

May 18, 1954

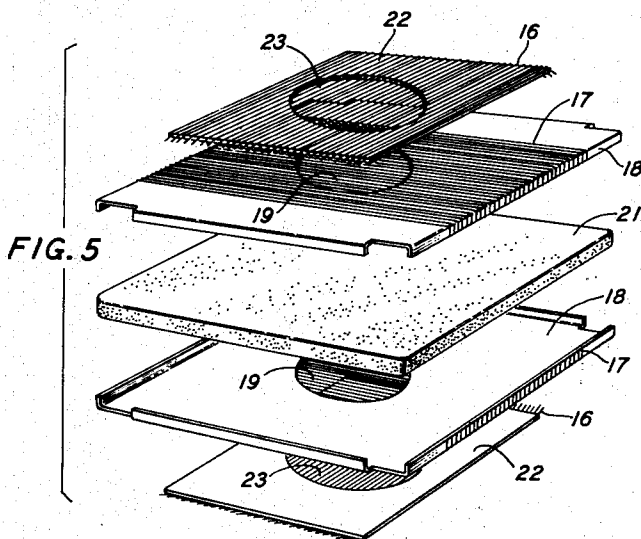
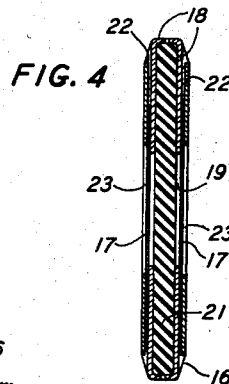
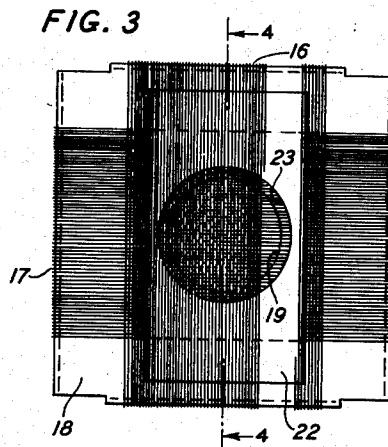
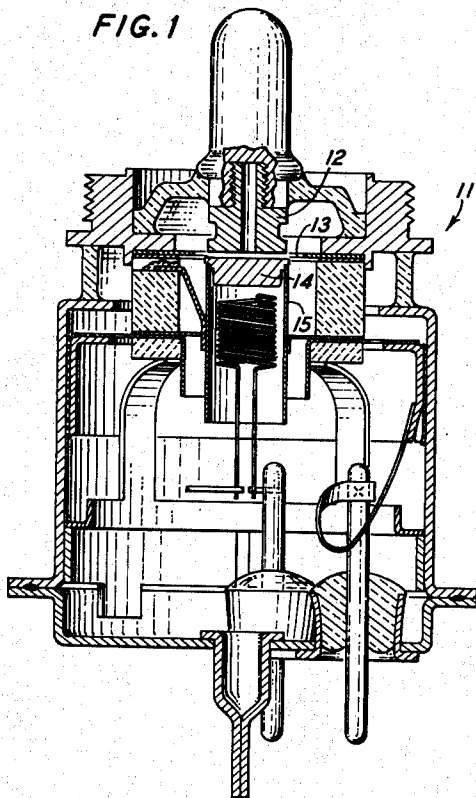
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2,678,486

GRID FOR ELECTRON DISCHARGE DEVICES

Filed Oct. 11, 1949

3 Sheets-Sheet 1



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FIG. 2

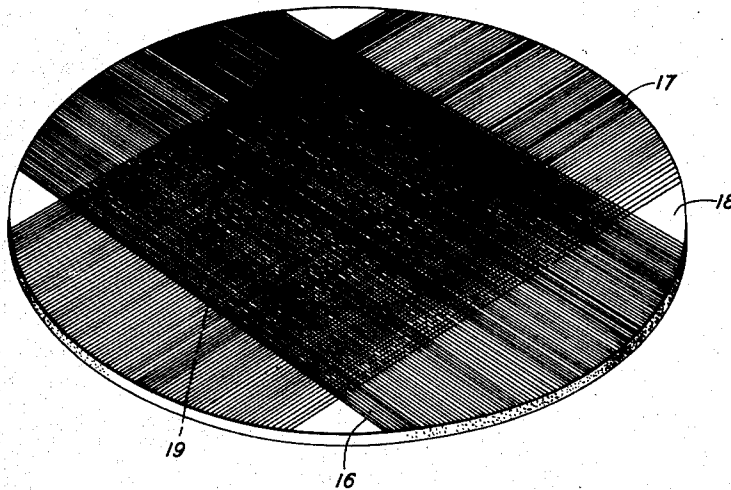


FIG. 6

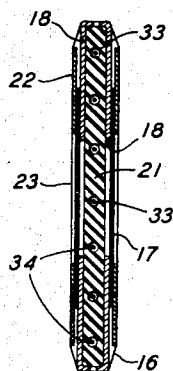
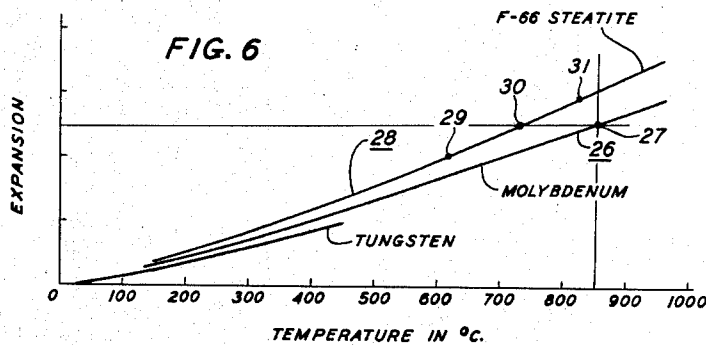


FIG. 7

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FIG. 8

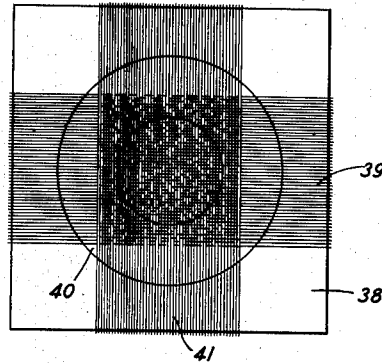
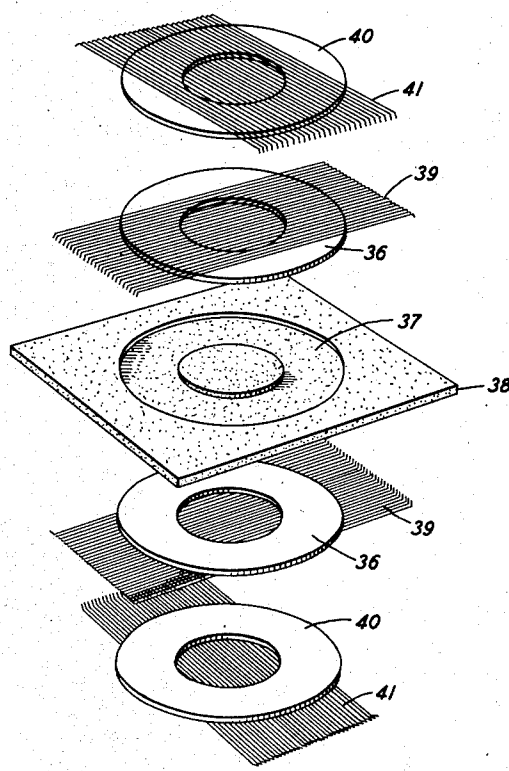


FIG. 9



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GRID FOR ELECTRON DISCHARGE DEVICES

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5 Claims. (Cl. 29—25.14)

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This invention relates to electron discharge devices and more particularly to the fabrication of a grid for such devices.

In such devices particularly suitable for use in broad-band frequency systems with high gain, difficulty has been encountered due to grid wire vibration. Because of the very small spacings involved in such devices, between the cathode emitting surface and the grids even slight vibrations in the grid wires cause large changes and distortions in the characteristic output of the device. Such vibrations may be caused by non-uniformity of electron emission which causes unbalanced magnetic forces between adjacent wires, by internal electrostatic forces, or by mechanical shock or vibration of the tube. However, basically in each case these troublesome vibrations are most severe when the grid wires are loose.

In tubes of the type above referred to, an illustrative example of which is that described in Patent No. 2,527,127, granted October 24, 1950, to R. S. Gormley, C. Maggs, and L. F. Moose, planar grids are used for very accurate spacings of the cathode, grid and anode assemblies in pile-up arrangement. In one typical grid assembly, the grid wires are brazed to one surface of a grid support ring or frame which is supported in accurate prescribed relation to the cathode and anode. While the grid wires may initially be wound on this support ring or frame with quite high tension, the subsequent heating and brazing operation may cause this initially high tension to be quite drastically reduced.

Such wires are often wound on two grid frames, back to back, at the same time. If the wires and frames are of different materials, the different expansivities cause the initial tension with which the wires were wound to drop very drastically following the brazing operation. Even if the wires and the frames are of the same material the different masses involved result in different expansions giving rise to the same deleterious result.

If the wires, such as of tungsten, were initially tightly wound on two grid frames, such as molybdenum, and then merely heated to a brazing temperature and cooled, but not brazed, the grid wires would be stretched in the process beyond their elastic limit and a permanent set introduced. In cooling the wires would contract but would retain this permanent deformation, causing the grid wires to be wound very loosely around the frames.

In one known process when the wires are

wound over some brazing material and then heated to a brazing temperature, the permanent deformation still takes place. When the brazing takes place the wires are held by the solidified brazing material in this elongated position. The molybdenum frame will then contract more than the wires so that the final product is still a grid with wires below the initial tension prior to brazing.

One primary object of this invention is to improve grid assemblies for electron discharge devices.

A further object of this invention is to provide grid assemblies wherein the grid wires are tighter so that deleterious vibrations are substantially reduced.

A still further object is to facilitate the fabrication of grids for electron discharge devices.

A still further object is to provide a method wherein the grid wires are not ruptured or materially destroyed during fabrication.

In accordance with one feature of this invention, a separator is inserted between the grid frames prior to the winding of the grid.

In accordance with another feature of this invention, the separator has a larger thermal expansion over a range of temperatures of moment, than the grid frame or wires.

In accordance with a further feature of this invention, the separator has a higher value of relaxation time than either the grid frame or wires.

In accordance with a still further feature of this invention, an additional stress is given to the grid wires just prior to the solidification of the brazing material to increase the final tension of the grid.

As is known, the grid wires are very taut on the frame immediately following the brazing, while the frames and wires remain at the elevated temperatures. This is because the wires have been held to the frame in their elongated position, so that the permanent set has no harmful effect. It is a feature of devices constructed in accordance with this invention that a further stress is introduced into the wire, beyond that which is given by the expansion of the frame, to cause a taut grid at these elevated temperatures and a resultant tauter grid following the contraction of the materials.

More specifically, it is a feature of this invention that following the flowing of the brazing material and before the heating source is withdrawn to allow the brazing material to solidify, the separator expands more than the grid frame

to give an additional small stress to the grid wires, which causes a large percentage increase in the grid tension at room temperatures.

The separator may be of any one of a variety of materials, either insulator or metal, though if of metal it must be coated with a ceramic material, such as aluminum oxide, to prevent adhesion to the frame during the brazing operation. It is not essential that the expansivity of the material be greater than that of the frame or the wire. It is, however, important that the total expansion be greater. Thus, while materials having higher expansivities, or incremental changes per unit length, have been found to be advantageous, a material having a lower expansivity, but a larger mass or thickness may also be used as it is the total expansion that is of major importance.

Further, it is to be realized that the expansivity should not be too greatly above that of the frame and wire materials lest the greater expansion during the brazing cause the grid wires to rupture.

It is also important that the separator temperature lag that of the grid frame. This it will tend to do to some extent regardless of the relative thermal characteristics of the materials because normally the heat is applied for the brazing operation from outside the wires and the frame and must therefore be transferred to the separator. However, it has been found advantageous to have a separator whose thermal characteristics are such that it will take a longer time to attain a certain temperature; this may also be expressed by saying that the separator must have a higher relaxation time. The relaxation time is a constant for any material which is defined by the expression

$$\tau = \frac{4x_0^2}{\pi^2 h^2} \quad (1)$$

where τ is the relaxation time, x_0 is the distance from one side to the center of a slab of the material of infinite length, and h is the thermal diffusivity of the material which is defined by the expression

$$h^2 = \frac{K}{\rho c} \quad (2)$$

wherein K is the conductivity of the material, ρ its density, and c its specific heat. It is thus seen that the relaxation time is a constant for a given material within the ranges in which the significant terms are constant. It can be shown that the relaxation time may be interpreted as the time for a heat pulse to travel into the center of the slab, a distance x_0 . The exact numerical value of τ , the relaxation time, is of course, determined by the thickness of the slab chosen; it is generally followed that the slab is of two-centimeter thickness so that x_0 is one centimeter, and values given herein for relaxation time are calculated using that value. For different values of x_0 , the time required for the heat to penetrate to the center of the slab is of course proportional to x_0^2 .

If a separator is chosen having too short a relaxation time, the overexpansion of the separator will also cause the grid wires to rupture.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing, in which:

Fig. 1 is a sectional view of one illustrative dis-

charge device employing a grid assembly fabricated in accordance with this invention;

Fig. 2 is a perspective view of a grid assembly such as may be fabricated in accordance with this invention;

Fig. 3 is a front view of one dual grid sandwich during the fabrication;

Fig. 4 is a sectional view taken along the line 4-4 of Fig. 3;

Fig. 5 is an exploded view of the sandwich of Fig. 3, showing particularly the internal separator;

Fig. 6 is a graph showing the expansivities of various materials that may be employed in the method in accordance with this invention;

Fig. 7 is a sectional view of a sandwich, similar to Fig. 4, and showing one modification of this invention;

Fig. 8 is a part view of another dual grid sandwich during the fabrication; and

Fig. 9 is an exploded view of the sandwich of Fig. 8, showing particularly the interval separator.

Referring now to the drawings, Fig. 1 shows one device 11 suitable for use in microwave applications in which high transconductance, high gain, low capacitance losses, and high power output are of paramount importance. This device 11, which is described in detail in Patent No. 2,527,127, granted October 24, 1950, to S. Gormley, C. Maggs, and L. F. Moose, comprises an anode button 12, a planar grid 13, and a cathode disc 14 having an emissive coating applied thereto and being supported in a sleeve member or supporting housing 15.

The planar grid 13, as shown in Fig. 2, is a cross-lateral grid, the windings 16 and 17 being brazed to a circular frame 18 having a central aperture 19; either the wires or frame may advantageously be of tungsten or molybdenum. In the fabrication of this planar grid as shown clearly in Fig. 5, two rectangular frames 18 are placed back to back, the frames having their edges rounded off as by bending and the apertures 19 centrally located therein. A separator 21 is placed in the space between the two frames 18 and the fine wire 17 wound over the pair of plates by the winding methods disclosed in Patent No. 2,566,848, granted September 14, 1951, to J. A. Morton. A foil of brazing material or alloy 22 having an aperture 23 coinciding with aperture 19 in frame 18 is then placed on each frame on top of the wound wires 17. Wire 16 is then wound over the brazing foil 22 at right angles to the wire 17. The dual-grid assembly, which combination will hereinafter be referred to as a sandwich, then appears as shown in Figs. 3 and 4.

In accordance with a feature of this invention, the separator 21 is of a material having particular thermal characteristics with respect to the materials of the grid frame and wires. Specifically, the separator has a larger expansion at the brazing temperature and a higher value of relaxation time. A fuller appreciation of these limitations on the separator 21 and of its effect in the brazing operation whereby a final tauter grid is produced can be had from the following description of one specific arrangement that has been advantageously employed. The grid wires 16 and 17 in this illustrative embodiment are of tungsten strands, of 0.00032-inch diameter. The separator 21 is of steatite, while the frames 18 are of molybdenum and are first properly degreased and cleaned and then given a flash coating of copper by plating.

This copper coating is sintered to a smooth even

layer. The wires 16 and 17 are wound at 65 per cent of their breaking strength.

For brazing, the sandwich is supported along its two edges in a framework located within a heater coil contained in a hydrogen bottle. A hydrogen flow rate of from 75 to 100 cubic feet per hour is used. Power is applied in approximately 10-second steps until the brazing metal is visually observed to flow; a brazing alloy known as "BT" alloy, which has a composition of 71.8 percent silver and 28.2 per cent copper is employed. This alloy melts at 778° C., but a brazing temperature of approximately 850° C. is employed.

Referring now to Fig. 6, the expansivities of the various materials of this sandwich are therein plotted as against temperature. While the following explanation is not strictly quantitatively accurate, it is believed to be clearly explanatory of the operation of the separator in the sandwich. However, it is to be understood that this invention and the known beneficial results therefrom are not dependent on this theory or explanation. As heat is applied to the sandwich, the molybdenum frames, having a very low relaxation time, heat up rapidly along curve 26 and quickly reach the expansivity at point 27 when the temperature is maintained at 850° C. The steatite separator 21, having a much higher value of relaxation time and also being shielded from the heat supply by the frames, progresses much more slowly along its curve 28 so that at the time that the frames are initially at point 27, the separator may have only reached a point such as 29. As is easily seen, the expansion at this point is below that of the molybdenum frames. However, heat is supplied to the sandwich for about 45 seconds at this highest temperature of 850° C., during which time there is no additional expansion of the molybdenum frames, as they have already reached this temperature; this additional heat allows the slower heating separator to continue to increase in both temperature and expansion, until it passes the point 30, at which its expansion and that of the molybdenum are the same, and reaches a point, such as 31, where the separator has forced the molybdenum frames to expand further and thus has introduced a further tension on the tungsten wires. At this point, the power supplied to the heating coil is turned off and the sandwich allowed to cool down, with the tungsten wire brazed and held to the molybdenum frame in this last elongated condition. The separator thus gives, in effect, an additional elongation to the wire, as represented graphically in Fig. 6 by the distance along the ordinate between the points 30 and 31, which causes a tauter final grid structure than is otherwise obtained.

When the sandwich has cooled down, the two frames are separated by cutting the wires 16 and 17 along the edges of the frames and the separator 21 removed for use in another operation. The frames are then punched to proper circular size and have the appearance shown in Fig. 2.

In the specific illustrative embodiment described above, the materials employed have the following characteristics:

	Thickness	Expansivity at 850° C.	Relaxation Time
	Mils	Mils/in.	Seconds
Steatite.....	40	6.2	53
Tungsten.....	0.3	4.7	0.55
Molybdenum.....	10	5.1	0.77

Tests made with other separators illustrate

that the proper thermal characteristics both as to relative expansion and as to lag in heating of the separator are essential; these conditions are generally to be met in terms of a higher expansivity and higher relaxation time, but as explained above, may be otherwise met. In one test, a 30-mil platinum separator, which has the same thermal expansion as 40 mils of steatite, was employed; however, the wires broke due to the expansion of the separator even before the brazing temperature was reached. This is because the relaxation time for platinum is only 1.69 seconds. On the other hand, a separator of a zircon porcelain body, commercially known as Alsimag 475, which has a relaxation time of 23 seconds and is thus less than that of steatite, produced no improvement in wire tension because the thermal expansion of Alsimag 475 is even less than that of tungsten and only about 0.73 that of the steatite.

It is of course to be realized that other materials may be employed as the separator. Thus, a forsterite body, known commercially as Alsimag 243, which has a much higher expansivity than steatite and a relaxation time of 28 seconds may be employed, the thickness of the ceramic being proportioned to provide the proper total expansion. Further the separator need not be a single substance or element, but may itself be composed of different layers of materials, provided that the composite thermal characteristics of the body are within the requirements explained above. Thus, the poor expansivity of Alsimag 475 may be compensated for by using a thin layer of molybdenum between two layers of this ceramic. Other possible materials and combinations will be apparent to those skilled in the art.

Further control of the expansion of the separator may be obtained by the use of an internal heater element, as shown in Fig. 7. As seen there, the separator 21 has therein, through one length, several apertures 33, which may be drilled through the separator. A heater element 34 is threaded through these apertures and brought out through the sandwich to external connections. No insulation problem need be considered when the separator is a ceramic. In the case of this modification, when the brazing temperature has been reached and the brazing material observed to flow, the internal heater 34 may be energized to cause additional heat to flow to the separator 21 to overcome its slow relaxation time and cause sufficient expansion and subsequent elongation of the grid wires. The time that power is applied to the heater element 34 is of course so chosen that the grid wires will expand to their maximum advantage without rupturing. This localized heating of the separator then causes the additional thermal expansion to further tighten the grid wires.

If both the grid frames and wires are of tungsten a different sandwich may be employed, as shown in Figs. 8 and 9. As it is very difficult to work with tungsten or to punch out circular portions, the frames 36 are initially made in the desired ring shape. The frames are placed in apertures 37 on the surfaces of the rectangular separator member 38, the apertures being of the same size as the frames, as shown in Fig. 9. A grid 39 is then wound around the separator over the grid 36. The brazing foil, which may be in the form of a circular ring 40 of the same size as the grid frames 36, is placed over the grid wires 39, and a second grid 41 is wound around

the separator 38 on top of the foil 40 and at right angles to the grid 39. Because the expansivities of the grid frames and wires are the same and because of the particular shape of the separator member, very tight grids may be achieved. It is of course to be understood that this sandwich is not limited in its use to these materials, but may also be employed when the grid frame is molybdenum or any other advantageous material and the wires are of tungsten molybdenum or other material.

It is to be understood that the above-described arrangements are illustrative of the principles of this invention and that numerous other arrangements may be devised by those skilled in the art without departing from the spirit and scope of the invention.

What is claimed is:

1. The method of fabricating grids for electron discharge devices comprising winding grid wires around two frames having a separator between them, heating the wires and the frames so that the frames expand and introduce a permanent set into the wires, additionally heating the separator while maintaining the temperature of the frames and wires substantially constant until the separator causes said frames to separate causing an additional elongation of the wires, and attaching the wires to the frames following the separation of the frames and this additional elongation.

2. The method of fabricating grids for electron discharge devices comprising winding very fine wire around two frames having a separator between them, the tightness of the winding approaching the breaking strength of the wire, heating the wire and frames to expand frames and introduce a permanent set into the wires, additionally heating the separator while maintaining the temperature of the frames and the wire substantially constant so that the separator expands causing an additional expansion of the frames and the wire, and attaching the wire to the frames following this additional expansion.

3. The method of fabricating grids for electron discharge devices comprising winding very fine

wire around two frames, heating the wire and frames so that the frames expand and extend the wire, separating the frames while maintaining the temperature of the frames and the wire substantially constant to cause an additional extension of the wire, and attaching the wire to the frames following this additional extension.

4. The method of fabricating grids for electron discharge devices comprising winding very fine wire around two frames having a separator between them, said separator having a larger thermal expansion and a longer relaxation time than said grid wire and said frames, heating said frames and wires to a brazing temperature, continuing to heat said separator while maintaining the temperature of said frames substantially constant to cause said frames to separate and additionally expand said wire, and attaching the wire to said frames following this additional expansion.

5. The method of fabricating planar grids for electron discharge devices comprising placing a separator member between two grid frames, said separator member having a higher thermal expansion and a longer relaxation time than said frames, placing brazing material on said frames, winding a grid wire on said frames in one direction, winding a second grid wire on said frames in the direction perpendicular to said first grid wire, heating said wires and frames to a temperature sufficient to melt said brazing material, maintaining said temperature substantially constant to expand said separator member and cause said frames to separate, and cooling said frames and wires following the separation of said frames.

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