and/or the poorly focused bombarding electrons from creating a hole therein. In this manner the operating life of the cathode emitter is greatly extended and consequently the tube life greatly enhanced.

The principal object of the present invention is to provide a novel improved charged particle emitter capable of providing continuous, high current density emission into relatively high accelerating fields.

One feature of the present invention is the provision of a novel refractory insert for the cathode emitter whereby the cathode is capable of withstanding high energy bombardment for extended periods of time.

Another feature of the present invention is the provision of a taper upon the side walls of the refractory insert whereby the insert may be pressed into a mating bore in the cathode emitter thereby providing a most intimate contact between the insert and the surrounding metal such that both mechanical bonding and thermal effects (heat flow) are maximized.

Other features and advantages of the present invention will be more apparent after a perusal of the following specification taken in connection with the accompanying drawings wherein,

Fig. 1 is a cross sectional view of a portion of a cathode assembly embodying features of the present invention,

Fig. 2 is a cross sectional view of a portion of the structure of Fig. 1 taken along line 2—2 in the direction of the arrows, and

Fig. 3 is an enlarged cross sectional view of a portion of the structure of Fig. 1.

Referring now to Fig. 1 there is shown a cross sectional view of a portion of the anode and cathode assembly of a high power klystron amplifier substantially identical to the klystron amplifier of the aforementioned copending patent application except for the incorporated novel features of the present invention.

An annular concave emitter 1 as of, for example, tantalum forms the emitter portions of a Pierce type electron gun assembly. A circular disk-like cathode center insert 1' is provided in the center of the annular cathode emitter 1. The cathode insert 1' is made of material having a more refractory composition or lower vapor pressure than the annular emitter 1 such as, for example, tungsten or thoriated tungsten. The peripheral edge of the cathode insert 1' is tapered (see Fig. 3) and pressed into the center of the annular cathode emitter 1. Although 4° has been shown as the degree of taper other degrees of taper should work equally well. The press fit allows an excellent conducting junction between the insert 1' and the emitter 1. A good conducting junction facilitates the flow of heat energy through the junction and thereby aids in obtaining a uniform temperature distribution over the cathode emitter 1.

A plurality of resilient fingers or struts 2 are fixedly secured at one end thereof to the outside peripheral edge of the emitter 1 as by spot welding. The resilient fingers 2 are made of a material having a high melting point such as, for example, tantalum. The resilient fingers 2 are carried tangentially at the other ends thereof by the inside wall of a hollow cylindrical support 3 of a material having a high melting point such as, for example, tantalum. The cathode support 3 also serves as a heat shield to help retain the heat energy within close proximity to the cathode emitter 1. The cathode support 3 is operated at cathode potential.

A double spiral wound filament 4 is positioned in spaced apart relation from the convex face of the cathode emitter 1. The filament 4 serves as the electron emitter for supplying the electrons for bombarding the back or convex face of the cathode emitter 1 and insert 1'. The double spiral configuration is provided to facilitate even heating of the back surface of the cathode emitter 1 and insert 1'. In addition, the double wound spiral filament 4 is slightly concave shaped to further aid even bom-

bardment of the back surface of the cathode emitter 1 and insert 1'.

The filament 4 forms a direct electron emitter having its heating current supplied via two supporting filament support posts 5. The filament heating current is normally 60 cycle A.C. current derived from the 60 cycle line. The two end portions of the double spiral wound filament 4 are bent substantially at right angles to the plane of the filament thereby forming two filament legs. The filament legs are fixedly secured to the filament support posts 5 via two filament clips 6 and two wire wraps 7.

The filament clips 6 and wire wraps 7 are made of a material having a high melting temperature such as, for example, molybdenum. Although the double spiral wound filament 4 is not a unipotential emitter the potential gradient effects are minimized by the double spiral winding configuration. The operation potential of the filament 4 is approximately 2500 volts more negative than the potential applied to the cathode emitter 1. In this manner the necessary accelerating voltages are applied between the filamentary emitter 4 and the unipotential cathode 1.

A filament center support post 8 is connected to the center of the double spiral wound filament 4 substantially at the midpoint thereof to prevent sagging of the filament 4 in use. The filament center support post 8 is electrically insulated from the double spiral filament 4 via an electrical insulator (not shown). The center support post 8 is made of a material having a high melting point such as, for example, tungsten.

A hollow cylindrical filament focus electrode 9 is positioned concentric to the double spiral filament 4 and serves a dual function of retaining the heat energy within the filament vicinity and of focusing the electrons emitted from the filament 4 against the back side of the cathode emitter 1 and insert 1'. The filament focus electrode 9 is operated at the same potential as the filament emitter 4.

An apertured, flat anode 11 is positioned in spaced apart relation from the concave surface of the cathode emitter 1. The anode 11 is provided with a flared aperture 12 in alignment with the cathode emitter 1 to facilitate focusing of the emitted electrons into a beam. The electron beam passes through the flared aperture without appreciable beam interception. The anode operates at a high positive potential with respect to the potential of the cathode emitter, for example, 17,500 volts more positive.

A flared hollow cylindrical cathode focus electrode 13 is positioned concentric to the cathode emitter 1 and in overhanging spatial relation thereto to aid in focusing the emitted electrons through the aperture 12 in anode 11. A hollow cylindrical cathode focus support 14 serves to carry the cathode focus electrode 13. The cathode focus electrode 13 and support 14 operate at the same potential as the cathode emitter 1 and both are made of a material having a high melting temperature such as, for example, tantalum.

A tubular member 15 forming a portion of the outer cathode envelope is positioned concentric of the inner cathode assembly and is carried by the anode 11. The tubular member 15 is made of a non-magnetic material such as, for example, copper to prevent perturbation of the magnetic focusing field in this region. A second thin walled tubular member 16 as of Kovar is carried upon one end of the tubular member 15 and is coupled to a hollow cylindrical dielectric insulator 17 as of glass. The thin tubular Kovar member 16 is made yieldable to allow for thermally caused expansion and contraction of the dielectric insulator 17 in use. The insulator 17 serves to insulate the anode 11 from the much lower voltage applied to the cathode assembly.

In operation electrons are emitted from the filament 4 and focused upon a back side of the cathode emitter 1 including the cathode insert 1'. Since the potential difference between filament 4 and cathode emitter 1 and

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1' is approximately 2500 volts the electrons bombarding the back side of the emitter transform their kinetic energy into heat energy. In this manner the operating temperature of the cathode emitter 1 and insert 1' are brought up to approximately 2000° C. which allows the cathode 1 to become electron emissive.

The electrons emitted by the concave cathode emitter 1 are drawn away from the cathode 1 and focused into a beam due to the combined action of the cathode focus electrode 13 and anode 11. The beam passes through the flared aperture 12 in the anode 11 and passes into the energy interaction area of the vacuum tube.

Positive ions created due to the collision of electrons within the beam and residual gas molecules within the tube collect in the center of the electron beam. Upon collecting the positive ions are accelerated toward the cathode emitter 1 and insert 1' and focused thereupon due to well known physical phenomena. The bombarding positive ions having obtained considerable kinetic energy collide upon the cathode 1 and insert 1' and cause additional heating thereof. Due to the edge cooling of the cathode 1 by the supporting resilient fingers 2 and cathode support 3 and due to imperfect focusing of the bombarding electrons the center of the cathode becomes somewhat hotter than the edge. However, due to the more refractory composition of the center insert 1' and lower vapor pressure of the insert 1' and due to the good heat conducting junction between the insert 1' and the annular emitter 1 adverse effects caused by overheating of the cathode are eliminated. It is believed that when the annular cathode emitter 1 is made of tantalum and the center insert 1' is made of tungsten emission takes place from the center insert 1' as well as from the annular emitter 1 thereby minimizing perturbations of the electron beam which might arise from a hollow beam.

Since many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. An electron emitter apparatus for applications where portions of the emitter are subjected to higher temperatures than other portions including, a first emitter member for providing high current density emission at normal operating temperatures in excess of 1500° C., a second member made of a material having a more refractory composition than said first member and disposed within said first emitter member in the areas of higher average temperature thereof whereby the deleterious effects of the higher temperature may be counteracted and the operating life of the electron emitter greatly extended.

2. In an apparatus as claimed in claim 1 wherein said first emitter member comprises a portion of a concave emitter.

3. In an apparatus as claimed in claim 1 wherein

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said first emitter member comprises a portion of a substantially unipotential emitter.

4. In an apparatus as claimed in claim 1 wherein said first and second members comprise portions of a substantially unipotential emitter.

5. In an apparatus as claimed in claim 4 wherein said second refractory member is centrally disposed within said emitter member and in contiguous relationship thereto.

6. In an apparatus as claimed in claim 4 wherein said first emitter member comprises a substantially annular segment of a sphere, and said second refractory member comprises a substantially circular disc mounted within and closing over the central aperture in said first annular emitter member.

7. In an apparatus as claimed in claim 6 wherein said second refractory member of substantially circular configuration is provided with a tapered peripheral edge for press fitting within the central aperture of said first annular emitter member to thereby facilitate mechanical bonding and heat flow through the bond to minimize deleterious effects produced by local concentrations of heat energy.

8. In an electron discharge apparatus utilizing a high current density electron beam for interaction with high frequency electromagnetic fields and having a cathode assembly including a first high current density emitter for supplying the electrons making up the beam and said first emitter being disposed in axial alignment with the beam of electrons, a filamentary emitter member disposed in spaced apart relation from said first high current density emitter on the side thereof remote from the electron beam and serving as a source of electrons for bombarding said first emitter member, the bombarding electrons serving to heat said first emitter member to an operating temperature in excess of 1500° C., a tungsten member disposed in axial alignment with the electron beam and adjacent said first high current density emitter, and said tungsten member having a more refractory composition and lower vapor pressure than that portion of said first emitter immediately adjacent to said tungsten member to thereby prevent damage to said first emitter caused by local concentrations of heat in the vicinity of said first emitter and said tungsten member.

9. In an apparatus as claimed in claim 8 wherein said first emitter member comprises an annular tantalum segment of a sphere, said tungsten member comprises a circular disc mounted within a central aperture in said first emitter member, and said filamentary emitter comprises a double spiral wound filament having a concave shape to facilitate even heating of said first emitter member.

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