ABSTRACT OF THE DISCLOSURE

In an electron discharge device of the type having opposed anode and cathode surfaces and in which upon heating the anode elongates and tends to reduce the inter-electrode spacing, a compensating structure consists of a refractory cylinder which surrounds the anode out of the path of the electron flow so that it operates at a lower temperature than the anode itself and which has a higher coefficient of terminal expansion than the anode material and expands in a direction opposite to that of the anode. The refractory cylinder is sealed between the edge of a supporting flange of the anode and a ceramic cylinder having its other end sealed to a conventional annular type control electrode disk.

This invention relates to high current density electron discharge devices and particularly to such a device including a structure whereby the high temperature expansion of the anode is compensated.

In high current density electron discharge devices such as disclosed and claimed in my copending application Ser. No. 410,570, filed Nov. 12, 1964, and assigned to the assignee of the present invention, the discharge device electrodes operate at high temperatures; for example, the anode structure of these devices frequently reaches temperatures on the order of 600° C. as a result of electron bombardment from the cathode. This discharge device anode is relatively large in size compared to the other electrodes and is provided with cooling structure in order to increase the present electrode capabilities thereof. When the anode operates at a high level of dissipation it expands in a direction toward the grid structure causing the output capacitance to increase, therefore resulting in detuning and other relatively disadvantageous effects, especially when the tube is operated at very high frequencies. The magnitude of the elongation can be reduced somewhat by making the anode from a metal having a low coefficient of thermal expansion. Even so, the elongation contributed by anode support structure cannot be decreased by this means, since the support structure must be formed of a material having a high expansion similar to that of a ceramic insulating or envelope portion of the tube, to which such support structure is bonded. Furthermore, this support structure should desirably provide a long enough path to prevent transmission of thermal and mechanical strains from the anode to the ceramic body. Therefore, the extent to which expansion can be reduced, through choice of material, is limited.

It is, therefore, an object of the present invention to provide an anode structure wherein the movement of an electron discharge device anode with temperature change is substantially reduced or eliminated.

In accordance with the present invention, an anode structure, and particularly an anode support structure, provides compensation for the expansion of the anode of an electron discharge device toward the grid of the same electron discharge device. This anode, rather than being supported from a lower or depending portion of an anode support ring, is supported from the opposite side of an anode support ring that is the side remote from grid-anode interelectrode gap. The support ring is provided with a thin section whereby a maximum temperature drop occurs in the thin section of the anode support ring. Then this thin section expands away from the discharge device interelectrode gap as the anode expands towards the interelectrode gap, achieving compensation between the two. Furthermore, the temperature drop in the thin section facilitates sealing to a ceramic portion of the device envelope at this point.

The subject matter which I regard as my invention is particularly pointed out and distinctly claimed in the concluding portion of this specification. The invention, however, both as to organization and method of operation, together with further objects and advantages thereof, may best be understood by reference to the following description taken in connection with the accompanying drawings wherein the reference characters refer to like elements and in which:

FIG. 1 is a view partially in cross-section of a tube construction as employed heretofore,

FIG. 2 is a view partially in cross-section of a tube construction in accordance with the present invention wherein the expansion of the anode electrode is compensated, and

FIG. 3 is a view partially in cross-section of a tube construction in accordance with another embodiment of the present invention.

Referring to FIG. 1, a tube construction includes a relatively massive cylindrical anode 1 having a planar electrode end face 2 disposed opposite a grid electrode 3 supported from grid support ring 4. An anode support ring 5 providing an anode connection and including a depending annular flange 6 is circumferentially secured to the anode under a shoulder 7. Anode aperture support ring 8 is separated and insulated from grid ring 4 with a cylindrical ceramic envelope spacer 8 which may, for example, be formed of ferrite.

Depending flange 6 of anode support ring 5 is narrow in cross-section and takes a substantial amount of heat drop between the anode and its support ring 5 whereby support ring 5 does not reside at an excessively high temperature where it is joined to ceramic cylinder 8. Depending flange 6 is also long enough to prevent transmission of mechanical strains from the anode to the anode wherein to maintain the seal between the ring and ceramic spacer 8. In addition, anode support ring 5 including flange 6 is usually formed of a material having a coefficient of expansion similar to ceramic cylinder 8 to prevent fracture of the bond therebetween. Unfortunately, at high temperatures, both the anode 1 and flange 6 expand downwardly bringing face 2 of anode 1 closer to grid 3 causing the capacitance therebetween to increase. In accordance with the present invention, this movement of the anode towards the grid is substantially compensated with the structure as illustrated in FIGS. 2 and 3.

Referring to FIG. 2, having corresponding elements referred to with like reference numerals, an anode support and connecting ring 5 includes a thin portion extending cylindrical member or section 9, supporting and secured to the periphery of anode 1 under shoulder or flange 10 thereof which it immediately adjoins. Section or cylinder 9 is thin to afford a maximum temperature drop between flange 10 of anode 1 and support ring 5 where it is joined to ceramic cylinder 8 and the length of section 9 is not considerable. However, since thin section 9 extends upwardly, axially of the device, the expansion thereof is in the opposite direction from that of the anode 1 and a selected degree of compensation can be secured according to the material of section 9 and the length and thickness of section 9, in the direction along the axial length of the discharge device. Thin section 9 is coextensive with a portion of the anode electrode and close to flange 10 so that the heat drop which takes
place in section 9 occurs within this region whereby an extensive region of the support ring does not reside at too high a temperature and over compensates the downward expansion of anode 1. The anode support surface can thereby be held at a relatively stationary position relative to the grid electrode 3 in spite of a considerable rise in the anode temperature, and therefore the grid-anode capacitance can be held substantially constant.

The anode support ring 5 including compensating section 9 is a refractory material having lower thermal conductivity than the anode, therefore enhancing appreciable heat drop along thin section 9 between the anode and anode support ring 5 where it is joined to ceramic cylinder 8. Ring 5 should also have a coefficient of expansion compatible with the ceramic, titanium being a preferred material therefor. Zirconium, tantalum and niobium are also suitable materials.

Anode 1 is desirably provided with a relatively thin cylindrical section 11 between the main portion of anode 1 and flange 10. Flange 10 being materially behind the planar face 2 of anode electrode 1. In the illustrated embodiment, the anode 1 is desirably formed of molybdenum or tungsten, refractory materials which are quite thermally conductive, thus maintaining the anode at a relatively uniform temperature and aiding in conducting heat to a radiator 12 or other heat exchange mechanism. Radiator 12 is then situated closer to the anode surface to increase the anode's dissipation capabilities. The anode material has a lower thermal coefficient of expansion than anode support ring 5, thus aiding the facility of compensation.

Because of the comparatively higher upward linear expansion of thin section 9, it can compensate for downward expansion of the anode even though the anode is at a higher temperature and has a greater overall vertical dimension. Ceramic cylinder 8 also expands upwardly somewhat, adding slightly to the expansion thin section 9. The following table illustrates examples of dimensions that can be employed to effect compensation. In each of these examples, for the instance of exact compensation, the thin section 9 of support ring 5 is thin enough to permit ceramic cylinder 8 to operate at about 35% of the anode temperature in the case of the molybdenum anode, and at about 20% of the anode temperature in the case of the tungsten anode.

<table>
<thead>
<tr>
<th>Material</th>
<th>Length (inches)</th>
<th>Coefficient linear expansion</th>
<th>Average temp., °C</th>
<th>Elongation (relative to grid node)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Molybdenum anode</td>
<td>0.25</td>
<td>0.000005</td>
<td>500</td>
<td>+1.25</td>
</tr>
<tr>
<td>Titanium support ring</td>
<td>0.25</td>
<td>0.000001</td>
<td>553</td>
<td>+0.87</td>
</tr>
<tr>
<td>Ceramic cylinder</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tungsten anode</td>
<td>0.25</td>
<td>0.000004</td>
<td>600</td>
<td>+1.0</td>
</tr>
<tr>
<td>Titanium support ring</td>
<td>0.25</td>
<td>0.000001</td>
<td>100</td>
<td>+0.75</td>
</tr>
<tr>
<td>Ceramic cylinder</td>
<td></td>
<td></td>
<td></td>
<td>+0.25</td>
</tr>
</tbody>
</table>

In many cases the linear compensation need not be exact but rather the opposite of downward expansion by the anode with upward expansion by thin section 9 is valuable in producing compensation to nearly any desired degree according to the respective electrode lengths and their heat distribution.

FIG. 3 illustrates another embodiment of the present invention including an anode support ring as well as an anode extension and shoulder which are both formed of relatively uniform thickness metal materials. In this embodiment, support ring or cylinder 13 is L-shaped in cross-section, having a lower portion resting on and bonded to ceramic cylinder 8 and an upwardly extending section supporting shoulder or flange 14 of anode extension 15. Anode extension 15, which can if desired form the anode itself, is again desirably formed of a lower expansion coefficient and more highly conductive material, while annular support ring 13 is desirably a higher expansion material which is a poorer conductor of heat.

Support cylinder 13 is quite thin in cross-section to provide a maximum heat drop. The upwardly extending portion compensates the downward expansion of anode 1 including extension 15 whereby the anode surface can remain stationary as the operating temperature of the discharge device changes. Since most of the heat drop occurs across the upwardly extending portion of support cylinder 13, most of the compensating expansion takes place in this part of support cylinder 13.

According to another aspect of the invention, the anode is formed of high thermal conductivity materials as given, to aid dissipation and conduction of heat to radiator, while the anode support includes a thin section of lower conductivity material, e.g., titanium, for separating the high temperature anode from the ceramic envelope member, the latter desirably operating at a much lower temperature. This construction has been illustrated in FIGS. 2 and 3 as well as in FIG. 1. Therefore, the anode may operate at a high temperature without fracturing the ceramic or the bond between the metal support ring and the ceramic.

While I have shown and described several embodiments of my invention, it will be apparent to those skilled in the art that many changes and modifications may be made without departing from my invention in its broader aspects; and I therefore intend the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

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

1. In an electron discharge device of the type having an anode member having a planar surface with a radially extending supporting flange thereon and an opposed planar cathode surface with a control electrode positioned between said surfaces and wherein during operation of the device electrons from said cathode heat said anode to cause thermal expansion thereof and movement of the anode surface toward the cathode surface, a structure for compensating the expansion of the anode in the direction of the cathode comprising a refractory cylinder having one end sealed to said flange and spaced radially outward from the anode member, said refractory cylinder having its other end mechanically connected to said cathode surface and being formed of a material having a coefficient of expansion greater than that of the anode member and upon heating of said device expanding in a direction opposite to the direction of expansion of the anode member, said cylinder being removed from the electron flow path between the cathode and anode surfaces, said flange being exposed to ambient temperature and heat from said anode flowing to said cylinder through said supporting flange, whereby said cylinder is maintained at a lower temperature than the anode member during operation of the device.

2. In the device of claim 1, a ceramic spacing cylinder having one end sealed to the other end of said refractory cylinder, said refractory cylinder having a thinner wall than said ceramic cylinder to form a high thermal resistance path between said flange and the ceramic cylinder.

3. In the device of claim 2, a planar radially extending annular metallic supporting member for said control electrode, said ceramic spacing cylinder having its outer end sealed to said annular supporting member.

4. In the device of claim 3, a radially extending metallic contact member for said cathode and a ceramic cylinder sealed between said annular supporting member and said cathode contact member.

5. The device of claim 1 in which said anode member is formed of a metal selected from the group consisting of molybdenum and tungsten and said refractory cylinder is formed of a metal selected from the group consisting of titanium, zirconium, tantalum and niobium.

6. The device of claim 5 in which the refractory cylinder is formed of titanium.
7. The device of claim 2 in which said refractory cylinder has a portion extending parallel to the longitudinal axis of the anode and which is sealed to the outer edge of said supporting flange, and a portion extending in a direction transverse to such longitudinal axis and sealed to said one end of said ceramic cylinder.

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