May 16, 1950 W. GRONROS 2,507,709

GRID ELECTRODE AND METHOD OF MANUFACTURE

Filed Sept. 26, 1946 2 Sheets-Sheet 1

FIG. 1

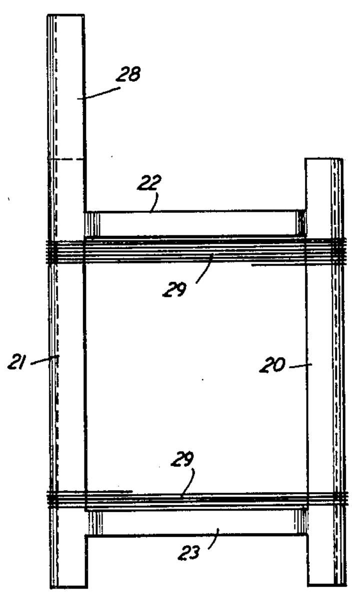


FIG. 2

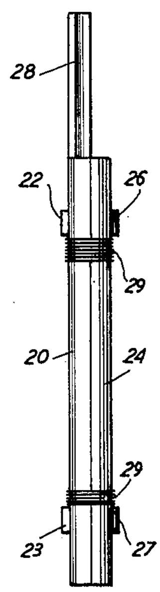


FIG. 4

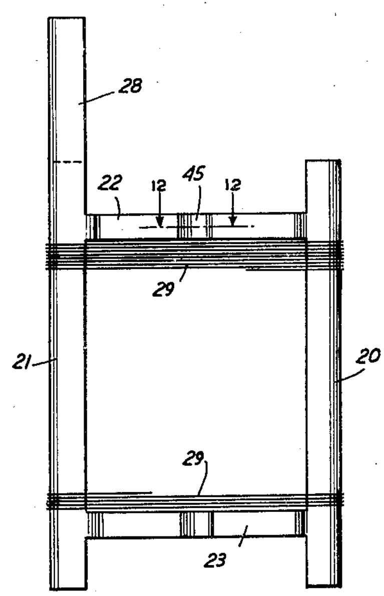


FIG. 3

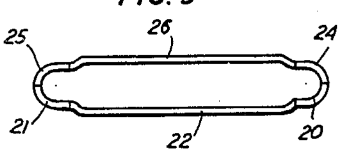
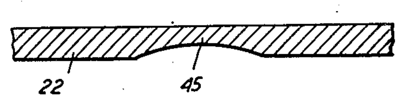


FIG. 12



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Filed Sept. 26, 1946 2 Sheets-Sheet 2

FIG. 5

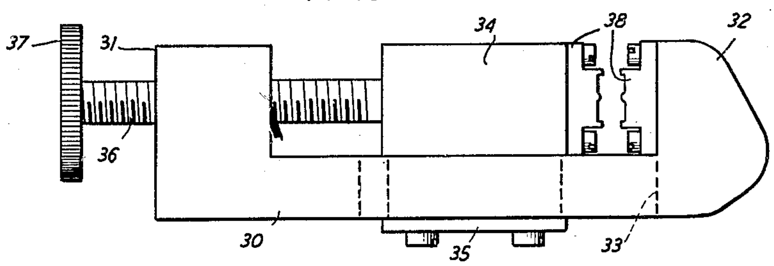


FIG. 6

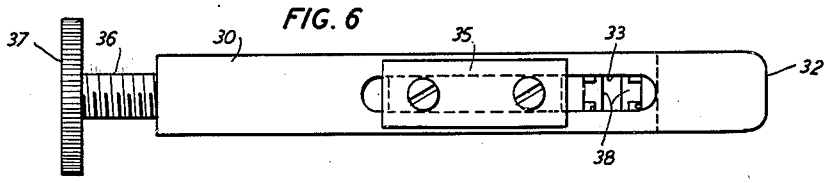


FIG. 7

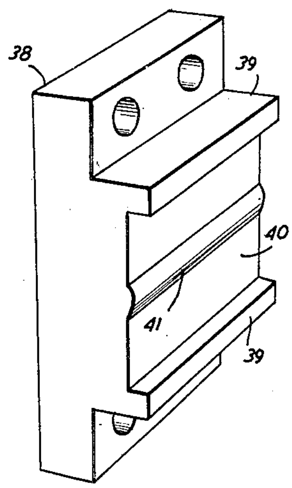


FIG. 8

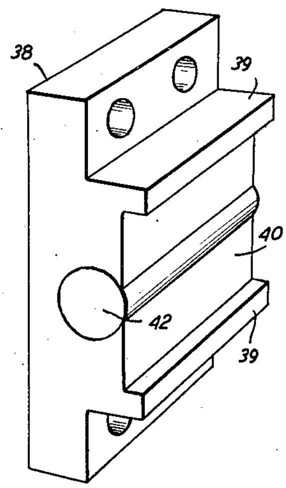


FIG. 9

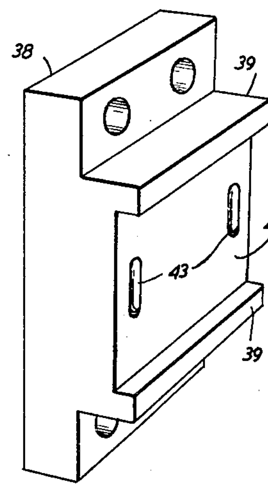


FIG. 10

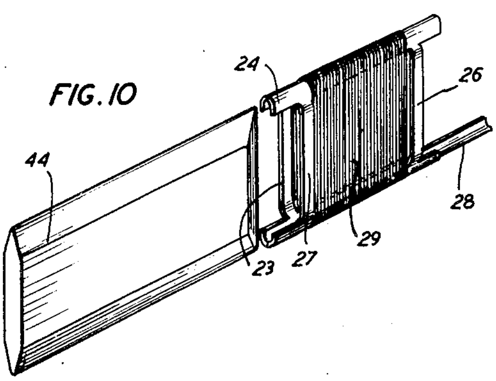
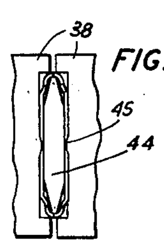


FIG. 11



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UNITED STATES PATENT OFFICE

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GRID ELECTRODE AND METHOD OF MANUFACTURE

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Application September 26, 1946, Serial No. 699,423

9 Claims. (Cl. 250—27.5)

1

This invention relates to electronic discharge devices and more particularly to methods of manufacture of electrodes for such devices.

In ultra-high frequency signaling systems, including electronic discharge devices, one of the factors enabling short wavelength operation is the small inter-element spacing in the devices which results in a high transconductance to capacity ratio and thereby allows attainment of high efficiency.

When the electrodes or elements in the device are reduced in size to micro-midget dimensions to attain relatively close spacing, particular difficulties are usually encountered in the construction and fabrication of the grid or control electrode. This electrode is conventionally formed of a continuous wire helix mounted on upright wire supports and such a construction is inadequate with respect to self-supporting qualities when the components of the grid and particularly the lateral wires are materially reduced in diameter. In order to achieve micro-dimensional spacing, the grid must be as close as possible to the cathode or emitter and the anode must closely surround the grid to secure a symmetrical mounting of the elements in the device. Since the width and length of the element compares in magnitude with the diameter thereof, the micro-midget size materially differs from the conventional dimensions of these elements. For example, a typical grid structure may have a major axis of .228 inch, a minor axis of .0325 inch and a useful length of .255 inch. In such a small construction, the grid lateral wire or helix must be of relatively small diameter, e. g. .0005 inch, to provide a large number of turns on the grid for attaining the desired controlling action. Such fine wire, about equivalent in diameter to a fine spider web strand, is substantially devoid of self-supporting characteristics and requires a framework structure to sustain the laterals in uniform and constant relationship with the other elements in the assembly.

An object of this invention is to facilitate the manufacture of micro-electrode structures.

Another object of the invention is to stabilize the space relation of the surfaces of cooperating electrodes.

A further object of the invention is to reestablish linearity of the laterals of the grid electrode after heat treatment.

Another object of the invention is to overcome loss of tension in the laterals of the grid electrode and to increase the efficiency of the controlling action in the flow of electrons in the discharge space between the electrodes.

2

These objects are attained in accordance with features of this invention by winding the fine grid wire on a hollow metallic frame structure having reinforcing bridging arms at opposite ends of the frame, securing, e. g. brazing, the laterals of the grid to the frame, and finally mechanically stretching the laterals by compression molding of the metal bridging arms to provide tension in the laterals so that they are realigned in uniform lateral relation on opposite sides of the frame structure.

A feature of this construction is the limited elongation of the bridging arms to take up the slack in the lateral wires due to heat treatment during the brazing operation. This is accomplished by placing a mandrel in the completely wound grid and inserting the assembly between pressure dies which contain embossments to engage the outer surfaces of the bridging arms on opposite sides of the grid structure. Pressure exerted on the dies and the interposed grid assembly causes the metal in the bridging arms to flow at the point of contact of the embossments in the dies. Consequent elongation of the arms increases the spacing of the side frame portions with resultant tensioning of the grid lateral wires to align them in uniform parallel relation.

The deformation of the bridging arms does not materially alter the dimensional limits of the grid structure since the stretching may be only one or one and a half thousandths of an inch. Furthermore, the elongation is well within the limits of the breaking strength of the fine wire and the bending limit of the frame material so that no deleterious effects are caused by the stretching operation. On the other hand, the expansion of the arms equalizes the pull on the grid lateral wires so that all the laterals are stretched simultaneously and the stresses set up in the laterals reset the wires in positive linear relation both longitudinally and transversely across the grid frame structure. This construction materially improves the inter-element spacing in the device and increases the transconductance to capacity ratio in the discharge path.

These and other features and advantages of the invention will be set forth in more detail in the following description which, together with the accompanying drawings, disclose illustrative physical aspects of the invention. In the drawing,

Fig. 1 is an elevational view on a greatly enlarged scale of one embodiment of the grid electrode to which the fabrication methods of this invention appertain;

Fig. 2 is an edgewise view in elevation of the electrode of Fig. 1;

Fig. 3 is an end plan view of the grid frame structure;

Fig. 4 is the same as Fig. 1 except that it shows the stretching indentations in the bridging arms of the frame;

Figs. 5 and 6 are side and bottom views, respectively, of a clamping vise assembly utilized in the fabrication of the electrode structure;

Figs. 7 to 9, inclusive, show in enlarged perspective views, various forms of compression dies which may be employed in the vise of Figs. 5 and 6.

Fig. 10 is a perspective view showing the relationship of the grid structure and a mandrel prior to insertion of the latter into the grid;

Fig. 11 is a fragmentary view of the grid and mandrel mounted between a pair of cooperating dies; and

Fig. 12 is an enlarged exaggerated view in cross-section of a portion of a bridging arm of the frame structure, taken on the lines 12—12 of Fig. 4, to illustrate the deformation in the surface of the arm to achieve the tensioning of the grid laterals on the frame.

The invention is concerned primarily with the fabrication of electrodes and particularly the control electrode or wire wound grid of the symmetrical type employed in electronic discharge devices in cooperation with other electrodes, such as a cathode or emitter and a surrounding anode, all the electrodes being usually mounted in a unitary assembly between top and bottom spacer insulators to maintain the respective electrodes in uniform and constant spaced relationship in order to realize the desired electrostatic and dynamic characteristics suitable for particular operating functions. The conventional form of grid is usually produced by winding a wire in the form of a flattened helix around a pair of parallel support wires with the lateral turns spaced on the support wires by swaging the lateral turns in notches in the supports or welding the turns to the supports. This form of construction requires that the lateral wire be of sufficient cross-section to produce a self-supporting electrode assembly.

The conventional type of grid electrode seriously limits the design possibilities of devices employed in ultra-short wave operation. For example, to secure micro-dimensional spacing the diameter of the grid winding wire must be materially reduced but then the wire is not sufficiently rigid to form a self-supporting structure. The swaging or welding methods of securing the grid laterals to the supports limits the spacing of the laterals, and the support rods or wires produce variations in the major and minor axes of the grid so that the assembly deviates widely from the optimum dimensions desired.

In order to overcome these difficulties and to produce elements of micro-midget dimensions, this invention provides a construction of control electrode of the frame type to sustain the fragile wire laterals in constant and uniform spaced relation. Referring to the drawings, and particularly to Figs. 1 to 3, inclusive, the grid electrode is shown enlarged ten times actual size. The dimensions of the micro-midget grid are .228 inch major axis, .225 inch useful length, .333 inch over-all length and .0325 inch minor axis or distance between laterals on opposite sides of the wound grid. The lateral wire for the grid helix is one-half mil or .0005 inch wound at a pitch of 340 turns per inch with a total of 72.5 turns over a length of .213 inch of the grid frame. Of course, other dimensions can be applied to different forms of electrodes depending on the characteristics desired in the discharge device, the above data being given as an example to indicate the minute configurations of the electrodes embodying features of this invention.

The frame of the grid electrode is preferably formed of molybdenum, to reduce the amount of metal to a minimum and also to provide a material of high tensile strength. Other metals may be used, such as nickel or steel for certain applications. The frame is formed of sheet metal which may be punched and shaped to desired configurations, and as shown, involves two half-sections in abutting relation along the lateral sides to form a hollow rectangular structure. One section has an upright column or portion **20** of arcuate cross-section on one side of the frame and a similar column **21** on the other side, the two columns being connected together by spacing beams or bridging arms **22** and **23** adjacent opposite ends of the columns. The arms are slightly bowed or extend outwardly beyond the surface of the columns, as shown in Figs. 2 and 3, to bring their inner surfaces in line with the lateral winding of the grid. The other section is also provided with a pair of cooperating columns **24** and **25** which are spaced by arms **26** and **27**. One of the columns, for example **21**, is provided with an extension **28** for anchoring or connecting purposes in the unitary mount assembly of the other electrodes coupled with the proposed grid electrode. The two sections are accurately formed and assembled to provide a hollow frame having accurately dimensioned surfaces and contours so that the major and minor axes may be held to very definite limits to insure the resultant characteristics desired in the device. The minor axis dimension can be readily fixed by the accurate channel shape of the juxtaposed columns **20** and **24**, and **21** and **25** since the terminating surfaces of the accurate columns are plane outer boundaries on opposite sides of the hollow frame. The major axis dimension may be held constant and within close limits by the bridging arms connecting the columns at opposite ends. Although the proposed frame structure is shown as formed of two half-sections, it is possible to construct the frame of a single body if a tubular form is substituted instead of one of sheet material.

In fabricating the bi-part frame of molybdenum, the two sections, after forming, are plated with a noble metal, such as gold, and placed in an oven supplied with a non-oxidizing atmosphere, such as hydrogen, and the two sections are brazed together by fusing the gold film over the longitudinal joints along the abutting edges of the sections. Since some of the gold film is lost by flowing in the brazed joints, it is desirable to recoat or plate the complete frame to replenish the surface film on the channel columns. This may be performed in a non-oxidizing atmosphere to avoid contamination of the coating and to produce positive adherence of the plating film.

The plated hollow frame is then ready for the winding operating in which very small diameter wire, for example .0005 inch tungsten or smaller, is wound around the columns over a length between the bridging arms at opposite ends of the frame. The winding is performed by rotating the frame on a suitable mandrel and applying the fine wire in continuous rotation around the channel columns at a desired pitch, for example

340 turns per inch for a grid structure of the micro-midget dimensions described above, the total number of turns of the fine wire being 72.5 to cover the area between the arms. The winding is applied with a tension of about 15 grams for the half mil wire and the tension may be somewhat less for three-tenths mil wire. After winding the helix on the frame, the laterals 29 are uniformly spaced over the useful area of the grid electrode and the assembly forms a rectangular cage, with the grid laterals at predetermined spacing to produce the desired controlling action on the electron stream in the discharge device.

The grid laterals are secured to the channel columns by brazing in a hydrogen oven at a temperature of about 1100 degrees centigrade. In this operation, the excess gold plating flows over the wire in contact with the columns and also flows along the wire laterals thereby gold-plating the fine tungsten wire. This eliminates the necessity for using gold-plated wire to reduce emission from the grid during operation of the device. During the brazing operation, the slightly greater expansion of the frame relative to the tungsten laterals maintains sufficient tension on the laterals and prevents their sagging during the time the gold film is fluid and thus incipient adherence between adjacent laterals is prevented. After the brazing operation and cooling of the assembly, the laterals are no longer under tension, due to loosening produced by embedding of the wire turns in the gold plating and by permanent set in the wire while under tension at the elevated brazing temperature.

To restore the grid laterals 29 to the desired tension to realign them uniformly with the surfaces of the channel supports, the major axis of the frame is increased one or two-thousandths of an inch by deformation of the bridging arms or beams so that expansion of the channel columns will stretch the wires to their original tension but not sufficiently to cause breakage of the wire or bending of the columns.

This is accomplished, in accordance with a feature of this invention, by a compression molding operation in which the surface of the beams or arms is distorted sufficiently by cold flow to expand the frame and realign the grid laterals on the frame. This pressing or squeezing step is performed in a vise, impression fixture or jig, shown in Figs. 5 and 6. The vise comprises a hardened metal frame 30 having an internally threaded head 31 and a solid terminating head or jaw 32 at opposite ends of the frame to form a U-shaped structure. The frame is also provided with an elongated slot 33 to form a sliding track for a movable head or jaw 34 which is secured to the frame by a plate 35 attached to an extension of the movable head projecting through the slot 33. The movable head is actuated by a lead screw 36 extending through head 31 and controlled by knob 37 on the screw. The jaws 32 and 34 are provided with cooperating hardened dies 38, shown more clearly in Fig. 7, the dies being removable to accommodate various shapes and configurations of electrodes to be compressed in the jig.

The pressing die of Fig. 7 is formed with limit projections 39 to embrace the width of the grid frame assembly and a bearing surface area or land 40 between the projections to form a seat for the grid frame. The central portion of the land 40 is provided with an integral elongated embossment 41 of convex contour. As a typical example of the dimensions of the principal surfaces of the die for forming grids of the micro-midget type heretofore mentioned, the height of the projections 39 above the land 40 is approximately 0.15 inch, the radius of the convex embossment is .025 inch and the embossment extends .002 inch above the surface of the land 40.

A somewhat different die construction is shown in Fig. 8 in which the embossment is produced by embedding a hardened wire 42 in the base of the land 40 with only a segment of the curved surface of the wire projecting above the land surface. The same effect, although of different configuration, may be produced by the die shown in Fig. 9 in which integral beads 43 are formed on the central land surface but at opposite ends to engage the bridging arms on the grid frame when placed in the vise.

Prior to placing the grid assembly in the vise between the cooperating dies, a hardened steel mandrel 44 is inserted in the grid frame. This mandrel has beveled edges to fit into the channel columns of the frame and opposite plane surfaces to engage the bridging arms of the frame in face-to-face relationship. The frame and mandrel assembly is placed between the cooperating dies, as shown in Fig. 11, the embossments 41 of the dies being in contact with the outer surfaces of the arms 22, 23, 26 and 27, and the grid frame is located between the projections 39 on opposite dies. In this position, the projections 39 on the dies are slightly spaced apart, as shown in Fig. 11, due to the thickness of the arms on the frames. When pressure is applied to the dies by the screw advancing the movable jaw 34, the embossments 41 simultaneously are forced into the outer metal surfaces of the bridging arms and the metal at the point of contact flows under the impact to spread or expand the arms, thereby increasing the major axis dimension of the columns by a slight amount, approximately one or two-thousandths of an inch.

The resultant pressure forms an indentation 45 in the arms, as shown in Fig. 4 and more clearly in Fig. 12, and since the force is exerted only on the outer surfaces of the arms and across the width thereof, the tendency of the arms to expand under pressure causes the grid laterals 29 to be pulled outwardly by the movement of the columns so that tension is restored in the laterals and they are realigned in uniform spaced relationship on opposite sides of the frame assembly.

Aside from the major function of the frame in supporting the grid laterals, this form of construction is admirably suited to meet the close limits required for the space relationship of the electrodes. This is particularly true when the electrodes are reduced to micro-midget dimensions since the rigid molybdenum frame can be accurately shaped to define the major and minor axes and thereby insure definite interelectrode spacing while securing reduction of the capacity values between the elements in the electrode assembly.

The rigid frame also provides a broad bearing area for the support of the grid electrode in mica insulators so that misalignment of the grid with respect to the other electrodes is minimized. Further, the gold plating facilitates the relatively close spacing of the fine wire laterals and decreases secondary emission from the grid under high temperature operation. The substantial surface area of the frame also affords greater heat dissipation so that the grid is maintained cooler during operation and the inductance is reduced by avoiding supplemental flexible conductors between the electrodes and terminals of the device. The rugged construction of the grid provides less hazard in the handling and assembly of the device and protects the laterals from distortion. Finally, the uniformity of the grid laterals and their close planar relation insures high transconductance to capacitance ratio at ultra-high frequencies.

What is claimed is:

1. An electrode for electronic discharge devices, comprising a metallic frame including parallel side channel portions and intermediate bridging portions adjacent opposite ends connecting said channel portions, a plurality of lateral wires extending along said frame and secured in uniform spaced relation to said channel portions parallel to and between said bridging portions, and indentations on said bridging portions for stretching said laterals on said frame.

2. An electrode for electronic discharge devices, comprising a metallic frame including parallel side channel portions and intermediate bridging portions adjacent opposite ends connecting said channel portions, said bridging portions extending outwardly beyond the surface of said channel portions, a continuous helix wound on said frame, lateral portions thereof spanning the space between said channel portions, and central depressions formed in the outer surface of said bridging portions, to tension said lateral portions between said channel portions.

3. An electrode for electronic discharge devices, comprising a metallic frame including parallel side channel portions and intermediate bridging portions connecting said channel portions, and a continuous helix wound on said frame, lateral turns of wire thereof spanning the space between said channel portions and affixed thereto, and said bridging portions having limited sections reduced in thickness to expand said frame and tension the lateral turns of wire.

4. A grid electrode for electronic discharge devices, comprising a metallic frame including parallel side channel portions and intermediate bridging portions connecting said channel portions, and a continuous wire helix wound on said frame including spaced laterals extending across the space between said channel portions, said bridging arms having expanded portions to apply tension to said laterals extending between said channel portions.

5. The method of tensioning an electrode having a metallic frame including channel side portions and bracing arms at opposite ends connecting said portions, which comprises winding uniformly spaced wire laterals on said frame, affixing said laterals to said side portions, and tensioning said laterals by compression forces applied to said arms.

6. The method of fabricating a grid electrode having a metallic frame including channel side portions and bracing arms at opposite ends connecting said side portions, which comprises coating said frame with a noble metal layer, winding a continuous wire helix on said frame, heating said electrode to affix said helix to said side portions, and flowing the metal of said arms by compression to tension the helix laterals between said side portions.

7. The method of forming a grid structure including a metallic frame having channel side portions and bridging arms spacing said side portions, which comprises gold-plating said frame, winding a continuous helix about said side portions, embedding said helix in said gold-plating, inserting a mandrel into said frame, placing said frame between forming dies, said dies having embossments engaging said arms, and forcing said embossments against said arms thereby to expand said arms to tension said helix between said side portions.

8. The method of forming a grid structure including channel side portions and bracing arms at opposite ends connecting said side portions, which comprises winding a continuous helix about said side portions, affixing the turns to said side portions, inserting a mandrel into said frame, placing said frame between forming dies, said dies having embossments engaging said arms, pressing said bridging arms between said embossments and mandrel, and tensioning said helix by the expansion of said arms.

9. The method of forming a grid structure including a frame having channel side portions and spacing arms at opposite ends of said portions, which comprises winding a continuous helix about said side portions to span the space encompassed by said arms and side portions, embedding said helix in said side portions to anchor the spaced lateral turns of said helix, inserting a mandrel into said frame, placing said frame between forming dies, said dies having projections in contact with said arms, and squeezing the outer surface of said arms simultaneously against said mandrel to flow the metal by elongation whereby tension is imposed on said helix affixed to said side portions.

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